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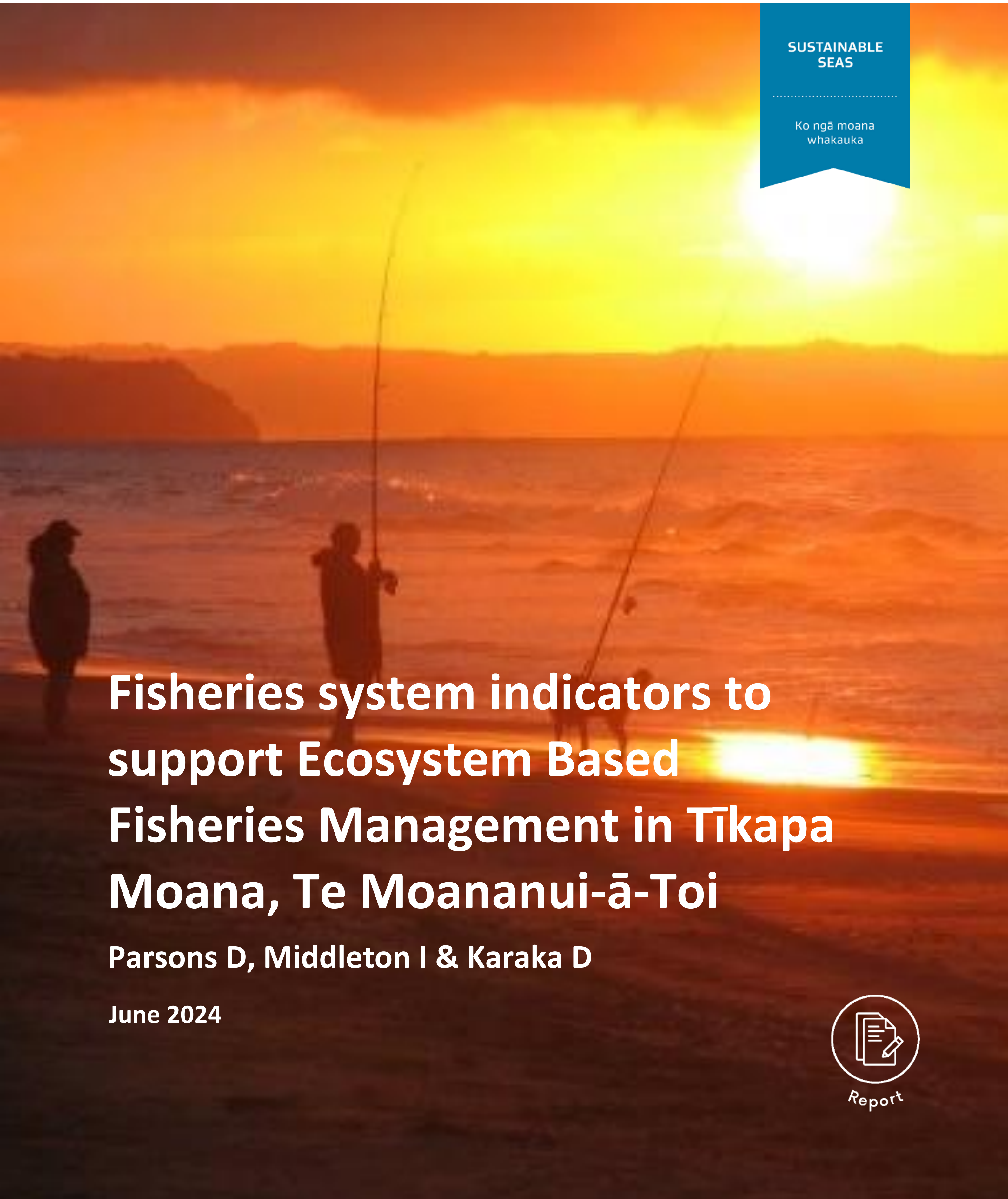

Fisheries system indicators to support Ecosystem Based Fisheries Management in Tīkapa Moana, Te Moananui-ā-Toi

Parsons D, Middleton I & Karaka D

June 2024

Report

Report for Sustainable Seas National Science Challenge project *EBFM in the Hauraki Gulf (Project code S4)*

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Date of publication

June 2024

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About the Sustainable Seas National Science Challenge

Our vision is for Aotearoa New Zealand to have healthy marine ecosystems that provide value for all New Zealanders. We have 75 research projects that bring together around 250 scientists, social scientists, economists, and experts in mātauranga Māori and policy from across Aotearoa New Zealand. We are one of 11 National Science Challenges, funded by the Ministry of Business, Innovation & Employment.

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Cover image: Surfcasting at dusk. Tracey Parsons.

Acknowledgements

We would like to extend our utmost gratitude to the co-development partners and other experts who provided their time, knowledge, expertise and input over multiple years to make this project possible. This includes, but is not limited to: Alex Rogers, Bruce Hartill, Carolyn Lundquist, Denham Cook, Drew Lohrer, James Williams, Joe Davis, John Wilmer, Jordi Tablada, Judi Hewitt, Laurie Beamish, Manuel Greenland, Mathilde de Forges, Matt Pinkerton, Matt Rayner, Matt von Sturmer, Megan Carbines, Michael Townsend, Nathan Reid, Nick Shears, Nicola MacDonald, Paula Holland, Peter Longdill, Raewyn Peart, Rochelle Constantine, Sam Woolford, Sue Neureuter, Sydney Curtis, Tame Te Rangi, and Valmaine Toki.

A special thanks to Fisheries New Zealand as co-leaders on this project for your unwavering support, guidance and input, specifically Kathryn Lister, Adam Slater, Alexandra Schwaab, Jacob Hore, Apanui Skipper, and Ian Tuck.

We would also like to thank Scott Champion and Kelvin Whall from Primary Purpose for their expert guidance with workshop facilitation. Thanks to Kirsten Revell for production of graphics as well as Lisa Bragg, Emma Macfarlane, Drew Lohrer, Mel Underwood, Richard O'Driscoll, Chloe Hauraki, and Jonathan Moores (all NIWA) for your help with editing, reviewing and formatting this report.

A big thanks to the Sustainable Seas team for funding this project and the support provided by Julie Hall, Linda Faulkner, Caitlyn Shannon, Sophie Sparrow, Jayne Webb and Magnolia Lowe.

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Executive summary

The fisheries of the Hauraki Gulf, and the system that supports them, are highly valued but showing signs of degradation. *Revitalising the Gulf* is the Government's action plan to restore the mauri of the Hauraki Gulf through a more holistic process of Ecosystem Based Fisheries Management (EBFM). Central to the concept of EBFM is broadening the values considered by management and trying to achieve balance (not exclusion) in a multi-valued space.

In 2020, Aotearoa New Zealand's Sustainable Seas National Science Challenge funded a project involving Māori partners, stakeholders, and government agencies to make progress in putting EBFM into action. The Hauraki Gulf and *Revitalising the Gulf* were the case study elements of the project.

The objective of the project was to evaluate indicators (and associated monitoring) that could be used to better understand and communicate changes in status of the components of the Hauraki Gulf fishery system (including values, stressors, and the implementation of management actions). Central to the process was co-development, which was facilitated by a co-development group including mana whenua.

Indicator co-development was hierarchical. The process was started by developing a framework aligned with the Hauraki Gulf Fisheries Plan. This contained three 'Desired Outcomes' that covered the ecosystem that supports fisheries, the fisheries themselves, and the engagement and support for mana whenua and local communities to participate in governance. Candidate indicators aligning with these Desired Outcomes were suggested by co-development partners and subject matter experts. Evaluation and rating of more than 150 candidate indicators was documented using a traffic light system, which provided flexibility (and transparency) when conducting a qualitative assessment of each candidate indicator against a series of assessment criteria.

In parallel, indicators of particular significance to mana moana were also developed, while ensuring that both sets were elevated to the same level, were aligned, and followed a similar structure. This framework, Te Niho Tanhiwha, is intended to provide a framework that individual hapū can subsequently add specific place-based context to. Te Niho Taniwha is similar to the co-development-group-led indicators associated with the three Desired Outcomes, as both are hierarchical in structure. Te Niho Taniwha extends from overarching principles (Ngā mātāpono), through pillars of success (Ngā pou), to indicators (Ngā tohu) themselves. Both Te Niho Taniwha and the co-development-group-led indicators also incorporate a traffic light system for evaluating indicator utility.

The indicators evaluated in this report represent substantial progress towards EBFM as they capture a much broader socio-economic-cultural ecosystem than is currently considered within the scope of fisheries management. Single species indicators will continue to be a part of those considerations. We have also made substantial progress in the journey towards EBFM more generally through greater engagement, education, and awareness of others' perspectives. From here a suite of indicators can now be selected by Fisheries New Zealand, and associated monitoring recommendations can also be considered and monitoring initiated. Ultimately, Māori still need to be enabled as kaitiaki alongside existing management and for the management actions of *Revitalising the Gulf* to be implemented. This will only be possible through greater cross-government coordination.

Introduction

A fundamental aim of the Sustainable Seas National Science Challenge is improved decision-making in Aotearoa New Zealand's marine realm and expansion/operationalisation of Ecosystem Based Management (EBM) approaches. The concept of EBM is to holistically manage the environment while considering the multiple values, uses and stressors of ecosystems. Expansion and operationalisation of marine EBM requires the involvement of groups with a diversity of interests. In Aotearoa New Zealand, partnerships and participation of Māori in decision making is essential to ongoing improvement of management processes, and to ensure that a Te Ao Māori worldview is supported to enable mātauranga Māori application in marine EBM.

Te Moananui-a-Toi, Tīkapa Moana, or the Hauraki Gulf as it is commonly referred to today, is highly valued and used, with multiple stressors acting on it (Hauraki Gulf Forum 2023). There are signs the health of the Hauraki Gulf, and its fisheries, have declined (Hauraki Gulf Forum 2023). Through a collaborative co-governance process, a plan to enable multiple uses of the Hauraki Gulf while restoring its health, *Sea Change – Tai Timu Tai Pari Hauraki Gulf Marine Spatial Plan,* was released in 2017 (Sea Change 2017). In 2018, the Government initiated an engagement process which resulted in *Revitalising the Gulf* - Government Strategy in response to the Sea Change Plan in June 2021(New Zealand Government 2021).

Revitalising the Gulf is organised into eight themes addressing threats to the health and mauri of the Hauraki Gulf. The Fisheries Management theme has developed a Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2023b) (supported by the Hauraki Gulf Fisheries Plan Advisory Group, and the indicators and monitoring framework). This plan was designed to progress Ecosystem Based Fisheries Management (EBFM) using an integrated approach to manage competing values for resources while maintaining the ecosystems that support them. To assess the overall ecosystem health of the Hauraki Gulf and determine how the Fisheries Plan is progressing towards these goals, indicators will need to be selected to reflect the status of the fisheries and ecosystems in the Hauraki Gulf. These indicators will monitor the status of fisheries and other cultural, socio-economic and ecosystem components of value to mana whenua and stakeholders. Note that Ecosystem Based Fisheries Management (EBFM) and Ecosystem Based Management (EBM) are similar and the terms are sometimes used interchangeably, though obviously EBFM is more fisheries focused.

Te Moananui-a-Toi - Tīkapa Moana - The Hauraki Gulf Marine Park

The Hauraki Gulf Marine Park spans 1.2 million hectares, extending twelve nautical miles seaward from the east coast of the Auckland and Waikato regions (Figure 1). It encompasses a diversity of habitats from sheltered estuaries to fully exposed open ocean over 250 metres deep (Hauraki Gulf Forum 2023, Sea Change 2017). The Hauraki Gulf is a taonga (treasure) of cultural and spiritual significance to mana whenua through the rich history of settlement and use since the first waka navigated its waters.

Given the beauty, diversity, and importance of the Hauraki Gulf, it is not surprising that it is used for a variety of purposes and has high value to many different people. Its many uses include customary, commercial and recreational fisheries, as a place of cultural and spiritual significance, aquaculture, tourism, as a major commercial port and transport route, sightseeing, recreation and as a home to a diversity of marine life (Hauraki Gulf Forum 2023, Sea Change 2017). Catchments of the Hauraki Gulf encompass New Zealand's largest city, Auckland, and large areas of farmland in the Waikato. Some of the stressors that the Hauraki

Gulf faces include fishing, pollutants, nutrients, sediment, invasive species, and climate change (Hauraki Gulf Forum 2023, Sea Change 2017).

From a fisheries perspective, many of the Hauraki Gulf's taonga fish species have been depleted. This includes tarakihi (*Nemadactylus macropterus*), kōura (rock lobster, *Jasus edwardsii*), tipa (scallops, *Pecten novaezelandiae*), and tuangi (cockles, *Austrovenus stuchburyi*) (Fisheries New Zealand 2023a, Hauraki Gulf Forum 2023). Fish extraction can also impact other parts of the ecosystem. For example:

(1) bottom trawling, Danish seining and dredging all impact benthic fauna, which provide habitats supporting many fish species; prior to the 1960s large areas of green-lipped mussels were removed from the Gulf by dredging (Paul 2012) — bottom trawling has reduced the diversity of soft-sediment fauna throughout the Gulf (Thrush et al. 1998)

(2) fishing (both recreational and commercial) can catch unwanted species, some of which are threatened (e.g., black petrel) (Richard et al. 2020)

(3) fishing can also affect ecosystem structure — the presence of kina (*Evechinus chloroticus*) barrens on rocky reefs may be a consequence of fishery related predator removal (Shears & Babcock 2002).

Non-fishing related factors can also affect fisheries. For example, nutrients and sediments from the land can also impact pelagic and benthic community structure, with flow-on effects for fish and the habitats that support them (Morrison et al. 2009). Many species will be sensitive to climate related factors, potentially leading to reduced abundances or altered distributions (Portner & Peck 2010). To address these broad-reaching concerns for the Hauraki Gulf's fisheries, the ecosystems that support them, and the cultural, social, and economic value systems connected to them, a new, more holistic, approach to fishery management is required.

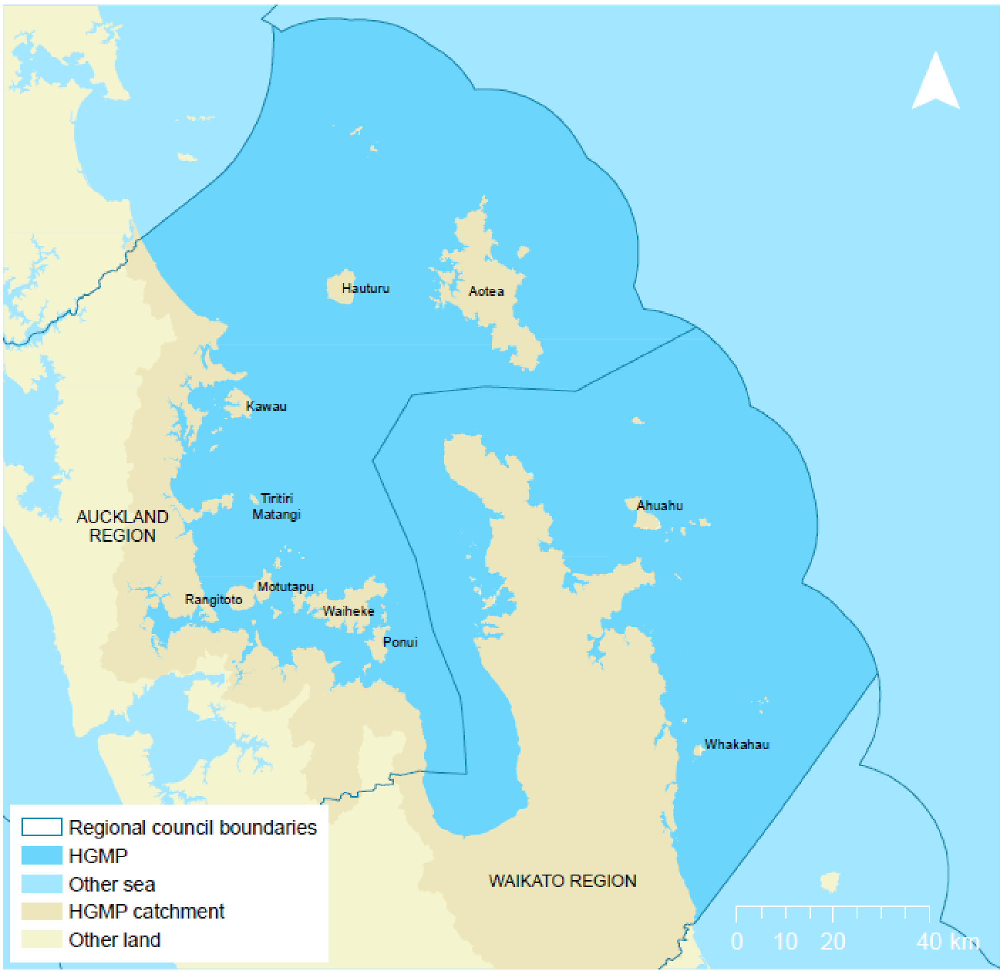


Figure 1 The Hauraki Gulf Marine Park

Ecosystem based management (EBM) and indicators

The underlying concepts of EBM are not new, having been considered by scientists for over a century and more formally discussed since the 1970s (Link & Marshak 2021). The Te Ao Māori world view, which shares principles such as interconnection of humans and nature, has been around for much longer. Some key principles of EBM in Aotearoa new Zealand include (Hewitt et al. 2018):

- Co-governance: Governance structures that provide for Treaty of Waitangi partnership, tikanga and mātauranga Māori.
- Human activities: Humans, along with their multiple uses and values for the marine environment, are part of the ecosystem.
- Collaborative decision making: Collaborative, co-designed and participatory decision-making processes involving all interested parties.
- Knowledge based: Based on science and mātauranga Māori and informed by community values and priorities.
- Sustainability: Marine environments, and their values and uses, are safeguarded for future generations.
- Adapts: Flexible, adaptive management, promoting appropriate monitoring, and acknowledging uncertainty.
- Tailored: Place and time specific, recognising all ecological complexities and connectedness, and addressing cumulative and multiple stressors.

Indicators are an important component of the implementation of EBM and a Te Ao Māori worldview. Indicators allow complex systems to be monitored through a subset of characteristics (which act as a proxy for a broader set of ecosystem attributes), communicating the trends in that system (identifying the stressors acting on it), the response of management, and progress towards objectives (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010). Indicators should cover ecological, environmental, economic, cultural, social, and management aspects, and are often arranged into a hierarchy (i.e., nesting from many indicators at the bottom level into higher levels with fewer categories). A good indicator is meaningful and easy to understand, is easily measured, has already been measured for a period of time, is sensitive to stressors, and complements other indicators to avoid redundancy. There are a variety of approaches to the development of an indicator suite, but they largely have the following steps in common (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010):

1. Relevant partners, end-users, and managers are identified to co-develop objectives and a framework for the indicators.
2. Candidate indicators are co-developed, often facilitated by subject matter experts.
3. Candidate indicators are scored against a set of screening criteria. A variety of screening criteria can be used, with each candidate indicator scored against each criterion in a process that involves researching existing information about the candidate indicator and the use of expert judgement where needed. The scores for the screening criteria are then combined so that overall scores for each candidate indicator can be compared. It is important that decisions made during this process are well documented.
4. The screening results are summarised and a final decision on the indicator suite is made with the co-development group.
5. The results are communicated, and the process is updated and iterated going forward.

Ultimately, indicators are intended to support management decisions. However, this requires an understanding of the directionality of the indicators selected (is a bigger number better or worse), how the response of these indicators relate to one another (some indicators may get better while others may get worse), and eventually the setting of management reference points and targets. The consideration of reference points across an entire suite of interrelated indicators and establishing the data to support decisions around these reference points, is clearly a big step forward. First, the indicators themselves need to be established. Their subsequent monitoring will lead to an understanding that will result in the setting of management reference points beyond the life of this project.

A key objective of the Hauraki Gulf EBFM project was to provide advice so that Fisheries New Zealand (FNZ) can implement one of the fisheries management components of *Revitalising the Gulf* by co-developing (with mana whenua and stakeholders) suitable indicators for monitoring the Hauraki Gulf fisheries system. This indicator suite should include indicators that detail progress made with management and monitoring implementation aspects of *Revitalising the Gulf* (i.e., what progress has been made with marine protection implementation), as well as indicators that describe the status of different components of the fishery system (i.e., what is the abundance of certain fish species in protected vs. non-protected areas). It is intended that the indicators that FNZ ultimately select from this process will have great utility as both a communication and management tool in allowing managers and co-developers to understand how ecological, economic, social, and cultural components of the Hauraki Gulf fishery system change as EBFM strategies (and other management interventions) are implemented.

Methods

Co-development

A crucial aspect of indicator development is co-development. A group of co-development partners, representing Hauraki Gulf mana whenua, recreational and commercial fishers, environmental interests, researchers, and government departments / local government was formed at the outset of this project. Engagement with this group (the co-development group) was initiated during the proposal development phase to ensure that the project plan was co-developed, as well as the ensuing steps. During this initial co-development a number of key messages were taken on board, including:

- The project should incorporate a meaningful partnership with mana whenua.
- It should give effect for Te Tiriti o Waitangi – a korowai (cloak) for both Te Ao Pākehā and Te Ao Māori indicators.
- A Te Ao Māori perspective should be embraced to promote interconnectedness as fish do not recognise boundaries.
- Te Ao Pākehā and Te Ao Māori indicators should be aligned, but not forced together. This can be thought of as a waka taurua (double hulled canoe) – both sets of indicators have space to co-exist in their respective hiwi (hulls) with the opportunity to come together in the shared space on the papanoho (deck). The overarching principle is to keep the indicators navigating together aligned.
- Mātauranga Māori and local knowledge should be incorporated. The sources of this knowledge should be appropriately acknowledged so that the knowledge remains with the hau kainga that have shared it.
- The indicator development process should be transparent and simple, with a clear scope. This process should incorporate and respect a diversity of perspectives/values, so that it captures 'the voice of the Gulf'. The scope should incorporate a connection to the land, and a connection to other themes within *Revitalising the Gulf* but recognise that the key area of focus is the Hauraki Gulf fisheries system. Whatever is produced should be effectively communicated.
- Datasets with an existing time series are valuable. Likewise, potential indicators with no existing data should also be identified.
- The indicator suite that is developed should: have broad coverage, be complementary, be informed by data, include measurable indicators but also explore qualitative indicators, be cost-effective, include place-based indicators, be spatially and temporarily representative, and have a fisheries focus.
- Where possible, indicators should take into account the connectivity of the Hauraki Gulf to a broader system.
- The indicator suite should link, where practical, to the Desired Outcomes, and Management Objectives of the Fisheries Plan, but not to the extent of ruling out aspects identified during the process as being of importance for 'the voice of the Gulf'. While it is urgent that indicators be established, they should also be nimble/responsive going forward.

Mana moana indicator framework

One aspect of critical importance from the key messages above was the need to co-develop indicators that are informed and aligned with iwi, hapū, and whānau outcomes for EBFM in the

Hauraki Gulf (Smith 1997). The intention here was to follow the waka taurua analogy, where both sets of indicators have their own space but are aligned (Maxwell et al. 2020).

The development of these mana moana indicators was conducted with a subset of the co-development group consisting of Hauraki Gulf mana whenua, referred to as the Mana Moana Advisory Group (MMAG). Given the importance of place-based knowledge and specific place-based values for different taonga species, which will vary across the different iwi, hapū, and whānau of the Hauraki Gulf, the intention of this component was to focus on just the upper levels of the mana moana component of the indicator framework. However, it is important that this mana moana framework allows for the more specific place-based context from individual uri (i.e., the indicators themselves) to be added at a later stage.

The development of a mana moana indicator framework is further discussed in the Tīkapa Moana, Te Moana nui-a-Toi - Mana moana section below. Unlike other sections of this report, the Tīkapa Moana, Te Moana nui-a-Toi - Mana moana section is largely self-contained, in that it includes contextual material, methodological descriptions, results and discussion all in the one section.

Co-development-group-led indicators

For co-development-group-led indicators, the intention was to follow the five-step co-development process used elsewhere (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010) and outlined above. Below we describe the specific approach that was implemented when following this process.

Framework co-development

The upper levels of a framework (the backbone that the indicators will connect to) was developed to ensure that the coverage of indicators themselves (developed at a later stage) was complete. While some indicator projects follow a DPSIR (Driver, Pressure, State, Impact Response) approach to ensure that indicators cover all aspects of the system (Atkins et al. 2011), we chose not to for a variety of reasons. Firstly, one of the main purposes of developing these indicators was to measure progress and evaluate the impact of the Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2023b). Therefore, the Hauraki Gulf Fisheries Plan was a good starting point to consider indicator coverage. Further, the DPSIR approach can be very categorical and lack flexibility, and the differences between some of the categories (e.g., drivers and pressures) can be somewhat vague.

In addition to the Hauraki Gulf Fisheries Plan, we also wanted to ensure diversity of indicator coverage via co-development group input. This input was facilitated through a workshop held during December 2022. At this workshop participants were asked: (1) What aspects of the Gulf are most important to you? (2) What are some indicators associated with these values? (3) What different categories might they be grouped into? and (4) How do these groupings compare to the Hauraki Gulf Fisheries plan? The feedback received from this workshop was subsequently used to supplement the framework provided by the Hauraki Gulf Fishery Plan.

Co-development of candidate indicators

Once the indicator framework had been co-developed, candidate indictors were required so that their utility could be evaluated. To facilitate the development of these candidate indicators we surveyed the co-development group to understand what indicators they thought would be useful. This process was conducted using an online survey where co-development group members were asked three questions: (1) What indicator do you suggest? (2) Why is this a useful indicator? (3) Are there any existing data sources for this indicator?

These survey questions were organised around the nine Focal Components of the indicator framework (see the Results section for definitions and descriptions of the indicator framework levels). Through the diversity of coverage of the Focal Components and also the diversity of knowledge of the co-development group members, this process was intended to provide a wide range of potential indicators with good coverage across the indicator framework and so represent the 'voice of the Gulf'.

Survey submissions were groomed so that similar indicators were given the same name and subsequently used to create a word cloud for each Focal Component, where the text font was larger for the indicators that were suggested more frequently. These word clouds were used to facilitate discussion (relating to suggested indicators and available data sets for each Focal Component) during a workshop in August 2023.

After the workshop, this additional feedback was then considered alongside the submissions received from the online survey. All the suggested indicators were then sorted into groups of similar indicators, which were then aligned with the indicator framework. Each of these indicator groups was then investigated so that candidate indicators could be refined and assessed against evaluation criteria (see below).

Candidate indicator refinement and evaluation

The indicator investigation process used experts and knowledge holders relevant to each of the indicator groups as well as the scientific literature on indicators. Once experts relevant to each indicator group had been identified, one on one conversations were held to ask: (1) What monitoring is taking place or could be suggested? (2) What specific indicators could be derived from that monitoring? And (3) What advantages and disadvantages are associated with different indicator options?

While the scientific literature (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010) suggested quite a discrete step-wise process from candidate indicator development to indicator screening, our experience was much more iterative and differed from the suggested process for a number of reasons. We found that we could not refine candidate indicators in isolation of an understanding of existing data or monitoring options or the consideration of whether a potential indicator would be a good one or not; these three considerations were interwoven. To produce candidate indicators without any consideration of data/monitoring options and indicator quality could have led to the generation of an endless list of meaningless candidate indicators.

Once candidate indicators had been refined and developed from the expert driven and interwoven process described above, the utility of these candidate indicators needed to be more formally considered. While the literature suggested a screening process that produced a discrete, somewhat finalised and constrained list of indicators (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010), that was not possible here for a number of reasons. First, it was important to be open to feedback from the co-development group rather than fixed. The final indicator suite would ultimately be decided at a later stage by FNZ, who would have additional management, political and budgetary trade-offs to consider. For these reasons we developed a traffic light approach which provided guidance about candidate indicator utility, but left room for subsequent feedback and final decisions to be made. The end result of this traffic light approach was to give each candidate indicator a High, Medium, or Low rating. The evaluation criteria considered in coming to this rating were derived from a review of screening criteria used in the literature (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010) as well as considerations specific to the Hauraki Gulf fisheries system and *Revitalising the Gulf* and are detailed in Table 1. Each of these eight evaluation criteria were themselves given a rating (according to specific categories described in Table 1) based on our understanding of the candidate indicator in question. The overall rating for the candidate indicator (i.e., High, Medium, or Low), was not arrived at by any specific combination of weighting or formulation from the eight evaluation criteria. Rather, more flexibility was allowed for in giving the overall rating for each candidate indicator.

Table 1 Evaluation criteria used to assess candidate indicators

Selection criteria	Categories
Relevance - the indicator is of importance to fisheries management in the Hauraki Gulf.	(N) No, (S) Somewhat, (Y) Yes.
Simplicity - the indicator is simple to understand and of public interest.	(N) No, (S) Somewhat, (Y) Yes.
Data availability - is there an existing time series of data that is available and likely to continue, or is more work needed to establish a time series?	(D) New method needs to be developed, (N) New data collection required, (P) Data collection planned, (E) Existing time series and will be continued, (C) There is an existing time series, but data collection has ceased.
Practicality & cost-effectiveness - is the indicator directly measurable, practical to measure and cost-effective to collect?	(N) No, (S) Somewhat, (Y) Yes.
Specificity - The indicator is sensitive to and therefore responds to the properties (environmental, management actions etc…) that are intended to be measured rather than other factors.	(N) No, (U), Unknown, (S) Somewhat, (Y) Yes.
Spatial scale - the indicator reflects the spatial scale of the Hauraki Gulf, or maybe more broad, limited or detailed.	(B) Broader than just the Gulf, (L) Limited site(s) within Gulf, (G) Whole of Gulf scale, (D) Detailed spatial resolution, (U), Unknown.
Quality - the data collection methods are of high quality.	(N) No, (S) Somewhat, (U) Unknown, (Y) Yes.
Comparability - has the indicator been used elsewhere in New Zealand or overseas?	(N) No, (U) Unsure, (Y) Yes.
Overall rating.	(H) High rating - the indicator could be adopted now, (M) Medium rating - some limitations to consider before the indicator could be adopted, (L) Low rating - limiting factors may be insurmountable, (W) Wait until new method/data collection has been developed/implemented before deciding.

The results from this indicator evaluation process were shared with the co-development group and then subsequently discussed during a workshop held during March 2024. Additional feedback was also sought after the workshop and where necessary this was used to refine the evaluation criteria and assessment of those criteria and in some cases introduce new candidate indicators.

Beyond the evaluation of individual candidate indicators on a line-by-line basis, it was also important to assess whether there were gaps in the existing research and monitoring to support the indicator suite as a whole. This step also enabled us to assess any efficiencies that could potentially be gained where data for multiple indicators could be gathered from the same deployment.

Communication of results

It is important that the final indicator ratings, and surrounding context as to how those ratings were reached, are effectively communicated with the co-development group and the public. Such communication helps to provide context and transparency. This report helps to serve that purpose, but additional shorter form communication is also required.

Results

Co-development-group-led indicator framework

Following the workshop in December 2022, the three Desired Outcomes from the Hauraki Gulf Fisheries Plan were used as the top level of a hierarchical indicator framework. These were:

(1) Healthy and functioning aquatic ecosystems

(2) Fisheries resources meet the needs of partners and stakeholders

(3) Inclusive and integrated participation in fisheries governance.

Together, these Desired Outcomes provide broad coverage of the Hauraki Gulf fisheries system by including:

- the fish populations that are exploited and the values that are associated with them
- the ecosystems that support those fish populations and fisheries
- the participation of the people that value those fisheries in the management of the fisheries themselves.

Co-development group feedback provided the lower levels of the indicator framework hierarchy, which are termed Focal Components and Key Attributes (Figure 2).

In general, this feedback emphasised the importance of non-extractive value, mātauranga/local knowledge, economic, social and cultural values, attitudes of the community, ecosystem functioning as opposed to just abundance, land-based effects, and the implementation of management actions. It is important to note that the initial version of this framework had multiple Key Attributes associated with 'Implementation of management and monitoring' interspersed throughout the framework. For clarity, and as outlined in the Introduction, implementation indicators are intended to detail progress that has been made with the implementation of the management and monitoring aspects of *Revitalising the Gulf*. For example, a potential management implementation indicator might be the % marine protection in the Hauraki Gulf, whereas an associated status indicator would be the relative abundance of fish in protected vs. non-protected areas. As indicators were developed and refined (see below), however, it was deemed more appropriate for these implementation indicators to be summarised at a higher level (otherwise there would be an implementation indicator associated with each management action specified in the Hauraki Gulf Fisheries Plan). As a result, most of these implementation Key Attributes were removed from the framework, other than for areas where implementation monitoring was already well developed (i.e., the Protected species and Fishery Focal Components). More generic implementation indicators covering the rest of the Hauraki Gulf Fisheries Plan are still developed below but sit alongside (not within) the indicator framework.

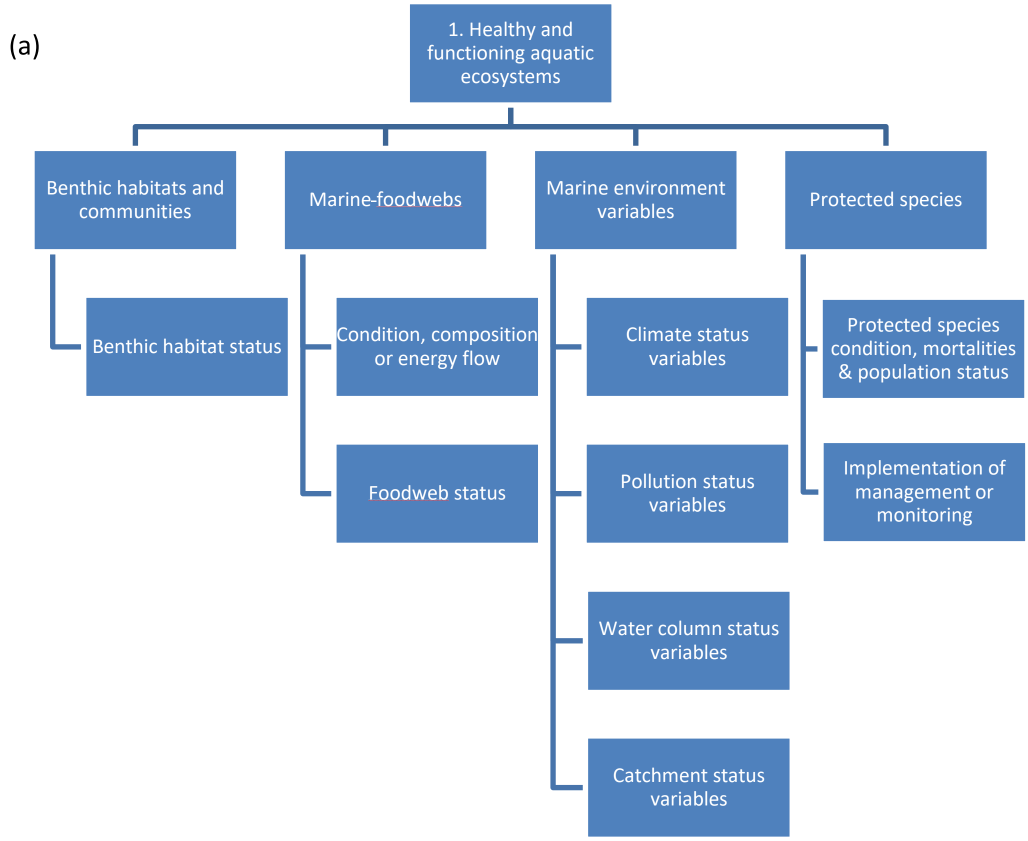


Figure 2 Hierarchical indicator framework co-developed to support the refinement and evaluation of fishery system indicators in the Hauraki Gulf. (a) Desired Outcome 1: Healthy and functioning aquatic ecosystems, (b) Desired Outcome 2: Fisheries resources meet the needs of stakeholders and partners, (c) Desired Outcome 3: Inclusive and integrated participation in fisheries governance. The lower levels of each Desired Outcome were derived from co-development group feedback and are referred to as Focal Components (middle level) and Key Attributes (bottom level). The indicators themselves are associated with the Key Attributes.

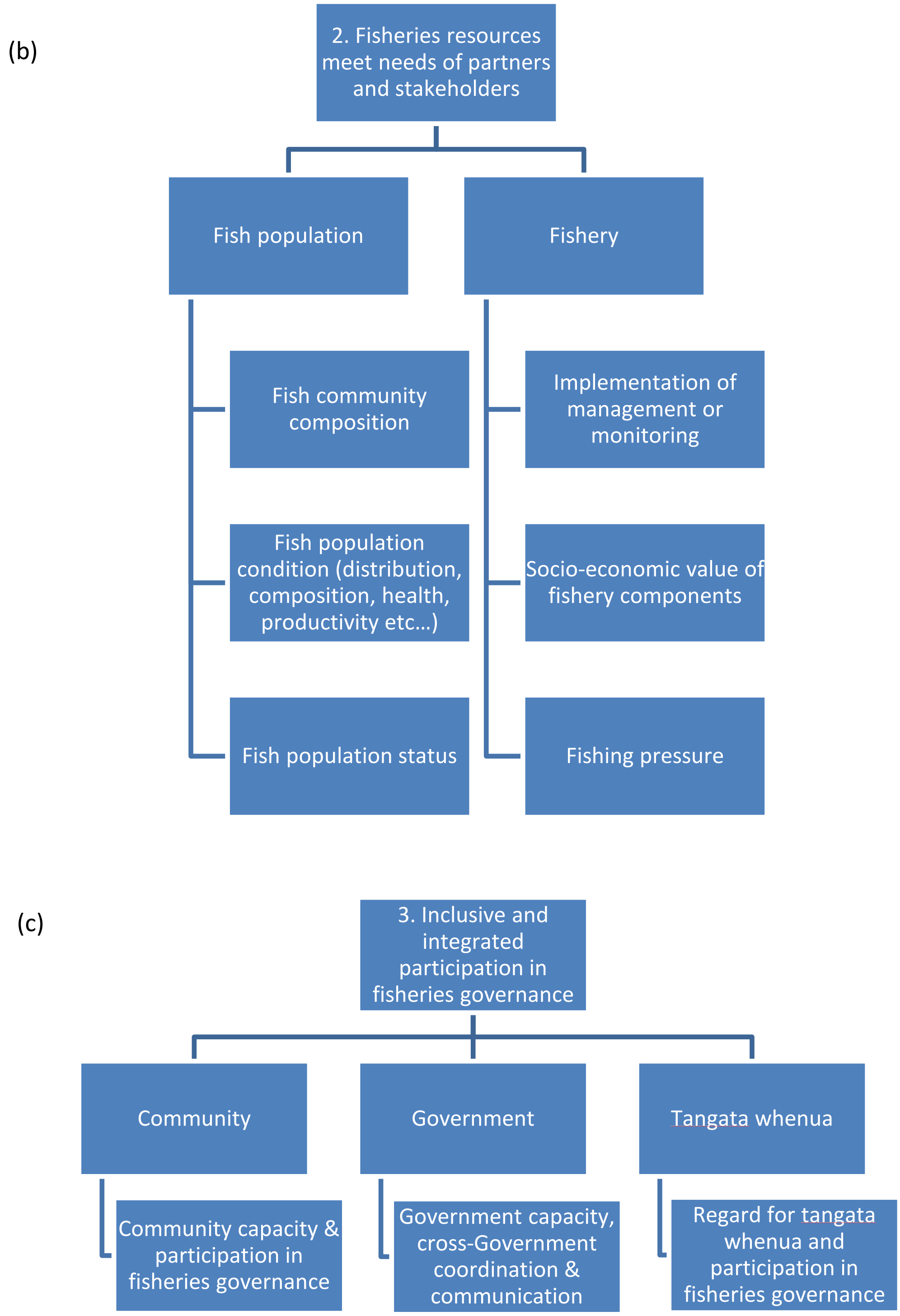


Figure 2 continued (legend on previous page).

Co-development-group-led indicators

A total of 530 indicator suggestions (289 of them unique) were provided by 36 co-development partners prior to the workshop held during August 2023. Indicator suggestions associated with the Government, Community, and Tangata Whenua Focal Components were the least common, while suggestions associated with the Marine Environment Variables, Benthic habitats and communities, and Fishery Focal Components were the most common.

Word clouds developed from these co-development group indicator suggestions can be found in Appendix 1. These indicator suggestions were then refined to a smaller set of more defined candidate indicators (utilising input from discussions with experts and knowledge holders), which were subsequently evaluated using the traffic light system described above. Below is a detailed discussion of the considerations that went into this refinement and evaluation process, organised according to the indicator framework hierarchical structure. All the specific candidate indicators considered are listed in ***bold italics*** (regardless of whether an indicator ultimately received a low or high rating). The purpose of this discussion is to provide transparency around what these considerations were (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010). The individual candidate indicator evaluation ratings and associated considerations are contained in the traffic light evaluation table found in Appendix 2. Together, the detailed discussion and the ratings in the traffic light evaluation are intended to be a resource to assist FNZ with selecting a suite of indicators to represent the Hauraki Gulf fishery system.

Healthy and functioning aquatic ecosystems

Benthic habitats and communities

Benthic habitat status

Known relationships exist between benthic infauna, the epibenthos and the water column, through biotic interactions and nutrient fluxes. Remote surveying of the epibenthos can represent overall benthic ecosystem functioning by documenting visually observable traits, also known as ***Benthic Functional Integrity*** (de Juan et al. 2014). The functional integrity elements that can be documented include spatial heterogeneity, structural complexity and functional diversity. A major advantage of such a method is that it is conducted visually from towed video transects, so is relatively quick and cheap to implement, and the traits that are documented are generic (non-location or species specific), so are able to be applied across a region. Such a process has been applied to a case study in Kawau Bay (de Juan et al. 2014), with a manual (Hewitt et al. 2014) subsequently developed for the application of this methodology.

While some towed video monitoring of habitats has already been conducted within the Gulf (e.g., Lohrer & Douglas 2019), coverage has not been comprehensive and the methodology used not standardised. Monitoring of benthic habitats in the Hauraki Gulf, however, is already planned through an existing FNZ and Department of Conservation (DOC) project to use a new towed video methodology called Swath Cam to document habitat recovery in relation the implementation of trawl corridors and High Protection Areas (HPAs). Application of a functional integrity methodology to such monitoring could therefore provide a useful indicator of soft sediment habitat quality.

Such monitoring also offers great potential to explore additional aspects and applications. For example, combination of Swath Cam transects with multi-beam mapping could enable broader coverage. The videos collected could also allow the identification of particular organisms (e.g., sensitive species often referred to as Vulnerable Marine Ecosystem taxa) so that their distribution and occurrence could be compared through time. Voyages utilising Swath Cam for monitoring may also have potential to gather additional information for other parts of the indicator suite. For example, demersal fish abundance, sediment type, and suspended sediment could also be obtained from Swath Cam videos. In addition, the Swath Cam voyages themselves could also be used to deploy other monitoring methodologies such as running acoustic transects or deploying other sampling techniques such as Baited Underwater Remote Video (BRUV).

The Swath Cam surveys planned by FNZ and DOC in 2024 will only document habitats in water >40 m (where the trawl corridors are). Additional surveys will be needed to document shallow water habitats which are known to have great value to fishes (especially as nursery habitats for juvenile fishes (Parsons et al. 2016)).

There are a few important considerations for this shallow water habitat work. Juvenile fishes generally respond to the structural elements of habitat rather than the particular types of structure, so the functional integrity methods described above are likely also suitable for documenting nursery habitats. Different sampling methodologies may be more appropriate in very shallow water (e.g., aerial or satellite images of shallow water seagrass) and murkier water (e.g., acoustic methods such as side scan or multi-beam).

Work conducted on these shallow water habitats should be conducted in coordination with FNZ guidelines for habitats of particular significance for fisheries management (Fisheries New Zealand 2022a), which is still under development. In this regard, the utility of habitat monitoring conducted by WRC and AC is worth considering. The core of this estuarine monitoring programme is based around the quantification of intertidal macrofauna and sediment quality across a number of Hauraki Gulf estuaries. The data are then used to categorise an estuaries' relative ecosystem health, based on its community composition and predicted responses to storm-water contamination (Hewitt & Ellis 2010). These ***Benthic Health Model scores*** could provide a useful indicator in themselves and they are freely available on the Land, Air, Water Aotearoa (LAWA) website (https://www.lawa.org.nz/explore-data/estuaries/) (Figure 3).

While their direct relevance to fisheries (considering the intertidal nature of the monitoring) may be questionable, recent work suggests that the relationships used to form Benthic Health Programme scores may still apply well down to 25 m depth (D. Lohrer, NIWA, pers. comm.). A selection of the sites monitored could be used to provide the best overlap with locations known to have value in providing habitat to fishes.

Other options for documenting ***shallow water habitat*** include habitat mapping conducted by WRC and AC, who have used a combination of aerial/satellite footage combined with ground truthing to map habitats in intertidal areas. This mapping would need to be expanded into shallow subtidal areas (potentially using drop camera and grab samples) to provide utility in documenting shallow water habitats of value to fishes (e.g., to document seagrass etc.).

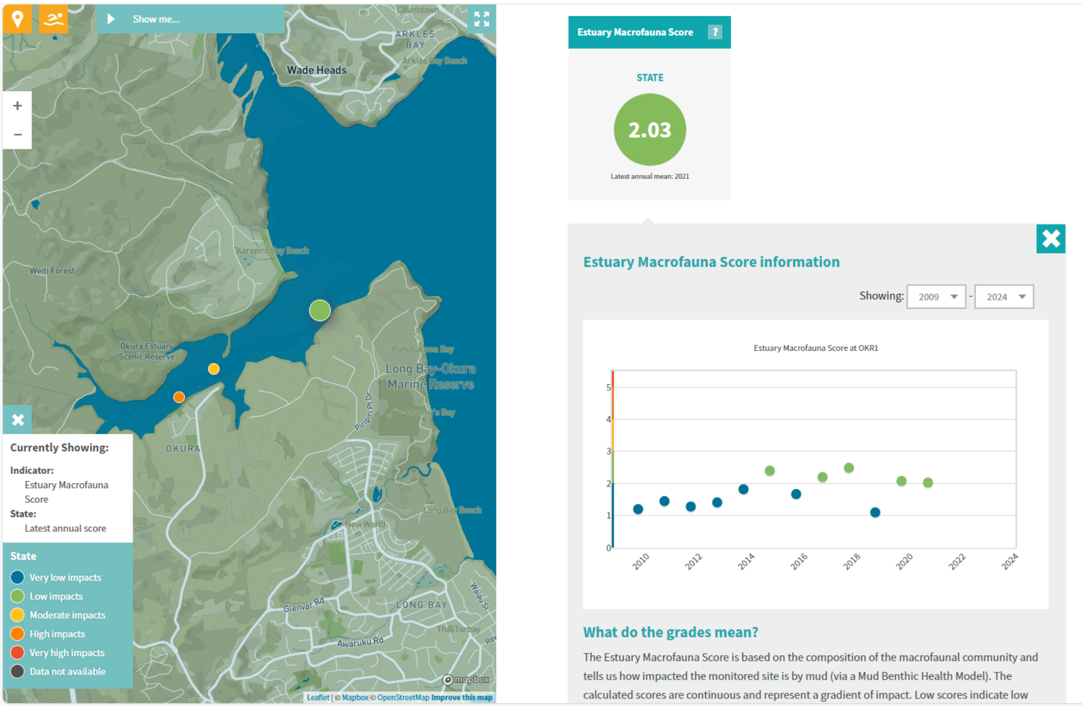


Figure 3 Example of Estuarine Macrofauna Index score from the LAWA website https://www.lawa.org.nz/explore-data/estuaries/. This example is from the Okura monitoring site with data collected by Auckland Council (image captured 29 April 2024).

Large areas of rocky reef in the Hauraki Gulf are dominated by kina barrens in shallow coastal areas where kelp once thrived. Kina barrens support a lower biodiversity due to the loss of ecosystem services, including provision of food and shelter, provided by kelp forests. And once established, they are difficult to reverse.

While a lot of very valuable research has been conducted on kina barrens in the Hauraki Gulf by the University of Auckland (Shears & Babcock 2002, Shears et al. 2004, Shears et al. 2008), FNZ is currently in the process of investigating kina barren monitoring options. For example, a project to establish a timeline of kina barrens formation (from historical photography, satellite imagery, and local ecological knowledge from fishers and iwi) is being set up and a standardised kina barrens monitoring programme could be established in the future.

Any indicator suggested to monitor the extent of kina barrens in the Hauraki Gulf could potentially change as these methodologies and associated monitoring are developed. However, there is already an extensive data set on kina barrens in the Hauraki Gulf from University of Auckland research (Balemi & Shears 2023 and Peleg et al. 2022). This research has used a combination of dive transects, drop camera and drone footage to record habitat type every five metres along transects down the reef. The suggested indicator is the ***% of reef that is kina barren***, but this needs to be limited to the maximum depth of kina (which is about 15 m, but varies by location) (Nick Shears, University of Auckland, pers. comm.).

Five Gulf locations (Mokohinau Islands, Cape Rodney to Okakari Point (CROP), Tawharanui, Hahei and Long Bay) have been included in this monitoring back to 1999. At all but the Mokohinau Islands these sites have paired comparisons of kina barrens inside vs outside of marine reserves. Three additional monitoring locations (Hauturu Little Barrier Island, Noises Islands, Mercury Islands) were subsequently added in 2017. As previously mentioned, this indicator will need to be adapted to account for method development and/or additional sites included through potential upcoming FNZ funded research and expanded HPA monitoring.

Marine environment variables

Water column status variables

A wide range of water column status variables can be monitored and many different data sets are available. There are two datasets from the Firth of Thames, which can be thought of as a sentinel site as it is the Hauraki Gulf location most likely to be influenced by land-based effects (which can flow through to influence fisheries).

A NIWA dataset from the Firth of Thames, which has two components (Zeldis & Swaney 2018). The first of these relates to measurements conducted from two moorings (inner and outer Firth), which extends back to 1998 at the outer mooring and 2005 for the inner mooring. The variables available from these moorings include: conductivity, temperature, dissolved oxygen, turbidity, and Chlorophyl a (Chl a), which are measured throughout the water column.

The second component of the NIWA dataset relates to quarterly voyages that were conducted to maintain the moorings where additional variables were measured including nutrients, conductivity, and temperature measurements through the water column (i.e., Conductivity Temperature Depth (CTD) measurements), pH, total chlorophyll, pH, microphytoplankton, microzooplankton, mesozooplankton, and picoplankton/bacterio-plankton. Both of these data sets, however, were discontinued in May 2023.

WRC monitoring of the Firth of Thames. Similar to the NIWA dataset, this includes some variables monitored at an inner and outer Firth location by buoyed instrumentation (providing conductivity, temperature, dissolved oxygen, turbidity and Chl a, but only through the water column at the outer buoy location). In addition, monthly sampling is also conducted at ten Firth of Thames sites for additional variables including: turbidity, total suspended solids, nutrients, Chl a, and various measures of carbon. These datasets were initiated in 2022 (buoy data) and 2020, respectively, and are planned to be ongoing (dependent on budget availability). The inner WRC buoy location is close to the location of the discontinued inner NIWA mooring, so it could be possible to merge datasets to provide an extended and ongoing timeseries. WRC also conducts monthly sampling (for the same variables they measure throughout the Firth), but at the mouths of the Piako and Waihou Rivers (the two Firth of Thames rivers responsible for about 80% of the Gulfs freshwater discharge (Green & Zeldis 2015)). WRC also has a network of sediment settlement plates that monitor sedimentation concentrations in a handful of Gulf estuaries, with the Firth of Thames having the longest dataset.

The ***Firth of Thames in situ observations*** described above are accurate, can provide more variables (e.g., nutrients, oxygen, plankton samples), but conversely are more expensive to conduct (and therefore may not provide time series certainty), and do not have the temporal frequency, spatial coverage or cost efficiency of ***satellite observations***. A range of water column variables can be measured remotely from satellites through NIWA-SCENZ (Seas, Coasts and Estuaries, New Zealand) at 100–250 m spatial resolution on a monthly basis back to July 2002 (Gall et al. 2022, Pinkerton et al. 2023a) (e.g., Figure 4). Variables available include: ADET, Absorption of detrital material at 443 nm (/m); BBP, Particulate backscatter at 555 nm (/m); CHL, Chlorophyll *a* concentration (mg/m^3); EBED, Light (Energy) at the sea bed (mol photons(E)/m^2/d); HVIS, Black disk horizontal visibility distance (m); KPAR, Downwelling light attenuation of PAR (400–700 nm (/m); PAR, Photosynthetically Active Radiation (mol photons(E)/m^2/d); POB, Proportion of Observations (0-1); SEC, Vertical visibility of a black and white Secchi disk (m); SST, Sea Surface Temperature (degrees C); TSS, Total Suspended Solids (g/m^3) (Gall et al. 2022, Pinkerton et al. 2023a).

Satellite observations are well suited as indicators given their cost-effectiveness, time series certainty, and the flexible spatial coverage they provide. Of the many variables provided by satellite observations, SST, Chl a, and TSS are the simplest to understand and most likely to relate to fisheries. The spatial domain for indicator time series for these variables could be defined for the whole of the Hauraki Gulf or spatial subcomponents as needed.

Satellite observation-based indicators could also be supplemented by WRCs ongoing monthly water sampling and buoys to monitor the Firth of Thames and river mouth sediment concentrations as a sentinel site. The most relevant variables from these samples are Total Nitrogen (which underpins primary production), turbidity and DO (an indicator of eutrophication). An additional water column status variable index that may be worth considering is ***Firth of Thames river mouth deposition rates*** measured from settlement plates, which may help to understand the relationship between sediment discharges at the river mouth, suspended sediment in the water column and settlement on the seafloor (which can impact habitats of importance to fisheries). In addition, mud content scores are monitored at a number of estuarine sites (by AC and WRC), with ***mud content scores*** freely available on the LAWA website. While measurements of various components of the ***plankton*** could be informative, there is no ongoing monitoring, they are expensive to monitor and they can be substituted (at a coarse level) by Chl a obtained from satellite observations.

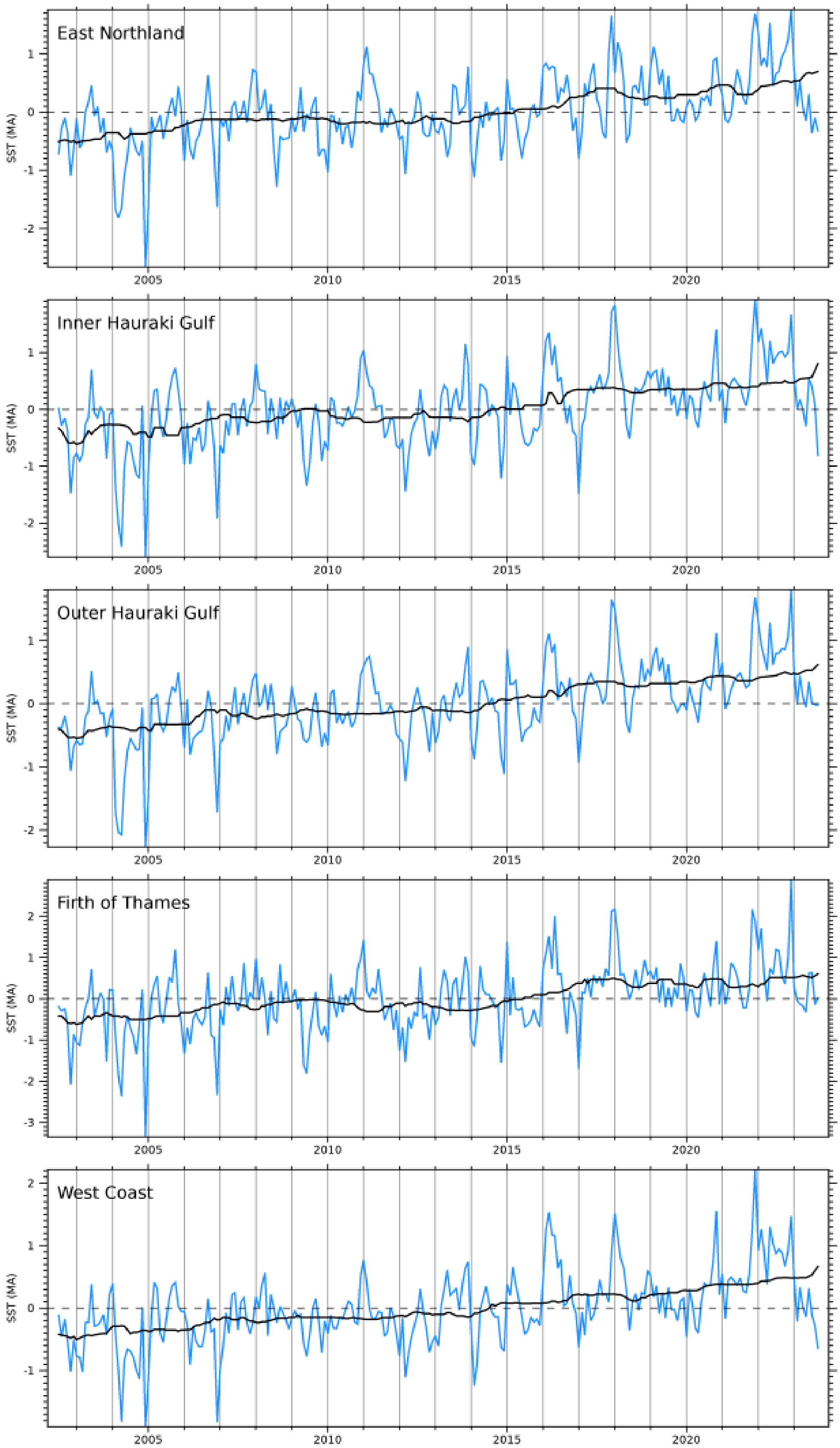


Figure 4 Example of satellite data available from NIWA-SCENZ (Pinkerton et al. 2023a) for monthly sea surface temperature anomalies (°C) (difference compared to the average monthly temperature over the time period of the plot) for custom defined regions around the upper North Island (black line is a 4-year rolling median).

Catchment

Variables that describe changes in land-based processes, which can subsequently affect marine systems, could make useful indicators relevant to fisheries.

The ***Land Cover Database*** (LCDB) uses remote sensing to describe the extent of vegetation, built environments, water bodies, and bare natural surfaces throughout New Zealand every five years, including the catchment of the Hauraki Gulf (https://www.landcareresearch.co.nz/publications/). While land cover is important, by itself it does not describe changes in land use practices, which can be more dynamic. For example, if forestry practises, housing density, stormwater management, livestock density or farming practises are changed but the underlying land cover type does not, this will not be reflected by the LCDB.

It is possible to derive more informed land use that incorporates these practises, but information is not always available on changes in ***land use*** practice and such a product would need to be derived every time an update is required. Given the doubt around land use practice and the ongoing requirement for update it may therefore be more effective (and directly related to fisheries) to monitor the consequences of changes in land use practise, which will be seen in riverine and marine environments through changes in nutrients and turbidity. The previous section on water column status variables detailed a number of nutrient and turbidity indicators that could serve as proxies for catchment variables.

Climate status variables

Climate can influence a range of variables (e.g., temperature, wave action/currents/water mixing, nutrient availability, turbidity) which themselves can impact fisheries. There are well-known relationships between climatic variables and fishery or fish population productivity (Dunn et al. 2009), and climate conditions contribute to variability that drives marine environments. In addition, there are multiple climatic variables that have extensive time series which are regularly updated and are freely available.

The choice of which climate variables are important for monitoring marine systems and fisheries hinges on the appropriate spatial scale being examined and the relative degree of direct or indirect impact on the marine environment. At the large-scale, indicators such as the ***Southern Oscillation Index*** relate to climatic processes across large parts of the atmosphere that are distant to New Zealand, but which influence our oceans and atmosphere via teleconnections. Alternatively, indicators such as ***Trenberth indices*** (Trenberth 1976) (e.g., Figure 5) or ***Kidson's synoptic weather types*** (Kidson 2000) describe atmospheric conditions over the New Zealand region that lead to highly variable and localised impacts on air-flow temperatures and rain. These more localised indices help to capture the idiosyncratic nature of localised climate conditions while being connected to *in situ* marine observations as well as larger climate modes such as El Niño-Southern Oscillation (Andrew Lorrey, NIWA, pers. comm.).

The Trenberth indices are relatively simple because they establish a difference in atmospheric pressure between two fixed locations that reflects wind flow strength in a generalised direction. The Trenberth indices are available as extensive time series and have enough spatial granularity to provide both regional and local impacts from prevailing winds. The most appropriate Trenberth indices for the Hauraki Gulf are likely:

- M1: the pressure difference between Hobart, Australia, and Chatham Island, New Zealand, which measures north-south flow over that region
- Z4: the pressure difference between Raoul Island and Chatham Island which measures west-east flow over that region.

These indicators could be useful in understanding how nutrient availability changes in response to climate regimes through wind-driven upwelling (Zeldis et al. 2005) and seasonally due to surface temperature anomalies.

Another indicator for consideration could relate to rainfall as a driver of sediment transport to nearshore marine systems. A number of rain gauges within the Hauraki Gulf catchment could be used for that purpose. It would be possible to develop an index that uses these gauges to represent ***integrated rainfall*** across a user defined area (Beck et al. 2019). Of particular interest may be a ***rainfall volatility index***, which would reflect episodic extreme rainfall and impacts of those events like sediment erosion/deposition. Further work would need to be conducted to develop either a catchment integrated rainfall index and/or a rainfall volatility index specific for fisheries.

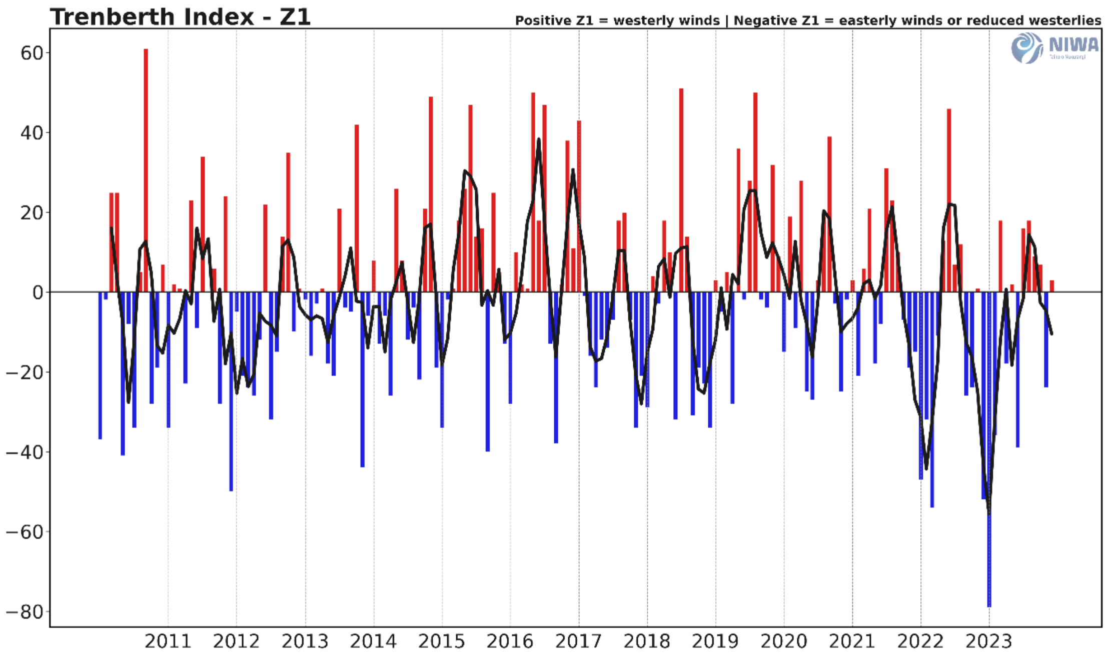


Figure 5 Z1 Trenberth Index between 1 January 2010 and 30 November 2023. Positive values indicate westerly winds, and negative values indicate easterly or reduced westerly winds. Each bar represents the monthly values, and the black line shows the three-month rolling average Z1 index. Grey vertical lines indicate January of the corresponding year.

Pollution status variables

Pollution and invasive species are recognised as posing significant risks to the functioning and health of the Hauraki Gulf. Due to the recognition of their impacts, both pollution and invasive species are monitored regularly and systematically. Several long-running datasets are available for contaminants. However, datasets regarding novel pollutants like plastic debris and new to New Zealand species are more sporadic and spatio-temporally restricted. Due to the broad range of variables that can be monitored, there are several relevant indicators and data sets available. Briefly, some of the most relevant of these are:

Faecal bacteria (E. coli and Enterococci) concentrations, and swimmable days are monitored by regional councils and authorities around New Zealand. For the Hauraki Gulf area, both AC and WRC record and report on 'swimability' and bacterial loads for public-health purposes.

Although the data collection methods vary, both AC and WRC submit these data to the LAWA website which presents both current and historical data to the public. *E. coli* is a bacteria commonly found in freshwater systems originating from human and animal waste and stormwater runoff. *E. coli* bacteria can cause illness in humans when concentrations reach threshold levels. Many Regional Councils monitor *E. coli* levels in freshwater systems as part of their State of the Environment monitoring (Auckland-Council 2021) and during the summer months at coastal swimming locations.

In marine and coastal environments Enterococci are the preferred biological indicator for faecal contamination. WRC monitors beach water for faecal contamination for 22 weeks over summer, however AC uses a combination of stormwater and freshwater discharge monitoring and predictive models to forecast water quality at swimming sites which are reported in real-time on the safeswim website (https://www.safeswim.org.nz/).

Additional to bacterial sampling and modelling, as part of the Long-Term Plan process, AC records the number of beaches permanently closed for swimming, the number of swimmable days and performance against a baseline year (2017) for swimability and bacterial contamination (M. Carbines, Auckland Council, pers. comm.).

Both regional councils have in the past monitored the faecal contamination of shellfish, but these datasets have been discontinued. Faecal bacteria loads, and swimming water quality are unlikely to impact the fisheries stock status in the Hauraki Gulf. However, high faecal bacteria loads, and subsequent beach closures may impact people's access to, and enjoyment of, recreational fisheries. Despite the indirect links to commercial fisheries, the availability of high-quality data and the high level of public concern related to faecal contamination in the Hauraki Gulf suggests that an indicator based on faecal bacteria monitoring would have high utility.

In a 2021 survey of the public attitude toward the Hauraki Gulf, plastic pollution was recognised as the threat that had the most significant negative impact on the Hauraki Gulf (Figure 6) (Stevenson & Colman 2021). The ***amount of plastic pollution on beaches*** in the Hauraki Gulf is a novel indicator of ecosystem health in New Zealand and the Hauraki Gulf. Although anthropogenic litter and plastic waste is reported intermittently in peer reviewed literature (Backhurst & Cole 2000, Shetty 2020, Young & Adams 2010) this information and data is scattered across sources, impacts and locations.

In 2018, the litter intelligence project was launched, which uses a standardised survey method to collect beach litter data nationally (https://litterintelligence.org/about/) (Figure 7). AC supports and utilises the litter intelligence surveys to inform their pollution management and long-term plan. AC also have tetra traps on some stormwater drains, which they use to report the volume of debris flowing from freshwater systems into the coastal environment. However, these data are patchily distributed around the region. The litter intelligence project categorises the types and sources of rubbish found on beaches, which could be used to develop a metric describing plastic volume obtained during these surveys. While it would be possible to create a specific index of fishery-derived plastic, this type of plastic only makes up a small proportion of the plastics found on beaches in the Auckland region. Therefore, a generic plastic pollution volume metric is probably more appealing. Beyond macro-plastics, microplastics are being found in marine sediments and food webs. Recent studies of microplastics in fish (snapper, yellow belly flounder, gurnard, jack mackerel, kahawai and pilchard) found that 25% of all fish samples in the Hauraki Gulf contained microplastics (Shetty 2020). Faecal sampling of Brydes whales has also identified microplastics are present in these top predator diets (Zantis et al. 2022). In fish, microplastics can cause tissue damage, oxidative stress, and changes in immune-related gene expression as well as antioxidant status (Bhuyan 2022). These impacts can lead to reduced growth, reproductive capacity, and survival. The impacts of microplastics on human health are poorly understood.

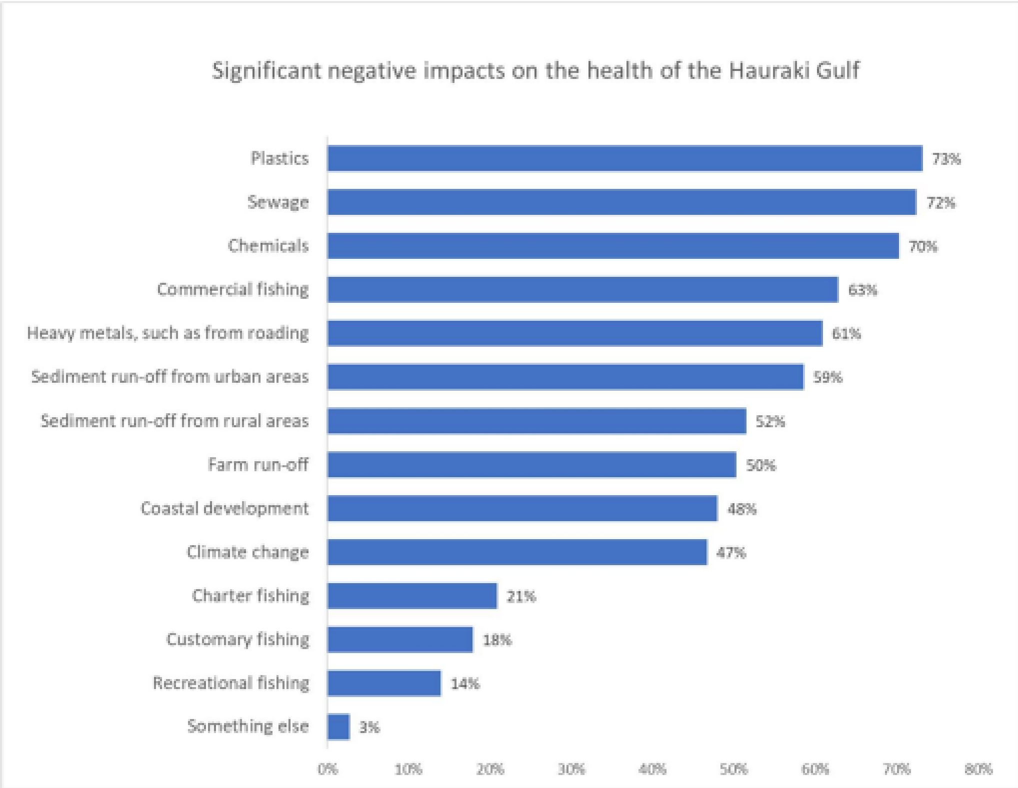


Figure 6 Results of Horizon Research Hauraki Gulf survey conducted for the Hauraki Gulf Forum for a question related to the public perception of the most significant risks to the health of the Hauraki Gulf Source: https://gulfjournal.org.nz/2021/11/results-of-hauraki-gulf-poll/

The amount and composition of marine plastic may not affect fisheries at a Hauraki Gulf scale or management directly, but fisheries are likely contributing to plastic pollution. If the perceived or actual amount of fisheries-origin marine plastics is high it could impact public perception, social licence, and support for fisheries and there may be management implications to ensure gear doesn't end up breaking away as pollution. Although the data for the quantity and source of microplastic contaminations in sediments and the food chain are less readily available than other litter data, microplastics could reduce fishery species growth and fecundity. The public importance, access to data, and the potential fisheries impacts suggest that the amount of plastic pollution on beaches in the Hauraki Gulf is a high priority indicator.

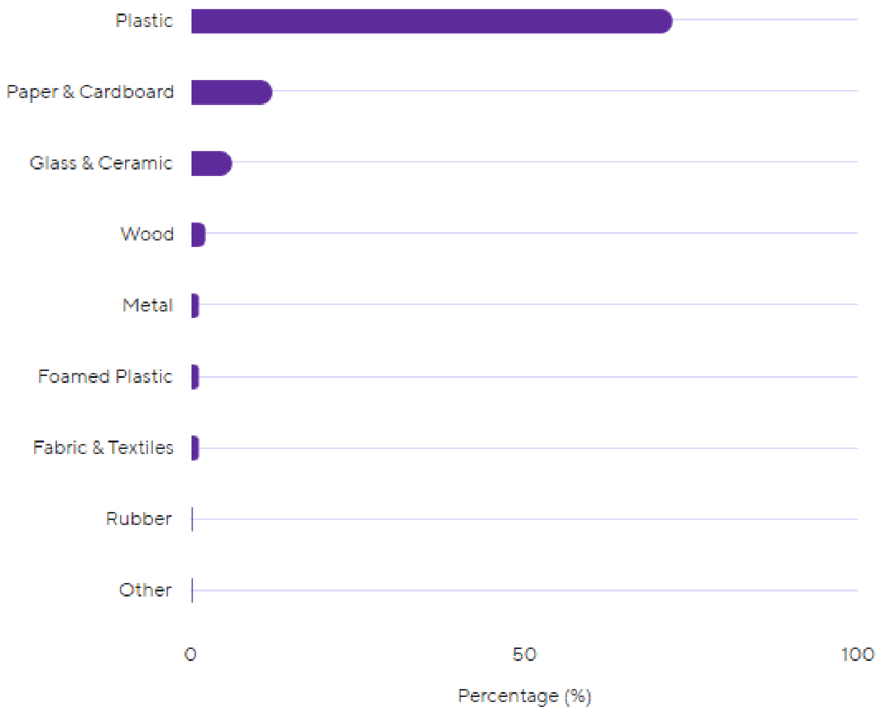


Figure 7 Beach litter intelligence monitoring data for Little Bucklands Beach - South end depicting the composition of the litter collected over 11.3 survey hours. These data were collected using the standardised methods designed by litter intelligence. Source: https://litterintelligence.org/data/survey?id=3043

Heavy metal concentrations in marine sediments in the Hauraki Gulf have been monitored by AC at approximately 120 sites as part of the Regional Sediment Contaminant Monitoring Programme (RSCMP) since 1998 (Aguirre et al. 2016, Mills & Allen 2021). Copper, lead and zinc are monitored every two years with other metals (including arsenic and mercury), and organic contaminants monitored approximately every four years since 2012 (Aguirre et al. 2016).

A key focus of the RSCMP is to manage the impacts of urban development, which means sampling is focussed on predominantly urban catchments within the Hauraki Gulf (industrial areas, commercial and residential areas, and new and developing urban catchments).

Sediment contaminant concentrations are graded according to AC's Environmental Response Criteria (ERC) traffic light system. ACs monitoring of estuarine sediments indicates that lead and copper are decreasing in concentration at most sites, whereas zinc is increasing (Mills & Allen 2021). Arsenic and mercury show no clear trends over time, but mercury is typically higher at sites that are also high in copper, lead, and zinc (e.g., sites affected by stormwater and wastewater discharges, Allen (2023)). These data are publicly available for estuaries and selected monitoring sites and is reported through the LAWA website (https://www.lawa.org.nz/explore-data/auckland-region/estuaries/waitemata-harbour-central).

One major concern with using heavy metal concentrations from sediments is their relevance to fisheries, due to limited overlap with fished species. This could be partially addressed by refining any metric derived to represent just the locations where intertidal shellfish harvesting commonly occurs.

An alternative method for assessing heavy metal concentrations that is more relevant to fisheries and the food web is to assess ***heavy metal concentrations in seabird blood and feather samples.*** Blood and feather samples can be used to inform about the level of heavy metals in seabird populations but by proxy also the heavy metals in their prey species which are fisheries resources (Bowman et al. 2020, Choy et al. 2009). However, monitoring of heavy metals in the food web or mesopelagic species is difficult due to the logistical constraints and costs associated with sampling organisms that may occur far out to sea and at appropriate spatio-temporal scales (Furtado et al. 2021). Although the data collection and sampling has been initiated, extracting spatial information regarding the levels of contaminants in the Hauraki Gulf from seabird feathers may be challenging (Lyver et al. 2017). For wide-ranging and oceanic seabirds determining prey and feeding locations can be difficult. Seabirds may be feeding well outside of the Hauraki Gulf meaning that this indicator may not provide much relevant insight into the impact of heavy metals on fisheries in the Hauraki Gulf. While this metric could be a valuable source of information specifically related to seabirds themselves, it has too many uncertainties and artefacts to be a high utility indicator.

The impacts of dredging on benthic ecosystems in the Hauraki Gulf are of high public concern, particularly in areas near shellfish beds and where there is significant resuspension of sediment. For the purposes of this section of the report, we define ‘dredging’ as the movement or removal of marine sediments. Dredging for fisheries or biosecurity purposes are excluded.

Monitoring the ***frequency of dredging activities and the amount of substrate moved*** annually in the Hauraki Gulf could inform about the impacts to benthic communities by physical damage or smothering resulting from sediment resuspension (Gregory et al. 1993). Dredging activities in the Hauraki Gulf coastal area are non-complying or discretionary activities in both the AC unitary plan and the WRC coastal plan.

To undertake dredging works and discharge sediment in the coastal marine area requires resource consent throughout the Hauraki Gulf. These consents will generally include information on the dredge location, frequency, volume, and potential discharge locations.

Consent data can be used to inform an environmental indicator. However, the collation of the regional council consent data would require manual data collection from actual consent applications, reporting, and consent requirements. Dredging activities are very patchily distributed and may not be occurring in areas where fisheries are concentrated. Any dumping of dredge spoils or waste beyond the 12 nautical mile limit is controlled by the Environmental Protection Authority (EPA). While an additional consent is required this may be non-notified in specific locations. The location specific impacts and volume of materials to be dumped outside the 12-mile limit would likely still be able to be obtained from EPA records. Due to the patchy spatio-temporal distribution and frequency of dredging and the likely localised impacts on fisheries, we suggest that an indicator based solely on the amount of dredging activity in the Hauraki Gulf may not have great utility. However, if dredging does occur regularly in areas of known importance to fishery species or restricting access to fisheries this may need to be reconsidered.

The Hauraki Gulf is adjacent to the largest city in New Zealand and is a major international, domestic, commercial, and recreational shipping hub. The amount of international and domestic vessel movements to and within the Hauraki Gulf makes it a high-risk location for non-indigenous species introduction and domestic spread. By measuring the ***diversity and number of records of invasive and non-indigenous marine species*** in the Hauraki Gulf managers and stakeholders will be informed about the prevalence and spread of novel species that may pose risks to fish populations and their supporting habitats. Globally Non-Indigenous

Marine Species (NIMS) have been known to impact biodiversity, ecosystems and the local economies by outcompeting or smothering native species (Anton et al. 2019). Invasive crustaceans, molluscs and seaweeds have been identified as the taxonomic groups that have the most significant ecological impacts (Molnar et al. 2008). NIMS are classified as a 'National Indicator' of the condition of New Zealand's marine environments (Seaward & Inglis 2018).

By 2017 approximately 214 marine non-indigenous species had become established in New Zealand (https://www.stats.govt.nz/indicators/marine-non-indigenous-species/). Although most NIMS will likely have minimal impacts, some species can modify natural habitats (*Arcuatula senhousia*, Asian bag mussel, *Sabella spallanzanii,* Mediterranean fanworm (Atalah et al. 2019, Tait et al. 2020), and *Undaria pinnatifida* (James 2016)), some are predators of native species (*Charybdis japonica,* Asian paddle crab (Fowler 2011)) and some are nuisance foulers in aquaculture systems (*Eudistoma elongatum,* Australian droplet tunicate, *Styela clava,* clubbed tunicate (Soliman & Inglis 2018), Mediterranean fanworm, and *Undaria* (Watts et al. 2015)).

There are three main datasets for invasive species in the Hauraki Gulf that are collated and publicly available on the biosecurity porthole, an online database of verified non-indigenous species occurrences managed by NIWA on behalf of Biosecurity New Zealand (BNZ) (https://www.marinebiosecurity.org.nz/). The interactive mapping-based platform displays verified observations on the distribution of NIMS from a series of biological baseline surveys conducted in ports, ongoing Marine High Risk Site Surveillance (MHRSS) and records from specimens reported via the passive surveillance system and identified through the Marine Invasives Taxonomic Service (MITS) (Figure 8).

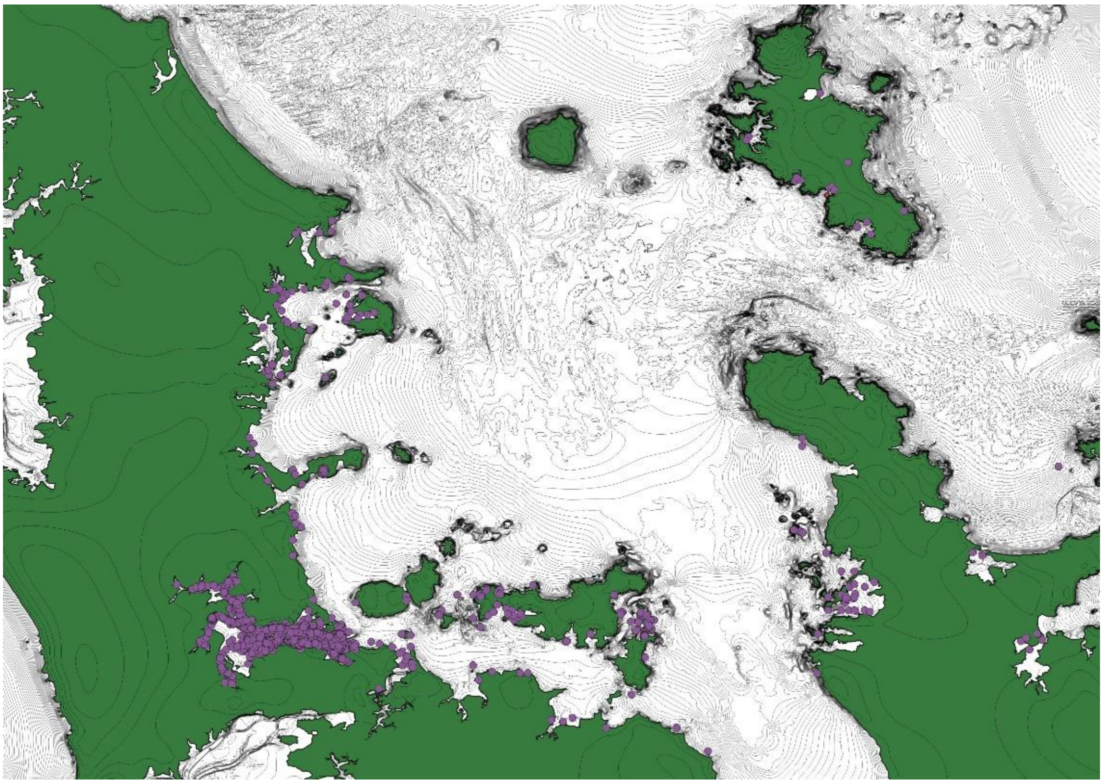


Figure 8 All non-Indigenous Marine Species (NIMS) records for the Hauraki Gulf to 2023 from the Marine Biosecurity Portal. Source: Marine Biosecurity Portal (2023) available online at https://marinebiosecurity.org.nz/search-for-species/ licenced under a Creative Commons Attribution 4.0 International Licence

Although there is a significant amount of data captured within the biosecurity portal it is spatially restricted and somewhat patchy. Within the Hauraki Gulf, the marine biosecurity porthole has over 41 000 records of NIMS (K. Seaward, NIWA, pers. comm.), most of the porthole data is sourced from the MHRSS, a programme undertaken every six months by NIWA in 12 of New Zealand's busiest international shipping ports and marinas. Although this is a long-running and replicated dataset the sampling within the Hauraki Gulf is restricted to the inner Waitemata and port area (Seaward et al. 2015) which may be spatially misaligned with important fisheries or fishery species habitats. Additional to the MHRSS, AC and WRC have undertaken surveillance diving for certain species in high value or high-risk locations in the wider Hauraki Gulf for the last five years. There is currently a push from regional authorities and citizen science groups to develop a marine biosecurity data-sharing portal, this may increase the coverage of surveillance datasets to be more useful to evaluate fisheries and ecosystem indicators in the Hauraki Gulf.

The impacts of most NIMS on commercial and recreational fisheries and target species in the Hauraki Gulf are yet to be determined. Anecdotal evidence for certain established NIMS (the Mediterranean fanworm, *S. spallanzanii;* exotic Caulerpa, *Caulerpa brachypus* and *Caulerpa parvifolia*) suggests that they may impact fisheries species in particular benthic bivalves such as scallops. Although data for occurrences of all NIMS in New Zealand are readily available on the Marine Biosecurity Portal, simply reporting the number of NIMS within the Hauraki Gulf or the number of sightings annually may not be a useful indicator relevant to fisheries.

Developing indicators for those established and novel NIMS that have suggested known fisheries impacts may be the most effective use of resources. For example, the known infested area of exotic Caulerpa in the Hauraki Gulf could be a useful indicator particularly when combined with the distribution of the species it is known to impact (i.e., dog cockles and scallops). The establishment and spread of novel NIMS that have recognized fisheries implications overseas (*Caulerpa taxifolia, Carcinus maenas* and *Asterias amurensis*) from MHRSS data could be a useful future indicator.

Currently, the most topical marine pest incursion in the Hauraki Gulf is the discovery of exotic Caulerpa at Aotea Great Barrier Island, Waiheke Island, the Mokohinau Islands, Rakino Island, and Kawau Bay. Exotic Caulerpa could potentially impact benthic bivalve stocks and fisheries and population monitoring data could be useful for assessing the impacts of marine pest species on fisheries in the Hauraki Gulf if monitoring intensity is maintained and expanded. An indicator measuring the ***area of seafloor in the Hauraki Gulf with exotic Caulerpa*** will inform about prevalence of exotic Caulerpa, the rate of spread and the threat it may pose to fish and shellfish populations or their supporting habitats. NIWA, AC, Ngāti Rehua, Ngāti Manuhiri, Ngāti Paoa and citizen scientists have undertaken diver-towed camera and Remote Operated Vehicle (ROV) based surveillance, which could be used to inform about such an indicator. Currently, the data is restricted to areas within the proximity of known infestations including Aotea Great Barrier Island, Ahuahu Great Mercury Island, Waiheke and Kawau Island.

Exotic Caulerpa is likely to persist in the Hauraki Gulf for some years to come, mapping the extent of the infestation through time will assist in identifying areas and habitats that have been impacted negatively by the alga. Particularly relevant will be the amount of interaction between exotic Caulerpa infestations and known biogenic habitats or shellfish beds including scallops, sponge beds, dog cockles, and horse mussels. Since the discovery of exotic Caulerpa in the Hauraki Gulf, BNZ, and local hapū have implemented access and fishing closures to slow the spread. Areas around Aotea/Great Barrier Island have been closed for over three years, and closures have been implemented at Waiheke Island. These closures reduce access to both commercial and recreational fisheries and can have significant impacts on isolated island communities. However, these closures particularly the statutory closures made by BNZ, are designed to be a short-term measure and are highly localised. As exotic Caulerpa continues to proliferate, or management actions change, the ***area of the Hauraki Gulf that is closed to fishing as part of a marine biosecurity response*** will also change. Although this is an easy metric to quantify, the localised and sporadic nature of the closures suggests that the impact on fisheries in the Hauraki Gulf is unlikely to be significant.

Protected species

Condition and mortalities & population status

Fishing activity can unintentionally, but detrimentally, interact with a range of different protected species (Edwards 2023). As such, variables that describe the response of protected species to fishing would be useful indicators. There are a few different types of indicator that are worth considering under the Protected species Focal Component. The first is the ***population status***, or abundance, of protected species.

An important consideration here is that population status can be affected by a number of different variables (such as environmental variation) beyond just the direct (e.g., mortalities) or indirect (e.g., fishing effects on the food sources of protected species) influence of fishing.

Many protected species are wide ranging and can spend considerable time outside of the Hauraki Gulf. The overall population status of a species will reflect the combination of all of these influences, including fishery captures from outside of the Hauraki Gulf (and for some protected species this will include fishing mortality from other countries (e.g., Rayner et al. 2011)). For the same reasons, the condition or health status of protected species would also not be useful indicators. With this in mind, the best indicator to reflect the response of protected species to fisheries in the Hauraki Gulf is one that documents the interaction of fisheries and protected species at the scale of the Hauraki Gulf.

Captures of protected species by commercial fisheries are well documented (https://Protectedspeciescaptures.nz/). The captures described on this website utilise captures documented by fishery observers and self-reporting. Spatially Explicit Fishery Assessments (SEFRAs) are then used for each species to calculate estimated captures given the overlap between a species' distribution and the amount of fishing effort in an area. Such an approach can be useful when observations are rare, as they are for protected species captures. With the rollout of camera observations on commercial fishing vessels, estimated captures will likely incorporate camera observation going forward.

For the Hauraki Gulf, the majority of protected species or species groups (covering birds, cetaceans, pinnipeds, protected invertebrates, turtles, sharks and rays) have very few interactions with commercial fisheries (Phillip Heath, Campbell Murray, William Gibson, FNZ, pers. comm.). The two exceptions are black petrel (*Procellaria parkinsoni)* and flesh footed shearwater (*Ardenna carneipes)*, which together account for the majority of estimated protected species captures in the Hauraki Gulf. Given the high level of interaction with Hauraki Gulf fisheries, the ***estimated captures of black petrel and flesh footed shearwaters in the Hauraki Gulf*** would make good indicators representing the response of protected species to fishing in the Hauraki Gulf (e.g., Figure 9).

These indicators could additionally be paired with risk assessments for each species, which would place the estimated captures within the context of how vulnerable the population is as a whole (Edwards 2023). As described above, ***other protected species estimated captures*** were also considered, but are infrequently caught within the Hauraki Gulf and unlikely to produce trends. An additional consideration is the contribution of ***recreational fishery seabird interactions***, which would not be reflected in the indicators described above. There is some information in this regard, through DOCs Protected Species Captures application (https://docnewzealand.shinyapps.io/protectedspeciescatch/), from FNZs national panel survey of recreational fishing (Wynne-Jones et al. 2019), and also the recording of seabird interactions during FNZ funded boat ramp surveys. Unfortunately, these datasets suffer from under reporting, with a low overall number or seabird interactions with recreational fishing being recorded.

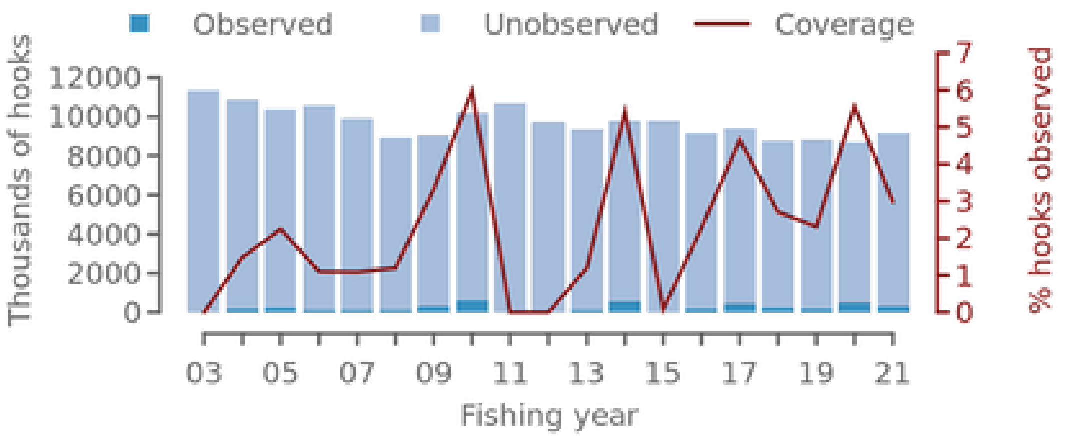


Figure 9 Observed and estimated captures of flesh-footed shearwater in bottom longline fisheries in Northland and the Hauraki Gulf relative to fishing effort. Image obtained from https://Protectedspeciescaptures.nz/

Implementation of management and monitoring

The implementation of management and monitoring itself can also be reported as an indicator, as opposed to just developing indicators that describe the state of variables that respond to management interventions and the monitoring that feeds into it. A section of this report is devoted to the implementation of management and monitoring of the entire Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2023b). However, because specific monitoring and management measures are already well established for protected species, those metrics are discussed here. The use of cameras on fishing boats allows for the ***% of fishing events where a camera is operating*** to be calculated. Not all camera footage, however, is reviewed, so an additional metric describing the ***% of camera footage events selected for review*** may also be worthwhile. It is worth noting, however, that the review of camera footage is targeted towards gears, locations, and times when protected species interactions are likely to be higher, so these monitoring metrics may appear lower than their actual effectiveness. From a management perspective, the use of mitigation devices (% of fishing events using mitigation), such as tori lines, could also be reviewed from this footage and reported.

Marine food webs

Condition, composition or energy flow

In this section, we consider a number of indicators related to small-to-medium-sized pelagic fishes (e.g., kahawai (*Arripis trutta*), pilchard (*Sardinops neopilcahrdus*), jack mackerel (*Trachurus spp*.), saury (*Scomberesox saurus*), blue mackerel (*Scomber australasicus*), and anchovy (*Engraulis australis*) - also referred to as forage fish). These forage fish are an important source of food for larger predators such as megafauna, seabirds and larger fish (Gaskin et al. 2019a, Pinkerton et al. 2023b). This suggests that indicators that capture the dynamics of forage fish are highly relevant to marine food webs and are of high public interest.

A substantial body of work has been done on the occurrence of predators such as cetaceans and seabirds throughout the Gulf, especially in relation to their presence in Multi-Species Feeding Aggregations (MSFAs), where they feed on the small-to-medium-sized pelagic fish in question (as well as dietary items such as krill). The two main data collection options are on water observations obtained from the Auckland Whale and Dolphin Safari (AWADS) tourist vessel (Gostischa et al. 2021) and aerial surveys (Stephenson et al. 2023). The AWADS data has the advantage of being freely available, but the disadvantages are that data is collected opportunistically (i.e., not based on survey design) and spatial coverage is limited. Alternatively, aerial surveys would have a higher cost, but can be conducted in accordance with a proper survey design allowing for much better spatial coverage. In addition, the cost of aerial surveys could potentially be reduced through the use of camera observation and artificial intelligence to identify MSFA types (and their component predators) (Davis 2022), and efficiencies gained by the use of aerial surveys as a general sampling opportunity to document additional indicators relating to the presence of sharks, other cetaceans, and seabird colonies (see below). Aerial surveys would likely need to be conducted seasonally, because the location of cetaceans taking part in MSFAs are dynamic and seasonal (Stephenson et al. 2023). Considering all of this together, aerial surveys would likely be a better option, but ultimately such a decision would come down to available budget.

In terms of what to measure, metrics related to the cetaceans and seabirds themselves are likely to be influenced by multiple variables (e.g., seasonal cycles, environmental variation, non-fishing related mortality, and for wider ranging species the influence of factors from outside of the Hauraki Gulf). A metric specifically focussed on the MSFAs themselves (where cetaceans and seabirds are interacting with forage fish) may therefore provide a more focussed reflection of how the availability of forage fish to these predators is changing in the Hauraki Gulf. While MSFA duration would likely be a good indicator, it would not be possible to quantify without devoted research vessel survey methods. Potentially the indicator with the most utility would be ***MSFA niche type encounter frequency*** (Gostischa et al. 2021), documented by either AWADS data or from a customised aerial survey.

In addition to the interaction of cetaceans and seabirds with MSFAs, it may also be worth considering seabirds themselves as an indicator of marine foodwebs and small-to-medium-sized pelagic fishes. A primary consideration is that many seabirds have ranges much wider than the Hauraki Gulf (e.g., Rayner et al. 2011), so will not be reflective of just the Hauraki Gulf ecosystem and its fisheries. The nesting strategy of seabirds also contributes to the ease with which information can be gathered. The Australasian gannet (*Morus serrator*), surface nests at just a few locations in the Hauraki Gulf (Gaskin et al. 2019b), has a range that is largely restricted to the Hauraki Gulf (N. Adams, Unitec, unpub. data), and already has some existing data documenting a timeseries of counts at Hauraki Gulf colonies (Gaskin et al. 2019b). Gannets could therefore be efficiently aerially counted (via drone or combined with an aerial survey of MSFAs as per the previous section) with ***Australasian gannet nest count*** potentially providing an indication of the small-to-medium-sized pelagic fish that they prey upon (Gaskin et al. 2019a, Gaskin et al. 2019b). While an indicator for gannets by itself would not cover the entire forage fish community (Gaskin et al. 2019a), some of these aspects would be covered by MSFA quantification as per the previous section. Alternatively, most other seabirds are nocturnal burrowing nesters (e.g., fluttering shearwaters *Puffinus gavia*, fairy prions *Pachyptila turtur*) or nest in multiple separate small aggregations (e.g., little blue penguins *Eudyptula novaehollandiae*), some of which are more ephemeral than others (e.g., white-fronted tern *Sterna striata* and red-billed gull *Chroicocephalus novaehollandiae scopulinus*) (Gaskin et al. 2019b). Such nesting strategies would require land-based field work to be conducted, often across multiple locations. These ***other seabird nest counts*** are therefore unlikely to have utility as indicators. It is worth noting, that many factors beyond forage fish abundance could affect gannets and other seabirds.

More focused methodologies investigating ***seabird diet, stable isotope signature, breeding success and physiology*** could serve as more direct indicators of the forage fish community (Dunphy et al. 2020, Gaskin et al. 2019a). These more detailed metrics could be developed if the coarser metrics relating to population size (i.e., if gannets are chosen as a focal species) prove useful.

Beyond documenting MSFAs and seabirds, a more direct measure of forage fish abundance is also worth considering. Fish population abundance metrics are generally covered in the Fish Population Focal Component, but forage fish will be covered here due to their relevance to marine food webs. In general, the best source of information on fish population abundance comes from the fisheries research and monitoring commissioned by FNZ. For each individual species the available research and monitoring data is compiled, and where there is sufficient information a stock assessment is performed to determine the biomass for that species in each management area and the status (relative to management targets) of each stock. With respect to forage fish species, excepting kahawai which is covered later in the Fish Population Focal Component, there are no indices of abundance or assessments available for any of the component species (e.g., pilchard, anchovy, saury, blue mackerel and jack mackerel) in the Hauraki Gulf (Fisheries New Zealand 2023a).

The most abundant individual forage fish species in the Hauraki Gulf is jack mackerel (Parsons & Bian 2022). In the Hauraki Gulf, the majority of jack mackerel are *Trachurus novaezelandiae*, but all three jack mackerel species are reported under one code, which complicates assessments. One method of assessment that has been investigated is the utility of aerial sightings of jack mackerel (and other pelagic species) schools from purse seine spotter planes (***small and medium sized pelagic fishes aerial sightings***). This index, however, had high interannual variation (likely due to varying environmental conditions and the migratory behaviours of the species which can extend over very large home range) and was subsequently abandoned. The commercial fishing industry are currently looking into reestablishing an aerial sightings index, but this would unlikely cover the Hauraki Gulf because nearly all commercial jack mackerel catch occurs in the Bay of Plenty (Hartill et al. 2022) (D. Cook, Faber R & D, pers. comm.). The commercial fishing industry are also investigating the utility of a size-based indicator of abundance, but at this stage it is not clear if this work will produce a useable index of abundance or not (Denham Cook, Faber R & D, pers. comm.). Another option includes a ***jack mackerel age-based indicator*** of abundance which the fishing industry may investigate (Marc Griffiths, FNZ, pers. comm.).

An alternative option with more localised relevance would be a ***small and medium sized pelagic fishes acoustic indicator***. An assessment of acoustic data obtained from recent Hauraki Gulf trawl surveys was conducted for this purpose by Pinkerton et al. (2023b) (Figure 10). They found that the major limitation of using this acoustic data is the ability to identify the species associated with different acoustic mark types. This is because estimates of biomass derived from acoustic data are composite of the amount of acoustic backscatter and the target strength of particular species. An understanding of the mark types generated by different species could be conducted by first speaking to experienced commercial skippers and then conducting ground truthing surveys where fish are caught (using trawl, purse seine, or sabiki flies) or observed (using a drop camera) to confirm the species associated with a particular mark type. It should be noted, however, that even without mark identification, understanding the total amount of acoustic backscatter would still have some utility. While Pinkerton et al. (2023b) investigated acoustic data from the Hauraki Gulf trawl survey, it is not clear (and is potentially unlikely) whether this survey will continue. While there may be some form of replacement survey other acoustic data collection options should be investigated. This could include attaching acoustic equipment to a vessel of opportunity such as the Great Barrier Island ferry. This could provide a cost-effective sampling platform that essentially conducts a frequent transect that covers the depth gradient of the Hauraki Gulf. A second cost-effective alternative would be to utilise autonomous seacraft, for which preliminary trials were very promising (Pinkerton et al. 2023b). The advantage of a vessel of opportunity, however, is that additional sampling equipment could potentially be paired with the acoustic (e.g., continuous plankton recorder, see below).

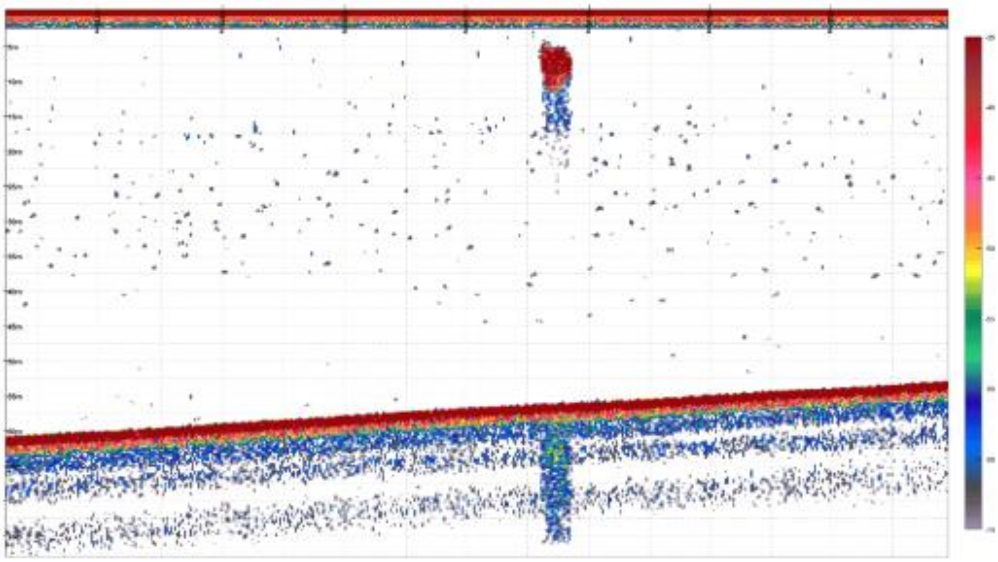


Figure 10 An example acoustic echogram showing a surface school observed on the RV Kaharoa trawl survey in 2019. Acoustic data such as this could be used to generate an index of total acoustic backscatter or the acoustic signal associated with particular pelagic species if mark identification work was successful. For this example colours represent acoustic strength (red = strong, blue = weak). The red line near the bottom of the echogram is the seabed (at a depth of about 55 m), horizontal extent is about 1.5 km. Plot reproduced from Pinkerton et al. (2023b).

Phytoplankton and zooplankton are at the base of the food chain and their levels of productivity will directly influence the rest of the Hauraki Gulf ecosystem (Zeldis et al. 2005), including the fish species which we all value. While phytoplankton abundance can be remotely and cost-effectively monitored via satellite observation of Chl a (see previous section on Marine Environment Variables), it may be worth considering an indicator related to ***zooplankton abundance and species composition*** (which is especially relevant to the cetaceans, seabirds, MSFAs and pelagic fishes covered in this section). An extensive zooplankton dataset was briefly described in the Marine Environment Variables section. This NIWA dataset is focussed on the Firth of Thames and extends quarterly back to 1998, but data collection has been discontinued. An indictor to document zooplankton abundance and composition would require ongoing data collection as well as sample identification and enumeration, which could be cost prohibitive. Given this, any indicator developed would need to rely on more cost-effective methodologies. Some options in this regard could include using a continuous plankton recorder attached to a vessel of opportunity (e.g., the Great Barrier Island ferry) (Pinkerton et al. 2020) or the incorporation of zooplankton net tows into the operations of cooperative vessels (e.g., AWADS collected some samples for Gaskin et al.

(2019a)). Samples collected from any surveys that are initiated in the Hauraki Gulf (i.e., a replacement for the Hauraki Gulf trawl survey) would not be conducted frequently enough to be useful. In addition to improving sampling efficiency, sample processing efficiency would also need to be improved. Significant potential for these efficiencies is offered through the application of eDNA metabarcoding (Gaskin et al. 2019a, Yang & Zhang 2020).

The remainder of this section relates to the abundance of large predators. Abundant populations of large predators are an indication of a healthy ecosystem containing fisheries that have not been overexploited (Natsukawa & Sergio 2022, Pauly et al. 1998). It is often the larger individuals from a population that exert the most influence on structuring the rest of the ecosystem (Langlois et al. 2006), or are of the highest value to fishers (Lindner 2010). Given this, indicators representing the abundance of large predators could potentially be relevant to multiple aspects or Focal Components of this indicator suite.

One large predator index of interest could relate to the presence of ***large rocky reef predators***, which have a greater ability to predate on kina, and thus have more influence on regulating the balance between algal dominated vs kina barrens dominated reefs. The two main known predators of kina that could be used to construct such an index are spiny rock lobster (*Jasus edwardsii*) and snapper (*Chrysophrys auratus*).

Feeding experiments have indicated that rock lobster with a Carapace Length (CL) greater than 100 mm are able to eat all sized kina while lobsters smaller than 100 mm CL are restricted to eating kina less than 50 mm Test Diameter (TD) (Andrew & Macdiarmid 1991).

For snapper, diet work looking at the size of urchins eaten by different sized snapper suggests that snapper greater than 55 cm Fork Length (FL) are able to eat kina larger than 50 mm TD (J. Marinovich, University of Auckland, unpub. data).

Given this, large reef predator indices could be generated to reflect the abundance of rock lobster greater than 100 mm CL and snapper greater than 55 cm FL. It may be desirable to average these indices to generate an overall large reef predator index.

There are a few different data sources to consider. For rock lobster the Rock Lobster Industry Council (RLIC) collates logbook data from commercial pot fishers who measure the size and catch rate of lobsters caught. The collection of this data is voluntary, and its use would require the permission of the RLIC. An alternative data source that could be utilised are dive survey estimates of rock lobster abundance and size that have largely been conducted by the University of Auckland, and often funded by DOC (Diana et al. 2021, Hanns et al. 2022). These data consist of a 40 year time series, but are spatially restricted to fished and unfished areas relating to the CROP, Tawharanui and Hahei marine reserves.

For snapper, monitoring of recreational catches at boat ramps does provide catch rate (a proxy for abundance) and the size of fish caught (Hartill et al. 2019). However, it would be difficult to determine which of these catches related to rocky reef habitat. Commercial fishing data has less utility as the majority of the commercial fishery (and the associated size data that is collected) is not associated with rocky reefs. Potentially, the most useful data set has been collected by the University of Auckland and DOC, using BRUV deployments to document the abundance of snapper inside vs outside of marine reserves in the Hauraki Gulf (again mostly CROP, Tawharanui, and Hahei) (Willis et al. 2003).

BRUV monitoring for snapper and dive surveys for rock lobster are likely to continue at these sites and could be expanded to monitor in and around the HPAs that will be implemented as part of *Revitalising the Gulf*. These two methods are spatially paired and would be the best option to produce large reef predator indices. It should be noted, however, that the BRUV methodology that has been used has a known size related bias (Evans 2017) which would need to be accounted for. This is further discussed in the section relating to the Fish Population Focal Component.

An indicator describing the abundance of ***large pelagic sharks***, which are vulnerable to fishery exploitation (Pacoureau et al. 2021), is also worth considering. The abundance of large pelagic sharks (such as bronze whaler *Carcharhinus brachyurus*, hammerhead *Sphyrna zygaena,* thresher shark *Alopias vulpinus*, mako *Isurus sp.,* blue shark *Prionace glauca,* and white shark *Carcharodon carcharias*) has been documented aerially (Stephenson et al. 2023). A sightings per unit effort metric for large sharks could therefore be developed if aerial surveys were adopted as a monitoring tool to address multiple aspects of the Hauraki Gulf ecosystem (e.g., MSFA frequency, gannet colony counts, large shark abundance). In designing such a survey, it would be important to account for potentially high variation likely to arise from infrequent encounters with pelagic organisms which spend a proportion of their time below the surface where they are visible.

Another indicator relating to the level of predatory regulation retained within marine ecosystems that has been used elsewhere is the proportion of predatory fish (https://indiseas.org/; Shin & Shannon 2010) (also referred to as catch ratios of functional groups (Cury et al. 2005)). Generally, this indicator is calculated from survey data and includes fish species that are piscivorous, or feed on invertebrates larger than 2 cm. The catch ratio of other different functional groups, however, can also be calculated. These different catch ratio indicators are discussed together below under the Food web status Key Attribute.

Food web status

This indicator group is intended to measure the strength of interactions (e.g., energy flow/predation) between different components (or trophic levels) of the Hauraki Gulf fisheries ecosystem. Such trophodynamic indicators have been identified as very important to fish populations (Bax 1988), and there are a large number of potential indicators (Cury et al. 2003). However, given the often extensive data requirements, complexity and sensitivity to uncertainty of some of these indicators (Fulton et al. 2004) we have chosen to address simpler potential indices more directly focussed on the fish populations at the centre of interest for this indicator suite. There were potentially relevant indicators that we did not consider here because they are addressed in other parts of the indicator framework (i.e., fish diversity, fish distribution, fish size-based indicators were all considered under the Fish Population Focal Component).

Two indicators relevant to food web interactions are catch or biomass ratios of species/functional groups (referred to as ***catch ratios***) and the ***trophic level of fish communities***. Catch ratios could be used to describe the ratio of predatory, demersal, or planktivorous fish and were partially covered above, from the perspective of the predatory fish functional group. Such catch-ratio-based indicators are easily measured and understood, and have been shown to be sensitive to fishing (Cury et al. 2005). Alternatively, trophic level indicators identify the position of a fish within the food web, which varies according to the functional group and size of the fish (Tuck et al. 2014). As fisheries generally catch the larger and predatory fish first, the mean trophic level of the fish remaining in the community can reduce with time (Pauly et al. 1998). One way to document these changes is through the Mean Trophic Index (MTI), which is the mean trophic level of fishery catch (where a set trophic level is assigned for each species) (Pinkerton et al. 2017, Shin & Shannon 2010) (Figure 11). The utility of MTI has been assessed from a New Zealand perspective (Pinkerton et al. 2017). Given that many of these recommendations would also apply to catch ratios, both indicator types are considered together here. Specifically, Pinkerton et al. (2017) noted: (1) when these indicators are based on commercial catches the MTI (or catch ratio) can be influenced by gear selectivity, targeting, and market forces (also important factors, but not covered in this section, see the Fishery Focal Component); (2) The amount of shellfish catch (which are typically low trophic level species) can influence the MTI, so interpretation of the MTI can be complex; (3) Applying a single trophic level value (or functional group for catch ratio indicators) is an oversimplification as trophic level can change with fish size.

Given these limitations, survey data should be used to calculate MTI or catch ratios in the first instance. This is problematic given the doubt around the continuation of the Hauraki Gulf trawl survey, but may be possible if a new fisheries survey is initiated. It should also be considered, however, that fishery surveys also catch fish selectivity, which may mean that some functional groups or trophic levels are less likely to be caught or observed. For example, baited methods (e.g., bottom longline or BRUV surveys), by their nature, will capture predatory or high trophic level species. Alternatively, benthic towed video methods like Swath Cam are less likely to observe pelagic predators or planktivorous fish. The size of fish captured/observed would also need to be taken into account given changes in trophic level or functional group that occur with fish size.

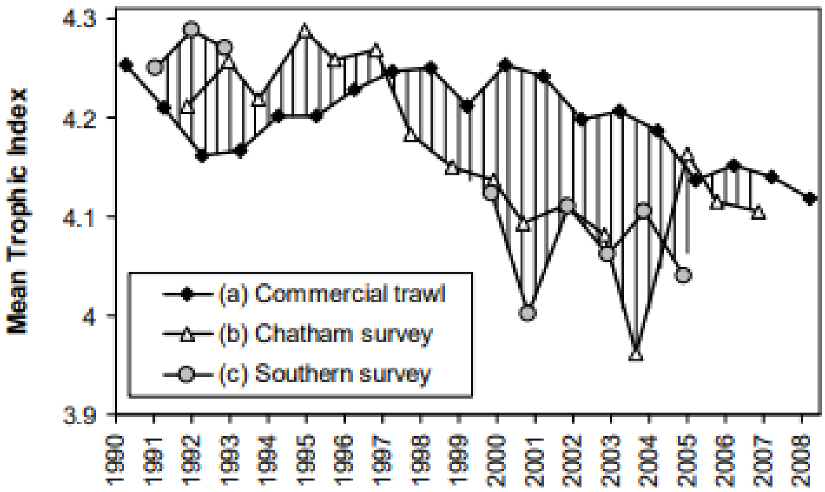


Figure 11 Example of Marine Trophic Index (MTI) data for research and commercial bottom trawling for some deepwater fisheries in New Zealand. Data and plot reproduced from (Pinkerton 2012, Tuck et al. 2009)

An alternative approach would be to try and use the commercial catch data, but account for the factors that may influence those catches. The spatio-temporal modelling framework known as VAST (Vector Autoregressive Spatio-Temporal) has potential in this regard, and even has the ability to integrate multiple data sources (Grüss et al. 2023a, Grüss et al. 2023b). To this end, VAST could simultaneously use commercial catch data for all species together and incorporate survey data if/when it is available to standardise for the fishing behaviour and gear selectivity influences discussed above. Such a platform could then be used to generate indicator values (for a set area and year) for measures such as diversity, maximum size (discussed in the Fish Population Focal Component), trophic level or functional group.

The downside of such an approach is the complicated standardisation step that VAST provides, which also means that a substantial amount of data exploration would need to be conducted before any indicators could be produced.

The advantage, however, is that once that exploration is done and a method has been validated, food web status indicators could be produced with the data that is available now. As such, there would be value in exploring ***VAST estimates of average trophic level*** to utilise commercial catch data and also to reassess the utility of survey data contributing to these food web status indicators if and when a new survey methodology is confirmed.

We also considered other potential food web status indicators. One of these relates to a ***trophodynamic model generated indicators*** (there is an existing trophodynamic model of the Hauraki Gulf that could be used for this purpose) (Pinkerton et al. 2023b).

The main limitation here is that new abundance data would be required for all model components (i.e., fish species) each time an index of fish community change was needed. An additional and more generic limitation, however, in that our understanding of the connections between species in the Hauraki Gulf ecosystem (and within any ecosystem model) is often based on a relatively low number of diet samples often collected a long time ago (Pinkerton et al. 2023b). This is especially relevant because understanding these connections underpins EBFM.

Routinely collecting tissue samples from a set of key ecosystem components (e.g., highly abundant or disproportionately influential system components as identified by the trophodynamic model above) for stable isotope analysis could be an effective way to address this deficiency. However, stable isotopes by themselves are unlikely to provide the detail about diet composition and shifts that would be required (Ladds et al. 2020).

Taking a similar approach, but routinely documenting the diet of key system components could be very informative, but diet analysis can be time consuming and expensive. If eDNA metabarcoding methods were developed for the Hauraki Gulf system, this may have the potential to offer a cost-effective supplement to traditional diet-based methods (although noting the limitations, reduced detail, and artefacts of eDNA metabarcoding methodologies (Canals et al. 2023)). The collection of the diet samples for key system components could be associated with a new survey methodology if one is initiated. As mentioned above, monitoring of ***individual species diet or trophic levels*** (and the variation in these diets) would not only be informative as a food web status indicator, but also has the potential to underpin ecosystem modelling to support the transition to EBFM in the Hauraki Gulf.

Fisheries resources meet the needs of partners and stakeholders

Fish population

This Focal Component describes the status, composition, and condition of the fishery resources (i.e., the fish populations themselves) that Māori partners and stakeholders use. Much of this Focal Component is related to single-species metrics that are already part of the QMS. Given this, it is important to recognise that these single-species metrics still form an important component of EBFM, but that it’s also important to broaden the scope beyond these single-species metrics (which this indicator framework has done). The best source of information for many of these metrics comes from the monitoring and assessments conducted through the existing fishery science working group process. These working groups have put much thought into determining indices that are highly relevant to this Focal Component.

Our first step was to choose the fish species or fish species groups for which to assess population status, condition and composition. We used our knowledge of the main fish species caught on fishery surveys and by commercial and recreational fishers in the Hauraki Gulf (Fisheries New Zealand 2023a, Hartill et al. 2019, Parsons & Bian 2022, Walsh et al. 2022). We also considered species where current biomass was low and took onboard feedback provided by stakeholders and Māori partners. It was not possible to include indicators for every species because this adds complexity, which ultimately undermines the utility of the indicator suite as a communication and management tool. The species or species groups we considered here are:

- **Snapper** (*Chrysophrus auratus*) (the most abundant fish in the Hauraki Gulf)
- **Kahawai** (*Arripis trutta*) (highly important to recreational fishers)
- **Hāpuku & bass** (*Polyprion sp.*) (currently restricted to the outer Gulf and at low biomass levels)
- **Tarakihi** (*Nemadactylus macropterus*) (an important part of the inshore mixed fishery, currently restricted to the outer Gulf and at low biomass levels)
- **Small-to-medium pelagic fishes** (an important food web connection as a forage fish for predators)
- **John dory** (*Zeus faber*) (an important part of the inshore mixed fishery)
- **Trevally** (*Pseudocaranx dentex*) (an important part of the inshore mixed fishery)
- **Red gurnard** (*Chelidonichthys kumu*) (an important part of the inshore mixed fishery)
- **Kingfish** (*Seriola lalandi lalandi*) (a highly valued sport fish and inshore commercial fishery bycatch)
- **Scallops** (*Pecten novaezelandiae*) (highly valued recreational and commercial species that is currently at low biomass levels)
- **Rock lobster** (*Jasus edwardsii*) (highly valued recreational and commercial species that is currently at low biomass levels)
- **Intertidal shellfish** (cockle *Austrovenus stuchburyi* and pipi *Paphies australis*) (highly important by Māori)
- **Reef fish** (a valued non-fishery component of the fish community)

When considering indicators for each of these species or species groups, not all candidate indicator types were relevant for all species. In some cases, this was because one indicator type could serve as a proxy for another indicator type. To some extent this was also true when considering the Fish Population vs the Fishery Focal Components. The main differences between these being that where possible indicators within the Fish Population Focal Component would be informed by fishery independent survey data whereas comparable indicators within the Fishery Focal Component would be informed by data related to fishery experience. But as mentioned above, the interwoven nature of the indicator framework necessitated vision across Focal Components, and in some cases the indicators evaluated have relevance to multiple parts of the indicator framework.

Fish population status (abundance)

The metrics in this section describe the best information available (or that could be collected in the future) related to the abundance of the valued species groups listed above. In the majority of cases we describe abundance (relative or absolute) indicators (e.g., Spawning Stock Biomass (SSB)), but where management targets are available indicators relative to those targets could be an alternative option (e.g., % of the population biomass without any fishing, or% B_0). An important consideration described for each species group is the spatial scale of the abundance information. Assessments are usually conducted at spatial scales reflecting the level of biological mixing for the population unit being assessed (the nominal 'stock'). This means that often the Hauraki Gulf is only part of the broader spatial scale that an assessment is conducted at. Given concerns relating to differential localised abundance, reflecting the actual experience of fishing within the Hauraki Gulf, we try to pair these broader scale stock abundance estimates with finer scale abundance estimates in a following section describing the distribution of fish populations.

Snapper – The Hauraki Gulf population of snapper (Tāmure, *Chrysophrys auratus*) falls within the SNA 1 Quota Management Area (QMA) where it forms a highly important shared fishery. Regular fishery monitoring takes place to inform a fully quantitative stock assessment scheduled for every five years. The data sources include catch-at-age sampling, historical tagging biomass estimates, a trawl survey series, recreational harvest estimates and Catch Per Unit Effort (CPUE) analyses. An assessment for the Hauraki Gulf-Bay of Plenty population complex (snapper mix across both areas) was accepted in 2023, although there were difficulties with defining reference points (Fisheries New Zealand 2023a). An index of abundance for snapper at an appropriate spatial scale already exists and could be utilised now (***snapper assessment (Hauraki Gulf population) SSB***) (Figure 12). It should, however, be noted that future assessments will likely not just simply add additional points to this time series, but will undertake a new assessment which will mean the whole indicator time series will need to be updated at that time. It now seems likely that some of the main data inputs used in the current assessment will not be available or wanted to be used going forward (e.g., the Hauraki Gulf trawl survey and commercial bottom trawl CPUE). Given the high value of the Hauraki Gulf snapper population it is likely that an alternative survey will be conducted to enable future assessments.

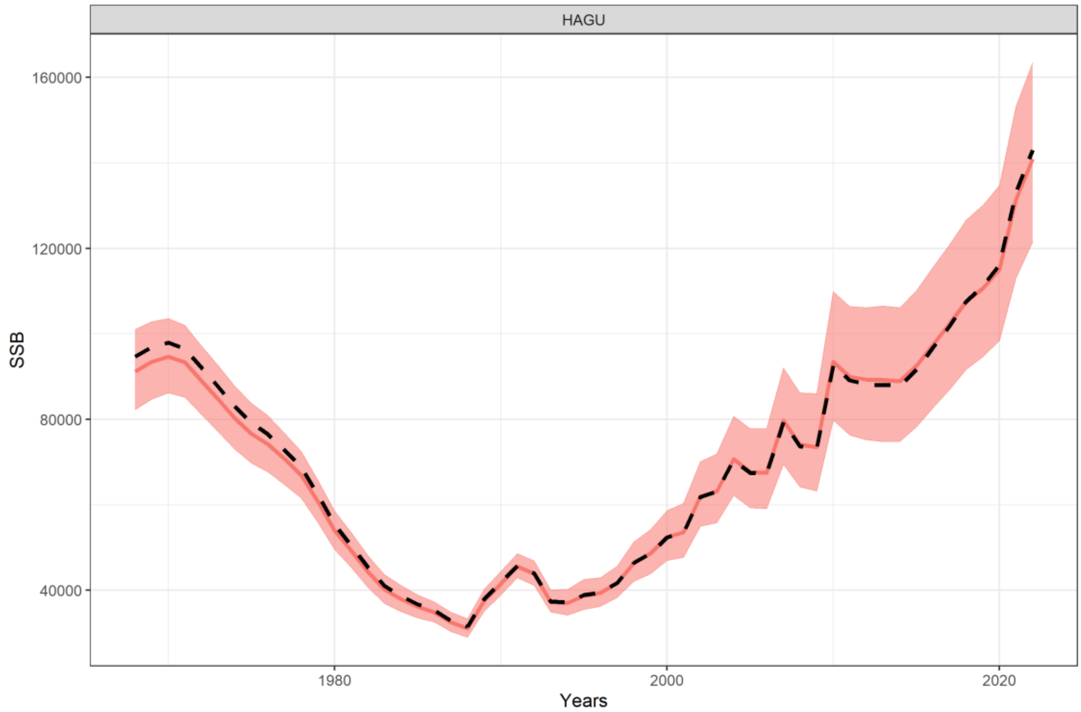


Figure 12 A potential indicator for snapper could be the estimated Spawning Stock Biomass (tonnes) by year for the Hauraki Gulf. For this example, estimates are: MCMC median (solid line); 95% confidence intervals (shaded regions); MD estimates (dashed line). Plot reproduced with permission from Fisheries New Zealand (2023a).

Kahawai – The Hauraki Gulf population of kahawai (*Arripis trutta*) falls within the KAH 1 QMA where it forms a highly important shared fishery. Regular fishery monitoring takes place to inform a fully quantitative stock assessment scheduled for every five years. The data sources used include catch-at-age, recreational CPUE, recreational harvest estimates, and aerial sightings associated with the purse seine fishery. An assessment for the whole of the KAH 1 QMA (North Cape to East Cape) was accepted in 2021 (Hartill & Doonan 2022). An index of abundance for kahawai does exist and could be used now (***kahawai assessment (KAH 1) SSB***), but the spatial scale of this assessment is larger than the Hauraki Gulf. This is especially relevant considering the mobility of kahawai. In previous years, the abundance of kahawai observed in the Hauraki Gulf has changed very quickly due to migration. Such localised changes would not be expressed by a metric describing biomass at the scale of the whole of KAH 1.

Hāpuku & bass – This species group consists of two species, *Polyprion oxygeneios* (hāpuku) and *P. americanus* (bass), the catches of which were reported together until recently. Hāpuku & bass are highly valued fish species, so establishing an indicator of abundance relevant to the Hauraki Gulf would be desirable. Hāpuku & bass are mobile, but the size of the population units relevant to management are unknown. Alternatively, only a small proportion of the Hauraki Gulf overlaps with where hāpuku & bass presently occur (i.e., just the back of Aotea Great Barrier Island and parts of the eastern coast of the Coromandel Peninsula). The Hauraki Gulf falls within the HPB 1 QMA (North Cape to East Cape), where recent reductions to the Total Allowable Catch (TAC) suggest over exploitation has occurred. There is however, no accepted assessment for HPB 1 or any of the HPB QMAs. The options already considered by the inshore fishery assessment working group are as follows (Fisheries New Zealand 2023a). Commercial ***bottom longline CPUE*** information has been determined to have little utility because the fishery focusses on seabed features where hāpuku & bass aggregate and therefore maintain catch rates regardless of abundance (i.e., hyperstability) (Hartill et al. 2020a). The utility of commercial ***bottom trawl CPUE*** is also currently being assessed, but has limitations in that it predominantly catches juveniles and the indices produced are at the scale of all of New Zealand (D. Middleton, Pisces research, unpub. data). The potential for a bottom longline survey was assessed but deemed not cost-effective. Work has also been conducted to assess the potential of utilising population age structure to determine abundance (known as ***catch curve*** analysis) (Maggs & Parsons 2023). While it is possible that a pilot project may be conducted, it is unlikely that this would initially include the Hauraki Gulf, so a relevant catch curve estimate could be many years away (if at all).

Two alternative and less conventional options could be investigated. It is possible that deep water Stereo Baited Remote Underwater Video (SBRUV) surveys will be conducted to monitor the abundance of fish such as hāpuku & bass inside and outside of the HPAs that will be emplaced as part of *Revitalising the Gulf*. Therefore, a ***SBRUV fished vs unfished ratio*** for hāpuku & bass, similar to that produced by Hanns et al. (2022) for rock lobster, could be attempted. Such a metric has good potential and should be investigated, however, only some of the new HPAs will include deepwater hāpuku & bass habitat, and the variability of SBRUV survey estimates (and associated replication required) remains to be determined. A second alternative would be to investigate the potential for a ***extent of occurrence*** metric. While the current depth distribution of hāpuku & bass ranges from about 100 to 500 m, historically they were present in much shallower water and this contraction in their range is likely related to abundance. Commercial bottom longline catches may have utility here, although detailed spatial reporting for bottom longline is only available from 2008, by which time much of the abundance reduction (and likely range contraction) in response to historic fishing would have already occurred. Such a metric would therefore only be future looking, in that it would describe any future expansion of range that may occur in association with increases in abundance. The metric most commonly used to describe extent of occurrence when utilising fishery dependent data is the top 50% CPUE polygon (the area of the polygon that contains the highest 50% of commercial bottom longline CPUE). The advantage of a range metric is that it could be calculated now from existing data, but it is unclear how sensitive a range metric is to changes in abundance. Alternatively, the SBRUV survey abundance ratio described above will cover a small proportion of the Hauraki Gulf, may require more replication than is feasible, and will require multiple surveys (i.e., many years) to be conducted before a useful relative abundance index will exist.

Tarakihi – Tarakihi (*Nemadactylus macropterus*) are a valued part of the inshore mixed species fishery. The Hauraki Gulf falls within the TAR 1 QMA, which encompasses the northern half of the North Island west and east coasts. TAR 1 has had two TAC reductions in recent years. Tarakihi are highly mobile, in that tarakihi off the east coast of both the North and South Islands are considered to form part of a single population. Given the high value of tarakihi, regular fishery monitoring takes place to inform a fully quantitative stock assessment scheduled for every five years. This model is informed by commercial bottom trawl CPUE, catch-at-age information and trawl survey abundance estimates. The last assessment for eastern tarakihi was conducted in 2022 and was accepted (Langley 2022). An index of abundance for tarakihi does exist and could be utilised now (***tarakihi assessment (east coast New Zealand) SSB or % B_0***), but the spatial scale of this assessment is much larger than the Hauraki Gulf. This is especially relevant considering the mobility of tarakihi. Essentially patterns of abundance observed at the scale of the whole stock may or may not be the same as observed in the Hauraki Gulf

Small to medium pelagic fishes – Potential indices of abundance for small to medium sized pelagic fishes were covered in the Marine Food webs Focal Component above.

Trevally – Trevally (*Pseudocaranx dentex*) are a valued part of the mixed species inshore fishery (along with snapper, red gurnard, John dory and to some extent tarakihi). The Hauraki Gulf falls within the TRE 1 QMA (North Cape to East Cape), which is divided into two populations for stock assessment, east Northland-Hauraki Gulf and Bay of Plenty. Given the high value of trevally regular fishery monitoring takes place to inform a fully quantitative stock assessment scheduled for every five years. This model is informed by commercial bottom trawl CPUE and catch-at-age information. The last ***trevally assessment for east Northland-Hauraki Gulf (SSB)*** was conducted in 2022, but was not accepted due to a conflict between CPUE and catch-at-age information (McKenzie 2023). This creates uncertainty with regard to how either of these data sources can inform about abundance. If a bottom long line survey is initiated in the near future it is also unlikely to be informative because bottom long line catch rates of trevally are low. The proposed Swath Cam surveys that will document benthic habitats may also be able to observe fish, however the use of ***Swath Cam for fish abundance*** is yet to be validated. Until Swath Cam has been validated the best option is likely to utilise commercial ***bottom trawl CPUE*** while noting the limitations identified by the assessment. If trawl corridors are introduced to the Hauraki Gulf this will spatially restrict the amount of trawling, so any index based on bottom trawl will be less representative of the whole of the Hauraki Gulf.

John dory - John dory (*Zeus faber*) are a valued part of the mixed species inshore fishery (along with snapper, red gurnard, trevally and to some extent tarakihi). The Hauraki Gulf falls within the JDO 1 QMA, which encompasses the northern half of the North Island west and east coasts. JDO 1 received a TAC reduction in recent years. For stock assessment purposes JDO 1 is divided into three populations, east Northland-Hauraki Gulf, west coast North Island, and Bay of Plenty. The east Northland-Hauraki Gulf stock assessment is a partially quantitative assessment based on commercial bottom trawl CPUE. While the last ***John dory assessment for east Northland-Hauraki Gulf (SSB)*** was conducted in 2022 and was accepted (Fisheries New Zealand 2023a), it is unclear what future assessments will be based on because the implementation of trawl corridors may limit the spatial coverage and therefore utility of bottom trawl CPUE. A trawl survey based index is unlikely to be an option if the Hauraki Gulf trawl survey is discontinued, and catch-at-age sampling is not conducted for John dory (ruling out catch curve analysis as an option). As per the section discussing trevally, a bottom longline survey (if it is initiated) will likely catch too few John dory to be useful and the utility of ***Swath Cam for fish abundance*** still needs to be validated. Given these considerations, the existing bottom trawl survey index could serve as an indicator, but will become outdated. At this point the best future option is likely to be to utilise commercial ***bottom trawl CPUE*** while noting limitations due to restricted spatial coverage of trawling (assuming the trawl corridors are introduced).

Red gurnard - Red gurnard (*Chelidonichthys kumu*) are also a valued part of the mixed species inshore fishery (along with snapper, John dory, trevally and to some extent tarakihi). The Hauraki Gulf falls within the GUR 1 QMA, which encompasses the northern half of the North Islands west and east coasts. GUR 1 received a TAC reduction in recent years. For stock assessment purposes GUR 1 is divided into three subpopulations, east Northland-Hauraki Gulf, west coast North Island, and Bay of Plenty. The other considerations for red gurnard are identical to John dory above.

Kingfish – Kingfish (*Seriola lalandi*) are a pelagic fish species that are prized as a sport fish and a significant bycatch of inshore commercial fisheries. The Hauraki Gulf falls within the KIN 1 QMA, which encompasses North Cape to East Cape. The age structure of recreational catches suggests that kingfish off east Northland/Hauraki Gulf and in the Bay of Plenty/East Cape regions may comprise separate populations. No assessment is conducted for the Hauraki Gulf, but partially quantitative assessments are conducted for east Northland, with inshore fish assessed via a standardised ***bottom longline CPUE*** analysis in 2023 and offshore fish by catch curve analysis in 2016 (Fisheries New Zealand 2023a). An assessment result is available for a population connected to the Hauraki Gulf; however, it is not clear how representative this assessment is for Hauraki Gulf kingfish abundance.

Scallops – Scallops (*Pecten novaezelandiae*) are a valued subtidal shellfish species. The Hauraki Gulf falls across two scallop stocks: SCA 1 (Northland), which extends from Hauturu Little Barrier Island to the top of the North Island, including part of the northern part of the west coast and SCA CS (Coromandel), which covers the rest of the Hauraki Gulf, including the eastern Coromandel. The SCA 1 commercial fishery was closed in 2021–22, while the SCA CS commercial fishery was closed in 2022–23 (Fisheries New Zealand 2023a). A time series of fishery independent survey monitoring exists for multiple scallop beds within both stocks, although there are substantial gaps in the time series (Williams & Bian 2021, Williams et al. in prep). This monitoring has generally consisted of dive surveys of some of the shallow scallop beds that are fished recreationally (Figure 13), and dredge surveys of the deeper scallop beds that are commercially fished. The dredge surveys were used to inform assessments for the commercial beds, however, a number of issues with the survey methodology and assessment methods have meant that an assessment was not accepted for either stock for a number of years. As a result, FNZ are currently reviewing potential survey methods and also management reference points. Potential survey methods are likely to involve a combination of dive and camera-based surveys. Such surveys would be able to produce a range of different potential indicators. An important aspect to consider with regard to the decline of these scallop populations is that in addition to biomass, the density of scallops (being a sessile broadcast spawner (Joanna & Romuald 2004)) is likely to influence recruitment. One indicator that could be generated from these surveys is the ***effective spawning stock biomass*** (or number of scallops), which represents scallops that are >70 mm shell length and at effective densities to enable spawning. Further research would need to be conducted to set a density threshold that defines effective spawning density. Further, the biomass (or number of scallops) for the whole of SCA 1 or SCA CS would be somewhat uninformative considering the patchy distribution of scallops, and the need for effective scallop beds to be spread throughout the Gulf to ensure larval dispersal to all potential beds. Therefore, having time series of effective spawner biomass (or number of scallops) for each of a number of beds throughout the Gulf would be an indicator that incorporates abundance, the effectiveness of shellfish spawning and spatial distribution. Whether generating these indicators (at sufficient spatial representation) will be possible, however, depends on the review and research planning that is currently being undertaken.

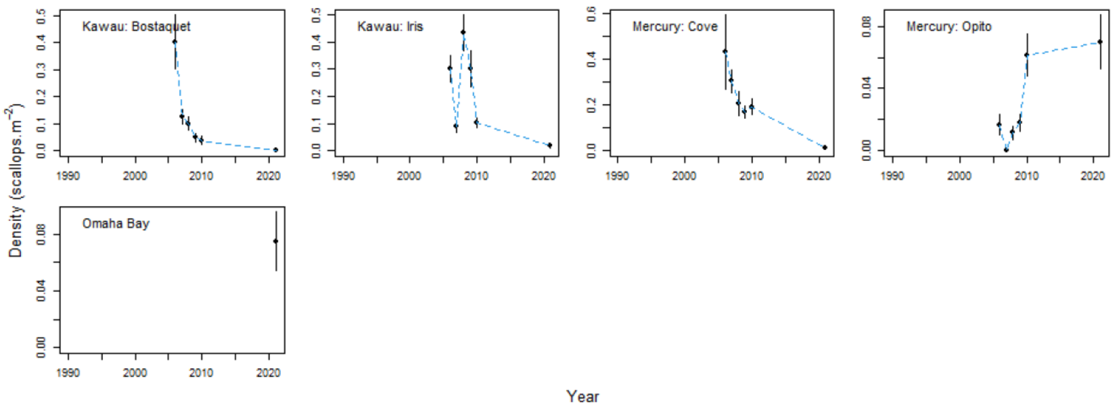


Figure 13 Example time series of scallop density (100–150 mm shell width) from Hauraki Gulf non-commercial beds. This data was collected by diver surveys, but could be collected via camera based methods. Plot reproduced from (Fisheries New Zealand 2023a).

Rock lobster – Spiny rock lobster (*Jasus edwardsii*) are a highly valued shellfish population. The Hauraki Gulf Marine Park aligns closely with the CRA 2 QMA. CRA 2 received a TAC reduction in 2018–19. For stock assessment purposes CRA 2 is considered as its own population. A fully quantitative stock assessment was accepted in 2022, with a rapid update in 2023, another rapid update scheduled for 2024 and a full assessment in 2025 (Pons et al. 2024). The assessment is based on commercial CPUE, commercial length and sex data, and tag recaptures. An index of abundance for rock lobster at an appropriate spatial scale already exists, is scheduled to be updated frequently and could be utilised now (***rock lobster assessment (CRA 2) SSB or %B_0***). It should be noted, however, that the majority of the CPUE data in this assessment is from the eastern Coromandel part of CRA 2 (statistical area 906), there is much less commercial effort from the western Gulf (statistical area 905) (Fisheries New Zealand 2023a), and patterns of abundance may differ between these areas. An index of commercial CPUE from the western Gulf, could be a useful supplemental indicator as it would capture any spatial differences in abundance trends (see section below addressing spatial distribution of fish populations).

Intertidal shellfish – Intertidal shellfish include a range of bivalve species that are highly valued, especially by Māori. Two species, cockle (*Austrovenus stuchburyi*) and pipi (*Paphies australis*) have been regularly monitored (supported by FNZ funding) across a number of North Island beaches with consistent methods since 1999–2000 (Berkenbusch et al. 2022). Six of these sites fall within the Hauraki Gulf, namely Whangateau Harbour, Cockle Bay, Umupuia Beach, Te Mata Bay, Whitianga Harbour, and Tairua Harbour. At each of these sites a stratified survey of the intertidal population of cockle and pipi (or just one species if only one occurs at a location) is undertaken with cores to produce biomass estimates. The size of the cockle and pipi are measured, which can be used to generate a time series (with biannual sampling frequency) of the density of large cockle (≥30 mm shell length) and large pipi (≥50 mm shell length). Such a metric (***large intertidal shellfish density (survey)***) could be a useful indicator as it is based off of a high quality, extensive and existing time series of survey data, has some spatial representation throughout the Gulf, and is translated into an end-user relevant metric by representing the density of large (harvestable) shellfish (Figure 14). A number of community shellfish monitoring initiatives (some of which are funded by DOC, AC, WRC) also exist, or did exist in the past (Hauraki Gulf Forum 2023). These community shellfish monitoring initiatives should be considered as a way of increasing the spatial representation provided by the core locations that are part of the FNZ surveys described above.

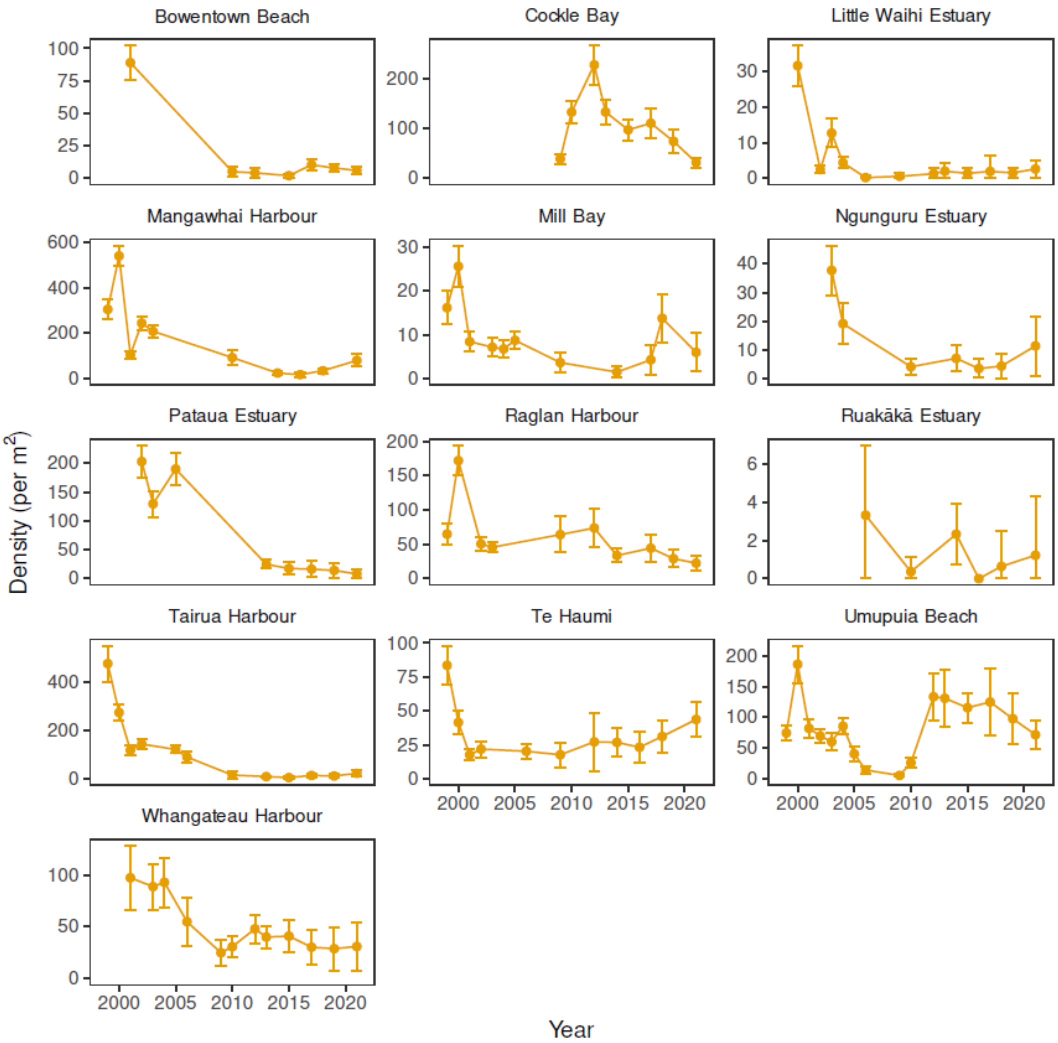


Figure 14 Example of a potential indicator for intertidal shellfish, specifically the density of large cockles (≥30 mm shell length) (Berkenbusch et al. 2022). Note, not all these sites are within the Hauraki Gulf. Bars represent 95% confidence intervals.

Reef fish – Reef fish consist of a range of finfish species primarily associated with rocky reefs and are of high public interest. This interest is not generally because they are harvested species (although some are), but because populations of diverse and abundant reef fish are a visual representation of a highly valued healthy ecosystem. Some of the species that might be considered part of this group include spotty (*Notolabrus celidotus*), red pigfish (*Bodianus unimaculatus*), Sandager's wrasse (*Coris sandeyeri*), black angelfish (*Parma alboscapularis*), demoiselle (*Chromis dispilus*), red moki (*Chirodactylus spectabilis*), marblefish (*Aplodactylus arctidens*), blue maomao (*Scorpis violacea*), and many others. The best method to survey these species is Underwater Visual Census (UVC). While BRUV methodology would capture some of these reef fish species, it is less appropriate than UVC because many of these species do not respond strongly to bait, and BRUV footage can become dominated by more aggressive predators such as snapper. A time series of UVC surveys (often conducted by the University of Auckland and supported by DOC) have been conducted inside and adjacent to Hauraki Gulf marine reserves (e.g., CROP, Tawharanui, Hahei and also a control site at the Mokohinau Islands), and in most cases extend back to the 1990s, although much earlier for CROP (Allard et al. 2022, Department of Conservation 2022). It is possible that such UVC monitoring will be expanded when the *Revitalising the Gulf* HPAs are implemented. Potential indicators for communities of fish are more complicated than considering individual fish species. Department of Conservation (2022) describes a range of potential indicators that could be calculated from UVC data and Tuck et al. (2014) discusses the attributes of various potential fish community indicators. In particular, Tuck et al. (2014) notes that measures of diversity can often miss changes in community composition, but from the New Zealand experience, Pielou's evenness and Shannon and Hill's indices of diversity have often shown relationships to fishing intensity. A metric documenting ***reef fish UVC diversity*** (Pielou's evenness or Shannon and Hill's index) could be worth investigating. It is important, however, to consider the factors that reef fish are likely to respond to, which relate to the direct effects of fishing (i.e., extraction), the indirect effects of fishing such as habitat change, and larger-scale changes not related to fishing. Allard et al. (2022) describes how these effects relate to individual reef fish species (for the Leigh area). A potentially simpler metric would be ***reef fish UVC total biomass or species group biomass*** for species that are known to respond to the factors of interest. Alternatively, ***biomass ratios*** for these groups (inside vs. outside of marine reserves or HPAs) could also be an effective indicator (e.g., simmilar to the ratio developed by Hanns et al. 2022).

Fish population condition (distribution)

In addition to understanding the population status of fish species or communities, it is important to consider other aspects of fish communities to progress towards EBFM. One of these aspects is the spatial distribution of fish populations. As discussed in the previous section, fish population assessments are generally conducted on discrete stock units with an assumption of limited mixing (immigration/emigration) and these stocks can encompass spatial scales much larger than the Hauraki Gulf. Changes in fish abundance at smaller spatial scales may differ from that at the scale of the entire population unit. This can come about through localised depletion, where extraction rates in a localised area are higher than that across the entire population unit, leading to reduced abundance (relative to the entire population unit) at localised scales. A New Zealand relevant example exists for blue cod (*Parapercis colias*), where localised depletion is exacerbated by the high levels of residency (Fisheries New Zealand 2019). Where localised depletion occurs, it does not necessarily mean that the entire population unit is overfished and given time, it might be possible for locally depleted portions of populations to recover. However, if localised extraction persistently supresses localised abundance this can create an ongoing issue where a range of values associated with that species may be continually suppressed at that local scale (e.g., ecosystem functions such as predation and competition; spawning success and larval dispersal; and end-user values). In this section we suggest additional metrics for some fish species which may provide information on abundance at more localised scales.

Snapper and kahawai are both commonly caught by recreational fishers. Ongoing monitoring of recreational catch at boat ramps throughout the Hauraki Gulf provides opportunities to assess spatial distribution (Hartill et al. 2020b). Using these data, it is possible to define specific areas/strata within the Hauraki Gulf that recreational catch of each species can be associated with. Because this boat ramp monitoring also measures captured fish it is possible to generate size specific indices for each of the areas/strata that are defined. This means catch rate (CPUE) of size classes relevant to end-users and/or for ecological functions (e.g., predation) could be produced for each area. For snapper, it may make sense to align such an index with the size of snapper described in the large predator metric above, because snapper that are ≥55 cm FL are also likely to be of high value to recreational fishers. For kahawai, some consideration of what sized fish are of value to recreational fishers would need to be undertaken. Overall, these spatially specific ***recreational CPUE at-length*** indicators have great utility as they simultaneously address the abundance, spatial distribution and size of important fish populations (Figure 15).

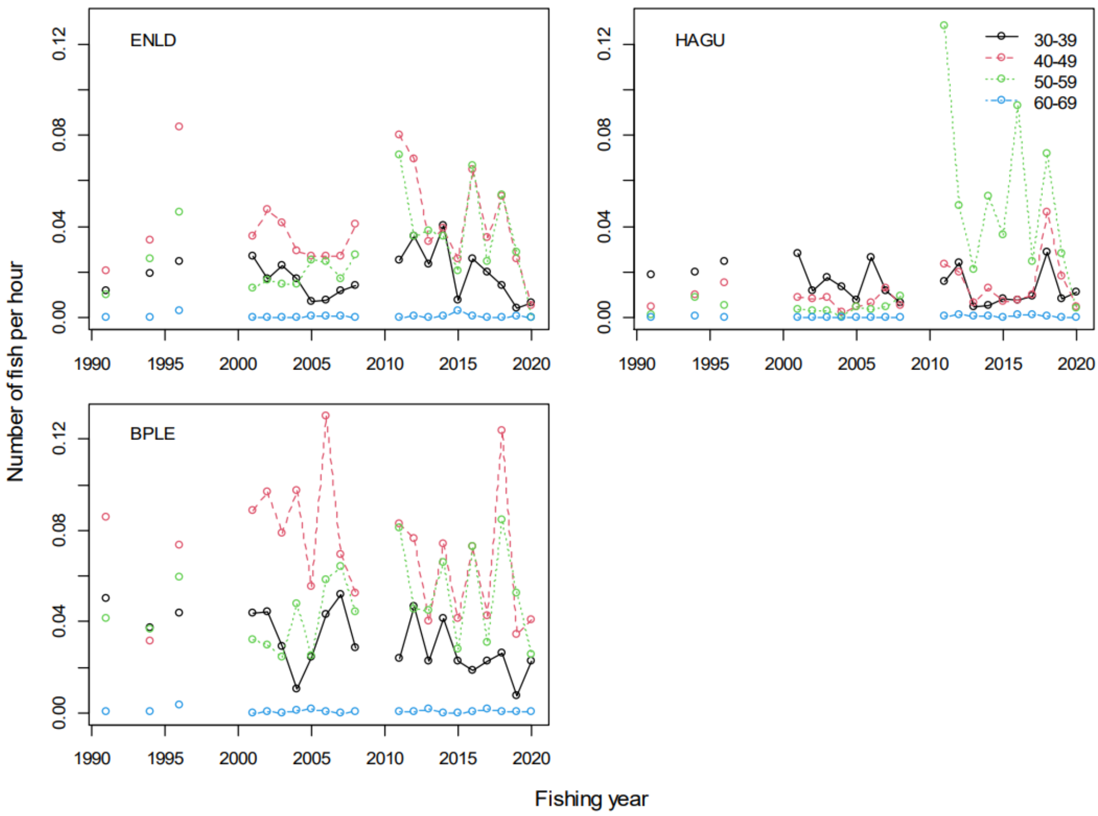


Figure 15 Example of unstandardised recreational CPUE at-length for four kahawai size classes by area. Similar indicators could be produced for snapper with specific size classes and areas defined as needed (Hartill & Doonan 2022).

Hāpuku & bass generally occur over specific habitat features and as a result are vulnerable to localised depletion and range contraction (Hartill et al. 2020a). A measure describing their spatial distribution could be worthwhile, but, as detailed above, there is a paucity of data relating to hāpuku & bass and it is not known what (if any) new monitoring will be put in place (e.g., deepwater SBRUV).

The best localised index of abundance for tarakihi would likely come from commercial ***bottom trawl CPUE***. While localised CPUE indices are used as inputs to the assessment model, the sub areas that they are calculated for do not align well with the Hauraki Gulf. Therefore, a CPUE analysis customised for Hauraki Gulf areas would need to be performed. Future restrictions on trawling may limit the utility of such a metric. If new survey options become available (e.g., Swath Cam, BRUV or bottom longline surveys) these might be able to provide fishery independent localised abundance indices, however, it is likely that catch rates of tarakihi via all potential survey methods will be low.

Trevally, John dory and red gurnard do not have any known localised depletion concerns. Further, the abundance indices discussed above were all in relation to commercial bottom trawl CPUE, which is likely to be spatially limited within the Gulf. As a result, spatial distribution indices for these species may not have that much utility.

While kingfish are highly mobile, they are also highly associated with seabed features, which receive varying amounts of fishing pressure, which can in turn result in localised depletion. Because kingfish are pelagic many of the available survey methodologies (e.g., trawl, BRUV, or towed video such as Swath Cam) would not effectively describe kingfish abundance. A customised survey methodology that accounts for the pelagic, schooling and feature dependent nature of kingfish would likely be required. One option that could be developed is a ***pelagic drop camera survey*** focussed on key seabed features where kingfish aggregate (and where fishing is concentrated). While the utility of such a survey method is unknown, it would likely be a logistically expensive approach.

Spatial distribution of scallops is highly relevant, as scallops are relatively sessile and can become locally depleted (Williams et al. in prep). The time series of survey-based estimates of effective spawner biomass by scallop bed/survey location discussed above would adequately address spatial distribution. Similarly, the survey-based estimates for large intertidal shellfish are also able to be represented by site and therefore provide information related to spatial distribution. Community based shellfish surveys provide an opportunity to increase the number of locations that shellfish abundance indices are available for.

Rock lobster commercial CPUE at the statistical area level may be able to provide information about patterns in abundance for the western (statistical area 905) vs eastern (statistical area 906) Hauraki Gulf. However, the western (905) statistical area has less commercial fishing effort, and the effort that does occur is mostly in the northern part of that statistical area. Another option which could provide more spatial detail would be to estimate the abundance of rock lobster by calculating the ***ratio of rock lobster inside vs outside of marine reserves*** (as observed from diver surveys or experimental potting). Such an indicator has been generated by Hanns et al. (2022), demonstrates different abundance patterns compared to the assessment and is being considered by the Rock Lobster Working Group. One of the main limitations of this latter method is that it depends on sampling data that at the moment are derived from two locations. The number of sampled sites may increase going forward as monitoring associated with the HPAs is implemented.

Reef fish abundance estimates are gathered using UVC collected on a site specific basis (which may expand if more sites are added to monitor HPAs when they are implemented). Regardless of whether diversity, total biomass, or species group biomass are utilised, separate ***reef fish site specific metrics*** for each of these sites could be produced to provide information about spatial distribution/localised abundance.

Fish population condition (size and age)

The size (and age) composition of a population or community reflects its life history strategy, and also its response to fishing, which is often size selective. A population or community's size composition can also provide insight about the level of predatory force it is able to exert (Pauly et al. 1998), its reproductive potential (Hixon et al. 2013), and its associated value for end-users. Metrics relating to size and age could be a powerful addition to traditional abundance or biomass focussed fish population metrics. Size and age information, however, are generally only collected in association with fishery surveys (of which there are few in the Hauraki Gulf), and for sampling associated with a small number of recreational (boat ramp sampling of kahawai and snapper) and commercial species (catch-at-age sampling for snapper, trevally, and tarakihi). As discussed above, a number of potential surveys or survey expansions (e.g., Swath Cam, bottom longline survey, BRUV monitoring), could also provide size and/or age data if they come about. A range of potential metrics to represent size or age are possible, including mean length (or age), the proportion of the population above a certain size cut off, and the slope of the size spectrum (reviewed by Tuck et al. 2014). These metrics can also be applied to entire fish communities and would serve as a useful measure of ecosystem functioning (Shin & Shannon 2010). The difficulty with community metrics is that they need to capture the size distribution of the entire community to be meaningful; such data do not currently exist.

Some of the fish population metrics discussed above already incorporate size, and therefore could be useful multi-purpose indicators. This is true for snapper and kahawai, where recreational boat ramp sampling has the potential to provide CPUE information for specific size classes (***recreational CPUE-at-length***), and for multiple strata throughout the Gulf. Such an indicator may therefore have great utility. An additional consideration is the extensive time series of age and length information for snapper obtained from sampling the commercial bottom longline fishery (dating back to the 1980s) (Walsh et al. 2022). This time series could be used to generate a mean age/size metric or the proportion of the population older/larger than a certain age/size. Given that predation, spawning productivity and stakeholder value are likely associated with size not age (Hixon et al. 2013), focussing on size based metrics is probably more relevant for this section (e.g., ***snapper mean size or proportion larger than a certain size***) (Figure 16). It will be important to consider what this metric would add above and beyond other metrics relating to snapper size, such as the large reef predator metric and the recreational CPUE-at-length metrics discussed above. Specifically related to the large predator metric, there is some concern about data quality because that metric is informed by BRUV deployments, which are known to underestimate the abundance of large snapper (Evans 2017). If survey methodology was modified to a horizontal camera system (SBRUV) this may have more potential to provide a reliable reef predator metric.

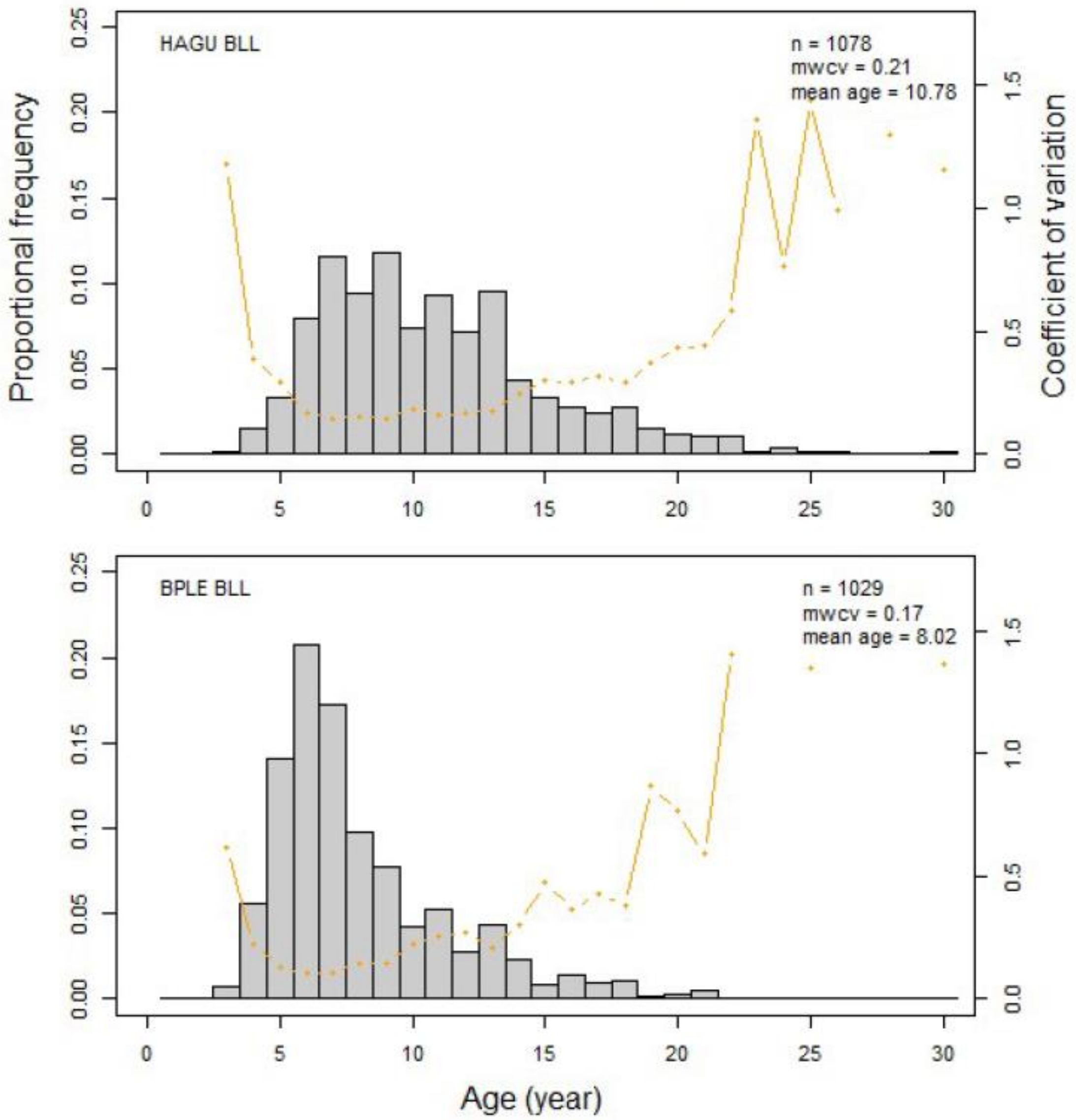


Figure 16 Proportion-at-age distributions (histograms) and coefficients of variation (lines) determined from snapper landings sampled from bottom longline fisheries in 2019–20. While these plots represent age distributions for just one year, a time series of length data back to 1989 is available and could be used to generate an index representing snapper mean size or proportion larger than a certain size (HAGU, Hauraki Gulf; BPLE, Bay of Plenty; n, sample size; MWCV, mean weighted coefficient of variation) (Walsh et al. 2022).

Rock lobster size information is available from the dive surveys (Hanns et al. 2022), but also potentially through fishery log book data that is voluntarily collected via commercial lobster potting. Either of these data sources could be used to generate a size-based metric. Again, it will be important to consider what this metric would add beyond other metrics relating to rock lobster size, such as the large reef predator metric. Separating out a component specifically for rock lobster (e.g., ***proportion rock lobster > 100 mm CL***) could be a useful metric that aligns with the rest of the indicator suite. The utility of such an indicator may increase if the dive surveys are expanded to monitor the implementation of HPAs.

The intertidal shellfish surveys already generate a ***large intertidal shellfish density*** metric. This metric therefore already incorporates size in a way that is relevant to end-users. Similarly, for scallops, the ***effective spawner stock biomass*** metric suggested above would also incorporate size in a way that is relevant to both ecological function and end-user value.

Size and age information is also available for terakihi and trevally through catch-at-age sampling of commercial catches (conducted every few years) (McKenzie et al. 2017, Parsons et al. 2022). This means size-based indicators (***mean size or proportion greater than a certain size***) could easily be calculated for these species. The value of adding such metrics (informative for ecological functioning or end-user value) to what could be an already sizeable list of indicators, needs to be considered. This may depend on whether there are abundance metrics for these species or not. Similar logic applies to reef fish size-based indicators. They could easily be calculated from size estimates associated with UVC data, but it remains unclear if an additional metric (beyond abundance or biomass) relating to size would be of value or not.

As stated above, a size-based indicator for the entire fish community has the potential to provide powerful insights describing how ecosystem functioning changes in response to fishing. The key limitation, however, is the requirement for size data for all components of the community, which can only come from survey data. Any potential future survey (such as Swath Cam, bottom longline survey or a BRUV survey series) will undoubtedly collect size information, enabling metrics such as the ***whole fish community mean size or proportion greater than a certain size*** to be calculated at that time. The selectivity of any survey method (i.e., each survey method will have its own selectivity when observing/capturing different species and different sizes of fish) will need to be taken into account when calculating such a metric.

Fish population condition (recruitment)

From a fisheries perspective, recruitment refers to the process of fish becoming available to the fishery (i.e., growing to a point where they are above a minimum legal size or vulnerable to fishing gears). Recruitment is important to fish stocks because it represents new cohorts of fish that will support those populations and their associated fisheries into the future. Potential indicators for recruitment were identified through the co-development process as potentially relevant. While recruitment is clearly fundamentally important to fish populations, it is not clear if separate recruitment indices (such as ***year class strength***) would provide valuable additional information. Recruitment is already inherently incorporated into fish population assessments i.e., if recruitment is consistently poor or good, this will flow through to overall population abundance/biomass estimates that are already being produced.

Fish population condition (condition and growth)

The condition (e.g., weight to length ratio) and growth of fish can vary both seasonally and in response to a variety of other longer-term factors. These issues are currently very topical for snapper, because the growth rate of Hauraki Gulf snapper has been declining for about two decades (Walsh et al. 2022) These reduced growth rates are likely the result of density dependent processes; As snapper populations have started to increase this reduces the food available on a per fish basis, resulting in decreased growth (Walsh et al. 2022). It is not clear what a ‘good’ growth rate is, because growth is likely to decrease as a population increases. Regardless, one way of illustrating these changes would be to generate a time series of the mean length of snapper for a particular age (e.g., 10-year olds) and represent that ***mean length-at-age*** for each year when catch-at-age samples were available.

In addition to growth, Hauraki Gulf snapper have also exhibited milky flesh syndrome since mid-2022 (Figure 17). The cause of this syndrome is uncertain, but fish with it have opaque white and mushy flesh, and testing indicates that they are nutritionally deprived (Johnson et al. in press). The syndrome is common among snapper along the northeastern coast of the

North Island, but also occurs at lower proportions in other inshore species and also outside of this region. During 2023 two of the major commercial fishing companies from this region started to estimate the catch weight of snapper with the syndrome in each landing. This is the best available information to monitor the syndrome and could generate a metric such as the ***proportion of landings (by weight) that are milky fleshed***, which could be averaged monthly to create a monthly time series. Similar growth and condition metrics could be considered for other species if and when condition or growth issues occur within those populations.

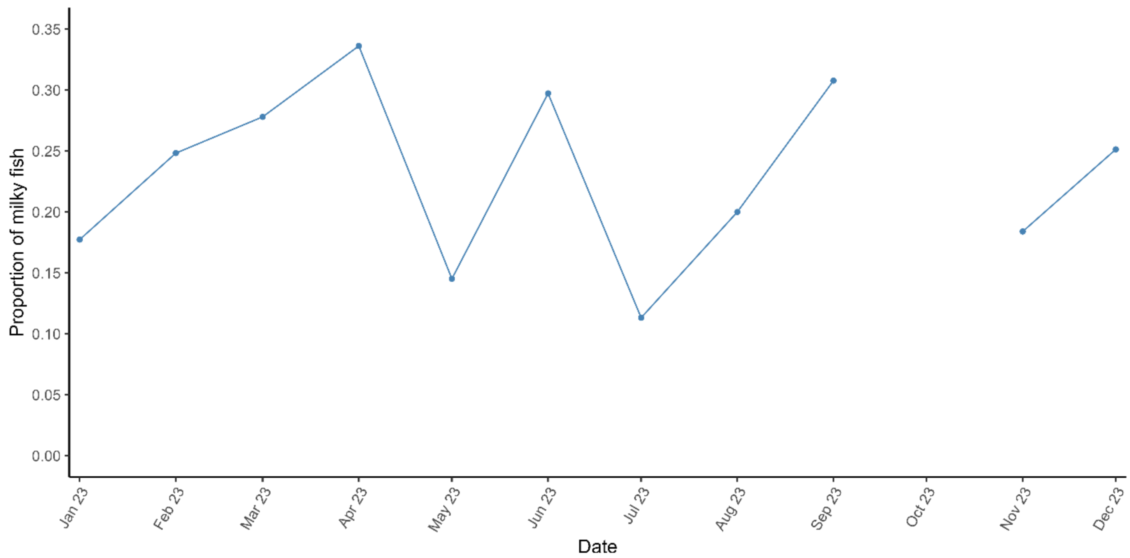


Figure 17 Proportion of milky fleshed snapper recorded at the Kai Ika filleting station and by recreational anglers from the Mairangi Bay Fishing Club in the Hauraki Gulf between 1 January and 31 December 2023. Similar data is also available from fish grading undertaken at commercial fish processing facilities and could be used to generate an indicator that encompassed a far greater sample size of fish (Johnson et al. in press).

Shellfish are prone to variation in condition, which is of importance to end-users because it influences meat weight (i.e., the weight of muscle + roe divided by the green catch weight). Much of this variation will be part of natural seasonal cycles related to spawning. However, it is possible that shellfish which occupy non-optimal habitats or those exposed to environmental degradation (e.g., land-based effects) may also exhibit poor condition. When the commercial scallop industry was operational in the Hauraki Gulf the proportion of the catch that was meat weight for each landing was recorded. Such a metric (***scallop landing proportion meat weight***) would be able to track the condition of scallops through time, but the influence of seasonal spawning related cycles relative to environmental stress would need to be considered.

Fish population condition (effective shellfish spawning)

As discussed above, shellfish are relatively sedentary and rely on being close to other shellfish for spawning (and subsequently population replenishment) to be successful. Therefore, a metric that describes whether shellfish populations are effectively spawning would be a useful addition to any metrics describing abundance or biomass. The survey-based metric described above for scallops (***effective spawning stock biomass***) incorporated abundance, size and the effectiveness of spawning (by assessing density) and has the potential to be a very useful multi-purpose indicator.

Fish population condition (disease)

Shellfish in particular can be prone to diseases which appear periodically. Potentially the best known New Zealand example is the *Bonamia* disease which has had severe impacts on the Foveaux Strait oyster fishery. *Bonamia* disease prevalence is now routinely monitored in Foveaux Strait (Michael et al. 2022). There are no comparable examples from the Hauraki Gulf: Hauraki Gulf scallops have had break outs of black gill disease (1990s and 2000s) (Fisheries New Zealand 2021); and tail fan necrosis can affect rock lobster, but to date observations have been limited to CRA 3 (i.e., outside of the Gulf) (Pande et al. 2021). Diseases and parasites can also affect finfish. The milky fleshed snapper syndrome was investigated as a potential response to parasites, but testing conducted by Biosecurity New Zealand did not find any link to parasites (K. Johnson and D. Parsons, NIWA, unpub. data). Potential indicators for diseases (and associated monitoring) amongst Hauraki Gulf fisheries are likely to be reactive to occurrences as they arise.

Fish community composition

Measures of diversity describe how many species are present (richness), and how similar their abundances are (evenness). Therefore, it would be reasonable to assume that a healthy fish community (i.e., one experiencing low levels of fishing or other stressors) will be more diverse. While diversity measures have been widely applied in community ecology (Anderson et al. 2006, Hewitt et al. 2005), there is some concern that changes in diversity can be misleading (as discussed in the reef fish abundance section above) (Fulton et al. 2004, Rice 2000).

For example, a large pulse of recruitment for one species may alter diversity. Interpretation (or the understanding of directionality) of diversity indices can therefore be challenging. Further, diversity indices are almost always calculated from survey data. This is because the diversity of fishery catches will be influenced by not just the fish community itself, but also by fishing behaviour which responds to market forces. As discussed in multiple previous sections, it is possible that the Hauraki Gulf trawl survey series will be suspended and at this stage it is not clear what new survey series will exist.

The type of survey methodologies that are available going forward will be important, due to the inherent selectivity that any survey methodology will have. For example, surveys that utilise bait (bottom longline or BRUV) will only capture the predatory proportion of the fish community. We know that in the Hauraki Gulf more than 90% of commercial bottom longline catch is snapper (McKenzie & Parsons 2012), so it is likely that a bottom longline or BRUV survey will only provide limited observations of non-snapper predatory fish that could be used to generate a diversity index. Alternatively, while a Swath Cam survey is non-baited, it will only observe the demersal part of the fish community and the experience of previous towed video methodologies suggests that few fish are observed overall (Compton et al. 2012). Nonetheless, towed video methods such as Swath Cam will likely provide the greatest potential to inform a ***whole fish community diversity*** metric (Figure 18).

In terms of the specific types of indicator to consider, Pielou's evenness and Shannon and Hill's indices of diversity have previously demonstrated relationships to fishing intensity (as discussed in the reef fish abundance section) (Tuck et al. 2014). In considering whether to include a whole fish community diversity metric, however, it is worth noting that some of the previously discussed metrics are somewhat similar (e.g., the average trophic level of landings (or MTI), proportion of functional groups such as predatory fish (Shin & Shannon 2010), and the trophic level of individual fish species), so it may be necessary to select from these to avoid redundancy.

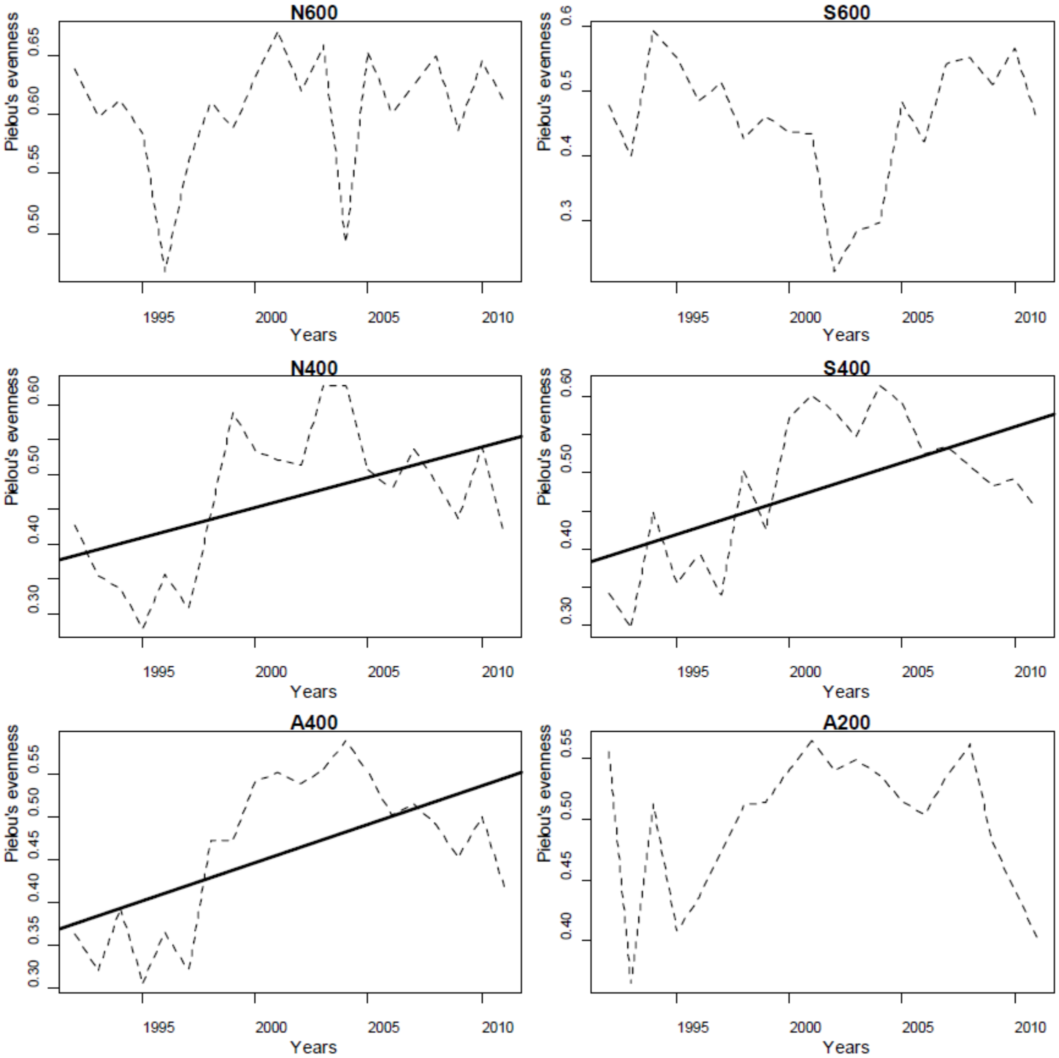


Figure 18 Example plots of Pielou's evenness of deepwater fish communities from the Chatham Rise trawl survey. Stratum level community evenness is plotted for each year, with the solid line representing a significant linear fit. Survey regions: N600 – Northern area, 600–800 m depth; S600 - Southern area, 600–800 m depth; N400 - Northern area, 400–600 m depth; S400 - Southern area, 400–600 m depth; A400 - whole area, 400–600 m depth; A200 - whole area, 200–400 m depth (Tuck et al. 2014).

Fishery

Socio-economic value of fishery components (contribution of fisheries to society)

Fishing makes a variety of different contributions to society, whether that be the direct economic value of commercial fishing, the indirect flow on consequences of commercial and recreational fishing through the economy and the jobs that are required to support these industries, the provision of food, and the recreational and cultural value that is associated with fishing. Estimating the value of different fishery components can help the public to better understand the contribution of each to society and can also enable managers to make informed decisions when assessing trade-offs (NZIER 2023). There have been a variety of economic analyses that have estimated the value of some or all of these different fishery components. These include: (1) an estimate of the economic impact of recreational fishing conducted in 2016 (Holdsworth et al. 2016) (although noting that this did not produce any specific estimates for the Hauraki Gulf); (2) a total economic value approach to valuing all of the ecosystem services in the Hauraki Gulf (NZIER 2023) which incorporated the direct contribution of commercial fishing as estimated by Kulwant & Carlaw (2022) and an estimate of recreational fishing value calculated using average willingness to pay estimates; and (3) the overall economic contribution (e.g., direct, indirect, and wages) of the seafood industry in New Zealand, which was calculated by fishing sector and region (Dixon & McIndoe 2022) (noting that while no specific estimates were made for the Hauraki Gulf this should be possible (H. Dixon, BERL, pers. comm.)). What is clear from these different pieces of work is that the approach to economic valuation varies, involves many assumptions, and that it can be challenging to provide specific estimates for just the Hauraki Gulf. Given these circumstances, a primary objective should be to establish consensus for a ***total economic valuation*** methodology across all user groups that can inform about the value of each fishery component going forward.

Fishing industry employment was used as part of some of the calculations above, however, it may be worth separating out employment as its own metric. Dixon & McIndoe (2022) describe a process for estimating seafood industry employment which is categorised by fishing sector components and region. While Auckland is one of these regions, Auckland based fishing companies will also fish outside of the Hauraki Gulf (including on the west coast). To get around this, one option would be to estimate the proportion of each company's catch from the Hauraki Gulf and use this as a coarse multiplier to estimate the Hauraki Gulf component of these employment figures.

An additional societal contribution metric that may be relevant is the ***quantity or proportion of commercially caught fish that supply local markets*** (i.e., fish that is exported vs. consumed in New Zealand vs. consumed in Auckland). Such a metric could potentially be calculated from existing commercial fishing company data (N. Reid, Moana, pers. comm.). While similar metrics have been used elsewhere (Shin & Shannon 2010) they only address one part of the overall contribution of fisheries to society relative to what would be incorporated into a total economic valuation approach. The utility of such an indicator, however, should not necessarily be overlooked because the value that it demonstrates is directly relatable to the public (i.e., the consumer) which could go a long way towards restoring social licence of commercial fishing (see below).

Socio-economic value of fishery components (commercial costs and financial viability)

Beyond the contribution (economic or otherwise) that fisheries make to society, it may also be worth having metrics that inform about the financial costs and financial viability of commercial fishing activities. Essentially these metrics would illustrate the economic consequences, for the commercial fishing industry, resulting from the management actions of *Revitalising the Gulf*. With respect to costs, a number of metrics could be considered which relate to aspects such as increasing fuel costs or the increasing cost of operation under more restrictive management arising from *Revitalising the Gulf*. It is important to recognise, however, that some of these costs will occur in response to much broader influences than local management measures (e.g., global inflationary pressure). ***Deemed values*** (a financial incentive for commercial catch to not exceed annual catch entitlements) were suggested as a measure that could potentially be informative, however, they are influenced by multiple variables, so it is not clear what aspects of fishery economics they would represent (Fisheries New Zealand 2020). An alternative approach would be to develop metrics that assess the financial viability of commercial fishing and how this changes in response to management interventions. Such a metric is highly relevant, as it represents one part of a societal trade-off (the other part being the alternative extractive or non-extractive uses of those fishery resources) that are created by those management interventions. To that end, understanding costs in the light of the revenue earned by commercial fishing operations, or profit, is potentially the best metric to understand financial viability. While data relating to ***fishing company profit*** is available from Statistics New Zealand (https://stats.govt.nz/integrated-data/integrated-data-infrastructure/), specific company names are redacted, and the data will only be reported for regions (which will not be connected to the specific location of fishing operation). Similarly, fishing company annual reports do list profit, but that profit is also not broken down by area of fishing operation (e.g., Moana NZ 2023). While it should be possible to use the methods described by Dixon & McIndoe (2022) to estimate revenue associated with Hauraki Gulf fishing operations (by using detailed catch reporting), area specific costs are not available. Estimating profit as a metric of the financial viability of commercial fishing will likely require cooperation from the major commercial fishing companies in the Hauraki Gulf, which may not be possible due to commercial sensitivity.

A less direct measure of financial sustainability is the amount of commercial fishing effort occurring in the Hauraki Gulf. For example, if part of a commercial fishing company's operation is less profitable it is likely that effort associated with that part of the operation will ultimately be redirected away from the less profitable component. Metrics relating to effort are discussed in the next section.

Socio-economic value of fishery components (commercial effort)

Information relating to commercial fishing effort has the potential to inform the public, treaty partners, and managers about a range of different aspects. In this section, however, we attempt to discuss commercial fishing effort from two perspectives: (1) The ease or difficulty for commercial fishers to catch fish, which will be influenced by a range of variables including fish abundance and the management restrictions in an area. This metric is not meant to be a proxy for fish abundance as per the CPUE metrics discussed in the Fish Population Focal Component; and (2) the overall amount of fishing effort expended in the Hauraki Gulf as a measure of the financial viability of fishing operations in the Hauraki Gulf. It is also worth noting that fishing effort is also relevant to the amount of fishing pressure an area experiences, but that is discussed in a subsequent section.

With regard to the ease or difficulty of commercial catch, a number of potential formulations are possible. One option would be to estimate the ***proportion of a fishing trip that is actively fishing*** (i.e., setting, towing/soaking or retrieving gear). Such a metric would need a way of accounting for multi-area trips, but this should be possible given the detailed effort reporting that is now required. As mentioned above, it is likely that the ease or difficulty of commercial catch will be influenced by a range of variables, so a better understanding of what these factors are and how they impact effort would need to be explored to properly understand what this metric describes. Another option relating to the ease or difficulty of commercial catch could be derived from the ***% of stocks that reach catch limits***. There are two main issues with such a metric. Few fish stock QMAs align with the Hauraki Gulf, and fishers are able to catch fish from any part of a QMA. Second, a variety of factors unrelated to the ease or difficulty that commercial fishers experience influence whether a stock reaches its catch limit. For example, in mixed species fisheries one species can reach its catch limit before the others, therefore limiting effort (and the ability to reach catch limits for other species) for the remainder of that fishing year.

There are a number of potential formulations describing the overall amount of fishing effort as a metric of financial viability of Hauraki Gulf fisheries. At the simplest level, the ***number of vessels fishing in the Hauraki Gulf*** could be calculated. Most vessels, however, will not restrict their fishing activities to the Hauraki Gulf alone. Therefore, a cut off (based on a minimum number of days fishing in the Hauraki Gulf) would be required when defining a 'Hauraki Gulf fishing vessel'. Such a metric could be generated for each of the major fishing methods (e.g., bottom trawl, bottom longline, Danish seine, setnet, lobster pot etc.). A more detailed alternative would be to calculate the amount of commercial fishing effort within the Hauraki Gulf (by fishing method) in terms of the number of days fished, the number of hooks set, or the total km trawled, etc. Although these more detailed effort variables are discussed under the Fishing pressure section below, the coarser level 'number of fishing vessels' metric may be a better match when considering the financial viability of Hauraki Gulf commercial fishing. While commercial fishing effort variables contain valuable information, they also have multiple interpretations. Understanding what variables influence commercial fishing effort and how effort respond to those variables will be paramount.

Socio-economic value of fishery components (commercial wellbeing)

The wellbeing of commercial fishers can be influenced by a variety of factors such as societal and environmental expectations, financial pressures, compliance with regulation, management interventions, and working remotely (Darren Guard, FirstMate, pers. comm.). These pressures can make the commercial fishing industry undesirable, which at the coarsest level can lead to fishers transitioning out of the seafood sector. Additional regulation or restriction within the Hauraki Gulf could further contribute to this picture, potentially resulting in additional decreases to the number of vessels fishing in the Hauraki Gulf. A ***number of vessels fishing in the Hauraki Gulf*** metric was discussed above. While its relevance to multiple parts of the indicator framework may suggest that it has great utility, it also emphasises the multiple factors that can influence a higher-level variable such as this. Other existing data sources which could inform about fisher wellbeing include a comparison of ***commercial fisher average wages relative to other employment sectors*** (e.g., Shin & Shannon 2010). While commercial fishing employment data is available, it would not be possible to estimate the average wage of Hauraki Gulf commercial fishing alone, which is the component relevant here due to changes in fishery restrictions within the Hauraki Gulf itself. A better understanding of commercial fisher wellbeing, however, could be gained from interviews conducted with Hauraki Gulf commercial fishers, to get a more explicit understanding of how their wellbeing is being affected.

FirstMate is a New Zealand charity that is currently supporting the wellbeing of commercial fishers. FirstMate have also been involved in research to better understand the mental health and wellbeing of commercial fishers, and also collate anonymised information about commercial fishers that approach them for support (FirstMate 2023). While the results of this research are not yet available, its findings could potentially be used to formulate indicators (e.g., ***number of FirstMate Hauraki Gulf based clients***) (Figure 19) or design a ***customised commercial fisher wellbeing survey***. The costs of conducting such a survey would have to be weighed up against the specificity of the data that it would provide, and also the quality of the data it would contain (questionnaire results can be subjective).

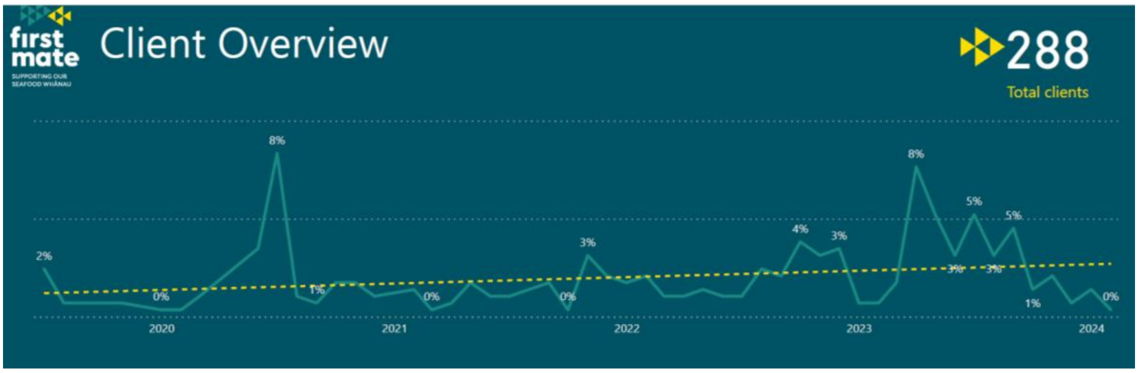


Figure 19 Number of commercial fisher clients (by month and year) being supported by FirstMate. A similar indicator could be developed for just the Hauraki Gulf area. Figure provided by FirstMate (https://www.firstmate.org.nz/).

Socio-economic value of fishery components (recreational value)

Recreational fishing is a highly valued and important pastime in New Zealand, with 32% of households containing at least one fisher, and close to two million fishing trips undertaken across New Zealand in 2017–18 (Wynne-Jones et al. 2019). Given this high level of value, indicators that describe recreational fishers values should be considered. Indicators relating to the abundance of fish populations, the value of recreational fishing to society, and the pressure resulting from recreational harvest are also relevant, but are discussed elsewhere.

The two most commonly caught recreational fish species in the Hauraki Gulf are snapper and kahawai (Hartill et al. 2019, Hartill et al. 2020b). In the Fish population Focal Component section ***recreational CPUE-at-length*** for both of these species was suggested as a multi-purpose indicator that would describe aspects relating to the abundance, size and spatial distribution of these species. Because the data used for this metric is obtained from ongoing boat ramp creel surveys of recreational fishers (Hartill et al. 2020b), these metrics also provide valuable information about the value recreational fishers obtain from the fishery. Beyond these most common species recreational fishers also obtain value from having a range of other species that can be caught. Using this creel survey data to generate an additional metric relating to the ***number of species caught per fishing trip (other than snapper and kahawai)*** may therefore be worthwhile.

Other species that are highly valued by recreational fishers include shellfish species such as rock lobster, intertidal shellfish and scallops. These species are caught less often by recreational fishers, so are infrequently documented by the standard recreational monitoring surveys in place (creel surveys (Hartill et al. 2020b), as described above, and the National Panel Survey (Wynne-Jones et al. 2019), described in more detail below). In response to this issue, a creel survey specifically designed to estimate the recreational harvest of rock lobster in CRA 2 (Hartill 2019) is currently underway. This survey could be used to generate a ***recreational rock lobster CPUE (number or weight of lobsters per hour fished)*** metric. There are no surveys, however, that reliably document recreational fisher value with regard to intertidal shellfish or scallops. For these species the abundance metrics suggested in the Fish population Focal Component section (***scallop effective spawning stock biomass*** and ***large intertidal shellfish density***) are likely the best available information.

An additional metric related to recreational fisheries that may also be worth considering is the ***total amount recreational fishing effort*** (e.g., Figure 20). The amount of recreational fishing effort can be derived from the National Panel Survey (Wynne-Jones et al. 2019). Briefly, this survey is conducted about once every five years and randomly recruits fishers from across the country, who are then periodically contacted to provide details relating to any fishing trips conducted. These details are then used to provide an absolute estimate of recreational effort and harvest by species. Between the years when the National Panel Survey is conducted, boat ramp creel survey estimates of effort and harvest (which are relative estimates) (Hartill et al. 2020b) can be scaled up to provide absolute estimates.

One advantage of the National Panel Survey approach is that it captures effort and harvest that won't be observed at boat ramps (e.g., shore-based fishing). However, when fishers that are recruited to the survey are subdivided down by region (e.g., Hauraki Gulf), the less frequently conducted fishing methods may not be well described. Regardless, total effort (total number of trips) could be derived on an annual basis from the combination of National Panel Survey and creel survey approaches. As to what such a metric informs is less clear.

Recreational effort is heavily influenced by weather, but is generally expected to increase with population growth. These expectations are not always borne out, however, and are influenced by a complex mixture of socio-economic factors (e.g., levels of disposable income, population demographics, the number of alternative entertainment options), and potentially fish availability (Bian & Hartill 2011). While effort will undoubtedly be related to the level of pressure recreational fishing imposes on fish populations, this is discussed below from the more direct perspective of harvest.

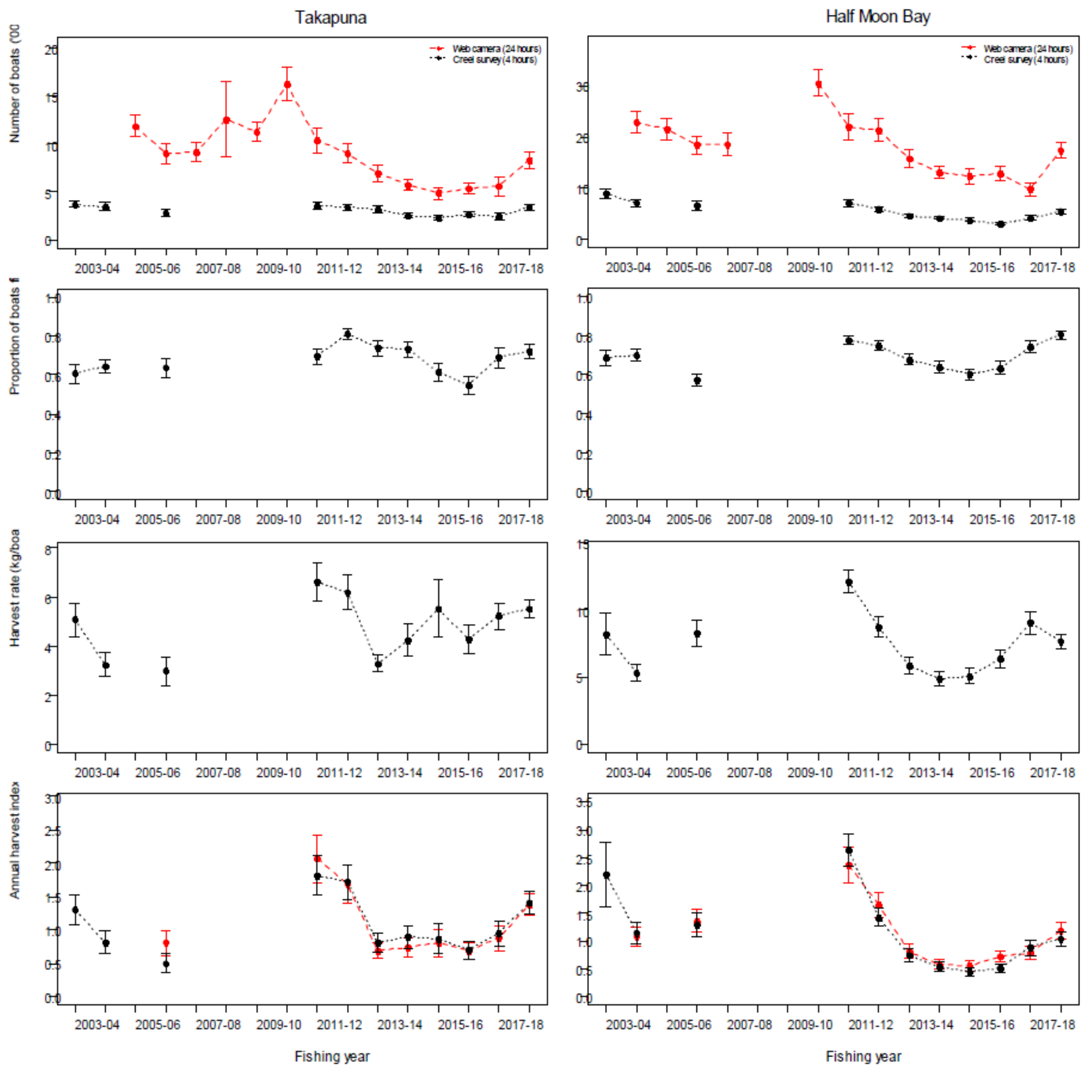


Figure 20 Example plots of the number of recreational fishing boats observed at two Hauraki Gulf boat ramps (Takapuna, left panels, Half Moon Bay, right panels) and associated recreational snapper harvest. Data such as these can be used in combination with National Panel Survey fishing effort and harvest estimates (Wynne-Jones et al. 2019) to produce indices of the total amount recreational fishing effort. Upper panels – for all hours of the day, based on digital camera imagery, and for the four hours of the day when peak traffic was expected, based on creel survey data, the proportion of observed boats that were used for fishing (second panels down), the average weight of snapper harvested per boat (third panels down), and indices of the annual snapper harvest landed at each ramp calculated from the product of the indices shown in the top three panels (bottom panels) (Hartill et al. 2020b).

A broader understanding of recreational fisher attitudes and values with respect to fishery resources may also be worth considering. This type of information could only be obtained from a ***customised recreational fisher attitudes and values survey***. As for any interview-based approach, responses can be subjective, emphasising the importance of survey design, and that care would be needed with interpretation. Options for a social science survey/questionnaire are discussed in the section relating to Desired Outcome three.

Socio-economic value of fishery components (customary value)

The value associated with kaimoana resources is a broad topic with a number of different aspects. This section, however, has a narrow focus on existing information that could be used to describe the value associated with customary fisheries specifically. Other aspects, such as shellfish edibility, the inclusivity and participation of Māori partners in fisheries governance, and the broader values of Māori (including their values for taonga species and the environment) are covered elsewhere in this report. It is important to define what is meant by customary fisheries, which is “the taking of fish, aquatic life, or seaweed or managing of fisheries resources, for a purpose authorised by Tangata Kaitiaki/Tiaki, including koha, to the extent that such purpose is consistent with Tikanga Māori and is neither commercial in any way nor for pecuniary gain or trade: those taken when authorised by Kaitiaki” (New Zealand Governement 1998).

A review of customary harvest reporting (for all of New Zealand) was undertaken by Hartill (2015) who noted that tangata kaitiaki are required to submit (to FNZ) the authorisations that they make, but there is no requirement for the amounts actually harvested to be reported. Where catches are reported, multiple units of measurement were provided (e.g., sacks, weights, numbers, bins, etc.). The customary authorisations that Hartill (2015) reviewed were dominated by shellfish (as opposed to finfish), but clearly there will be regional or hapū specific differences as to the taonga species that are valued and available within the Hauraki Gulf. Taking this information into consideration, a ***number of customary authorisations issued*** metric (which could be further divided by species) could be informative. However, there are a number of potential issues with such a metric. It is feasible that more permits might be issued if taonga species abundance was either high (the resource can sustain this harvest) or low (fishery regulations do not provide for the level of harvest that is required). Additional context, which could only be gained by conducting interviews with iwi/ hapū /whanau, may therefore be of value. Potentially more importantly, however, there is uncertainty around the confidentiality of customary authorisation data, even at an aggregated level, which could prevent use of such a metric.

In addition to the number of customary authorisations that are issued, it would also be worthwhile investigating more specific metrics that describe the catch rates (and therefore associated user value) of species that are valued by Māori. As described above, the reporting of ***customary authorisation catch rates*** is inconsistent, and would not be able to inform such a metric. Recreational harvest surveys, may have some potential in this regard because while recreational harvest is separate from customary harvest, many Māori will fish under amateur regulations as well. Metrics relating to recreational finfish catch rates for important species (***snapper and kahawai recreational CPUE-at-length***, as discussed above), may therefore be of some relevance in this section as well. However, as described by Hartill (2015), shellfish are clearly of importance to Māori, but are not well captured by the recreational harvest surveys conducted (Hartill et al. 2019, Wynne-Jones et al. 2019). Information relating to shellfish abundance (not catch) is likely the best information currently available. The ***large intertidal shellfish density*** metrics described above therefore has relevance to this section as well.

Beyond these existing data, it will also be important to utilise community and mātauranga led research that describes the abundance of taonga species (***iwi/community monitoring***). While there are many such initiatives, the Ministry for Business, Innovation and Employment Endeavour Programme (MBIE) “Pou rāhui, pou tikanga, pou oranga: reigniting the mauri of Tīkapa Moana and Te Moananui-ā-Toi” is particularly relevant. This programme is working with five Hauraki Gulf iwi to conduct surveys to document the abundance of the taonga species in their rohe. Community and mātauranga led research such as this could provide valuable insight to inform metrics relating to the taonga species valued within the Hauraki Gulf. Beyond these surveys, interviews conducted with iwi/hapū/whanau will also be important. These interviews would likely need to cover the ***attitudes and values*** associated with fishery resources as well as the broader values that are held in connection with the marine environment. A framework for these values is addressed in the Tikapa Moana, Te Moana nui-a-Toi – Mana Moana section of this report.

Socio-economic value of fishery components (edibility)

The edibility of seafood is highly relevant for anyone consuming seafood, but especially for shellfish, many of which are filter feeders and will therefore more closely reflect the environment around them. Given the importance of shellfish gathering to Māori (Hartill 2015), edibility may also have high relevance to Māori. Edibility concerns have a number of different dimensions which are discussed below.

The condition of shellfish will vary seasonally as productivity in the marine environment fluctuates and shellfish gonads mature. Taste or edibility will also vary with these seasonal cycles. ***Shellfish condition*** is not discussed further as it is part of a natural seasonal cycle.

Pollutants, such as heavy metals, can be accumulated by shellfish making them inedible. Levels of heavy metals are not currently monitored in shellfish themselves, but are monitored in surrounding sediments by AC and WRC (https://www.lawa.org.nz/explore-data/estuaries/). A metric based on sediment monitoring from locations where shellfish are harvested (***heavy metal (Lead, Copper, Arsenic and Mercury) concentrations in sediments***) could potentially be used to represent shellfish heavy metal levels (Figure 21), and is discussed in the Pollution status variables section above.

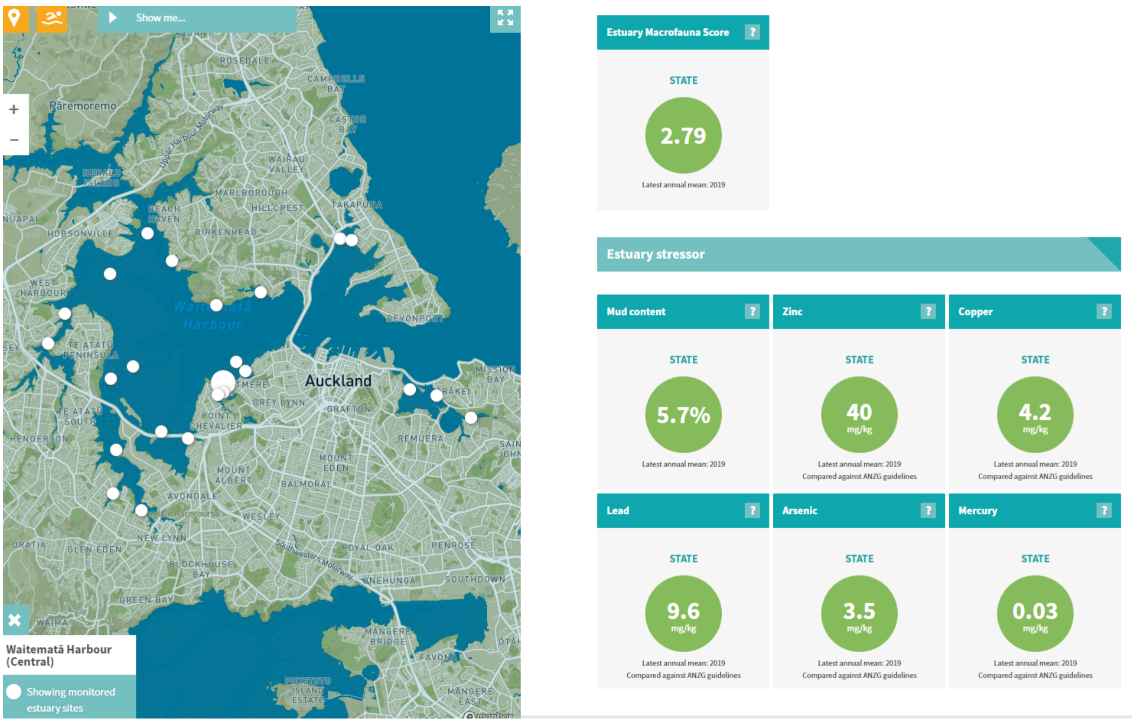


Figure 21 Example of estuarine stressor (heavy metal) monitoring from the LAWA website https://www.lawa.org.nz/explore-data/estuaries/ that could potentially be used as an indicator of shellfish edibility. This example is from the Meola monitoring site with data collected by Auckland Council (image captured 29 April 2024).

Marine biotoxins can periodically occur in the phytoplankton that shellfish consume, subsequently making the shellfish dangerous to eat. The Ministry for Primary Industries (MPI) conduct regular monitoring of shellfish biotoxin levels within marine farms and popular areas for recreational harvest (https://mpi.govt.nz/fishing-aquaculture/recreational-fishing/where-unsafe-to-collect-shellfish/). This testing can result in shellfish harvest closures, however, there is no evidence to suggest that the frequency of biotoxin poisoning in shellfish is increasing or that it is related to pollution (P. Harrison, MPI, pers. comm.). Further, an indicator related to marine biotoxins (***number of days shellfish harvesting closed due to biotoxins***) is unlikely to be connected to management interventions in the Hauraki Gulf.

Animal faeces can contaminate waters where shellfish grow, with the shellfish subsequently becoming dangerous to eat as they concentrate and retain bacterial and viral pathogens (Burrow 2020). MPI and the marine aquaculture industry conduct regular bacteriological testing (both of the water and in the shellfish themselves) within marine farms. This data has been used to develop models that predict how long shellfish harvesting should be closed after certain rainfall events. The relationships in these models are regularly updated based on the levels of bacteria revealed by the testing. If a catchment becomes more polluted with animal waste, this will likely result in slower shellfish cleansing times after rainfall events, leading to longer harvest closures. A metric could therefore be developed from these models describing the ***number of days shellfish harvesting closed due to bacteria levels***. While this metric would be partially reflective of climatic variation, it would also reflect the level of pollution and the first-hand experience of shellfish harvesters. It is important to note that the testing, models and closures relate to marine farms. However, the distribution of these farms is reasonably well spread throughout the Gulf (farms are located on the Coromandel Peninsula (both coasts), the Firth of Thames, Waiheke Island, Clevedon, Mahurangi Harbour, and Great Barrier Island). Such a metric would therefore also have relevance to recreational or customary harvesters of shellfish throughout the Hauraki Gulf.

A related additional metric could be derived from the safeswim model that uses wastewater, rainfall, wind and tide monitoring to predict if it is safe to swim at a number of Hauraki Gulf locations. These predictions could be utilised by selecting locations where shellfish are frequently harvested and calculating the number of days when it was unsafe to swim as a proxy for shellfish edibility (***safeswim number of days unsafe to swim***) (Figure 22). While this information would be freely available, its relationship to actual shellfish contamination is unclear.

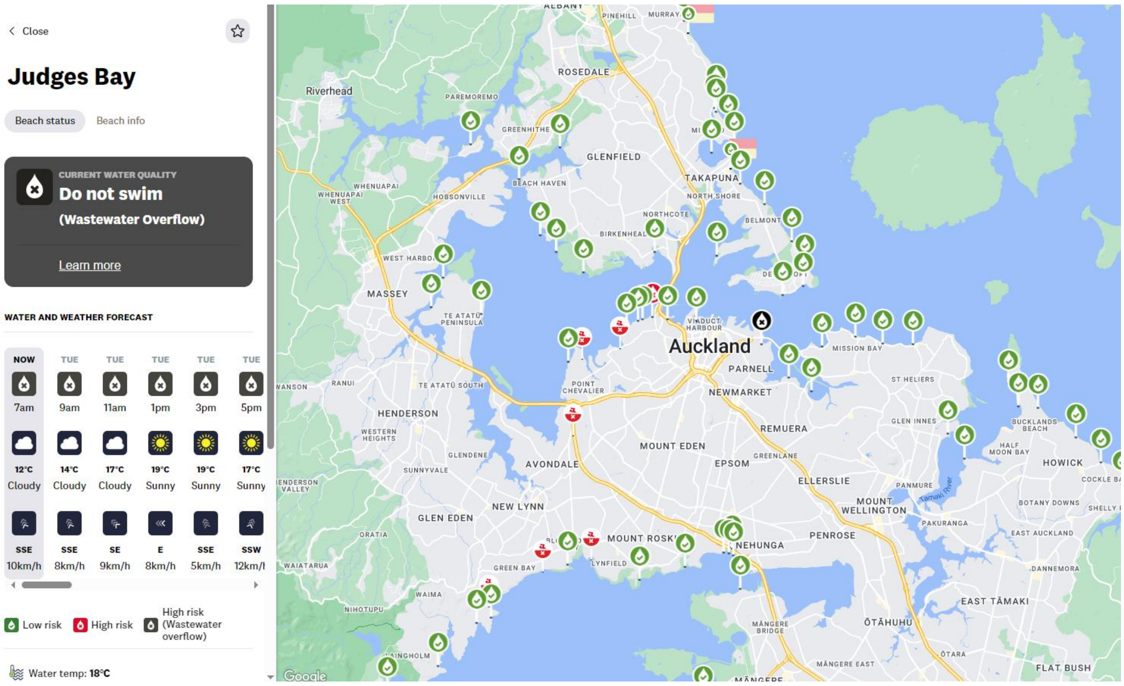


Figure 22 Example of water quality information available from the safeswim website (https://www.safeswim.org.nz/) illustrating a do not swim warning (due to sewage overflow) at Judges Bay. The number of days with high risk or do not swim warnings for sites where shellfish are harvested could form a potential indicator to inform about shellfish edibility.

Implementation of management and monitoring related to fisheries

As for the Protected species Focal Component, consideration of metrics relating to the management and monitoring of fisheries (and consequently fish populations) are described in a specific section below. This is again because the management and monitoring of fisheries is already well established, so specific metrics relating to the management and monitoring of fisheries can already be considered. Alternatively, the management and monitoring of other components of the Hauraki Gulf Fisheries Plan are less established, so a picture of what metrics could be associated with those components is less clear. As a result, management and monitoring metrics for the Hauraki Gulf Fisheries Plan as a whole are considered at a more generic level in a subsequent section.

Fishery management quality (spatial)

Many aspects of fishery management are spatial in nature. Fishery restrictions (whether initiated through *Revitalising the Gulf* or not) will likely not apply to the entirety of the Hauraki Gulf. Given this, metrics that describe the overall proportion of the Hauraki Gulf where certain activities are permitted or prohibited could be an effective way of communicating the level of protection afforded to Hauraki Gulf fishery resources and supporting habitats. Such metrics are unlikely to change with great frequency but do contain valuable information that could be communicated as statements of fact (as opposed to the figures or plots that will likely be used to communicate more dynamic indicators). Some potential spatial metrics to consider include: (1) ***% of the Hauraki Gulf where fishing is prohibited*** (i.e., marine reserves, HPAs or cable protection zones); (2) ***% of the Hauraki Gulf where the seafloor is protected*** from bottom contacting fishing methods such as trawling, Danish seining and dredging; (3) ***% of the Hauraki Gulf where Ahu Moana management measures are in place***.

Fishery management quality: fish stocks

It is important to have metrics which communicate the success and quality of fishery management. FNZ currently assesses individual fish stocks or populations against management reference points (targets, soft and hard limits) as described by the Harvest Strategy Standard (MPI 2008). The performance of fishery management can therefore be measured against these reference points. For example, Shin & Shannon (2010) report on an index of sustainability where the proportion of non-fully exploited stocks is calculated. In New Zealand, FNZ currently reports on a similar metric, the ***% of stocks above the soft limit*** (Fisheries New Zealand 2024) (Figure 23). This would be an informative indicator about the overall performance of fishery management that is relevant to the New Zealand context (i.e., the Harvest Strategy Standard) and comparable with indicators already in use. An important caveat, however, is that this metric does not include stocks that have an unknown status, so by itself could potentially be misleading. It may also be worth reporting the ***% of stocks with unknown status***. In developing this metric some consideration of which stocks to include would need to occur as it is likely that there will be a number of stocks that are within the QMS, but where catch is minimal (and so the threat posed by fishing is also minimal). Including these low catch stocks in calculations could unduly deflate the % of stocks with known status, so some cut off (potentially 10 t, as applied within the National Inshore Finfish Fisheries Plan (Fisheries New Zealand 2022b)) would need to be incorporated. Alternatively, these metrics could be reported for the top 20 stocks (based on Hauraki Gulf catch weight). In addition, consideration of the spatial scale of assessments would also need to be undertaken, as the Hauraki Gulf will not align with the spatial definition of the QMAs or population units being considered. The simplest approach would be to use the stock status for the QMA that the Hauraki Gulf falls within even if it is much larger than the Hauraki Gulf. Where the Hauraki Gulf falls across two stocks, the stock status of one would need to be used.

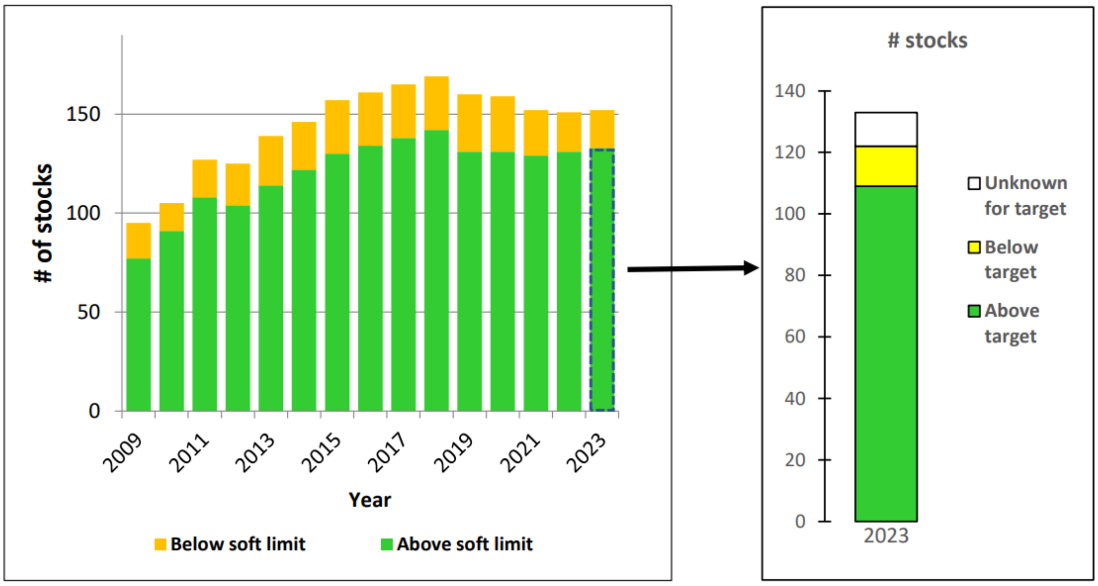


Figure 23 Time series of New Zealand fish stocks (of those that were assessed) which were above the soft limit (reproduced from Fisheries New Zealand 2024). A similar % of stocks above the soft limit indicator could potentially be developed for Hauraki Gulf fish populations.

With regard to the quality of fishery assessments that are applied to the various fish species in the Hauraki Gulf, one way of measuring this is to describe the stability of the fish populations in the Hauraki Gulf. This can be done by calculating the ***coefficient of biomass variation over the last 10 years***, as conducted by Shin & Shannon (2010). One issue with this approach, however, is that biomass can vary due to environmental fluctuations or strong recruitment pulses, as was observed for Hauraki Gulf kahawai (Hartill & Doonan 2022). An alternative could be to use the assessment quality categorisations that FNZ apply to stock assessments. Briefly, each assessment that FNZ conducts is categorised from Level 1–4 (fully quantitative (Level 1), partially quantitative (Level 2), qualitative evaluation (Level 3), and low information evaluation (Level 4)) (Fisheries New Zealand 2023a). A metric relating to assessment quality could therefore be developed to represent the ***% of Hauraki Gulf fish stocks that have a Level 1 or 2 assessment*** (i.e., at least partially quantitative).

Another aspect of management quality relates to the frequency with which stocks are assessed. A suitable metric could simply be the ***average number of years since the last assessment was conducted*** (across all Hauraki Gulf stocks with more than just a nominal catch). One issue with this metric, however, is that assessments are not always performed when stock biomass is understood to be high. This issue would unduly inflate a metric that described the average number of years since the last assessment. Another metric also considered is the ***% of Hauraki Gulf fish stocks that have catch limit reviews or with new science information***. As per the average number of years since the last assessment, the utility of understanding the % of stocks with catch limit reviews is not clear because they are not applied on a routine basis.

A management quality metric that has been used elsewhere relates to the ***intrinsic vulnerability*** of the species that are being landed (Shin & Shannon 2010). Essentially each species receives a vulnerability score based on its life history characteristics. These vulnerability scores are then weighted by the landings for those species, and averaged across all species caught. This metric has the potential to provide an indication of the overall vulnerability of all fished species in a practical way that does not require detailed information about stock status and that is comparable to metrics used elsewhere.

Two other metrics that were considered included the ***% of stocks that have Hauraki Gulf specific management settings***, and the ***% of stocks with localised depletion concerns***. Regarding the Hauraki Gulf specific management metric, the Hauraki Gulf has not been designated as its own Fishery Management Area (FMA). Management measures or settings for individual fish populations within the Hauraki Gulf will likely be part of the measures or settings that apply to those fish populations across a broader FMA. The scope for Hauraki Gulf specific management settings is therefore more likely to apply more generically than to individual fish populations, through spatial management measures such as trawl corridors or HPAs. Ahu moana areas could potentially apply species specific management measures, but it is too early to tell what the management interventions that will arise from Ahu moana areas will be.

With localised depletion, the difficulty here is defining which stocks have localised depletion concerns. This would likely require monitoring conducted at a reasonably fine spatial scale, or some form of area of occupation analysis of commercial catch data (as described in the Fish population Focal Component section above). Recommendations to describe the spatial distribution of some fish species (some of which have localised depletion concerns) as detailed in the research and monitoring section could serve as a more focussed way of describing these concerns.

Fishery management quality: compliance

Understanding how recreational, customary and commercial fishers comply with fishing regulations in the Hauraki Gulf is highly relevant because compliance is needed for fishery regulations to be effective, and because compliance demonstrates active engagement with management. Compliance metrics have two main aspects, the amount of effort that is being expended to identify non-compliance, and the amount of non-compliance that is occurring. These metrics can be monitored through the on-water compliance interviews conducted by fishery officers and using camera monitoring, which is currently being rolled out across the commercial fishing fleet.

Some potential metrics from fishery officer interviews include ***the number of inspections*** and the ***% non-compliance*** for those inspections (which covers both recreational and commercial fishing). These metrics would be cost effective as fishery officers already record all compliance interview details within a georeferenced compliance database. These metrics are available now and specific aspects (e.g., HPA compliance) could also be calculated. In terms of utilising camera monitoring (often referred to as 'digital monitoring'), there are a number of different metrics that are possible. Because not all commercial boats are equipped with cameras understanding the ***% of fishing events with cameras*** would be useful.

Not all the camera footage collected, however, is reviewed (review of footage is targeted to where specific aspects, such as protected species interaction, is more likely), so a metric describing the ***% of camera footage selected for review*** would also be useful. Finally, the ***number of non-compliant events per day*** could also be obtained from camera footage reviewed. Each of these metrics could be produced for each commercial fishing method or different spatial zones within the Hauraki Gulf if needed.

Fishing pressure

Fishing pressure metrics describe the level of exploitation that fish populations are exposed to. As fishing pressure increases, the biomass of those fish populations may therefore be expected to decrease. A number of different aspects of fisheries could be used to describe fishing pressure, including the number of fishing vessels, the amount of fishing effort (or effort intensity), catch, or the ratio of landings to biomass. The ***catch to biomass ratio*** (actually the inverse of that ratio) was used by Shin & Shannon (2010) to describe fishing pressure. While this metric is therefore internationally comparable, it has limited scope, in that it can only be applied to the species for which there are biomass estimates. For the Hauraki Gulf such a metric would exclude important species that have not had assessments accepted (e.g., trevally) or those that were assessed using CPUE analyses (e.g., John dory and red gurnard). ***Total catch*** (t) of all fish species may therefore serve as a simpler and more broadly applicable metric (and could be expressed relative to TAC) (Figure 24). Conversely, the main issue with catch, however, is that it is not standardised, so it will be vulnerable to fluctuations in biomass, which are known to occur especially for pelagic species (Hartill & Doonan 2022). One option that may partially ameliorate this issue would be to report total catch by method (e.g., trawl catch, bottom longline catch etc.). For recreational fishing, the total annual catch should be able to be reported by using a combination of National Panel Survey and boat ramp creel survey harvest estimates ((Hartill et al. 2020b, Wynne-Jones et al. 2019) and as described above).

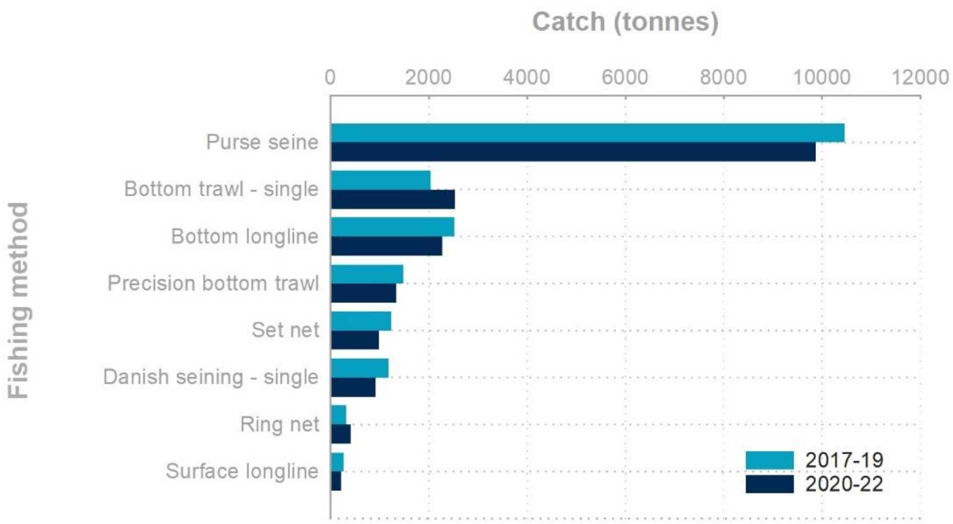


Figure 24 Commercial catch (for fishing methods that caught more than 50 t) of finfish in the Hauraki Gulf Marine Park between 2017–17 and 2018–19. A total catch metric such as this could potentially be produced annually (and could also incorporate recreational catch as well). Data supplied by FNZ, figure reproduced from Hauraki Gulf Forum (2023).

Fishing effort is another potential way of describing fishing pressure. Effort was briefly discussed above, but mostly from the perspective of a ***number of vessels*** metric to describe commercial fishery financial viability, as well as ***total recreational fishing effort*** (number of trips). As already discussed, effort can be highly influenced by a variety of variables. It is possible that effort could become somewhat disconnected from fishing pressure because catch rates can change through variation in fishing efficiency or fish availability. It is also not really possible to combine fishing effort across methods in any meaningful way, because the forms of effort are so different (e.g., hooks set vs km trawled vs pots lifted). Different effort variables would be needed for each method. One option would be to convey effort as ***fishing intensity for each commercial method***, by dividing the effort unit by the area within the Hauraki Gulf where that method is permitted (e.g., hooks per km^2, or aggregate area swept per km^2 etc.). These intensity metrics, however, will not change the relative pattern of an effort time series, but they would provide some spatial context for the use of each particular method.

Intensity is particularly relevant for towed fishing gears, because effort associated with these methods is not just related to the amount of fish that are caught, but also the amount of seafloor that is contacted (which can impact habitat complexity that supports fishery resources). The extent and intensity of bottom contact by trawling and shellfish dredging is described on an almost annual basis by FNZ, although no separate estimates are made for the Hauraki Gulf as its own spatial unit (but this would be possible) (MacGibbon & Mules 2023). The metric most relevant is likely the ***aggregated area of seabed contacted by trawl and dredge gears***, which could then be divided by the area of the Hauraki Gulf available to those methods, to create trawl and dredge intensity metrics (Figure 25). Adjustments would need to be made to the area available to these methods if restrictions such as trawl corridors were implemented. No estimates of the area of seabed contacted by Danish seine gear are currently calculated (MacGibbon & Mules 2023). Danish seine reporting did not previously have spatial information beyond statistical area, but since the advent of electronic reporting all Danish seine effort is reported by event with spatial details. A new analysis method, however, would need to be developed to describe Danish seine bottom contact (door spread and tow length as applied to trawl bottom contact analysis are not immediately transferable to describe Danish seining) (D. MacGibbon, NIWA, pers. comm.).

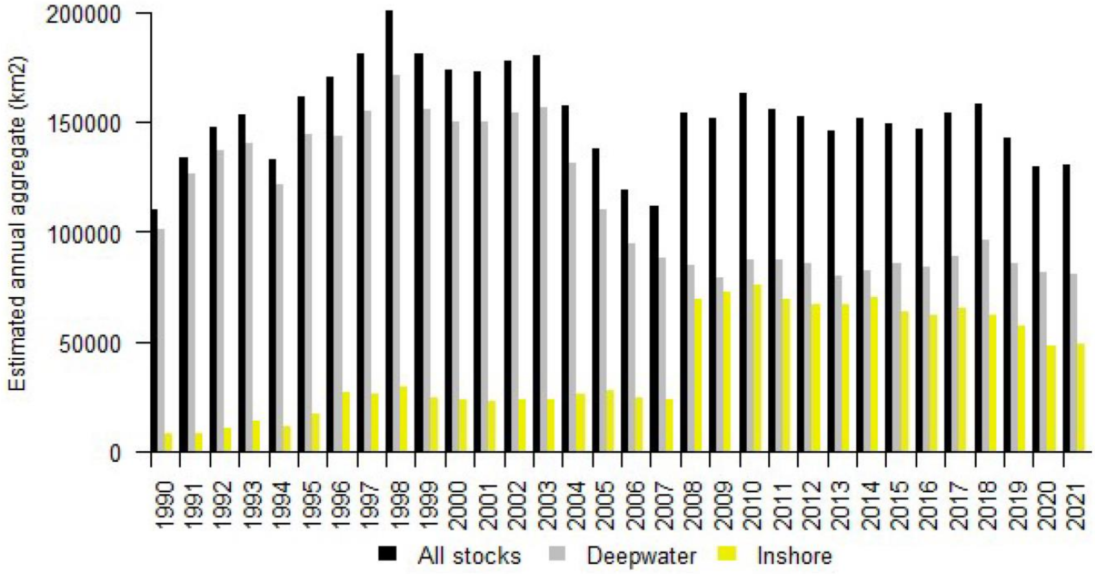


Figure 25 Annual estimated aggregate area of bottom-contacting trawl effort for All stocks, Deepwater stocks, and Inshore stocks between 1990 and 2021 (MacGibbon & Mules 2023). An indicator similar to this could potentially be developed for trawl and dredge effort conducted within the Hauraki Gulf.

An additional metric, of public interest, relates to the amount of discards from commercial fishing. In deepwater fisheries observers are used to estimate discards (e.g., Anderson & Finucci 2022), but observer coverage is too low in inshore fisheries for this to be possible. While cameras are rolling out across the inshore fleet, they are unable to quantify non-QMS discards. However, commercial fishers are required to report the ***weight of undersized fish released*** (e.g., separate species codes for under sized snapper, SNX, and tarakihi, TAX). The proportion of catch that is made up of undersized fish which are subsequently released will, however, be heavily influenced by the amount of recent recruitment, so it is unclear what this metric actually communicates.

What is apparent when considering metrics to describe fishing pressure, is that all potential metrics are likely to be influenced by multiple variables, so a direct relationship between a particular fishing pressure metric and fish population abundance may not always be possible or straightforward. Initially, investigating the relationships between potential fishing pressure metrics, fish population abundance and other influential variables would be prudent. Ultimately, the metrics chosen to describe fishing pressure (and the other related Key Attributes above) will need to try and achieve a balance between providing relevant detail that is of value to public communication, minimising the number of metrics chosen so as not to duplicate or overwhelm, and avoiding metrics where it is not clear what they are communicating. In the short-term, total catch (potentially by fishing method) may be a simple way of conveying fishing pressure that is more directly connected to impacts on fish populations. Additional metrics describing the intensity (aggregate area) of bottom contact fishing gears would also be of high ecosystem and public relevance.

Inclusive and integrated participation in fisheries governance

Tangata whenua

To effectively undertake EBFM FNZ and other resource managers will need to align diverse knowledge streams (Alexander & Haward 2019, Reid et al. 2021), and one of the most effective and respectful approaches is to maintain parallel lines of indigenous and western scientific inquiry (Tengö et al. 2014). Despite this recognition, successful examples of implementation, especially in a fisheries context, are uncommon (e.g., Cooke et al. (2020), Laidler (2006)). In this report we adopt the waka-taurua (double-canoe) framework where two waka/canoes (each representing distinct knowledge systems) are lashed together for a common purpose (e.g., Maxwell et al. (2019)). This approach recognises that there are inherent differences in both approaches and assumes that both knowledge systems, values and actions are independent. As a result, two sections of this report assess indicators related to tangata whenua. In the present section we discuss indicators related to the resourcing of and capability building for iwi and hapū by FNZ and other Government agencies in the context of fisheries management in the Hauraki Gulf. Whereas the Tīkapa Moana, Te Moana nui-a-Toi – Mana Moana section below describes a framework and associated indicators to enable and identify critical levers for mana moana to exercise their rangatiratanga (chieftainship, right to exercise authority) within their rohe moana through the prism of EBFM.

The Crown's obligations to iwi and Māori concerning fisheries are set out through a number of pieces of legislation, including the Fisheries Act 1996 (New Zealand Government 1996), which sets out to enable tangata whenua input and participation into fishery sustainability proposals and consultation to ensure that kaitiakitanga is provisioned for.

To facilitate this FNZ have worked closely with iwi and hapū to initiate the establishment of Iwi Fisheries Forums throughout New Zealand. These collectives of kaitiaki and hapū members provide a formalised platform for dialogue and collaboration between local iwi, Māori commercial fishers and FNZ. These forums often also allow for more streamlined applications using the Kaimoana Customary Fishery Regulations (New Zealand Governement 1998), such as mātaitai. Currently 10 such forums exist in New Zealand.

One of the goals of *Revitlaising the Gulf* was to establish a Hauraki Gulf Iwi Fisheries Forum (New Zealand Government 2021) to provide a platform for iwi and hapu can to actively participate and advise fisheries management. Currently, a Hauraki Gulf Iwi Fisheries Forum is still in development and may be some time away from being formed. Until that point a more useful indicator to describe tangata whenua participation in fisheries management could be the ***proportion of Hauraki Gulf iwi or hapū represented at Hauraki Gulf wide fisheries wananga and hui.*** Often tangata whenua participation at fisheries related hui (e.g., working groups, special management area meetings, fisheries stock reviews and research meetings) is limited by capacity and the topic of the meeting. By tracking the proportional representation of Hauraki Gulf hapū or iwi (rather than individual attendees), FNZ has an opportunity to engage specifically with those hapū or iwi that are underrepresented. Further, the attendance relative to specific hapū and iwi's rohe can be identified. For example, if the hui specifically focussed on management issues relevant to the rohe of a hapū or iwi that were not represented this could be identified as an opportunity for improved communication and increased resourcing.

Mātaitai, taiāpure and rāhui are considered to be powerful mechanisms to achieve sustainability at local scales because iwi, hapū and wider communities can utilise their mātauranga Māori and local knowledge to adapt fishing and harvesting rules (Taylor et al. 2018). Voluntary closures, or rāhui, to maintain the health or mauri of their whenua (land) and moana (ocean) have been practised by tangata whenua for generations (Maxwell & Penetito 2007). These temporary closures are placed by kaitiaki, elders or leaders in response to reductions in kai moana species, a shift in the health of an ecosystem, or a death in the area (Taylor et al. 2018). Taiāpure and mātaitai are permanent fishery protection areas that limit the amount or method for fishing and harvesting within an area that is of special significance for iwi in relation to food gathering and traditional fishing. An indicator that monitors the ***number or area of Hauraki Gulf in voluntary customary fishery closure*** could be a useful metric to understand the level of concern by iwi for their rohe. Although these closures and management tools are applied at localised scales, an overview of the entire area in closures would be informative with respect to the level of engagement with fisheries management over time and the amount of the Hauraki Gulf where public access to fisheries is restricted. However, there are challenges with voluntary closures, which can be ignored or go unnoticed by the general public (Maxwell & Penetito 2007). To this end, there may also be value in an additional metric that addresses customary closures provided for through Section 186A of the Fisheries Act 1996 (New Zealand Government 1996) (i.e., rāhui, taiāpure or mātaitai) (the ***number or area of customary fishery closures through Section 186A of the Fisheries Act***) (Figure 26). For both of these indicators above, however, it is important to note that the area or number of customary fishery closures (both voluntary or through the Fisheries Act 1996) could be driven by multiple different factors. For example, greater iwi capacity and engagement with fishery management (and willingness from the Government to work with iwi) could lead to more closures. Alternatively, degraded fish population abundance could also lead to more closures independent of the level of engagement with fishery management. Interpretation of these metrics could therefore be problematic.

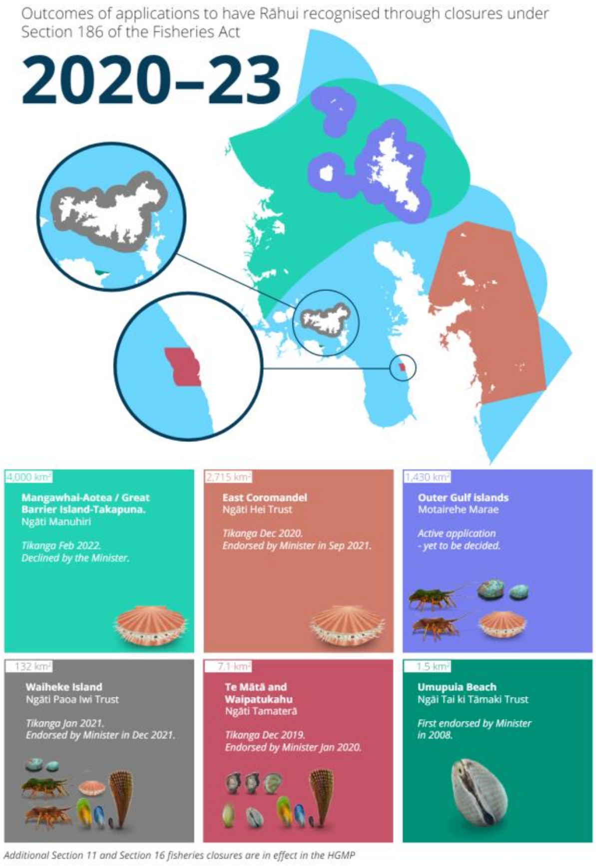


Figure 26 The area of the Hauraki Gulf in rāhui through Section 186a of the Fisheries Act 1996 in 2023. Reproduced from the Hauraki Gulf state of the environment report (https://gulfjournal.org.nz/wp-content/uploads/2023/08/SOER-online.pdf)

The ***number of customary authorisations issued*** by tangata kaitiaki is a metric of potential relevance to tangata whenua. This metric was discussed under the Socio-economic value of fishery components (customary value) Key Attribute above and contains potential issues with interpretation and data confidentiality.

FNZ is legally obliged to seek feedback from impacted stakeholders when making fisheries management decisions (e.g., see https://fs.fish.govt.nz/Doc/21817/consultation_standard%5B1%5D.pdf.ashx). For many stakeholders and community members, this opportunity for input may come toward the end of a process where requests for submissions related to a suggested management decision are called for. However, there is an additional obligation to ensure that tangata whenua are involved throughout the decision-making process. The ***number of responses to calls for submissions from FNZ by hapū and iwi*** is a metric for which data already exists (K. Lister, FNZ, pers. comm.) in the form of submission reports. However, it would be important to make a distinction between individual submissions and those made on behalf of hapū and iwi, which could be challenging. Further, many FNZ management and sustainability decisions are made at the fish stock level, which are often at spatial scales larger than the Hauraki Gulf. In addition, because tangata whenua should be involved throughout the decision-making process, this should infer that the rate of *post hoc* submissions on fisheries management decisions by tangata whenua should be low.

Stakeholder satisfaction with fishery management is a major driver of stakeholder participation in fisheries decision-making processes (Coffey 2005, Msomphora 2015, Salas & Gaertner 2004). An indicator that describes ***tangata whenua attitudes and values associated with fishery management***, could therefore be a useful way of describing metrics such as satisfaction, while also providing context around other potential indicators (e.g., including participation in fisheries related hui and wananga*,* the rate of responses to FNZ calls for submissions and the number of Section 186a closure applications)*.* To establish a metric to describe tangata whenua attitudes and values a survey questionnaire would need to be developed and implemented. Such a survey should consider the values, framework and indicators presented in the section addressing Tīkapa Moana, Te Moana nui-a-Toi – Mana Moana below. Such a survey would likely require significant investment to build trust and relationships between FNZ and key tangata whenua to ensure consistent participation. Consideration should also be given to the delivery of these surveys kanohi ki te kanohi to increase engagement, trust and uptake. When the Hauraki Gulf Iwi Fisheries Forum is developed, the survey could be distributed to the forum members as a core respondent group. To reduce potential bias that can arise from questionnaire surveys, the design and structure of questions included should be carefully considered, utilising advice from social scientists and the experience of previous/similar survey approaches (e.g., Msomphora 2015).

Community

EBFM is an approach that not only considers the ecosystem, but also the community depending on that system and their associated values. Community and public participation are key ingredients of good governance and are particularly relevant to the development of EBFM (Berghöfer et al. 2008). There are many advantages of involving stakeholders decision-making processes including the development of a common understanding of issues, building strong relationships, establishing trust, resolving/avoiding conflicts, increasing both parties responsibility and accountability, a higher level of acceptance of management policies and decisions, and more effective enforcement of rules (Jentoft 1989, Kapoor 2001, Pita et al. 2010). Involving resource users in the fisheries management decision-making process is not a new approach.

Globally, social, and scientific research recognises that community and stakeholder participation in fisheries processes is essential (Coffey 2005, Mikalsen & Jentoft 2008). However, most literature also suggests that often stakeholders are not satisfied with their level of participation and influence in the decision-making processes (Pita et al. 2010). In the European Union the top-down management of fisheries has been identified as one of the main barriers to stakeholders feeling that they can play a meaningful role in decision making and policy (Msomphora 2015). Fisheries management processes are often characterised as being only partially open, i.e., due to commercial or privacy interests not all information can be shared with key stakeholders or the community. This perceived lack of transparency can create an atmosphere of mistrust (Mikalsen and Jentoft, 2008). Throughout the development of the indicator suite as part of this project, community members and groups have expressed that they have similar concerns regarding their ability to participate in fisheries management processes in New Zealand. They cited some of the major challenges being the lack of ability to maintain long term engagement due to resourcing and investment shortfalls, a lack of champions to push forward the process and misalignment of expectations between partners.

FNZ has a range of tools and pathways which aim to enable the involvement of stakeholders in fisheries management decision-making processes. These range from involvement in research and local enforcement or management, advisory functions including review of research and participation in technical advisory groups or working groups, and feedback into fisheries management decisions (such as adjustments to the TAC). We suggest that using data related to one of these tools, namely the submission or management decision feedback process form the bases of a useful and informative indicator of community and public engagement with fisheries management across the Hauraki Gulf. The ***number of responses to calls for submissions from FNZ by community members*** is a straightforward metric for which data already exists (K. Lister, FNZ, pers. comm.). Public submissions are made available by FNZ after they have been incorporated into management decisions in the form of submission reports. These reports include details of the submitter, the proposal relevant to the submission and the submissions itself (e.g., https://www.mpi.govt.nz/dmsdocument/59164-Public-Submissions-Received-for-the-2023-October-Sustainability-Round). Although the data is readily available there are a number of challenges associated with making it relevant to fisheries management in the Hauraki Gulf. For example, many FNZ management and sustainability decisions are made at the fish stock levels which are at spatial scales larger than the Hauraki Gulf. Further, many submissions are made on behalf of multiple parties by advocacy groups or using standardised submission templates which, depending on format, can make data extraction more complicated. Identifying submissions that are spatially isolated to the Hauraki Gulf will be challenging and may require manual sorting of the submissions. It is also important to note that different sections of the community will have differing demographics, resourcing, awareness, and satisfaction with fisheries management, which will likely influence stakeholder ability to engage with the submission process and the fisheries decision making process in general (Msomphora 2015).

Fish stocks are shared resources and if resource scarcity increases or environmental issues are highlighted, public awareness of, and interest in, fisheries issues will also increase (Mikalsen & Jentoft 2001). One way this increased concern could be evidenced is an increase in the number and membership of community advocacy and self-management groups. In the Hauraki Gulf community groups, organisations and individuals have critical influence on fisheries management and governance. Groups such as LegaSea and the New Zealand Sport Fishing Council have been major contributors to recent legal decisions regarding the lawfulness of fisheries management decisions. Other groups and individuals have championed restoration efforts such as the reestablishment of green-lipped mussel beds around the Hauraki Gulf (https://www.reviveourgulf.org.nz/). Although a metric measuring change in these community groups could be useful, here we suggest that the ***number of multi-stakeholder fisheries advisory groups active in the Hauraki Gulf*** as an indicator with more potential utility for EBFM in the Hauraki Gulf. This is because active multi-stakeholder fisheries advisory groups are not only a measure of recreational or community participation in fisheries management, but also the level of value that FNZ places on these groups through their involvement in fishery management processes. An example of a potential multi-stakeholder fisheries advisory group could be a group formed to advise on the creation of Special Management Areas in the Hauraki Gulf (Fisheries New Zealand 2023a). However, many multi-stakeholder fisheries advisory groups are project specific and short lived which is a significant artifact that could influence long-term trends, potentially making this indicator problematic for inclusion in the EBFM indicator suite.

Research suggests that stakeholder satisfaction in fisheries management is the principal driver of the rate of stakeholder participation in fisheries decision-making processes (Coffey 2005, Msomphora 2015, Salas & Gaertner 2004). Although trends in fisheries submissions are relatively straightforward to analyse, we suggest that they will be more informative and relevant when combined with metrics describing stakeholder attitudes and values. An indicator based on ***community attitudes and values towards fisheries management as measured by a survey questionnaire*** will more accurately identify the motivation and drivers of participation in fishery management processes which may more accurately reflect community concerns. Many of the considerations for this metric would be similar to those for the similar metric focussed on tangata whenua attitudes and values, as discussed above. To that end, the development of such a survey should consider the most frequently encountered hurdles for community participation and inclusion in the management process. Surveys will likely require careful consideration of the demographics of Hauraki Gulf communities and be conducted at regular intervals to identify shifts and changes in community values and satisfaction. Consideration should be given to the use of scaled metrics, such as rubrics or multi-choice questions, and design could benefit from consultation with social scientists. These surveys could be circulated to existing community groups or as part of the consultation process, e.g., response letters could be sent to submitters and include a link to the survey. Examples of surveys used in similar contexts have been used by Msomphora (2015) and Gelcich et al. (2009).

Government

FNZ are responsible for the management of commercial, recreational, and customary fisheries resources in New Zealand (Gerrard 2021). Since 1986 the QMS has been used to manage the sustainability of New Zealand's fish and shellfish species (Lock & Leslie 2007). The QMS continues to underpin how fisheries in New Zealand are managed, providing a foundation for fisheries management now and into the future. But with the move towards EBFM there is a greater need to incorporate societal values and goals within this more holistic approach to management (Gerrard 2021). To achieve the potential benefits that EBFM can provide, greater support of the community and Māori partners and greater collaboration with other Government entities with responsibilities for the marine environment (Figure 27) will be required. The metrics proposed below have the potential to track progress towards this goal of more collaborative fisheries management in the Hauraki Gulf.

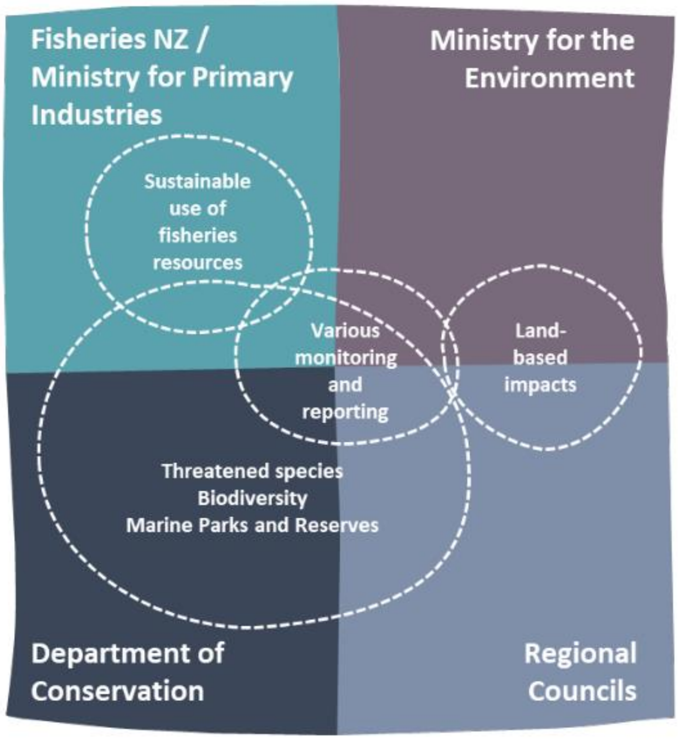


Figure 27 Responsibilities of the different Government agencies across the marine environment and fisheries in New Zealand. Reproduced from Gerrard (2021)

Monitoring the ***average number of years since last update for Hauraki Gulf fisheries indicators*** (i.e., the frequency at which chosen indicators are updated) would be a cost effective and informative metric detailing FNZs progress towards adopting, communicating, and monitoring the indicator suite and reflective of the understanding of values expressed by the stakeholders who had contributed to the development of these indicators. Once the indicator suite is established data reflecting the frequency with which indicators are updated would be straightforward to update.

Although FNZ has authority over fisheries resources and activities, this management must take into account principles regarding the impacts of fishing on the marine environment (Gerrard 2021). EBFM will require a collaborative approach to effectively manage and protect the wider ecosystem, land-based impacts and biodiversity within the Hauraki Gulf (Fisheries New Zealand, 2023c). By building relationships with the key regulatory agencies including the DOC, the Ministry for the Environment and Regional Councils, FNZ will be able to work toward integrated management of the complex issues that affect the health of the Hauraki Gulf and its fisheries. In terms of monitoring the progress to collaboration between FNZ and other management agencies, intuitive and informative metrics include the ***proportion of fisheries projects that are multiagency or with local government*** and the ***number of interagency fisheries publications and research outputs for the Hauraki Gulf.*** Both of these metrics are practical and cost effective despite the fact that historic baseline and ongoing data collection methods would need to be established. Data collection could be in the form of attendance demographics at current and previous meetings, workshops, hui and wananga related to fisheries management, the structure and number of fisheries projects with one or more key agency in a lead role or online search engine data extraction for papers and publications related to fisheries management in the Hauraki Gulf with one or more management agencies as a funder, author or acknowledged (i.e., Researchgate, Google Scholar). The most significant challenge with both indicators will be placing boundaries around what is considered a 'fisheries' project and output (K. Lister, FNZ, pers comm.), and spatially isolating effort to the Hauraki Gulf area.

FNZ have identified that aligning with and understanding different knowledge streams with western fisheries management is a key priority for the Hauraki Gulf (Fisheries New Zealand, 2023c). This sentiment was reflected by co-development partners during the development of the indicator suite for the current project. One of the metrics or indicators most cited by the co-development group was the consideration or ***use of local and indigenous knowledge in fisheries management***. Despite recognition of the value of indigenous knowledge in understanding aquatic ecosystems and fishery management (e.g., Bennett-Jones et al. (2022), Clapcott et al. (2018), Memon et al. (2003)), the practicalities of collecting data to inform this indicator are challenging. The definition of local and traditional knowledge in a western governance context can be subjective, and how to align two different world views within a legislative framework can be challenging. We suggest that using a combination of more quantitative indicators as a proxy for the use of local and indigenous knowledge in fisheries management could inform changes in the alignment of fisheries management with local and indigenous knowledge in a more consistent way. For example, metrics that measure the investment by FNZ in EBFM development, and alignment with local knowledge could include ***FNZ funding for community-based fisheries management groups, projects and research in the Hauraki Gulf***. Some of the pathways for community participation and fisheries management research supported by FNZ include co-management groups (e.g., quota owners, central and local government, non-Government Organisations, community spokespeople) and recreational self-management groups (Memon & Kirk 2010). FNZ may support communities by participating in, or funding these groups and the research outcomes or projects that may arise from them. While it would be possible quantify the level of budgetary funding and full-time equivalents employment allocated to these projects and groups, there would be significant work involved in the extraction and interpretation of the relevant information specific to the Hauraki Gulf.

FNZ has both legislative and voluntary pathways to facilitate fisheries co-management with mana whenua, return rangatiratanga (governance, chieftainship, self-determination) and acknowledge the rights of tangata whenua (Bennett-Jones et al. 2022). Some examples of these pathways include the legislative support of the development and management of Rāhui, Taiāpure and Mātaitai Reserves established using Section 186a of the Fisheries Act (Jackson et al. 2018, Memon et al. 2003). Another example is the contractual requirement set by FNZ for all fisheries research providers to acknowledge traditional ownership of fisheries resources and how to align their research with mātauranga. The annual change in ***resourcing allocated to build tangata whenua fisheries management capacity by FNZ*** is a valuable indicator for the regard and alignment of fisheries management with mātauranga and traditional knowledge. These data could be extracted for both previous, current and near future investments by analysing FNZ (and other Government agency) budget and employment information (K. Lister, FNZ, pers comm.) and by its nature is of high public importance and understanding.

Implementation of management and monitoring of the Hauraki Gulf Fisheries Plan

As mentioned in the Introduction and at the beginning of the Results section, it is important to develop indicators which detail progress made with the implementation of management and monitoring aspects of *Revitalising the Gulf* as well as developing indicators that describe the status of the fishery system itself. For example, a management implementation indicator might be the % marine protection in the Hauraki Gulf, whereas an associated status indicator would be the relative abundance of fish in protected vs. non-protected. These implementation indicators are important because they provide transparency as to whether the commitments of *Revitalising the Gulf* have eventuated, which is necessary for change in the fishery system itself to occur. Below we consider three indicators that might provide a higher-level assessment of progress made towards the implementation of management and monitoring commitments of *Revitalising the Gulf* and the Hauraki Gulf fishery plan.

The first option relates to the Management Actions in the Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2022b). The completion of these management actions could be documented and averaged for each component of the Hauraki Gulf Fisheries Plan. Due to the nested structure of the Hauraki Gulf Fisheries Plan, each of these components could be subsequently averaged up to provide an overall ***% of management actions achieved*** score at whatever level of the Hauraki Gulf Fisheries Plan that was desired. These % management action complete scores will be directly comparable to other aspects of the indicator framework described here because the higher levels of the framework were intentionally aligned with the Hauraki Gulf Fisheries Plan. Assessing completeness of each management action may not always be straightforward and may be somewhat subjective. For example, while some management actions will be explicit yes/no assessments (e.g., “Exclude bottom trawling and Danish seining”, others will be more vague (e.g., “Prioritise observer coverage on inshore bottom longline fishing trips”). This could be addressed by using a traffic light approach, where each management action is assessed to be either “complete”, “partially complete”, or “not complete”. An additional consideration is that one of the principles of EBM is adaptive management (Hewitt et al. 2018). A cumulative increase through time in the percentage of management targets complete would not be compatible with this principle. Rather, management actions should be updated and modified as new information becomes available and societal perspectives change. The percentage of management actions complete should consequently be refreshed as the management actions themselves are updated. FNZ currently updates management actions on an annual basis already by producing an annual operational plan for the Hauraki Gulf.

Therefore, the % of management actions achieved would be better connected with this operational plan than the Hauraki Gulf Fisheries Plan.

A second would be to document the amount spent (by Government departments as well as Auckland Council and Waikato Regional Council) on management and monitoring (i.e., ***Government operational budget ($) associated with each component of the Hauraki Gulf fishery plan***). This may require some apportioning of individual monitoring projects where only part of the project is conducted in the Hauraki Gulf or is relevant to fisheries. This should be possible, but may not be practical.

A third option is to document the frequency of relevant monitoring. This frequency could be documented as the number of years since the last monitoring event averaged across relevant monitoring aspects. This is likely to be more complicated than documenting the amount spent on management and monitoring. This is because there will be a much larger number of individual monitoring components that are relevant to the Hauraki Gulf Fisheries Plan. For example, the assessment of one fish species alone may have multiple time series that are monitored; each of these would be relevant to the Hauraki Gulf Fisheries Plan. As discussed above in the Fishery Focal Component, in some cases monitoring frequency may also be uninformative. A potential solution could be to wait until *Revitalising the Gulf* monitoring commitments have been finalised, and then pick a number of critical monitoring components (ensuring coverage across different aspects of the Hauraki Gulf Fisheries plan). The ***average number of years since monitoring for key components of the Hauraki Gulf Fishery plan*** could subsequently serve as an overall headline indicator related to monitoring.

Tīkapa Moana, Te Moana nui-a-Toi – Mana Moana

A critical component of this project was to support the integration of iwi and hapū interests within the indicator framework. There are many iwi and hapū within Tīkapa Moana, Te Moananui-a-Toi, the Hauraki Gulf. At the beginning of this project an iwi reference group was established (the MMAG, as referred to in the Methods above). This group was comprised of iwi leaders from across the Hauraki Gulf. Many of whom had advised on and been deeply involved with *Tai Timu, Tai Pari – SeaChange* (Sea Change 2017), as well as matters relating to their own iwi fisheries. The term 'mana moana' has been used here as an extension of mana whenua as it encompasses the connection that iwi and hapū have with their rohe moana (Tone & 'Ilaiū Talei 2024). Mana moana also encapsulates the environmental context in which this research was undertaken. The MMAG provided feedback and advice around the direction and implications of EBFM in the Hauraki Gulf. As a result of this feedback a framework was developed to enable mana moana, as well as central and regional government, to consider and apply effective EBFM with respect to mana moana rights and interests. To that end, this section (Tīkapa Moana, Te Moananui-a-Toi – Mana Moana) presents a largely self-contained (i.e., it includes contextual material, methodological descriptions as well as results and discussion) description of that framework.

To achieve effective EBFM that is inclusive of mana moana rights and interests, it was important that the mana moana framework for indicators was separate but aligned. The purpose of this framework is to enable and identify critical levers for mana moana to exercise their rangatiratanga (chieftainship, right to exercise authority) within their rohe moana (territorial waters) through EBFM. The framework is called Te Niho Taniwha. This name was adopted in recognition of the various roles and functions that taniwha have as kaitiaki. Taniwha embody kaitiakitanga and have many forms, symbolising leadership, prestige and strength (Rout et al. 2022). With dominion over our rivers, seas, and other territories, taniwha are powerful yet auspicious. Their presence reminds us to act correctly, to respect their authority, and respect the tikanga, kawa, and mātauranga associated within the domains of the taniwha. The taniwha is fitting for framing this research – EBFM in the Hauraki Gulf. For example, the role and function of the taniwha relates to the work around developing indicators that can support and enhance the mauri of the Hauraki Gulf. It also relates to the combined efforts and work being undertaken among mana moana, co-development partners, and other entities that have a shared vision and drive to address the recovery of the Hauraki Gulf and its associated fisheries. This is where the notion of the taniwha is also embodied, among people. The role and function of people and the political drivers that motivate people to take action. For the Hauraki Gulf, concentrated and multi-disciplinary approaches to address increasing concerns relating to the state of the Hauraki Gulf and its associated fisheries are examples of this. The taniwha itself is capable of transforming into different forms where it can take action as a guardian of not only the environment, but also for Māori people as well, and represents their right and ability to act autonomously in the interests of the collective (Rout et al. 2022). Niho represents the triangle shaped tooth of the taniwha (Figure 28). This is not a new concept as niho taniwha have been used as frameworks and structures in many areas such as education and health (Rout et al. 2022).

In terms of separating mana moana rights and interests from the other indicator groupings within this report, that was undertaken by design, and by request of the MMAG. Further, the project team were mindful of mana moana voices being diluted or relegated when situated alongside the co-development partners as simply, stakeholders. To rectify this and lift mana moana approaches to EBFM, the project team created Te Niho Tanihwa to specifically align with Desired Outcome three of the Fisheries Plan (Fisheries New Zealand 2023b).

While the focus of this project is to develop indicators specifically related to fisheries, this requires that broader principles related to effective EBM in Aotearoa New Zealand are taken into account (Reid & Rout 2020), namely:

- *Human activities* – this acknowledges that humans and our actions are part of the ecosystem.
- *Collaborative decision making* – endorses participatory decision-making processes.
- *Knowledge based* – based on science, mātauranga, and community values.
- *Sustainability* – marine environments are safeguarded for future generations.
- *Adapts* – Adaptive management that promotes appropriate monitoring.
- *Tailored* – spatial and temporal specificity that recognises ecological complexities and connectedness.
- *Co-governance* – governance structures that provide for partnership.

Te Niho Taniwha has bench marked indicators against these principles to ensure that interconnected and holistic approaches to EBFM are implemented for mana moana in the Hauraki Gulf. In addition, the indicators that have been developed from the advice and feedback of co-development partners are useful for advising mana moana also. Alignment in this sense, is necessary for ensuring that quantitative and qualitative data sets (and associated indicators) are relevant for mana moana to enable active participation, protection, and partnership through EBFM. Below, is an overarching view of Te Niho Taniwha.

Te Niho Taniwha

The framework depicted in Figure 28 illustrates a triangle which represents Te Niho Taniwha. There are three levels to Te Niho Taniwha, they are:

- Ngā Mātāpono – Overarching Principles
- Ngā Pou – Pillars of Success

- Ngā Tohu – The Indicators

Each of these levels is depicted around the boarder of the framework. Also around the outside of the figure are each of the overarching principles, Ngā Mātāpono - Kaitiakitanga; Mātauranga; Wairuatanga; Whakapapa; Mauri; and Manaakitanga. In the middle of the framework are the pillars of success, Ngā Pou, they are: Ngā Ture – Policy and legislation; Ngā Hapori – Community mobilisation; Ngā Kaihāpai - Stewardship and advocacy; and Ngā Pūtea - Investments and innovations. Not depicted are the individual indicators, Ngā Tohu, which would stem from the pillars of success, Ngā Pou. Each of the levels of Te Niho Taniwha are intended to provide a structural framework to ensure effective EBFM is facilitated in the Hauraki Gulf. The relationship between these three levels is not linear. Each level exists to support the notion of the ecosystem being a functional unit that is influenced and effected by many variables. Each of the three levels is discussed in detail below.

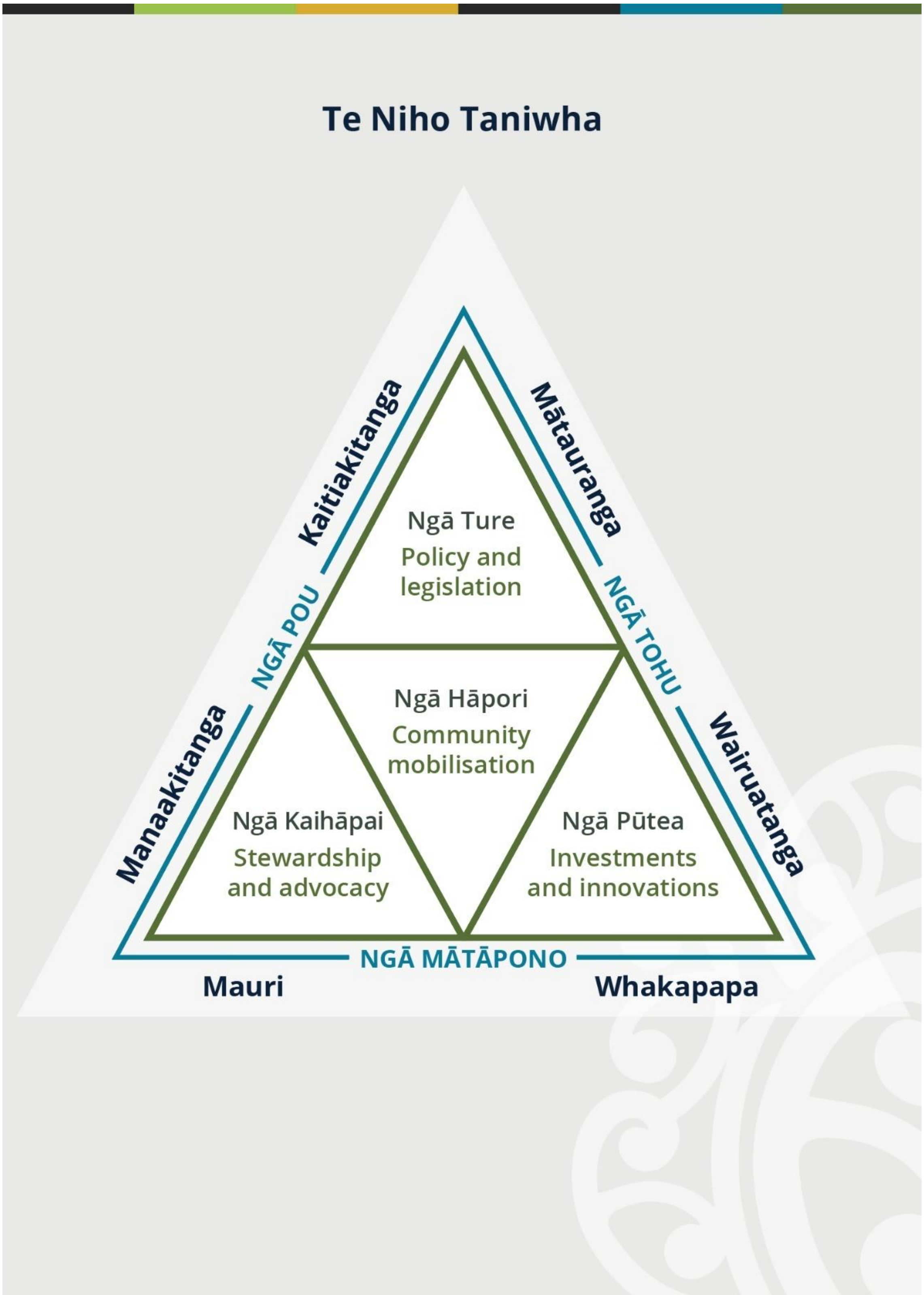


Figure 28 Te Niho Taniwha, a framework for indicator development in the Hauraki Gulf

Ngā Mātāpono – Overarching principles

The Mātāpono presented in this section provide a foundation from which indicators can be built and are based on the findings of Jackson et al. (2017). As overarching principles, these mātāpono have been selected on the basis of how they inform and uphold the Ngā tohu – indicators. To better understand these overarching principles, the following sections provide an overview of each principle with respect to how they relate to this research project and the Hauraki Gulf.

Kaitiakitanga

To support the understanding of kaitiakitanga (and many kupu Māori), it can help to break the word into its component parts that together form kaitiakitanga. According to Te Aka (2024), kai is a prefix to express an action through a human agent (i.e., the person doing the action). The term tiaki means to guard or protect, and tanga is used as a suffix to designate the quality derived from the base noun. The word kaitiaki therefore, refers to a guardian or protector, while adding tanga designates the qualities derived from the role of a guardian or protector to now become kaitiakitanga, or guardianship. The breadth of this term can be vast in that it is applicable across many areas, especially in the natural environment. However, in the context of this research we consider the term kaitiakitanga through Tīkapa Moana, Te Moananui-a-Toi, the Hauraki Gulf. We explore kaitiakitanga through the rich tapestry that mana whenua, mana moana have in relation to their rohe moana.

Manaakitanga

Following on from the method used to describe kaitiakitanga, the same approach is useful in helping to interpret and understand manaakitanga. Again, three kupu can be derived from manaakitanga. They are mana, āki, and tanga. Mana is a concept that is central in Te Ao Māori and is of critical importance. Mana refers to the prestige, authority, control, power, influence or status that a person, group, place, event, or object may possess or inherit (Te Aka 2024). This is a simple explanation for mana and does not take into account certain types of mana, such as mana tangata (the mana one inherits through their accolades or achievements) or mana tupuna (the mana one inherits from their ancestors). While we have introduced mana whenua as one example of mana, the scope of this review is not to provide great depth of analysis for certain kupu. Rather, to provide a basis of understanding and interpretation within this framework.

The next kupu is āki, to encourage, urge on, or enhance. When the two kupu are joined, manaaki is to support, take care of, give hospitality to, protect, look out for, show respect, generosity and care for others (Te Aka 2024). When conjoined with the suffix tanga, manaakitanga refers to the process of showing respect, generosity and care for others (Te Aka 2024). Therefore, to demonstrate manaakitanga is to actively enhance the mana of others through actions of respect, hospitality, and generosity.

A common way to express manaakitanga is through the sharing of kai at a hākari (feast). In the context of the moana, if a hākari features kaimoana (seafood), this is considered a delicacy, especially if the kaimoana is locally harvested. This is one example of the inherent relationship that Māori have with the moana or their pātaka kai (food source). For generations, the moana has offered a bountiful source of kai and nourishment for the wellbeing and longevity of iwi, hapū, and whānau. In addition, tangata whenua have been able to offer kaimoana to manuhiri (guests) at events and gatherings, which in turn has enabled them to express manaakitanga as just one example.

Wairuatanga

Spirituality is a common translation for wairuatanga. Yet this simplistic definition, while useful, does not fully encompass the vastness for which wairuatanga can be perceived or even understood. Similar to mauri, wairuatanga is subject to internal and external influences where it can flourish and languish depending on influences that are present (Ngawati et al. 2018). Wairuatanga also extends to groups of people whereby collective wairua can be identified. Similarly, that group can be subject to altering levels of wairuatanga whereby the collective wairuatanga can be influenced by stimuli from the outside and from within, positively and negatively.

If we consider the moana, the notion of wairuatanga can be subject to the relationship that one has with the moana, or that a group (such as an iwi, hapū, or whānau) might have with their rohe moana. This connection and intricate relationship that people have with the moana is deep. The moana has offered communities an abundant food source, a means to travel and navigate, and is even incorporated in ceremonial or other spiritual practices. It is imbued in karakia (prayer), waiata (songs), haka (dance), moteatea (chant, lament), pūrakau (stories), whakataukī (proverbs), and other oral traditions that permeate wairuatanga in Te Ao Māori (Kennedy et al. 2015). Thus, the moana is a significant catalyst for supporting and nourishing wairuatanga.

Mauri

Often translated as 'life force', mauri is a critical concept that exists in all things. That is, all things have a mauri. The moana in this sense, including the flora and fauna that reside within have a mauri. Like the tide, mauri is both susceptible to being regressive and resurgent (Durie 2015). In other words, mauri can be influenced positively and negatively from stimuli. Human activity is a critical catalyst for influencing mauri. We have seen examples where human activity has positively enhanced and negatively diminished the mauri of the moana. Below we explore different states of mauri.

Mauri noho - Languishing mauri

In health circles, we might consider an individual who is unwell and perhaps suffers from one or more symptoms of ill health as having languishing mauri (Durie, 2015). The same can be said for te taiao (the environment). It is possible that, aspects of te taiao are susceptible to the manner in which we treat them and therefore, are subject to a state of mauri noho as a result of human activity. Take for example, the presence of kina barrens in the Hauraki Gulf. Fishery extraction is an example of how human activity has altered these inshore ecosystems, leading to a reduction in the predators of kina, unconstrained grazing by kina, and the presence of kina barrens on shallow rocky reefs (Shears & Babcock 2002). In addition, kina from barrens are often in poor condition as they do not have a plentiful food source (Pert et al. 2018). These factors all contribute to a state of mauri noho, or languishing mauri.

Mauri rere – Unsettled mauri

This state of mauri is representative of imbalance. That imbalance can be due to many things, but the effect of distraction on mauri leading to imbalance is the key concept here (Durie 2015). Human activity in the Hauraki Gulf has undoubtedly led to a state of mauri rere. Our presence (through fishing, sedimentation, pollution etc…) has depleted the abundance and diversity of the Hauraki Gulf (Hauraki Gulf Forum 2023). To shift from this state of imbalance will require human intervention and most importantly, cooperation.

Mauri oho – Awakening mauri

The notion of mauri oho is often one that comes as a surprise or as a means to cause action to shift from one state to another. This is usually in a positive direction seeing as mauri oho or an awakening mauri pertains to the process of realisation that mauri is languishing and therefore needs to be activated to bring about the necessary change to move towards flourishing mauri (Durie 2015). It should be noted that mauri, like the tide is resurgent and regressive. There are many variables that can act on mauri to enhance or diminish it, but in relation to mauri oho, this is generally considered a linear pathway that focuses on resurgence as opposed to regression.

Given the state of the Hauraki Gulf (Hauraki Gulf Forum 2023) and the multiple groups, organisations, and people trying to restore the mauri of the Hauraki Gulf, it would seem as though mauri oho is an evidential state from which collective efforts are seeking to occupy. Some may argue that the Hauraki Gulf is in a state of mauri noho or mauri rere, which may be correct, however the concentrated efforts to restore the Hauraki Gulf could also suggest that the realisation of the current state of the Hauraki Gulf raises awareness and opportunity to shift the state of mauri.

Mauri tau – Settled mauri

While mauri rere is representative of an imbalanced state of mauri, the opposite is demonstrated for mauri tau where there is balance. More importantly, mauri tau encompasses an acceptance and openness to renewal and rejuvenation (Durie 2015). This is perhaps more obvious with people and individuals rather than the moana, but the concept is still applicable. This is evident in the restorative nature of the natural environment. When left alone, without disruption, without human interference, the environment often, but not always, replenishes itself. This is known as passive restoration. Given the diverse interests in the Hauraki Gulf and its proximity to Aotearoa New Zealand's largest population, it is unlikely that passive restoration by itself will be sufficient. That is not to say however, that the Hauraki Gulf is not, has not, or cannot reach a state of mauri tau. In fact, there are some reassuring examples from within the Hauraki Gulf where mauri tau has been exhibited. Such examples include the restoration of biodiversity and biomass through the implementation of marine reserves and rahui (Allard et al. 2022, Babcock et al. 1999, Babcock et al. 2010, Shears & Babcock 2002, Shears et al. 2006, Willis et al. 2003).

Mauri ora – Flourishing mauri

The final aspect of mauri is that of mauri ora. This concept is reasonably well known as it is more widely used and referred to. This is considered the highest state and represents flourishing vitality and life force (Durie 2015). For EBFM in the Hauraki Gulf, mauri ora can be a goal or outcome that the indicators and framework seek to reach. This does not necessarily mean that it is an end point. Rather, it denotes a state whereby the Hauraki Gulf, the surrounding ecosystems and us as people are able to reach. While this may not be considered to some as the current state of the Hauraki Gulf, having this vision and goal in mind might prove useful when measuring and assessing the state of the Hauraki Gulf in relation to the Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2023b) and broader development of a framework for EBFM indicators.

Whakapapa

This overarching principle of whakapapa is one that is of great importance to Māori through understanding the origin and connection to Te Ao Māori (Jackson et al. 2017). In a literal sense, whakapapa denotes the layering of one thing on another as seen in genealogical connections that people have with each other, with te taiao, with mātauranga, and with ngā atua Māori

(Māori deities) among other things (Jackson et al. 2017). When it comes to EBFM in the Hauraki Gulf, the whakapapa connections that mana moana have with their rohe moana, including the flora and fauna that reside within and around the moana, are important to recognise and understand to protect whakapapa and ensure mana moana are enabled to do so. Effective EBFM in the Hauraki Gulf should seek to incorporate and recognise the importance of whakapapa when implementing and assessing indicators for the fishery system.

Mātauranga

Mātauranga is encapsulated in Te Ao Māori, a Māori worldview where observation, experiences, and ways of knowing and understanding are those of Māori, the indigenous people of Aotearoa New Zealand (Jackson et al. 2017). Mātauranga has endured a turbulent colonial period in the history of the country's existence from before and after the signing of Te Tiriti o Waitangi and even today. Yet, mātauranga has endured, it is resolute in the iwi, hapū, and whānau that remain here and have done so for generations and centuries prior, that is where mātauranga has survived. Mātauranga has also survived through te reo Māori (the Māori language), said to be the key to the door of Te Ao Māori, the Māori language and the significant efforts towards the development and revitalisation of te reo Māori across generations has ensured mātauranga can prosper. Therefore, it should be noted that management of the fisheries of the Hauraki Gulf through indicators that are supposed to provide useful and meaningful information for people and place, should be informed by iwi, hapū, whānau, and communities where mātauranga resides. This method aligns with the principle of co-governance from the EBM principles developed in the Sustainable Seas National Science Challenge (Reid & Rout 2020).

Ngā Pou – Pillars of Success

The Pou described below have been designed as a tool that will enable mana whenua, mana moana, and other parties to assess the fishery system of the Hauraki Gulf through four key pillars; Ngā Kaihāpai - Stewardship and advocacy; Ngā hapori – Community mobilisation; Ngā Pūtea - Investments and Innovations; and Ngā Ture - Policy and legislation. These pillars are critical areas for supporting mana whenua, mana moana in active participation in EBFM through key partnerships for the protection of the Tīkapa Moana, Te Moana-nui-a-Toi, the Hauraki Gulf. A description of each attribute is as follows.

1. **Ngā Kaihāpai: Stewardship and advocacy -** Representation at all levels of the fisheries management system is vital to ensure equitable outcomes for iwi and hapū. This includes, but is not limited to: supporting the provision of roles and representation within and among governance structures and statutory authorities; increased capability and capacity for addressing iwi and hapū fishery management objectives; equitable resourcing for iwi and hapū; and addressing the biases and inadequacies and attitudes that permeate current governance structures that inhibit stewardship and advocacy for iwi and hapū.

2. **Ngā Hapori: Community mobilisation -** Communities are enabled to partake in decision making processes and outcomes effecting their rohe moana. The role of the community in fisheries management is a vital function in understanding the relationships that communities have with their rohe moana. Mobilising communities to actively participate in fisheries management will endorse a widespread approach to fisheries management and enable the community to feel empowered and connected to their rohe moana.

3. **Ngā Pūtea: Investments and innovations -** Committed funding and investment into Māori led research and innovations will enable opportunities and resourcing for iwi, hapū, and whānau. The realisation of the opportunities that exist in funding research and innovations has been showcased through the Sustainable Seas National Science

Challenge as well as other examples such as the MBIE Endeavour Programme "*Pou rāhui, pou tikanga, pou oranga: Reigniting the mauri of Tīkapa Moana and Te Moananui-ā-Toi*".

4. **Ngā Ture: Policy and legislation -** This pillar relates to the complex and fragmented system of policy and legislation across the Hauraki Gulf. All fisheries indicators proposed, considered, or implemented will be subject to legislation and policy in our marine and coastal area. An example is the mismatch that often occurs when considering spatial scales of biology (i.e., the scale of fish movement or fish population units) relative to management or legislative boundaries.

To assist users with the categorisation or scoring of the status of each of these pillars we have developed a rubric, which provides broad descriptors of the state of each pillar across a spectrum from inadequate to great (Table 2). A generic description of each of the standards within the rubric is:

Great -This is the highest standard within the rubric. To be considered within this standard, the associated indicators need to exhibit a standard of excellence.

Satisfactory - This standard suggests that the category assessed is at a decent level, but there may be some areas where improvement can be made.

Progressing - This demonstrates that the measured indicators are progressing within the category being assessed, but there are aspects which need attention or can be strengthened further.

Developing - This standard informs that the indicators within the category need work and are developing or need further development to move up the rubric. This denotes an unacceptable standard, but acknowledge that attempts are being made to progress.

Inadequate – An unacceptable standard that requires immediate attention.

Table 2 A rubric to assist users to categorise or score each of the Ngā Pou – Pillars of Success

Ngā Pou	Inadequate	Developing	Progressing	Satisfactory	Great
Ngā Kaihāpai - Stewardship and Advocacy	Iwi and hapū representation within governance structures and input into decision making is non-existent.	Advocacy for the interests and rights of iwi and hapū is minimal and is validated according to local government, central government, and other governance structures.	Iwi and hapū are represented at all levels of governance and are able to inform planning, management, outcomes, and ideas surrounding fisheries management in the Hauraki Gulf.	Iwi and hapū are represented at all levels of governance and are enabled to co-govern the management of the fishery in the Hauraki Gulf	Equitable representation from iwi and hapū exists at all levels of governance and they are equipped and enabled to co-govern the fishery within the Hauraki Gulf.

Ngā Pou	Inadequate	Developing	Progressing	Satisfactory	Great
Ngā Hapori - Community Mobilisation	Communities are disenfranchised and marginalised from their rohe moana, disenabling them from engaging within fisheries management planning and customary practices.	Communities are aware of decisions and actions surrounding fisheries management in the Hauraki Gulf, but are not permitted to inform and partake in the management of the fishery.	Communities can partake in decision-making processes and governance of fisheries management in the Hauraki Gulf.	Communities are resourced and enabled to have their perspectives and voices heard in the management and governance of the fishery in the Hauraki Gulf.	Communities are empowered to inform and partake in the governance, management, and decision-making processes around fisheries management in the Hauraki Gulf.
Ngā Putea - Investment and Innovations	No investment or funding into Māori led research and development, including mātauranga Māori is apparent in the management of the fishery in the Hauraki Gulf.	Some investment into science and mātauranga led research that supports Māori led research and innovations.	Investment in Māori led research and innovations, but further requirements needed for practical implementation.	Growing capability and capacity among researchers, communities, iwi, and hapū from targeted investment into Māori-led research and innovations.	Equitable investments and opportunities for iwi and hapū including greater capability and capacity for researchers, government, and institutes to enhance Māori-led research and innovations.
Ngā Ture - Policy and legislation	Policy and legislation development acts as a barrier for iwi and hapū involvement and engagement in fishery management.	Policy and legislation have some provisions that allow iwi and hapū to have some say in fisheries management.	Policy and legislation development addresses fragmentation and attempts to enable greater participation for iwi and hapū in fishery management.	Policy and legislation are developed to empower iwi and hapū to partake in the co-governance of the fisheries management.	Policy and legislation are developed and amended to rectify the fragmentation and ensure equitable outcomes and opportunities are afforded for iwi and hapū.

Ngā tohu – The indicators

In this section we suggest potential indicators to revitalise the mauri of the Hauraki Gulf fisheries system by recognising and considering barriers and enablers for mana moana and FNZ that take into consideration the iwi and hapū with mana whenua and mana moana status and rights within the Hauraki Gulf. It is important to recognise that these suggested indicators are just a starting point, and it is intended that they would be further developed to provide local and hapū specific context, with appropriate data sources identified (or appropriate monitoring established) as needed. A one size-fits all approach to fishery management will fail to take into consideration the rights and interests of individual iwi and hapū throughout the Hauraki Gulf and should be avoided. The rights and interests of mana moana should be recognised and acted on accordingly to appropriately apply and develop the indicator index and subsequent indicators as informed by mana moana. These ngā tohu should not operate in isolation from the indicators discussed throughout the rest of this report. Rather, both sets of indicators should be used in conjunction with each other to ensure that mana whenua and moana led indicators (ngā tohu) are positioned to leverage from all indicators and all data sets. This is important as it ensures that all indicators relevant to mana whenua, mana moana are recognised and supported alongside the other indicators to ensure effective EBFM in the Hauraki Gulf.

In developing and assessing these ngā tohu we followed a similar evaluation process to that conducted for the indicators developed and assessed throughout the rest of the report. Specifically, we utilised the same eight evaluation criteria described in Table 1. This evaluation process is discussed below in more detail, and is supported by a traffic light approach as detailed in Appendix 3.

Evaluation of ngā tohu

Ngā Kaihāpai

Customary take – During workshops with the MMAG, data relating to the quantity of customary take was identified as an area that could be better captured. This is discussed in more detail in the section above relating to Socio-economic value of fishery components. Aside from the consistency of data collection, of particular relevance are potential confidentiality issues relating to this data. Regardless, customary take still remains a potentially important data source and indicator of particular relevance to mana moana of the Hauraki Gulf.

Customary permits – Connected to customary take is the issuance of customary permits or authorisations by tanagta kaitiaki. Again, data relating to customary permits or authorisations are discussed in the section relating to Socio-economic value of fishery components, and again also contain the same issues relating to data confidentiality. It will likely be necessary to identify alternative data sets of relevance to tangata kaitiaki as they consider the issuance of customary permits. Data such as the large intertidal shellfish density metric discussed above may have relevance in this regard.

Ahu moana – Data sets, and associated indicators, describing the number and location of Ahu moana established throughout the Hauraki Gulf under *Revitalising the Gulf* (New Zealand Government 2021), are likely to be of high relevance to mana moana and coastal communities alike. In addition, it would also be useful to understand the state of the ecosystem within those Ahu moana locations. A potentially relevant example is the MBIE Endeavour Programme "*Pou rāhui, pou tikanga, pou oranga: Reigniting the mauri of Tīkapa Moana and Te Moananui-ā-Toi".* This is an iwi lead project, with those iwi identifying and measuring the abundance of taonga species within their rohe.

Governance structures – Capability and capacity for iwi, hapū, and whānau to partake in the governance of the Hauraki Gulf is a barrier for mana moana to actively participant in the governance of the Hauraki Gulf and its fisheries. As a result, the lack of representation of mana moana in decision making and governance structures limits the influence that mana moana are able to have in that decision making and governance. Data relating to the resourcing, capability and capacity building of mana moana (as supported by central and regional government) would be highly informative in understanding progress towards equitable outcomes for all partners of Te Tiriti o Waitangi.

Kaitiaki – There are a range of people who are either fulfilling professional or voluntary kaitiaki roles. Through these roles they uphold regulations, tikanga, kawa etc. Data that details the number of people in these roles would help to understand the level of guardianship that is being effected within the Hauraki Gulf fishery system.

Ngā Hapori

Community awareness – Awareness of the concepts relating to EBFM and progress towards the goals of EBFM in the Hauraki Gulf are an integral part of ensuring that the community is connected and engaged with fishery governance. Data pertaining to community awareness of these aspects (potentially obtained through a survey) could therefore be a relevant metric to consider.

EBFM for mana moana – There are a range of potential levers that can enable mana moana to participate in the governance and decision-making processes when working towards EBFM in the Hauraki Gulf. A structured survey of mana moana could help with the use of these levers and their effectiveness and impact in delivering EBFM for mana moana.

Locally led approaches – Across the Hauraki Gulf, there are several locally led approaches to EBFM, including environmental, habitat, fish and shellfish monitoring, as well as active habitat restoration. Some of these projects are supported via partnerships and resourcing, while others do not receive funding and/or support. Understanding the number of iwi, hapū and community led monitoring and restoration projects (and the level of support they receive) would be a useful indicator.

Partnering with communities and iwi - This is a treaty obligation for the Crown and government agencies; however, it is useful to monitor these partnerships to ensure that equitable outcomes for all partners are achieved. There are often inequities among these partnerships or a lack of partnering with iwi at all in some cases. Establishing a data set and associated indicators to describe the level of effective partnership would be especially useful in highlighting key areas where further development is required.

Inter-generational planning – This tohu relates to data that support the long term goals and outcomes for mana moana. This might include longitudinal data sets and research that can describe progress towards these long term aspirations.

Ngā Pūtea

Investments in iwi, hapū, and whānau led research and innovations – Data that describes the amount of funding allocated for and received by iwi, hapū, and whānau, for research and innovations. Such a data set, and associated indicators, would highlight any inequities in funding allocated to research and investments in iwi and hapū capacity and capability building.

Investments from government – Similar to the indicator described above, this indicator would detail the level of broader financial investment (i.e., beyond just research and innovation) from Government to support iwi organisations with kaupapa that is relevant to the Hauraki Gulf.

Funding requirements – An indicator that reflects the funding required (or the gaps in funding) for effective EBFM to be developed and operationalised. Further, the indicators developed in this report should assist with highlighting where these gaps exist so that the associated investment that would be needed to address each aspect could be calculated.

The Māori marine economy – An indicator that describes the size of the Māori marine economy in the Hauraki Gulf. Further, if such an indicator was broken down into its components it would help to identify opportunities for mana moana to participate in commercial activities to support the development mana moana of the Hauraki Gulf.

Ngā Ture

Regulatory frameworks of the Hauraki Gulf – The legislative framework relative to the management of the Hauraki Gulf is complex and fragmented. Indicators that simplify and describe this complexity will enable iwi, hapū, and whānau to better understand, utilise and suggest revision that could improve the legislative system and the outcomes it intends to deliver.

Legal enablers for mana moana – Data that informs about the legal levers that can be pulled to support mana moana expressions of rangatiratanga. For example, there are certain statutory rights that support mana moana to exercise their tino rangatiratanga through mechanisms such as Customary Marine Title, Protected Customary Rights, and Wāhi Tapu Rights (New Zealand Governement 2011).

Optimising future policy enactment – Data sets that quantify policy amendments and developments for mana moana going forward. This is a critical component to enabling effective EBFM as legislation governs the level of progress that is achieved.

Cultural impact assessments – Data that enables cultural impact assessments relating to activities in the Hauraki Gulf that impact cultural values. Data could be gathered from resource consent applications. An example of such data being utilised as an indicator is through the mauriometer (http://mauriometer.org/), a tool that provides a measure for assessing mauri in marine environments.

Operating outside of the regulatory framework – This indicator would describe the level of lobbying for greater policy and legislative provisions for mana moana in the Hauraki Gulf. To this end, it would document political and social movements and initiatives around the Hauraki Gulf.

Te Niho Taniwha, Desired Outcome three, and indicator implementation

Te Niho Taniwha has been designed to connect to and leverage from the other indicators developed throughout this report, and especially to connect with Desired Outcome three of the Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2023b). This interrelationship is illustrated in (Figure 29). To this end, it is envisioned that Te Niho Taniwha can support the implementation of management objectives such as improved support for tangata whenua engagement in fisheries management and decision making, improved regard for tangata whenua-led kaitiakitanga, tikanga and mātauranga Māori, and increased capacity for tangata whenua.

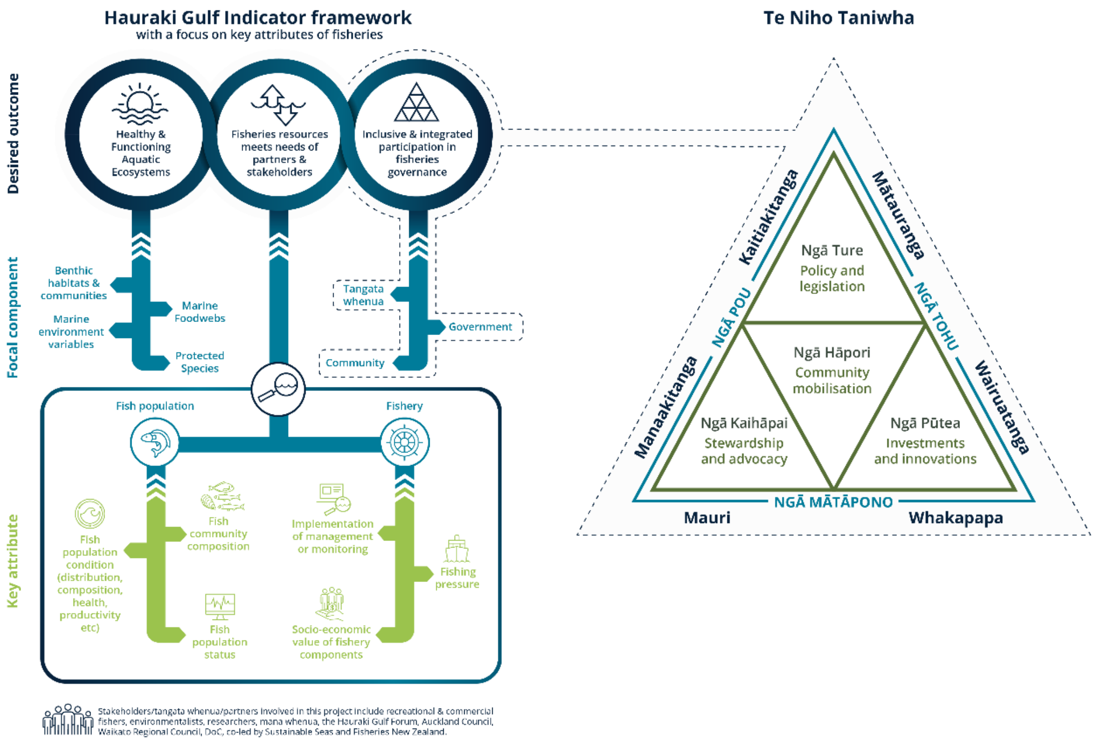


Figure 29 An overview of the interrelationship between Te Niho Taniwha and the Hauraki Gulf indicator framework, with some detail of the hierarchical structure of each framework

The structure of Te Niho Taniwha intends to allow for a breadth of indicator development from the Ngā tohu (the indicators themselves), through the four Ngā pou (pillars of success) to connect to the foundations for which positive impact are generated, the Ngā Mātāpono (the overarching principles). Measuring and quantifying these indicators is likely to be challenging. Not because of the legitimacy of the data, information, and knowledge, nor the sources from which they will be obtained or acquired. Rather, because of a mismatch between the science system and the thoughts, knowledge, and experiences of mana moana as the indigenous people of that land and sea. Efforts to enable mana moana to provide inter-generational knowledge and mātauranga-a-iwi to inform indicators/tohu are, however, essential to effectively implement EBM and support mana moana to exercise their mana motuhake as Treaty partners under Te Tiriti o Waitangi.

Adaptability is a key aspect of Te Niho Taniwha. We recognise that mana moana should be in the ‘driver's seat’ when it comes to determining the specific indicators that are relevant to them. Therefore, Te Niho Taniwha has not prescribed indicators, but rather provided a template for iwi, hapū, and whānau to adapt to meet their needs and requirements. Indicators could be inter-developed, expanded on, or swapped out accordingly, depending on the needs and wants of iwi, hapū, and whānau. In this context, we recognise the diverse rights and interests of mana moana in the Hauraki Gulf, including but not limited to, complications with contested land and the management of natural resources and the environment.

Efforts to develop specific data sets informed by mana moana are needed. We note the work being undertaken through the University of Waikato through the MBIE Endeavour Programme ‘*Pou rāhui, pou tikanga, pou oranga - reigniting the mauri of Tīkapa Moana and Te Moananui-ā-Toi*’. This project aims to develop capability among iwi to assess the need for and implementation of rāhui, creating a space for mātauranga and science-based decision-making and management. This research is likely to produce highly relevant data sets that could inform indicators of relevance to mana mona. Efforts to support similar developments across the wider fisheries system will be required to effectively implement and deliver EBFM.

Discussion

The Hauraki Gulf is a place of immense beauty and diverse values. But the Hauraki Gulf is under threat from the very uses that it is valued for. *Revitalising the Gulf* is the Governments action plan to protect and enhance the beauty and value associated with the Hauraki Gulf (New Zealand Government 2021) through a process of broadening the approach to management in line with the principles of EBM (Hewitt et al. 2018). The purpose of this project is to evaluate potential indicators, and associated monitoring, specifically related to the fishery system of the Hauraki Gulf. Therefore, it is just one part of a broader action plan. It is our intention that the indicators evaluated in this report will guide FNZ, other Government agencies and local authorities to select a suite of indicators that will enable a pathway towards EBFM by facilitating a greater understanding across a much broader fishery system than traditionally considered under a conventional approach to single species management.

Fundamental to the process of indicator development is co-development (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010). This is essential because many of the indicators being considered represent values, which can only be articulated by the stakeholders and mana whenua who cherish those values. To this end, the co-development process represents a journey, and while its aim is to evaluate indicators, it is the increased mutual understanding of others' perspectives (for all parties), the broader understanding of EBFM, increased knowledge of the Hauraki Gulf system, and the relationship building that happens along the way that will ultimately enable us to achieve EBFM. To that end, this project has been an incredibly rewarding journey of joint learning while also considering a suite of indicators.

Our original intention when developing fishery system indicators was for the final suite to be constrained to maximise management utility. For example, the original set of fisheries indicators established for the IndiSeas project only had seven indicators (Shin & Shannon 2010). While evaluating our candidate indicators, however, it became clear that the suite of indicators that will inevitably be selected by FNZ is likely to be a much larger. This is because the framework that we developed (which was intentionally aligned to the structure of the Hauraki Gulf Fishery Plan (Fisheries New Zealand 2023a)) was co-developed to represent the values, needs and concerns of the co-development group. Refining the indicator suite to reduce potential redundancy, reduce the likelihood of indicators trending in opposite directions, and maximise management utility will therefore be difficult to achieve without also decreasing its utility in representing the diverse values of the co-development group. However, once a suite of indicators (and associated monitoring) have been selected and established, their trends will need to be explored so that relationships and responses to other system components can be better understood. Through this process a greater understanding of system dynamics will be established, and the indicator suite could be further refined. Only at this stage would it really be appropriate for a much smaller subset of indicators with high management utility to be identified.

As previously mentioned, our original intention when developing indicators was to follow a discrete step-wise process that led to a set of indicators that scored highly against a formulaic combination of screening criteria (Boldt et al. 2014, Jennings 2005, Kershner et al. 2011, Rice & Rochet 2005, Shin et al. 2010). Our actual experience was quite different. First, it was not possible to decide on a list of candidate indicators without also considering whether they would be good indicators (i.e., indicator evaluation) and whether there was or could be data to support such an indicator. As a result, the indicator development process ended up being more circuitous and fluid, iterating back and forth across these development steps. We also adapted the indicator evaluation process to enhance flexibility, which will provide space for FNZ to make final decisions, considering that it is ultimately their role to achieve a balance from multiple perspectives. We attempted to achieve this by applying a traffic light system where each indicator was assessed against screening criteria, as well as providing an overall rating. While this may have been a subjective process it would not have been possible to more objectively score many of the indicators without established time series to assess some of the screening criteria (e.g., specificity & sensitivity). The added flexibility was also seen to outweigh this subjectivity, and while evaluating indicators we have attempted to be as transparent as possible by documenting our thought processes within the traffic light table (Appendix 2). Once a suite of indicators have been selected by FNZ and time series have been established this process could be reassessed and more formal scoring against screening criteria could be performed to assist with further refinement of the indicator suite.

A fundamental consideration for EBFM in Aotearoa New Zealand's marine environment includes governance structures that enable Te Tiriti o Waitangi partnerships through active participation, and the protection, revitalisation, and inclusion of tikanga, kawa, and mātauranga in shifting mauri to a state of mauri ora. This project attempted to develop an indicator framework for EBFM based on the feedback and advice from our co-development partners and the MMAG, so that indicators could be informed by and aligned with outcomes relevant to the rights and interests of mana moana. The waka taurua approach described by Maxwell et al. (2020), is a useful analogy to demonstrate the separate yet aligned space for a framework relevant to mana moana. It is important to recognise that indicators developed for the other hull of the waka (i.e., the co-development group indicators) are also useful for informing mana moana led EBFM approaches in the Hauraki Gulf as well. For that reason, it is vital that indicators which produce or yield quantifiable, scientific data sets are developed in collaboration with mana moana to ensure a balanced waka and therefore, an equitable approach to EBFM in the Hauraki Gulf. While indicator frameworks have been developed to describe the status of values relevant to mana whenua in other locations and for other systems (e.g., http://mauriometer.org/ and https://marineculturalhealth.co.nz/), we thought that it was important to develop a framework that encourages mana moana to make adaptations to meet the aspirations of their people, address localised requirements, and hold decision-makers and other partners accountable for delivering effective EBFM in the Hauraki Gulf. The Te Niho Taniwha framework described in this report is intended to serve this purpose by providing a framework that can be subsequently utilised by individual hapū to add specific place-based context relating to taonga species and values relevant to those iwi, hapū, and whānau.

Te Niho Taniwha has a number of similarities with the co-development group led indicators. Both are hierarchical in structure, Te Niho Taniwha extends from Ngā Mātāpono - Overarching principles, through Ngā Pou – Pillars of success, to Ngā Tohu – The indicators. A traffic light system for evaluating the utility of potential indicators is utilised for both frameworks. Further, a rubric to assist with the evaluation of each Ngā Pou – Pillars of Success is provided. To inform this process would likely require a well-designed survey involving face to face interviews. Developing indicators through a process of engagement at localised scales that will be meaningful to individual hapū and whānau is likely to be resource intensive, but a challenge that will be central to the success of an EBFM process that gives effect to Tiriti o Waitangi partnership.

Research and monitoring recommendations

An aspect that was emphasised by multiple members of the co-development group was the need to set up new monitoring to initiate data sets to support indicators that have not previously been considered as part of fishery management. The indicator evaluation process was also thought to weight existing data sets too heavily, likely at the expense of recommending new monitoring.

At this point it is important to reflect on the diversity of indicator categories assessed within the framework described in this report relative to the narrow scope of indicators considered under conventional single species fishery management. For example, existing data sets can support indicators describing habitats, protected species, food webs, fish population condition, socio-economic values, fishing pressure, and management implementation whereas conventional fishery management largely just utilises indicators of abundance/biomass for individual species as per the Harvest Strategy Standard (Ministry for Primary Industries 2008).

Clearly, even if only existing data sets were utilised this still represents substantial progress towards EBFM. It is also important to recognise the extra utility provided by existing time series as they will support an advanced understanding of how a particular ecosystem component responds to or influences other system components. Existing time series are likely to accelerate the setting of reference points and associated management actions that will enable more holistic management implementation and should therefore be taken advantage of where possible. It is important, however, to not limit thinking to just existing data sets and to consider what monitoring gaps need to be filled to support a comprehensive set of fishery system indicators.

As pointed out by the co-development group, the identification of sampling efficiencies is also important as these could make a fundamental difference as to what monitoring is possible. Accordingly, this section is intended to describe monitoring that, if initiated, would support such a comprehensive suite of fishery system indicators. These research and monitoring recommendations are not presented in any order of priority.

1. The establishment of a viable and socially acceptable fishery independent survey is fundamentally important (Erisman et al. 2011) to properly understand fish community diversity and structure as well as individual species assessments. Towed camera methodologies such as an upcoming Swath Cam survey could potentially fill this gap. A bottom longline survey is also likely to be initiated, but would have limited value beyond assessing snapper abundance. Any fishery independent survey methodology could be considered as a platform for deploying other survey methodologies (e.g., BRUV, acoustics, diet sample collection etc…).
2. Localised depletion could be monitored by the development of equipment, and a support network, to enable hapū, commercial fishers, boating operators and local fishing and boating communities to deploy semi-automated BRUV cameras (e.g., Brooker et al. 2020) as part of their normal operations. Data collected from these deployments could be analysed via the development of Artificial Intelligence methodologies (Marrable et al. 2022). The substantial additional benefit of a community-based approach would be the engagement with fishery management that would arise as communities take ownership of fishery monitoring in their area.
3. Supporting and utilising community data collection in general should be seen as a potential opportunity. This is especially relevant for shellfish due to their relative ease to

survey and high importance to Māori partners and stakeholders. Supporting hapū based monitoring of taonga species would allow locally specific indicators to be developed (which could support the Te Niho Taniwha framework described in this report) and would ensure that these surveys provide maximum benefit by aligning with tikanga while empowering those hapū as kaitiaki. The “Pou rāhui, pou tikanga, pou oranga: reigniting the mauri of Tīkapa Moana and Te Moananui-ā-Toi“ MBIE programme is an example of hapū based monitoring which should be utilised to inform indicators where possible.

4. Potential (and cost-effective) options to document local and indigenous knowledge include a web-based platform for local and indigenous knowledge practitioners to record observations or a network of highly engaged and frequent marine users who are routinely prompted to register significant observations. The substantial additional benefits local and indigenous knowledge capture would provide is better spatial and temporal coverage and better engagement with communities, fishers and hapū.
5. Interviews conducted with hapū, whanau and community groups (to understand their attitudes and values) would have great utility in supporting indicators related to ‘Desired Outcome three: Inclusive and integrated participation in fisheries governance’. This would require a well-designed survey to avoid any unintentional bias created through the interview process (Tesfamichael et al. 2014).
6. Total economic evaluation of all fishery components could inform managers (and society in general) as to the relative value of different aspects of fisheries. The key aspect here is establishing a methodology that all fishery sectors agree on.
7. Measurement of contaminants (such as heavy metals) in shellfish themselves would provide a direct measure of edibility. These measurements could be focussed on important shellfish beds and/or areas where contaminants are expected to improve cost-efficiency.
8. The extent of shallow water structured habitats that support fish populations is currently poorly understood. FNZ are currently working on an approach to address Habitats of Significance to Fisheries (Fisheries New Zealand 2022a), and Councils are likely to extend their mapping of habitats into the shallow sub-tidal, but more needs to be done to map the extent of these habitats. Due to the large areas and often poor water visibility involved, a combination of different survey methods would likely be required.
9. Considering the importance of sedimentation as a stressor, a broader network of sedimentation rate monitoring (settlement plates) could have utility.
10. Expanded monitoring associated with the potential implementation of marine protected areas (e.g., HPAs, SPAs etc…) could inform many indicators through the calculation of inside vs. outside of reserve ratios for multiple species (e.g., rock lobster, hāpuku & bass etc…). It will also be important to align this marine protection monitoring with the approach that FNZ are developing to document kina barrens.
11. Acoustic survey methods could have utility for assessing the abundance of small and medium sized pelagic fishes, especially if vessels of opportunity are able to collect acoustic data cost-effectively. A primary consideration is whether the species composition of different acoustic mark types can be reliably determined. A process for investigating acoustic mark types was described in the main body of the report.
12. Aerial surveys have the potential to serve as a highly efficient platform to collect a wide array of data types, many of which are related to pelagic food webs that support many of the Hauraki Gulf’s fisheries (Pinkerton et al. 2023b). Some of the aspects that could potentially be measured together via aerial surveys include MSFAs (which are associated with small and medium sized pelagic fishes), cetaceans, pelagic sharks, turtles, gannet nesting colonies, shallow water habitats, and recreational boat counts.

13. Cost-effective options to understand the diet (and trophic connections) of marine species should be considered. Diet samples could be routinely collected as part of other surveys already taking place. Samples could be targeted at a small number of key system components spread across trophic levels to provide focus. Further efficiency could potentially be gained from eDNA metabarcoding methodologies (Kim & Kwak 2022). One particular system component that could serve as a potential focal species is the Australasian gannet. Gannet colony counts (see aerial surveys above) paired with diet information could potentially provide substantial insight into the small and medium sized pelagic fishes that they prey on.

Conclusion

The fisheries of the Hauraki Gulf, and the system that supports them are highly valued, but are showing signs of degradation due to the many uses of the Hauraki Gulf. *Revitalising the Gulf* presents an action plan to restore the mauri of the Hauraki Gulf through a more holistic process of EBFM (New Zealand Government 2021).

Central to the concept of EBFM is broadening the values that are considered by management and trying to achieve balance (not exclusion) in that multi-value space (Haugen et al. 2024). This project is intended to contribute to that process by evaluating indicators (connected to the Hauraki Gulf Fisheries Plan (Fisheries New Zealand 2023a)) that capture those broad values, other system components, stressors of that system, and the implementation of management actions.

Once final indicators have been selected by Fisheries New Zealand, their utility will allow us to see if management actions are being implemented and whether the system (and the multiple values that it contains) is responding positively to achieve the multi-value balance that society desires (Jennings 2005). If that is not occurring, then the indicators will allow us to see that and adjust, in line with an adaptive management process (Folke et al. 2004). And so the cycle repeats.

The indicators evaluated here represent substantial progress towards EBFM as they capture a much broader system than is currently considered within the scope of fishery management. The indicators evaluated do include a large number of indicators relevant to individual fish populations. These single species indicators will continue to be important to fishery management; they should not be discarded as we make incremental steps of addition towards EBFM. Even these single species indicators contain substantial progress as they capture aspects such as the distribution and condition of fish populations that have not received as much emphasis from management previously.

Aside from management utility, indicators support communication about the status of various system components, what management actions are being implemented, and the level of stress the system is under. This is important because misconceptions can replace accurate information if it is not communicated. Even the single species indicators that we currently use are not well communicated, so having them all in one easily accessible place will be paramount.

We suggest the creation of a web portal to communicate the status of the indicators will be an essential next step after final decisions have been made about which indicators to adopt. There a number of high quality examples to base this step on (e.g., https://www.lawa.org.nz/, https://protectedspeciescaptures.nz/, https://marineculturalhealth.co.nz/).

At the conclusion of this project, it is important to note that there is still a lot of work to be done. Decisions need to be made about which indicators to adopt from the evaluations provided in this report. Monitoring recommendations need to be considered and monitoring initiated. And there is still a need for Māori to be enabled as kaitiaki alongside existing management and for the management actions of *Revitalising the Gulf* to be implemented. This will only be possible through greater cross Government coordination, which remains a challenge with the existing divisions of responsibility across multiple management agencies. An immediate challenge in that regard will be to coordinate and align the recommendations in this report with the broader research and monitoring plan for all of *Revitalising the Gulf*.

References

Aguirre, J.D.; Bollard-Breen, B.; Cameron, M.; Constantine, R.; Duffy, C.A.J.; Dunphy, B.; Hart, K.; Hewitt, J.E.; Jarvis, R.M.; Jeffs, A. et al. (2016). Loved to pieces: Toward the sustainable management of the Waitematā Harbour and Hauraki Gulf. *Regional Studies in Marine Science* 8: 220-233.

Alexander, K.A.; Haward, M. (2019). The human side of marine ecosystem-based management (EBM): 'Sectoral interplay' as a challenge to implementing EBM. *Marine Policy* 101: 33-38.

Allard, H.; Ayling, A.M.; Shears, N.T. (2022). Long-term changes in reef fish assemblages after 40 years of no-take marine reserve protection. *Biological Conservation* 265:

Anderson, M.J.; Ellingsen, K.E.; McArdle, B.H. (2006). Multivariate dispersion as a measure of beta diversity. *Ecology Letters* 9: 683-693.

Anderson, O.; Finucci, B. (2022). Non-target fish and invertebrate catch and discards in New Zealand orange roughy and oreo trawl fisheries from 2002–03 to 2019–20. *New Zealand Aquatic Environment and Biodiversity Report* No. 282. 117 p.

Andrew, N.L.; Macdiarmid, A.B. (1991). Interrelations between sea urchins and spiny lobsters in northeastern New Zealand. *Marine Ecology Progress Series* 70: 211-222.

Anton, A.; Geraldi, N.R.; Lovelock, C.E.; Apostolaki, E.T.; Bennett, S.; Cebrian, J.; Krause-Jensen, D.; Marbà, N.; Martinetto, P.; Pandolfi, J.M. et al. (2019). Global ecological impacts of marine exotic species. *Nature Ecology & Evolution* 3: 787-800.

Atalah, J.; Floerl, O.; Pochon, X.; Townsend, M.; Tait, L.; Lohrer, A.M. (2019). The Introduced Fanworm, Sabella spallanzanii, Alters Soft Sediment Macrofauna and Bacterial Communities. *Frontiers in Ecology and Evolution* 7:

Atkins, J.P.; Burdon, D.; Elliott, M.; Gregory, A.J. (2011). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. *Marine Pollution Bulletin* 62: 215-226.

Babcock, R.C.; Kelly, S.; Shears, N.T.; Walker, J.W.; Willis, T.J. (1999). Changes in community structure in temperate marine reserves. *Marine Ecology Progress Series* 189: 125-134.

Babcock, R.C.; Shears, N.T.; Alcala, A.C.; Barrett, N.S.; Edgar, G.J.; Lafferty, K.D.; McClanahan, T.R.; Russ, G.R. (2010). Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. *Proceedings of the National Academy of Sciences of the United States of America* 107: 18256-18261.

Backhurst, M.K.; Cole, R.G. (2000). Subtidal benthic marine litter at Kawau Island, north-eastern New Zealand. *Journal of Environmental Management* 60: 227-237.

Bax, N.J. (1988). The significance and prediction of predation in marine fisheries. *ICES Journal of Marine Science* 55: 217-224.

Beck, H.E.; Wood, E.F.; Pan, M.; Fisher, C.K.; Miralles, D.G.; van Dijk, A.I.J.M.; McVicar, T.R.; Adler, R.F. (2019). MSWEP V2 Global 3-Hourly 0.1° Precipitation: Methodology and Quantitative Assessment. *Bulletin of the American Meteorological Society* 100: 473-500.

Bennett-Jones, L.; Gnanalingam, G.; Flack, B.; Scott, N.J.; Chambers, P.; Hepburn, C. (2022). Constraints to effective comanagement of New Zealand's customary fisheries: experiences of the East Otago Taiāpure. *Ecology and Society* 27:

Berghöfer, A.; Wittmer, H.; Rauschmayer, F. (2008). Stakeholder participation in ecosystem-based approaches to fisheries management: A synthesis from European research projects. *Marine Policy* 32: 243-253.

Berkenbusch, K.; Hill-Moana, T.; Neubauer, P. (2022). Intertidal shellfish monitoring in the northern North Island region, 2021–22. *New Zealand Fisheries Assessment Report* 2022/57. 142 p.

Bhuyan, M.S. (2022). Effects of Microplastics on Fish and in Human Health. *Frontiers in Environmental Science* 10:

Bian, R.; Hartill, B. (2011). Modelling of recreational fishing effort in QMA 1 from 1970 to 2009. *New Zealand Fisheries Assessment Report* 2015/26. 50 p. .

Boldt, J.L.; Martone, R.; Samhouri, J.; Perry, R.I.; Itoh, S.; Chung, I.K.; Takahashi, M.; Yoshle, N. (2014). Developing Ecosystem Indicators for Responses to Multiple Stressors. *Oceanography* 27: 116-133.

Bowman, K.L.; Lamborg, C.H.; Agather, A.M. (2020). A global perspective on mercury cycling in the ocean. *Science of The Total Environment* 710: 136166.

Brooker, M.A.; de Lestang, S.; Fairclough, D.V.; McLean, D.; Slawinski, D.; Pember, M.B.; Langlois, T.J. (2020). Environmental and anthropogenic factors affect fish abundance: relationships revealed by automated cameras deployed by fishers. *Frontiers in Marine Science* 7: 279.

Burrow, R. (2020). Enumeration of *Escherichia coli* in Bivalve Molluscan Shellfish. MPI Method available from: https://mpi.govt.nz/resources-and-forms/publications/ 15 p.

Canals, O.; Lanzén, A.; Mendibil, I.; Bachiller, E.; Corrales, X.; Andonegi, E.; Cotano, U.; Rodríguez-Ezpeleta, N. (2023). Increasing marine trophic web knowledge through DNA analyses of fish stomach contents: a step towards an Ecosystem Based Approach to fisheries research. *bioRxiv* 2023.2012.2018.572137.

Choy, C.A.; Popp, B.N.; Kaneko, J.J.; Drazen, J.C. (2009). The influence of depth on mercury levels in pelagic fishes and their prey. *Proceedings of the National Academy of Sciences* 106: 13865-13869.

Clapcott, J.; Ataria, J.; Hepburn, C.; Hikuroa, D.; Jackson, A.-M.; Kirikiri, R.; Williams, E. (2018). Mātauranga Māori: shaping marine and freshwater futures. *New Zealand Journal of Marine and Freshwater Research* 52: 457-466.

Coffey, C. (2005). What role for public participation in fisheries governance? In, Participation in Fisheries Governance, edited by T. Gray, Springer Dordrecht, Newcastle upon Tyne, UK, pp. 27-44.

Compton, T.J.; Morrison, M.A.; Leathwick, J.R.; Carbines, G.D. (2012). Ontogenetic habitat associations of a demersal fish species, *Pagrus auratus*, identified using boosted regression trees. *Marine Ecology Progress Series* 462: 219-230.

Cooke, S.J.; Nguyen, V.M.; Chapman, J.M.; Reid, A.J.; Landsman, S.J.; Young, N.; Hinch, S.G.; Schott, S.; Mandrak, N.; Semeniuk, C.A.D. (2020). Knowledge co-production: A pathway to effective fisheries management, conservation, and governance. *Fisheries* 46: 89-97.

Cury, P.; Shannon, L.J.; Roux, J.P.; Daskalov, G.M.; Jarre, A.; Moloney, C.L.; Pauly, D. (2005). Trophodynamic indicators for an ecosystem approach to fisheries. *ICES Journal of Marine Science* 62: 430-442.

Cury, P.; Shannon, L.J.; Shin, Y.-J. (2003). The functioning of marine ecosystems: a fisheries prespective. In, Responsible fisheries in the marine ecosystem, edited by M. Sinclair and G. Valdimarsson, CAB International, Wallingford, UK, pp. 102-123.

Davis, W.C. (2022). Multi-species foraging associations in the Hauraki Gulf. MSc thesis, University of Auckland. 154 p.

Department of Conservation (2022). Marine monitoring and reporting framework. Department of Convservation report available at: https://www.doc.govt.nz/nature/habitats/marine/type-1-marine-protected-areas-marine-reserves/marine-monitoring-and-reporting-framework/ 224 p.

Diana, E.L.G.; Grace, R.V.; Haggitt, T.R.; Hanns, B.J.; Kelly, S.; MacDiarmid, A.; Shears, N.T. (2021). Small marine reserves do not provide a safeguard against overfishing. *Conservation Science and Practice* 3:

Dixon, H.; McIndoe, C. (2022). The economic contribution of commercial fishing. BERL client report for Fisheries Inshore New Zealand. 54 p.

Dunn, M.R.; Hurst, R.J.; Renwick, J.; Francis, R.I.C.C.; Devine, J.; McKenzie, A. (2009). Fish abundance and climate trends in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report* No. 31. 75 p.

Dunphy, B.J.; Vickers, S.I.; Zhang, J.; Sagar, R.L.; Landers, T.J.; Bury, S.J.; Hickey, A.J.R.; Rayner, M.J. (2020). Seabirds as environmental indicators: foraging behaviour and ecophysiology of common diving petrels (*Pelecanoides urinatrix*) reflect local-scale differences in prey availability. *Marine Biology* 167: 53.

Durie, M.K. (2015). Mauri Ora, Mauri Noho. Unpublished lecture given to Te Wananga o Raukawa, Otaki.

Edwards, C.T.T.P., T.; Goad D.; Webber, D.N. (2023). Update to the risk assessment for New Zealand seabirds. *New Zealand Aquatic Environment and Biodiversity Report* No. 314. 66 p.

Erisman, B.E.; Allen, L.G.; Claisse, J.T.; Pondella, D.J.; Miller, E.F.; Murray, J.H. (2011). The illusion of plenty: hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 1705-1716.

Evans, O. (2017). Refining underwater video methods for monitoring fish populations. University of Auckland MSc thesis, 81 p.

FirstMate (2023). FirstMate annual report 2022-2023. Available from: https://www.firstmate.org.nz/annual-report/ 17 p.

Fisheries New Zealand (2019). Review of blue cod fishing regulations. Proposed amendments to current blue cod regulations from the National Blue Cod Strategy. *Fisheries New Zealand Discussion Paper* No.: 2019/01. Available from https://www.fisheries.govt.nz/bluecod. 21 p.

Fisheries New Zealand (2020). Deemed value guidelines. Guidelines for he review of deemed value rates for stocks managed under the Quota Management System. *FNZ internal report* available from: http://www.mpi.govt.nz/news-and-resources/publications/ 9 p.

Fisheries New Zealand (2021). Review of sustainability measures for New Zealand scallops (SCA 1 & SCA CS) for 2022/23. *Fisheries New Zealand Discussion Paper* No: 2021/30. 51 p.

Fisheries New Zealand (2022a). Draft: Guidelines for the identification of habitat of particular significance for fisheries management. Available from https://www.mpi.govt.nz/consultations/. 16 p.

Fisheries New Zealand (2022b). National Inshore Finfish Fisheries Plan. Available from: www.mpi.govt.nz/news-and-resources/publications 44 p.

Fisheries New Zealand (2023a). Fisheries Assessment Plenary, May 2023: stock assessments and stock status. Compiled by the Fisheries Science Team, Fisheries New Zealand, Wellington, New Zealand. 1904 p.

Fisheries New Zealand (2023b). Hauraki Gulf fisheries plan. Available from: www.mpi.govt.nz/news-and-resources/publications 30 p.

Fisheries New Zealand (2024). The status of New Zealand's fisheries 2023. Report available from https://www.mpi.govt.nz/fishing-aquaculture/sustainable-fisheries/the-health-of-new-zealands-fisheries/fish-stock-status/. 8 p.

Folke, C.; Carpenter, S.; Walker, B.; Scheffer, M.; Elmqvist, T.; Gunderson, L.; Holling, C.S. (2004). Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology Evolution and Systematics* 35: 557-581.

Fulton, E.A.; Smith, A.D.M.; Webb, H.; Slater, J. (2004). Ecological indicators for the impacts of fishing on non-target species, communities and ecosystems: Review of potential indicators. *AFMA Final Research report* R99/1546: 119 p.

Furtado, R.; Granadeiro, J.P.; Gatt, M.C.; Rounds, R.; Horikoshi, K.; Paiva, V.H.; Menezes, D.; Pereira, E.; Catry, P. (2021). Monitoring of mercury in the mesopelagic domain of the Pacific and Atlantic oceans using body feathers of Bulwer's petrel as a bioindicator. *Science of The Total Environment* 775: 145796.

Gall, M.; Pinkerton, M.; Steinmetz, T.; Wood, S. (2022). Satellite remote sensing of water quality in New Zealand *New Zealand Journal of Marine and Freshwater Research* 56: 585-616.

Gaskin, C.; Adams, N.; Kozmian-Ledward, L.; Jeffs, A. (2019a). Indirect effects on seabirds in the northern North Island region. Final report on comparison of fish shoals and seabird diet prepared by NNZST for the Conservation Services Programme, Department of Conservation. POP2017-06. 48 p.

Gaskin, C.; Frost, P.; Friesen, M. (2019b). Indirect effects on seabirds in the northern North Island region. Final report on seabird colony and population assessments prepared by NNZST for the Conservation Services Programme, Department of Conservation. POP2017-06. 23 p.

Gelcich, S.; Godoy, N.; Castilla, J.C. (2009). Artisanal fishers' perceptions regarding coastal co-management policies in Chile and their potentials to scale-up marine biodiversity conservation. *Ocean & Coastal Management* 52: 424-432.

Gostischa, J.; Massolo, A.; Constantine, R. (2021). Multi-Species Feeding Association Dynamics Driven by a Large Generalist Predator. *Frontiers in Marine Science* 8:

Green, M.; Zeldis, J. (2015). Firth of Thames water quality and ecosystem health - a synthesis. *Waikato Regional Council Technical Report* 2015/23. 177 p.

Grüss, A.; Charsley, A.R.; Thorson, J.T.; Anderson, O.F.; O'Driscoll, R.L.; Wood, B.; Breivik, O.N.; O'Leary, C.A. (2023a). Integrating survey and observer data improves the predictions of New Zealand spatio-temporal models. *Ices Journal of Marine Science* 80: 1991-2007.

Grüss, A.; McKenzie, J.R.; Lindegren, M.; Bian, R.C.; Hoyle, S.D.; Devine, J.A. (2023b). Supporting a stock assessment with spatio-temporal models fitted to fisheries-dependent data. *Fisheries Research* 262:

Hanns, B.J.; Haggitt, T.; Shears, N.T. (2022). Marine protected areas provide unfished reference information to empirically assess fishery status. *Biological Conservation* 276: 109775.

Hartill, B. (2015). Review of ancillary sources of information that used to inform recreational harvest estimates. *New Zealand Fisheries Assessment Report* 2015/15. 33 p.

Hartill, B. (2019). Feasibility and design for a CRA 2 recreational harvest monitoring survey. *New Zealand Fisheries Assessment Report* 2019/31. 14 p.

Hartill, B.; Bian, R.; Rush, N.; Armiger, H. (2019). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report* 2019/23. 39 p.

Hartill, B.; Doonan, I.J. (2022). Stock assessment of kahawai (*Arripis trutta*) in 2021 for KAH 1, 1930–31 to 2019–20. *New Zealand Fisheries Assessment Report* 2022/54. 66 p.

Hartill, B.; McGregor, V.; Doonan, I.; Bian, R.; Baird, S.J.; Walsh, C. (2020a). Feasibility of fishery independent longline surveys for snapper, hāpuku, bass, and bluenose. *New Zealand Fisheries Assessment Report* 2020/25. 64 p.

Hartill, B.; Middleton, D.A.J.; Walsh, C.; Spong, K.; Ó Maolagáin, C. (2022). Catch-at-age sampling of *Trachurus novaezelandiae* from JMA 1 in 2019–20 and 2020–21. *New Zealand Fisheries Assessment* Report 2022/37. 16 p. .

Hartill, B.; Rush, N.; Payne, G.; Davey, N.; Bian, R.; Millar, A.; Armiger, H.; Spong, K. (2020b). Camera and creel survey monitoring of trends in recreational effort and harvest from 2004–05 to 2018–19. *New Zealand Fisheries Assessment Report* 2020/18. 50 p.

Haugen, J.B.; Link, J.S.; Cribari, K.; Bundy, A.; Dickey-Collas, M.; Leslie, H.M.; Hall, J.; Fulton, E.A.; Levenson, J.J.; Parsons, D.M. et al. (2024). Marine ecosystem-based management: challenges remain, yet solutions exist, and progress is occurring. *npj Ocean Sustainability* 3: 7.

Hauraki Gulf Forum (2023). State of our Gulf 2023. *State of the Environment Report*. Available from: https://gulfjournal.org.nz/wp-content/uploads/2023/08/SOER-online.pdf 99 p.

Hewitt, J.; De Juan, S.; Townsend, M.; D' Archinoi, R. (2014). Functional traits as indicators of ecological integrity. *NIWA client report for the Department of Conservation*. 41 p.

Hewitt, J.; Faulkner, L.; Greenaway, A.; Lundquist, C. (2018). Proposed ecosystem-based management principles for New Zealand. *Resource Management Journal* November 2018: 10-13.

Hewitt, J.E.; Anderson, M.J.; Thrush, S.F. (2005). Assessing and monitoring ecological community health in marine systems. *Ecological Applications* 15: 942-953.

Hewitt, J.E.; Ellis, J. (2010). Assessment of the benthic health model. Prepared by NIWA for Auckland Regional Council. *Auckland Regional Council Technical Report* TR2010/034. 36 p.

Hixon, M.A.; Johnson, D.W.; Sogard, S.M. (2013). BOFFFFs: on the importance of conserving old-growth age structure in fishery populations. *ICES Journal of Marine Science* 71: 2171-2185.

Holdsworth, J.; Rea, T.; Southwick, R. (2016). Recreational Fishing in New Zealand - A Billion Dollar Industry. Produced for the New Zealand Marine Research Foundation. 12 p.

Jackson, A.-M.; Hepburn, C.D.; Flack, B. (2018). East Otago Taiāpure: sharing the underlying philosophies 26 years on. *New Zealand Journal of Marine and Freshwater Research* 52: 577-589.

Jackson, A.-M.; Mita, N.; Hakopa, H. (2017). Hui-te-ana-nui: Understanding kaitiakitanga in our marine environment. Report to the Sustainable Seas National Science Challenge. Available from https://www.sustainableseaschallenge.co.nz/tools-and-resources/ 167 p.

Jennings, S. (2005). Indicators to support an ecosystem approach to fisheries. *Fish and Fisheries* 6: 212-232.

Jentoft, S. (1989). Fisheries co-management: Delegating government responsibility to fishermen's organizations. *Marine Policy* 13: 137-154.

Joanna, G.; Romuald, N.L. (2004). Allee effects in marine systems. *Marine Ecology Progress Series* 269: 49-59.

Johnson, K.S.; Gadd, J.; Bian, R.; Noll, B.; Pinkerton, M.H.; Taylor, R.; Madden, B.; Parsons, D.M. (in press). Distribution and potential causes of milky fleshed snapper in SNA 1. *New Zealand Fisheries Assessment Report* 2024/xx. 64 p.

Kapoor, I. (2001). Towards participatory environmental management? *Journal of Environmental Management* 63: 269-279.

Kennedy, V.; Cram, F.; Paipa, K.; Pipi, K.; Baker, M. (2015). Wairua and cultural values in evaluation. . *Evaluation Matters—He Take Tō Te Aromatawai* 1: 83-111.

Kershner, J.; Samhouri, J.F.; James, C.A.; Levin, P.S. (2011). Selecting Indicator Portfolios for Marine Species and Food Webs: A Puget Sound Case Study. *Plos One* 6:

Kim, H.G.; Kwak, I.S. (2022). Determination of spatial and individual variations in the dietary composition of *Ennahia argentata* in coastal waters of South Korea using metabarcoding and morphological analyses. *Regional Studies in Marine Science* 55:

Kulwant, R.; Carlaw, N. (2022). Revitalising the Gulf Stage 2: economic impact assessment of the marine protection proposals. Martin Jenkins Client Report Report for the Department of Conservation, 50 p.

Ladds, M.A.; Pinkerton, M.H.; Jones, E.; Durante, L.M.; Dunn, M.R. (2020). Relationship between morphometrics and trophic levels in deep-sea fishes. *Marine Ecology Progress Series* 637: 225-235.

Laidler, G.J. (2006). Inuit and scientific perspectives on the relationship between sea ice and climate change: the ideal complement? *Climatic Change* 78:

Langley, A.D. (2022). A stock assessment of eastern tarakihi for 2021. *New Zealand Fisheries Assessment Report* 2022/07. 68 p.

Langlois, T.J.; Anderson, M.J.; Brock, M.; Murman, G. (2006). Importance of rock lobster size–structure for trophic interactions: choice of soft-sediment bivalve prey. *Marine Biology* 149: 447-454.

Lindner, B. (2010). Cutting the cake in a shared fishery with a minimally managed non-commercial sector. Report to the Ministry of Fisheries, Economic Research Associates, 45 p.

Link, J.S.; Marshak, A.R. (2021). Ecosystem-based fishery management: progress, importance and impacts in the United States. Oxford University Press. 712 p.

Lohrer, D.; Douglas, E. (2019). Motu Aotea/Great Barrier Island: Subtidal habitat descriptions from a 2015 drop camera survey. Prepared by NIWA for Auckland Council. *Auckland Council Technical Report* TR2019/xx.

Lyver, P.O.B.; Aldridge, S.P.; Gormley, A.M.; Gaw, S.; Webb, S.; Buxton, R.T.; Jones, C.J. (2017). Elevated mercury concentrations in the feathers of grey-faced petrels (*Pterodroma gouldi*) in New Zealand. *Marine Pollution Bulletin* 119: 195-203.

MacGibbon, D.J.; Mules, R. (2023). Extent and intensity of bottom contact by commercial trawling and shellfish dredging in New Zealand waters, 1990–2021. *New Zealand Aquatic Environment and Biodiversity Report* No. 316. 174 p.

Maggs, J.Q.; Parsons, D. (2023). Design for a catch sampling programme survey to estimate the age structure of New Zealand hāpuku (*Polyprion oxygeneios*). *New Zealand Fisheries Assessment Report* 2023/34. 30 p.

Marrable, D.; Barker, K.; Tippaya, S.; Wyatt, M.; Bainbridge, S.; Stowar, M.; Larke, J. (2022). Accelerating species recognition and labelling of fish from underwater video with machine-assisted deep learning. *Frontiers in Marine Science* 9:

Maxwell, K.; Awatere, S.; Ratana, K.; Davies, K.; Taiapa, C. (2020). He waka eke noa/we are all in the same boat: A framework for co-governance from Aotearoa New Zealand. *Marine Policy* 121: 104213.

Maxwell, K.H.; Ratana, K.; Davies, K.K.; Taiapa, C.; Awatere, S. (2019). Navigating towards marine co-management with Indigenous communities on-board the Waka-Taurua. *Marine Policy* 111: 1-4.

McKenzie, A. (2023). Stock assessment of trevally (*Pseudocaranx georgianus*) for TRE 1 to 2021/22. *New Zealand Fisheries Assessment Report* 2023/61. 60 p.

McKenzie, J.; Parsons, D. (2012). Fishery characterisations and catch-per-unit-effort indices for three sub-stocks of snapper SNA 1, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report* 2012/29. 112 p.

McKenzie, J.R.; Beentjes, M.P.; Parker, S.; Parsons, D.M.; Armiger, H.; Wilson, O.; Middleton, D.; Langley, A.; Buckthought, D.; Walsh, C. et al. (2017). Fishery characterisation and age composition of tarakihi in TAR 1, 2 and 3 for 2013/14 and 2014/15. *New Zealand Fisheries Assessment Report* 2017/36. 80 p.

Memon, A.P.; Kirk, N.A. (2010). Barriers to collaborative governance in ew Zealand fisheries: Pt II. *Geography Compass* 4: 789-802.

Memon, P.A.; Sheeran, B.; Ririnui, T. (2003). Strategies for rebuilding closer links between local indigenous communities and their customary fisheries in Aotearoa/New Zealand. *Local Environment* 8: 205-219.

Michael, K.P.; Bilewitch, J.; Rexin, D.; Forman, J.; Hulston, D.; Moss, G. (2022). Surveys of the Foveaux Strait oyster (*Ostrea chilensis*) fishery (OYU 5) and Bonamia exitiosa prevalence, intensity, and disease related oyster mortality in February 2021. *New Zealand Fisheries Assessment Report* 2022/48. 78 p.

Mikalsen, K.H.; Jentoft, S. (2001). From user-groups to stakeholders? The public interest in fisheries management. *Marine Policy* 25: 281-292.

Mikalsen, K.H.; Jentoft, S. (2008). Participatory practices in fisheries across Europe: Making stakeholders more responsible. *Marine Policy* 32: 169-177.

Ministry for Primary Industries (2008). Harvest Strategy Standard for New Zealand Fisheries. Available from: https://www.mpi.govt.nz/dmsdocument/728-Harvest-Strategy-Standard-for-New-Zealand-Fisheries. 30 p.

Moana NZ (2023). Pūrongo tapatahi ā tau: Integrated annual report 2023. Available from: https://ar.moana.co.nz/ 136 p.

Molnar, J.L.; Gamboa, R.L.; Revenga, C.; Spalding, M.D. (2008). Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment* 6: 485-492.

Morrison, M.A.; Lowe, M.L.; Parsons, D.M.; Usmar, N.R.; McLeod, I.M. (2009). A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 37. 100 p.

MPI (2008). Harvest Strategy Standard for New Zealand fisheries. Available from: http://www.mpi.govt.nz/news-and-resources/publications/ 30 p.

Msomphora, M.R. (2015). Stakeholder participation and satisfaction in the process of developing management plans: The case of Scottish Inshore Fisheries Groups. *Ocean & Coastal Management* 116: 491-503.

Natsukawa, H.; Sergio, F. (2022). Top predators as biodiversity indicators: A meta-analysis. *Ecology Letters* 25: 2062-2075.

New Zealand Governement (1998). Fisheries (Kaimoana Customary Fishing) Regulations 1998 (SR 1998/434). Available from: https://www.legislation.govt.nz/ 31 p.

New Zealand Governement (2011). Marine and Coastal Area (Takutai Moana) Act 2011**. Available from: https://www.legislation.govt.nz/ 125 p**.

New Zealand Government (1996). Fisheries Act (1996 No. 88). Available from: https://www.legislation.govt.nz/ 584 p.

New Zealand Government (2021). Revitalising the Gulf - Government Strategy in response to the Sea Change – Tai Timu Tai Pari – Hauraki Gulf Marine Spatial Plan. Available from: https://www.doc.govt.nz/globalassets/documents/our-work/sea-change/revitalising-the-gulf.pdf. 144 p.

Ngawati, R.; Valentine, H.; Tassell-Matamua, N. (2018). He aha te wairua? He aha te mauri? Unpublished internship report prepared for Ngā Pae o te Māramatanga. Available from https://www.maramatanga.ac.nz. 35 p.

NZIER (2023). Valuing the Hauraki Gulf: An ecosystem services and natural capital approach. A report for The Hauraki Gulf Forum. 75 p.

Pacoureau, N.; Rigby, C.L.; Kyne, P.M.; Sherley, R.B.; Winker, H.; Carlson, J.K.; Fordham, S.V.; Barreto, R.; Fernando, D.; Francis, M.P. et al. (2021). Half a century of global decline in oceanic sharks and rays. *Nature* 589: 567-571.

Pande, A.; Brosnahan, C.; Jones, B.; Ross, A.; Phiri, B.; Pal, C.; Bestbier, M. (2021). Tail fan necrosis in New Zealand red rock lobster, *Jasus edwardsii*. *MPI Technical Paper* No: 2021/09. 33 p.

Parsons, D.M.; Bian, R. (2022). Trawl surveys of the Hauraki Gulf and Bay of Plenty in 2020 and 2021 to estimate the abundance of juvenile snapper. *New Zealand Fisheries Assessment Report* 2022/10. 134 p.

Parsons, D.M.; Bian, R.; Walsh, C.; McKenzie, J.; Armiger, H.; Taylor, R.; Spong, K.; Buckthought, D.; Ó Maolagáin, C. (2022). Length and age composition of trevally in TRE 1 (2017–18 & 2019–20) and TRE 2 (2019–20). *New Zealand Fisheries Assessment Report* 2022/12. 52 p.

Parsons, D.M.; Buckthought, D.; Middleton, C.; MacKay, G. (2016). Relative abundance of snapper (*Chrysophrys auratus*) across habitats within an estuarine system. *New Zealand Journal of Marine and Freshwater Research* 50: 358-370.

Paul, L.J. (2012). A history of the Firth of Thames dredge fishery for mussels: use and abuse of a coastal resource. *New Zealand Aquatic Environment and Biodiversity* Report No. 94. 27 p.

Pauly, D.; Christensen, V.; Dalsgaard, J.; Froese, R.; Torres, F. (1998). Fishing Down Marine Food Webs. *Science* 279: 860-863.

Pert, C.G.; Swearer, S.E.; Dworjanyn, S.; Kriegisch, N.; Turchini, G.M.; Francis, D.S.; Dempster, T. (2018). Barrens of gold: gonad conditioning of an overabundant sea urchin. *Aquaculture Environment Interactions* 10: 345-361.

Pinkerton, M.; Gall, M.; Steinmetz, T.; Wood, S. (2023a). NIWA Seas, Coasts and Estuaries New Zealand (NIWA-SCENZ): Image services of satellite (MODIS-Aqua) water quality products for coastal New Zealand. Data Product Version 5.0. NIWA, Wellington.

Pinkerton, M.H. (2012). Headline indicators for the New Zealand ocean. Internal NIWA report available from https://niwa.co.nz. 42 p.

Pinkerton, M.H.; Anderson, O.A.; Dunn, M.; Edwards, C.; Roux, M.-J. (2017). Ocean ecosystem indicators for New Zealand: review of the marine trophic index. *NIWA Client report prepared for the Ministry for the Environment*, 39 p.

Pinkerton, M.H.; Decima, M.; Kitchener., J.; Takahashi, K.; Robinson, K.; Stewart, R.; Hosie, G.W. (2020). Zooplankton in the Southern Ocean from the Continuous Plankton Recorder: distributions and long-term change. *Deep Sea Research I* 103303: 10.1016/j.dsr.2020.103303.

Pinkerton, M.H.; Moore, B.R.; O'Driscoll, R.L. (2023b). Role of low- and mid-trophic level fish in the Hauraki Gulf ecosystem. *New Zealand Aquatic Environment and Biodiversity Report* No. 301. 126 p.

Pita, C.; Pierce, G.J.; Theodossiou, I. (2010). Stakeholders' participation in the fisheries management decision-making process: Fishers' perceptions of participation. *Marine Policy* 34: 1093-1102.

Pons, M.; Webber, D.N.; Rudd, M.B.; Starr, P.J.; Roberts, J. (2024). Rapid updates for New Zealand rock lobster (*Jasus edwardsii*) stocks in 2023. *New Zealand Fisheries Assessment Report* 2024/13. 80 p.

Portner, H.; Peck, M. (2010). Climate change effects on fishes and fisheries: Towards a cause-and-effect understanding. *Journal of Fish Biology* 77: 1745-1779.

Rayner, M.J.; Hauber, M.E.; Steeves, T.E.; Lawrence, H.A.; Thompson, D.R.; Sagar, P.M.; Bury, S.J.; Landers, T.J.; Phillips, R.A.; Ranjard, L. et al. (2011). Contemporary and historical separation of transequatorial migration between genetically distinct seabird populations. *Nature Communications* 2:

Reid, A.J.; Eckert, L.E.; Lane, J.-F.; Young, N.; Hinch, S.G.; Darimont, C.T.; Cooke, S.J.; Ban, N.C.; Marshall, A. (2021). "Two-Eyed Seeing": An Indigenous framework to transform fisheries research and management. *Fish and Fisheries* 22: 243-261.

Reid, J.; Rout, M. (2020). The implementation of ecosystem-based management in New Zealand–A Māori perspective. *Marine Policy* 117: 103889.

Rice, J. (2000). Evaluating fishery impacts using metrics of community structure. *ICES Journal of Marine Science* 57: 682–688.

Rice, J.C.; Rochet, M.J. (2005). A framework for selecting a suite of indicators for fisheries management. *Ices Journal of Marine Science* 62: 516-527.

Richard, Y.; Abraham, E.; Berkenbusch, K. (2020). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report* No. 237. 57 p.

Rout, M.; Spiller, C.; Reid, J.; Mika, J.; Haar, J. (2022). Te Niho o te Taniwha: The teeth of the Taniwha.

Exploring present-future pathways for whānau and hapū in Māori economies of wellbeing. Ngā Pae o te Māramatanga:

Auckland. Unpublished report available from https://www.waikato.ac.nz/. 157 p.

Salas, S.; Gaertner, D. (2004). The behavioural dynamics of fishers: management implications. *Fish and Fisheries* 5: 153-167.

Sea Change (2017). Sea Change – Tai Timu Tai Pari Hauraki Gulf Marine Spatial Plan. Available from: https://gulfjournal.org.nz/wp-content/uploads/2022/01/5086-SCTTTP-Marine-Spatial-Plan-WR.pdf. 315 p.

Seaward, K.; Acosta, H.; Inglis, G.J.; Wood, B.; Riding, T.A.C.; Wilkens, S.; Gould, B. (2015). The Marine Biosecurity Porthole – a web-based information system on non-indigenous marine species in New Zealand. *Management of Biological Invasions* 6: 177-184.

Shears, N.T.; Babcock, R.C. (2002). Marine reserves demonstrate top-down control of community structure on temperate reefs. *Oecologia* 132: 131-142.

Shears, N.T.; Babcock, R.C.; Duffy, C.A.J.; Walker, J.W. (2004). Validation of qualitative habitat descriptors commonly used to classify subtidal reef assemblages in north-eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 38: 743-752.

Shears, N.T.; Babcock, R.C.; Salomon, A.K. (2008). Context-dependent effects of fishing: variation in trophic cascades across environmental gradients. *Ecological Applications* 18: 1860-1873.

Shears, N.T.; Grace, R.V.; Usmar, N.R.; Kerr, V.; Babcock, R.C. (2006). Long-term trends in lobster populations in a partially protected vs. no-take Marine Park. *Biological Conservation* 132: 222-231.

Shetty, D. (2020). Incidence of microplastics in coastal inshore fish species and surface waters in the Hauraki Gulf, New Zealand. Unpublished MSc thesis, University of Auckland. 93 p.

Shin, Y.-J.; Shannon, L.J. (2010). Using indicators for evaluating, comparing and communicating the ecological status of exploited marine ecosystems. Part 1: the IndiSeas Project. *ICES Journal of Marine Science* 67: 686-691.

Shin, Y.J.; Shannon, L.J.; Bundy, A.; Coll, M.; Aydin, K.; Bez, N.; Blanchard, J.L.; Borges, M.D.; Diallo, I.; Diaz, E. et al. (2010). Using indicators for evaluating, comparing, and communicating the ecological status of exploited marine ecosystems. 2. Setting the scene. *Ices Journal of Marine Science* 67: 692-716.

Smith, G.H. (1997). The development of Kaupapa Māori: Theory and practice. Unpublished PhD thesis, University of Auckland, 526 p.

Soliman, T.; Inglis, G.J. (2018). Forecasting the economic impacts of two biofouling invaders on aquaculture production of green-lipped mussels *Perna canaliculus* in New Zealand. *Aquaculture Environment Interactions* 10: 1-12.

Stephenson, F.; Hamilton, O.N.P.; Torres, L.G.; Kozmian-Ledward, L.; Pinkerton, M.H.; Constantine, R. (2023). Fine-scale spatial and temporal distribution patterns of large marine predators in a biodiversity hotspot. *Diversity and Distributions* 29: 804-820.

Tait, L.W.; Lohrer, A.M.; Townsend, M.; Atalah, J.; Floerl, O.; Inglis, G.J. (2020). Invasive ecosystem engineers threaten benthic nitrogen cycling by altering native infaunal and biofouling communities. *Scientific Reports* 10: 1581.

Te Aka (2024). Te Aka Māori dictionary. Available from https://maoridictionary.co.nz/.

Tengö, M.; Brondizio, E.S.; Elmqvist, T.; Malmer, P.; Spierenburg, M. (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. *Ambio* 43: 579-591.

Tesfamichael, D.; Pitcher, T.J.; Pauly, D. (2014). Assessing changes in fisheries using fishers' knowledge to generate long time series of catch rates a case study from the Red Sea. *Ecology and Society* 19:

Thrush, S.F.; Hewitt, J.E.; Cummings, V.J.; Dayton, P.K.; Cryer, M.; Turner, S.J.; Funnell, G.A.; Budd, R.G.; Milburn, C.J.; Wilkinson, M.R. (1998). Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. *Ecological Applications* 8: 866-879.

Tone, L.; 'Ilaiū Talei, C. (2024). Mana Moana: Understanding the Place of Moana in Aotearoa's Architecture. Art/Research International, 8(2), 471-498. *Art/Research International* 8: 471-498.

Tuck, I.; Cole, R.; Devine, J. (2009). Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report* No. 42. 188 p.

Tuck, I.D.; Pinkerton, M.H.; Tracey, D.M.; Anderson, O.A.; Chiswell, S.M. (2014). Ecosystem and environmental indicators for deepwater fisheries. *New Zealand Aquatic Environment and Biodiversity Report* No. 127. 143 p.

Walsh, C.; Parsons, D.; Bian, R.; McKenzie, J.; Armiger, H.; Evans, O.; Taylor, R.; Buckthought, D.; Smith, M.; Spong, K. (2022). Age composition of commercial snapper landings in SNA 1 and SNA 2, 2019–20. *New Zealand Fisheries Assessment Report* 2022/24. 136 p.

Watts, A.; Hopkins, G.; Goldstien, S.J. (2015). Characterising biofouling communities on mussel farms along an environmental gradient: A step towards improved risk management. *Aquaculture Environment Interactions* 8:

Williams, J.R.; Bian, R. (2021). SCA 1 and SCA CS survey time series 1990-2021: Projects SCA2020-02 and SEA2020-07. Presented at the MPI Shellfish Fisheries Assessment Working Group. Online presentation, 19 October 2021.

Williams, J.R.; Bian, R.; Middleton, C.M.; Hughes, R.; Evans, O.; Buckthought, D.; Parkinson, D.; Tayor, R. (in prep). Surveys of scallops in SCA 1 and SCA CS, April–May 2021. draft *New Zealand Fisheries Assessment Report*.

Willis, T.J.; Millar, R.B.; Babcock, R.C. (2003). Protection of exploited fish in temperate regions: high density and biomass of snapper *Pagrus auratus* (Sparidae) in northern New Zealand marine reserves. *Journal of Applied Ecology* 40: 214-227.

Wynne-Jones, J.; Gray, A.; Heinemann, A.; Hill, L.; Walton, L. (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report* 2019/24. 104 p.

Yang, J.; Zhang, X. (2020). eDNA metabarcoding in zooplankton improves the ecological status assessment of aquatic ecosystems. *Environment International* 134: 105230.

Young, M.; Adams, N.J. (2010). Plastic debris and seabird presence in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 44: 167-175.

Zantis, L.J.; Bosker, T.; Lawler, F.; Nelms, S.E.; O'Rorke, R.; Constantine, R.; Sewell, M.; Carroll, E.L. (2022). Assessing microplastic exposure of large marine filter-feeders. *Science of the Total Environment* 818:

Zeldis, J.R.; Oldman, J.; Ballara, S.L.; Richards, L.A. (2005). Physical fluxes, pelagic ecosystem structure, and larval fish survival in Hauraki Gulf, New Zealand. *Canadian Journal of Fisheries and Aquatic Sciences* 62: 593-610.

Zeldis, J.R.; Swaney, D.P. (2018). Balance of Catchment and Offshore Nutrient Loading and Biogeochemical Response in Four New Zealand Coastal Systems: Implications for Resource Management. *Estuaries and Coasts* 41: 2240-2259.

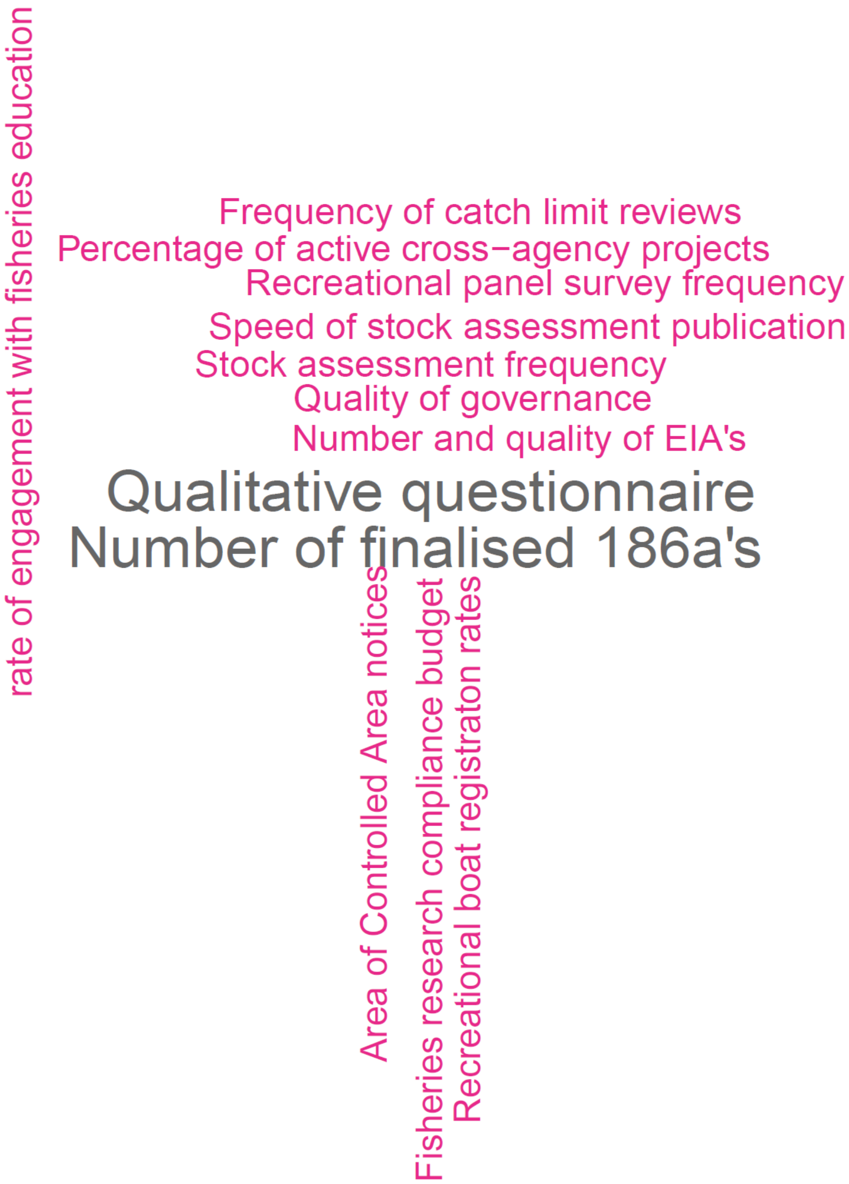
Appendices

Appendix 1

Word clouds produced from co-development group indicator suggestions. Text font size is large for indicators that were suggested more frequently. A word cloud was produced for each Focal Component of the indicator framework. Text font scales for Focal Component are independent.

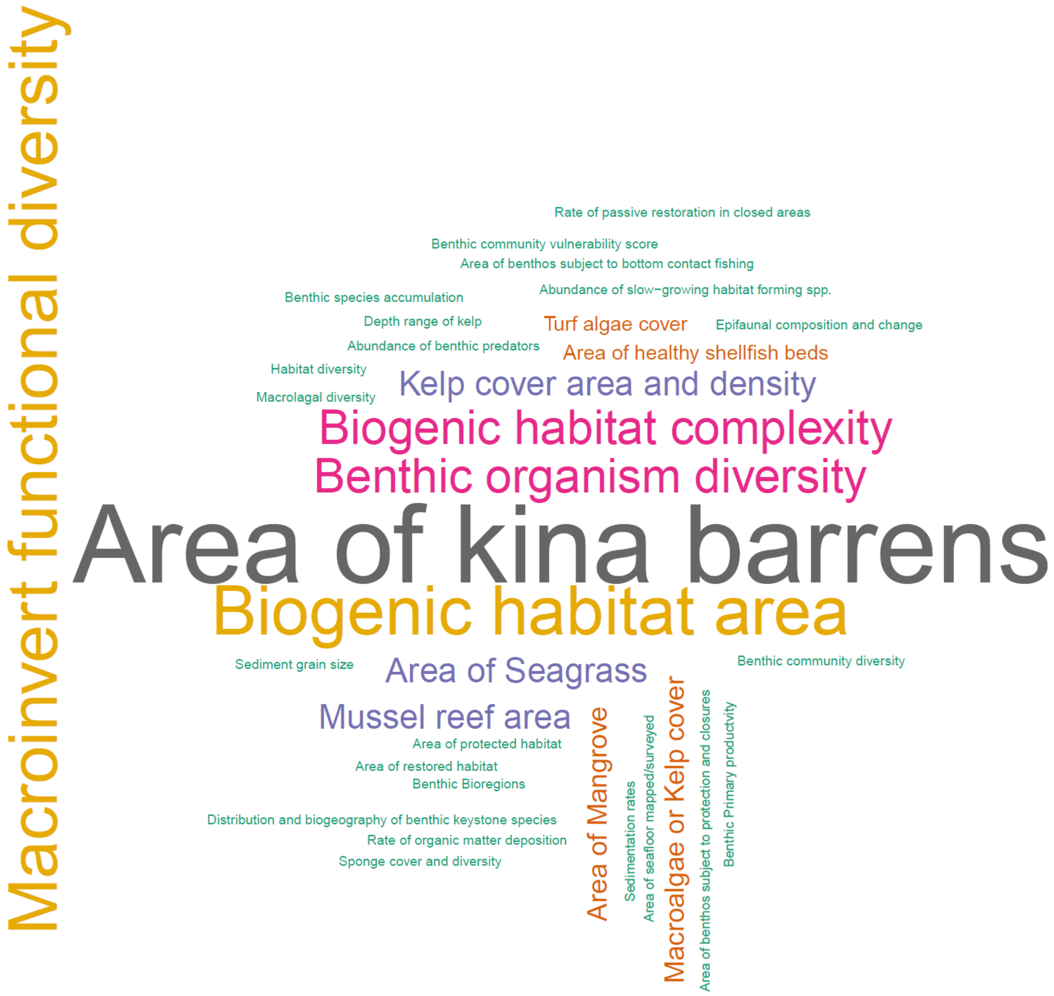
(a) Tangata whenua Focal Component.

(b) Government Focal Component.



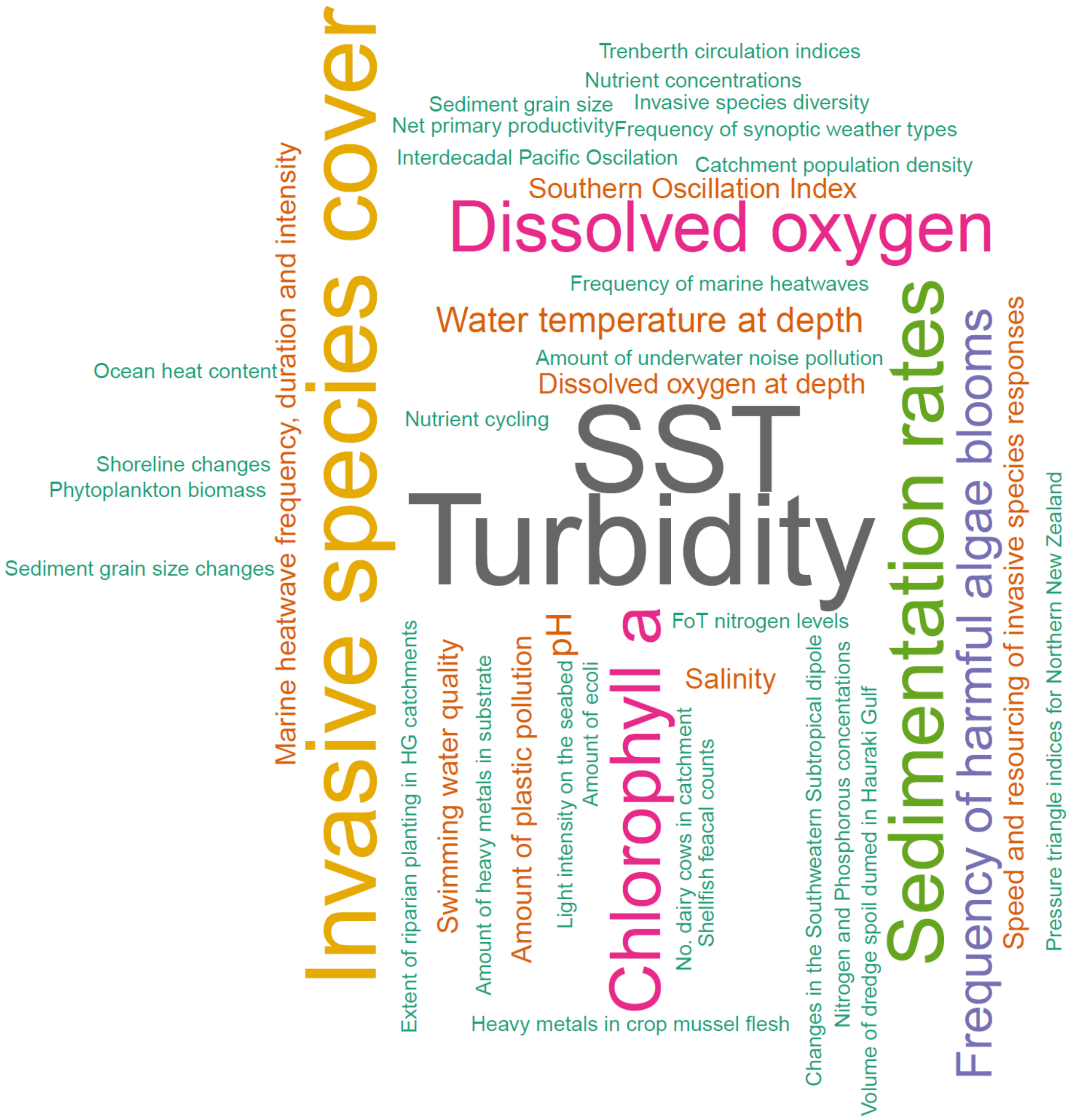
(c) Community Focal Component.

(d) Benthic habitats and communities Focal Component.

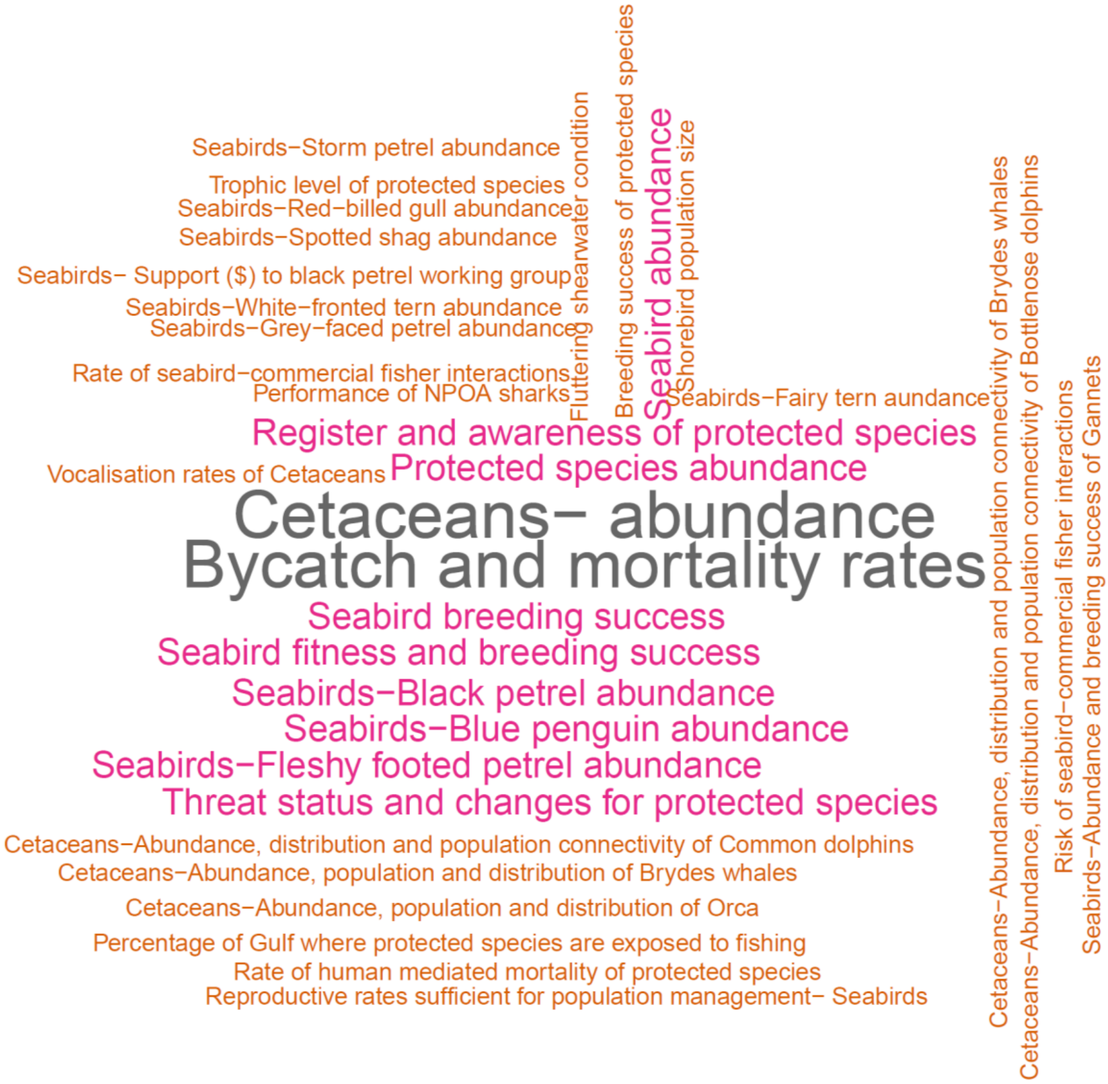


(e) Marine foodwebs Focal Component.

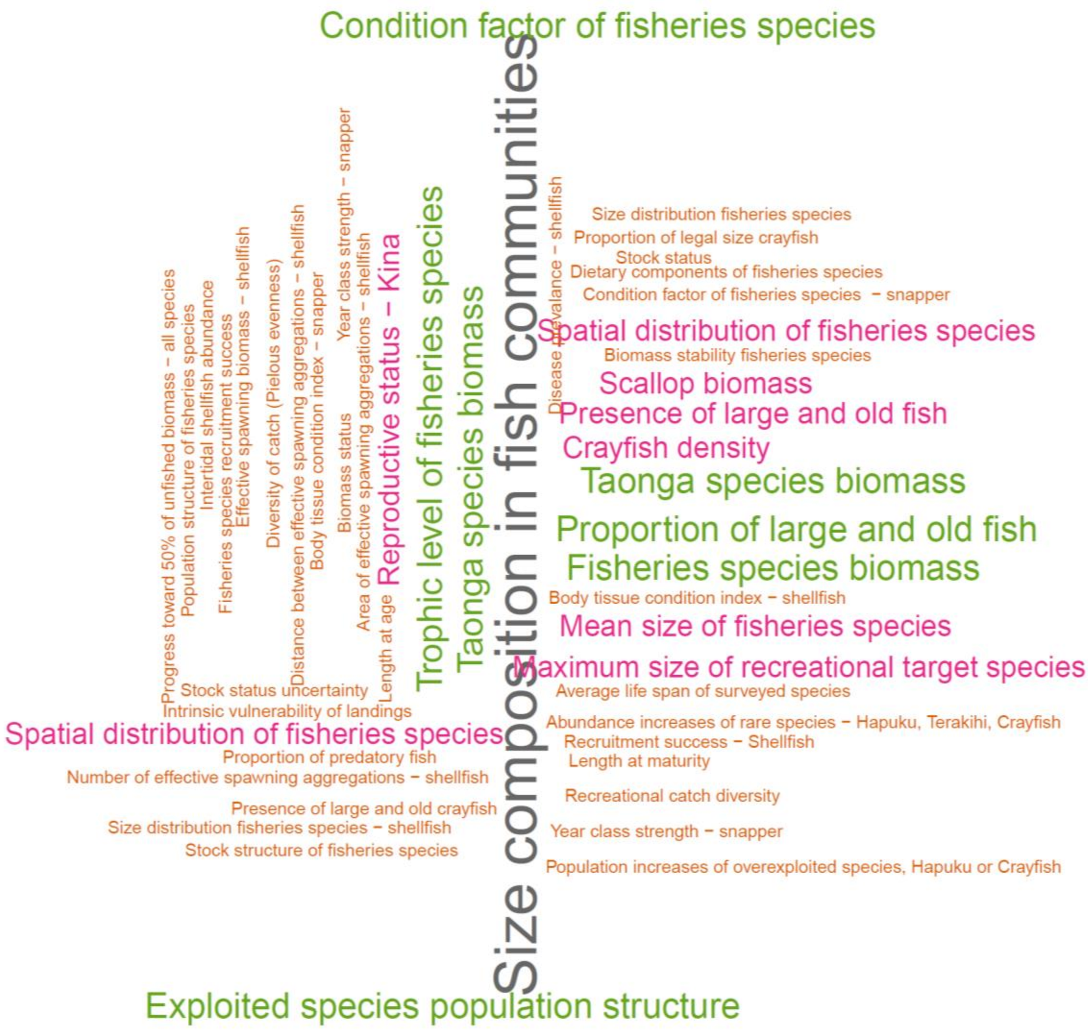
(f) Marine environment variables Focal Component.



(g) Protected species Focal Component.



(h) Fish population Focal Component.



(i) Fishery Focal Component.

Appendix 2

Traffic light evaluation and ratings of candidate indicators organised by the indicator framework hierarchical structure. Refer to the Methods section and Table 1. for a full description of how candidate indicators were refined and the evaluation criteria that were used to evaluate them. The intention of the indicator evaluations and ratings listed here is to inform FNZ so that a final indicator suite can be selected. Abbreviations as follows: Relevance - (N) No, (S) Somewhat, (Y) Yes; Simplicity - (N) No, (S) Somewhat, (Y) Yes; Data availability - (D) New method needs to be developed, (N) New data collection required, (P) Data collection planned, (E) Existing time series and will be continued, (C) Existing time series but data collection has ceased; Practicality & cost effectiveness - (N) No, (S) Somewhat, (Y) Yes; Specificity - (N) No, (U), Unknown, (S) Somewhat, (Y) Yes; Spatial scale - (B) Broader than just the Gulf, (L) Limited site(s) within Gulf, (G) Whole of Gulf scale, (D) Detailed spatial resolution, (U), Unknown. Quality - (N) No, (S) Somewhat, (U) Unknown, (Y) Yes; Comparability - (N) No, (U) Unsure, (Y) Yes; Overall rating - (H), High (M) Medium, (L) Low, (W) Wait until new method/data collection has been developed.

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Focal Component: Benthic habitats & communities										
Key Attribute: Benthic habitat status										
Benthic functional integrity	Y	Y	P	S	S	L	Y	Y	Informs about benthic habitat health based on the amount of structure observed from camera transects. Dependent on ongoing Swath Cam deployments, which are planned. Shallow water areas would also need to be included.	H
Shallow water habitat	Y	Y	D, N	N	S	L	Y	Y	Mapping to inform about shallow water structural habitats that may have value as fish nurseries. Likely dependent on rollout of council habitat mapping to subtidal areas and FNZ work on Habitats of Significance. Requires integration of multiple methods (aerial footage, sidescan, drop camera etc..).	M
Benthic Health Model score (LAWA)	S	S	E	Y	Y	L	Y	Y	Existing council monitoring feeds into a model that provides a macrofauna health score that is compared against guidelines about the level of impact. Available as an indicator through the LAWA website. Most sites are intertidal, but an available data set, well understood, and indicates general estuarine health.	H
% of reef that is kina barren	Y	Y	E	S	S	L	Y	Y	Metric informs about extent of kina barrens, which is likely connected to level of predation (or overfishing), but also other factors. High public relevance. Spatial coverage limited to sites around marine reserves monitored by DOC and University of Auckland, but likely to be expanded.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Focal Component: Marine Environment Variables										
Key Attribute: Water column status variables										
Satellite observations (Sea Surface Temperature, Chl a, Total Suspended Solids)	S	S	E	Y	S	D	Y	Y	Highly detailed and cost-effective variables that will continue to be collected. These are potential driver variables, but direct connection to fisheries not well understood. Other variables also available.	H
Firth of Thames *in situ* observations (Total Nitrogen, Turbidity, Dissolved Oxygen)	S	S	E, C	S	S	L	Y	Y	More detail and variables can be provided by *in situ* observations. Could supplement satellite observations as a sentinel site in the Firth, which is highly stressed. Ongoing data collection uncertain. Other variables also available. The Firth of Thames is also part of the NZ Ocean Acidification observing network, so metrics such as pCO_2 are also available.	M
Mud content score (LAWA)	S	S	E	Y	Y	L	Y	Y	Intertidal monitoring of % mud at a range of sites compared to national guidelines relating to when mud concentrations have negative impacts on macrofauna. Available as data through the LAWA website. Most sites are intertidal, but an available data set, well understood, and indicates general estuarine health.	H
Firth of Thames river mouth deposition rates	Y	Y	E	S	S	L	Y	Y	A driver variable known to influence fisheries productivity that is publicly relevant. A good supplement to other Water Column Status variables. Spatial coverage of existing data very limited, but these rivers are responsible for majority of Hauraki Gulf sediment input.	H
Plankton (abundance, species composition)	S	N	N	N	S	L	Y	Y	Plankton is the start of the food chain, so a metric that is an important driver. However, low cost-effectiveness, no data collection planned and already covered at a coarse level by satellite measurements of Chl a.	L
Key Attribute: Catchment										
Land Cover Database (e.g., % native bush, % dairy)	S	S	E	S	N	D	Y	Y	Land cover will not reflect changes in land use. It is not clear how land use cover affects fishery relevant variables. More direct proxies (suspended sediment) may be a better option.	L
Land use (e.g., live stock density)	S	S	N	N	N	D	Y	Y	Updating land use requires new layers to be constructed. It is not clear how land use cover affects fishery relevant variables. More direct proxies (e.g., suspended sediment) may be an easier option.	L

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Climate status variables										
Southern Oscillation Index	Y	Y	E	Y	S	B	Y	Y	Climate variables are potential drivers of fishery productivity and data are freely available. Direct relationship to fisheries is not well understood. Broad spatial scale.	M
Trenberth indices (e.g., Z4, M1)	Y	Y	E	Y	S	G	Y	Y	Freely available. Direct relationship to fisheries not well understood. More localised scale.	H
Kidson's synoptic weather types	S	S	E	Y	S	G	Y	Y	Freely available, but less easily understood. Direct relationship to fisheries is not well understood. More localised scale.	M
Integrated rainfall indicator	S	Y	N	S	S	D	Y	U	Integrates rainfall across Hauraki Gulf catchment, this is a driver of sedimentation, which may affect fisheries. Would require some set-up costs, but would be cost-effective thereafter. Relationship to fisheries variables unclear.	M
Rainfall volatility index	S	S	N	S	S	D	Y	U	Informs about intensity of rainfall, which may mobilise sediment, contaminants etc… Would require some set up costs, but would be cost-effective thereafter. Relationship to fisheries variables unclear.	M
Key Attribute: Pollution status variables										
Faecal bacteria (*E. coli* and *Enterococci*) concentrations, and swimmable days	N	Y	E	Y	Y	B	Y	Y	Metric informs about level of bacterial contamination in the water, which could flow through to fishery resources. Data is publicly available and well-resourced. The relationship to fisheries is unknown, the impacts of closures would be localised and short lived. Most relevant to recreational fisheries and harvesting. Minimal spatial overlap between monitoring sites and important fisheries habitats and grounds. The related edibility metric below may be more relevant.	H
Amount of plastic pollution on beaches	N	Y	E	Y	U	L	Y	U	Metric informs about the amount of plastic as a threat to fish populations, fisheries management and potentially fish edibility. Relatively new dataset (5 years of data), freely available citizen science generated. Relevance to fisheries is minimal, however public concern about this issue is very high. The data is spatially restricted to 55 beaches around Auckland.	M

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Heavy metal concentrations in marine sediments	N	Y	E	S	Y	L	S	Y	Metric informs about levels of heavy metals, which could flow through to fishery resources. Long-running and established sampling regime communicated through LAWA website, with contaminants compared to sediment quality guidelines. However, the public understanding of the impacts of sediment heavy metal loads may be lower than other indicators. Sampling is intertidal and sites may be spatially separated from fisheries. The impacts of heavy metals in sediments on fisheries is largely unknown, but may be more relevant to edibility. Metric could be refined to just represent heavy metal concentrations from locations where shellfish harvesting occurs.	M
Heavy metal concentrations in seabird blood and feather samples	S	N	N	N	U	B	U	U	Metric informs about levels of heavy metals in birds, which could be connected to fishery resources. Novel data stream being considered by Auckland Council, yet to be initiated. The spatial scale is more relevant to fisheries as these seabirds may be feeding directly on fisheries species, but may extend outside of the Hauraki Gulf depending on species specific feeding behaviours. The ability to detect heavy metals and the dilution rates are unknown.	L
Frequency of dredging activities and amount of substrate moved	N	Y	E	S	U	L	S	N	Metric informs about the amount of dredging activity which may resuspend sediments and impact benthic ecosystems. Data is patchily distributed through both space and time. Impacts and public concern most significant for benthic fisheries species such as scallops. Dredging intensity will vary significantly year to year and impacts will be very localised.	L
Diversity and number of records of invasive and non-indigenous species	S	Y	E	Y	Y	L	Y	U	Metric informs about prevalence of invasive species as a threat to fish populations or their supporting habitats. Data freely available. Direct relationship to fisheries not well understood and may be species specific, but individual metrics for species with known fisheries impacts could be developed as needed. More localised scale due to focus on high risk nodes such as marinas.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Area of seafloor in the Hauraki Gulf with exotic Caulerpa	S	Y	N	S	Y	L	N	U	Metric informs about prevalence of *Caulerpa sp*. as a threat to fish populations or their supporting habitats. The impact of Caulerpa on fisheries is not yet understood, but will likely impact benthic species such as scallops. Data is haphazard, localised and of varying quality and availability. Surveillance and removal effort is increasing in the Hauraki Gulf.	M
Area of the Hauraki Gulf closed to fishing activities as part of a marine biosecurity response	Y	Y	N	Y	U	L	S	N	Metric informs about access to fisheries as restricted by invasive species closures. Impact to fisheries is direct but localised and may not be long-term. Closures are rarely implemented by Biosecurity New Zealand and are usually a short term response tool. The data on area is updated regularly and available. Access to fisheries is the measure	L
Focal Component: Protected species										
Key Attribute: Condition, mortalities & population status										
Population status	y	y	N	N	N	B	Y	Y	Population status of individual protected species could describe response to fishery interactions. However, protected species populations can be influenced by factors beyond fishing, including factors outside of the Hauraki Gulf.	L
Estimated captures of black petrel & flesh footed shearwater in Hauraki Gulf	Y	Y	E	Y	Y	G	Y	Y	These are the two protected species that most commonly interact with commercial fishing gear in the Gulf. Captures are directly related to fishing, are already monitored and a portal communicating these metrics already exists.	H
Recreational fishery seabird interactions	Y	Y	E	Y	U	D	N	Y	FNZ funded boat ramp surveys also record seabird interactions with recreational fishers (species, site of hooking/entanglement, fate of seabird). Species identification has been an issue, but boat ramp staff now have pictures to assist. The main issue is the level of under reporting; records of seabird interactions are currently very minimal.	L
Other protected species estimated captures (e.g., other seabirds, cetacean, pinniped, protected invertebrates, turtles, sharks & rays)	N	Y	E	Y	Y	G	Y	Y	Other protected species are infrequently caught in the Gulf	L
Population risk assessment for black petrel & flesh footed shearwater	Y	Y	E	Y	S	B	Y	Y	Overall risk status could be a good supplement to provide broader context for estimated captures compared to the whole population risk.	M

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Implementation of management & monitoring										
% fishing events where a camera is operating	Y	Y	E	Y	Y	G	Y	U	A metric to inform about the level of monitoring. FNZ are developing indicators that combine observer and camera coverage to report on. Indicator could be split by fishing method.	H
% of camera footage selected for review	Y	Y	E	Y	Y	G	Y	U	Supplementary metric to the above because not all footage is reviewed. Further, review of camera footage is targeted, so number may seem lower than true level of effectiveness.	H
Focal Component: Marine Food Webs										
Key Attribute: Condition, composition and energy flow										
Multi-species feeding association niche type encounter frequency (from Auckland Whale and Dolphin Safari)	Y	Y	E	Y	S	L	S	U	A metric informing about the availability of forage fish that fuel higher trophic levels. Of high public interest. Data available, but not a survey and limited spatial coverage.	M
Multi-species feeding association niche type encounter frequency (aerial survey)	Y	Y	C	N	S	G	Y	U	Of high public interest. A quarterly survey would be required, but would provide high quality data with complete spatial coverage. Potential for efficiencies using technology and cost sharing with other aerial data gathering.	M
Australasian gannet nest count	Y	Y	C	Y	U	G	Y	Y	Gannets feed on small and medium sized pelagic fishes, so their abundance could relate to the abundance of these fish populations, but other factors likely influence nest counts. Of high public interest. Gannets range at the scale of the Gulf and data are practical to collect as they are surface nesters at restricted sites.	H
Other seabird nest counts	Y	Y	C	N	U	B	Y	Y	Of high public interest, feed on small pelagic fish. Not practical to collect for dispersed nesting or burrowing species. Most other seabirds also range wider than the Gulf. Nest counts likely influenced by multiple variables.	L
Seabird diet, stable isotope signature, breeding success and physiology	Y	Y	N	N	S	L	Y	Y	Extra detail likely to provide more specificity directly relating to pelagic fish abundance, but less practical to collect. Spatial scale depends on the species selected.	L
Small and medium sized pelagic fishes aerial sightings	Y	Y	N	N	N	G	N	Y	Aerial sightings index was associated with purse seine fishing, but had high variability and was abandoned. Could be re-established, but not for the Gulf.	L
Jack mackerel age based indicator	Y	Y	D	S	U	B	S	Y	New metric to inform about jack mackerel abundance. Nearly all jack mackerel catch is outside of Hauraki Gulf. Method would need to be developed first.	W

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Small and medium sized pelagic fishes acoustic indicator	Y	Y	D	S	U	G	Y	Y	Acoustic signal based metric to inform about abundance of small and medium sized pelagic fishes. Vessel of opportunity could make this a practical method, but uncertainty around identifying acoustic marks (total backscatter would still be useful, however).	M
Zooplankton abundance & composition	S	Y	D, N	N	U	L	Y	U	Zooplankton is the base of the food chain, so a metric that could inform about fishery productivity. No monitoring is currently planned. Cost-effective methodologies for collection and processing (e.g., continuous plankton recorder on vessels of opportunity and eDNA metabarcoding) would need to be developed.	L
Large rocky reef predator index	Y	Y	E	S	Y	L	Y	U	Abundance of large reef predators relevant to fishery effects on reef habitat and of public interest. Locations monitored (rock lobster dive surveys and fish BRUV surveys) could be expanded through HPA monitoring. However, size bias in current BRUV methodologies is limiting for snapper component.	H
Large pelagic shark index	Y	Y	N	S	Y	D	S	Y	Abundance of large predators often a good indicator of overfishing and of public interest. No survey planned, but could potentially be observed from aerial survey. Unclear what proportion of sharks can be seen from the surface.	M
Key Attribute: Food web status										
Catch ratios (e.g., proportion of predatory fish)	Y	Y	N	Y	S	G	Y	Y	Both catch ratio and trophic level indicators are widely used and describe the trophic level or proportion of different functional groups in a fish community, which is known to respond to fishing pressure. They are best applied to survey data, which aren't available. The selectivity of any survey method also needs to be considered. Wait to see what fish communities are sampled by Swath Cam.	W
Trophic level of fish communities (e.g., Marine Trophic Index (MTI))	Y	Y	N	Y	S	G	Y	Y	As above.	W
VAST estimates of average trophic level from fishery data	Y	N	E	Y	U	D	Y	U	An alternative to catch ratios or trophic level indicators that could be conducted now. More complicated, and its uncertain whether such an approach could disentangle fishing behaviour effects.	M

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Trophodynamic model generated indicator	Y	N	N	N	N	G	Y	U	A trophodynamic model exists for the Gulf, but would need new abundance data to generate an index of fish community change. The difficulty is obtaining new data for all components of fish communities.	L
Individual species diet or trophic level	Y	Y	N	N	S	L	Y	Y	Individual species diet or trophic level can inform about changes in community structure through changes in prey availability. A lack of understanding of diet is a fundamental limitation in advancing towards EBFM. Application of eDNA metabarcoding to diet samples could improve practicality. Stable isotopes may provide limited insight.	M
Focal Component: Fish population										
Key Attribute: Fish population status										
Snapper assessment (Hauraki Gulf population) SSB	Y	Y	E	Y	Y	G	Y	Y	A metric from the assessment that informs about fish population abundance. High quality stock assessment available now for a highly valued fish.	H
Kahawai assessment (KAH 1) SSB	Y	Y	E	Y	Y	B	Y	Y	High quality stock assessment available now for highly valued fish, but at a scale broader than Gulf.	H
Hapuku & bass bottom trawl CPUE (all of NZ)	Y	Y	E	Y	U	B	N	Y	CPUE can inform about abundance. However, bottom trawl predominantly catches small fish and CPUE index is at all of New Zealand scale.	L
Hapuku & bass bottom longline CPUE (Hauraki Gulf)	Y	Y	E	Y	U	G	N	Y	Metric informs about abundance. Bottom Longline CPUE known to be vulnerable to hyperstability, so may not reflect stock abundance, but does reflect localised experience.	M
Hapuku & bass catch curve	Y	S	N	S	Y	B	Y	Y	Catch curves use age structure to inform about abundance. Such an approach would be high quality, but age data collection for HPB 1 may not occur for some time if at all.	W
Hapuku & bass SBRUV fished vs unfished ratio	Y	Y	N	S	Y	L	Y	Y	SBRUV survey ratios could inform about hapuku abundance by comparing abundance inside to outside of protected areas, but spatial replication is likely to be limited.	M
Hapuku & bass extent of occurrence	Y	S	E	Y	S	G	S	Y	A metric describing the contraction/expansion of hapuku range from commercial catch data. While data is available now, it may have limited insight.	M
Tarakihi assessment (east coast NZ) SSB or % B_0	Y	Y	E	Y	Y	B	Y	Y	High quality stock assessment for a species with reduced abundance. Assessment at a very large spatial scale, but still informative about the status of the stocks that the Hauraki Gulf falls within.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Small and medium sized pelagic fishes acoustic indicator									Already discussed under Marine foodwebs Focal Component.	
Trevally, John dory, red gurnard assessment (SSB) or % B_0	Y	Y	C	Y	Y	B	N	Y	A metric from the assessment that informs about fish population abundance. Unclear where data inputs for assessments will come from with no trawl survey and reduced commercial trawling in the Gulf.	L
Trevally, John dory, red gurnard bottom trawl CPUE	Y	Y	E	Y	S	G	S	Y	CPUE metrics can inform about abundance. Bottom trawl likely to be reduced in the Gulf, which may limit the quality of CPUE. For trevally, bottom trawl CPUE disagrees with other assessment inputs so it's not sure which can be trusted.	M
Trevally, John dory, red gurnard Swath Cam abundance estimate	Y	Y	P	S	S	L	U	Y	Swath Cam fish encounter frequency could produce a high quality abundance estimate, but fish encounter rates and method validation needs to happen first.	W
Kingfish bottom longline CPUE	Y	Y	E	Y	N	B	Y	Y	Bottom longline bycatch of kingfish is currently used to inform CPUE analysis as an assessment for east Northland inshore kingfish. While east Northland and Hauraki Gulf kingfish populations are connected, it is unclear how representative this assessment would be.	L
Scallop effective spawning stock biomass or % B_0 (survey)	Y	S	D	S	Y	D	Y	U	Metric would be survey based and focussed on describing the abundance of scallops that are large enough to spawn and at effective spawning densities. High relevance due to current fishery closure. New survey development methods need to be confirmed. Separate metrics could be developed for recreational and commercial beds.	H
Rock lobster assessment (CRA 2) SSB or % B_0	Y	Y	E	Y	Y	G	Y	Y	Metric informs about lobster abundance. High quality stock assessment available now for a highly valued species that has experienced low abundance in recent years. CRA 2 assessment area aligns well with the Hauraki Gulf, but abundance may vary within this area.	H
Large intertidal shellfish density (survey)	Y	Y	E	Y	S	L	Y	Y	Metric informs about harvested shellfish species (pipi and cockle) abundance for harvested size classes. An existing survey time series at multiple sites. Community monitoring could be used to increase number of sites	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Reef fish UVC diversity	S	Y	E	S	S	L	Y	Y	Metric informs about diversity of reef fish species, which are of high public interest. There is an existing UVC survey series at a number of Gulf sites which may be expanded with HPA monitoring. Diversity indices can be hard to interpret, but could be paired with individual species metric below.	M
Reef fish UVC total biomass or species group biomass or biomass ratios (inside vs outside of marine reserves)	S	Y	E	S	S	L	Y	Y	As above, however total biomass of the whole reef fish community or targeted components (species or species groups) could be easier to interpret. Biomass ratios (inside vs outside of marine reserves) also have utility.	M
Key Attribute: Fish population condition (distribution)										
Snapper and kahawai recreational CPUE-at-length	Y	Y	E	Y	S	D	Y	U	Metric informs about spatial variability in abundance of large snapper and kahawai valued by endusers. High quality multi-purpose indicator that informs about size, abundance, spatial distribution for highly valued species. Data available from ongoing boat ramp creel surveys.	H
Tarakihi bottom trawl CPUE	Y	Y	E	Y	U	G	Y	Y	Metric informs about tarakihi abundance on a more localised scale by using bottom trawl CPUE. This may not reflect tarakihi abundance at the scale of the whole population. Trawling also likely to be much reduced.	M
Kingfish pelagic drop camera survey	Y	Y	D	N	U	D	Y	Y	Pelagic drop camera survey of key features where kingfish aggregate. Such a survey would be highly relevant to endusers, but would not likely be cost-effective.	M
Scallop effective spawning stock biomass or % B0 (survey)									Already discussed under Fish population condition (distribution) Key Attribute	
Large intertidal shellfish density (survey)									Already discussed under Fish population condition (distribution) Key Attribute	
Rock lobster commercial CPUE at the statistical area level	Y	Y	E	Y	S	D	Y	Y	Metric informs about spatial variability abundance at the statistical area level. Differences in abundance are known to exist between statistical areas so this could be a good addition. Less commercial data from western Gulf.	H
Ratio of rock lobster inside vs outside of marine reserves (survey)	Y	Y	E	S	Y	L	Y	U	An additional metric (requires dive surveys) which can provide more spatial detail, especially for the western Gulf not covered by commercial CPUE data. Surveys are currently at limited sites, but may be expanded through HPA monitoring. Would not incorporate deeper lobster habitat unless potting is also used.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Reef fish site specific metrics	S	Y	E	S	S	L	Y	U	Metric informs about spatial variability in reef fish abundance for the sites monitored.	M
Key Attribute: Fish population condition (size and age)										
Snapper and kahawai recreational CPUE-at-length									Already discussed under Fish population condition Key Attribute	
Large reef predator index									Already discussed under Marine food webs Focal Component	
Scallop effective spawning stock biomass or % B_0 (survey)									Already discussed under Fish population status Key Attribute	
Large intertidal shellfish density (survey)									Already discussed under Fish population status Key Attribute	
Snapper mean size or proportion larger than a certain size	Y	Y	E	S	S	G	Y	Y	Metric informs about snapper size composition, which is important to ecosystem functioning and enduser value. An extensive time series of snapper size is available, and these metrics could be exported from the assessment model for every year. Would need to consider what this metric adds if snapper size is already covered by recreational CPUE at-length and large predator metrics?	M
Proportion rock lobster > 100 mm CL	Y	Y	E	S	Y	L	Y	Y	Metric informs about size structure of lobster populations. Data obtained from UVC surveys (limited sights), or voluntary log book data (would require permission, but better spatial representation). Would this metric add anything not already covered beyond the large reef predator metric?	M
Tarakihi and trevally mean size or proportion greater than a certain size	N	Y	E	S	S	G	Y	Y	Metric informs about tarakihi and trevally age composition. Age time series are available for these species, but no known issues or value associated with size for these species, so value may be limited.	L
Whole fish community mean size or proportion greater than a certain size (survey based)	Y	Y	D, N	S	S	L	Y	Y	Metric informs about the size composition of the demersal fish community. A potentially valuable indicator that is used elsewhere, but will require a new survey method to be established. Survey method species and size selectivity will need to be considered.	W

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Fish population condition (recruitment)										
All species year class strength	N	S	E	S	S	G	Y	Y	Metric could inform about strength of new cohorts recruiting into fish populations. Recruitment indices could be generated for species such as snapper, tarakihi and trevally where monitoring is conducted, but may not add much value as recruitment information inherently incorporated into fish population assessments, and recruitment is not usually associated with enduser value.	L
Key Attribute: Fish population condition (condition and growth)										
Snapper mean length-at-age	Y	S	E	S	Y	G	Y	Y	Metric informs about snapper growth rate. Reduced growth observed for snapper and likely linked to increasing biomass (so unclear what "good" growth rates are). Extensive time series available to demonstrate these patterns.	H
Proportion of landings (by weight) that are milky fleshed (snapper)	S	Y	E	Y	U	G	Y	U	Metric informs about prevalence of milky fleshed snapper syndrome. Topical issue, but potentially only indirectly connected to fishing or land-based effects. Data available from commercial fishery landings grading data, which are likely underestimates for a number of reasons.	H
Scallop landing proportion meat weight	S	S	C	Y	U	D	Y	U	Metric informs about the condition of scallops. There would be an existing data set if the fishery is re-established, but unclear how stressors will drive meat weight beyond seasonal variation.	L
Key Attribute: Fish population condition (effective shellfish spawning)										
Already covered above under fish population status										
Key Attribute: Fish population condition (disease)										
Monitoring responses would likely be developed as disease issues arise										

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Fish community composition										
Whole fish community diversity (Swath Cam survey)	Y	Y	D, N	S	S	L	Y	Y	Metric informs about diversity of the whole fish community. Fish community diversity indices have been used elsewhere, but their relationship to fishing intensity is not always easy to interpret. Survey data not currently available and survey options will have selectivity issues to consider. Would need to wait until Swath Cam data is available and assess appropriate indicators, but would likely need a total abundance or individual species abundance metric to be paired with a community diversity metric to help with interpretation. Metrics discussed in other sections are similar, so it may be necessary to select from these to avoid redundancy.	W
Focal Component: Fishery										
Key Attribute: Socio-economic value of fishery components (contribution of fisheries to society)										
Total economic valuation of fishery components	S	Y	D	S	Y	G	Y	Y	An economic valuation indicator would inform about the contribution of fishing to society, across all sectors. A variety of approaches previously used, so consensus needed on methodology first (with input from all sectors).	H
Quantity or proportion of fish supplying local market	S	Y	E	Y	U	G	Y	Y	Metric informs about one aspect (local supply) of commercial fishing to society, but is potentially very relevant to demonstrating societal value of commercial fisheries. Company data should be able to inform such a metric.	H
Fishing industry employment	S	Y	N	S	Y	G	Y	Y	Metric informs about one aspect (employment) of commercial fishing to society. Difficult to calculate proportion of fishing company employment associated with just the Hauraki Gulf. Would require fishing company cooperation.	L
Key Attribute: Socio-economic value of fishery components (commercial costs and financial viability)										
Deemed values	Y	N	E	Y	N	G	Y	Y	Deemed values could inform about the cost of fishing, but are influenced by multiple variables, so unclear what deemed value prices (or the amount of deemed values paid) inform about.	L
Fishing company profit	Y	Y	D	Y	Y	G	Y	Y	Potentially the most informative metric to demonstrate the economic response of fishing companies to management measures in the Hauraki Gulf. Profit data are not publicly available, so would require fishing company cooperation, which may be commercially sensitive.	W
Number of vessels fishing in the Gulf									Described in next section	

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Socio-economic value of fishery components (commercial effort)										
Number of vessels fishing in the Hauraki Gulf	Y	Y	E	Y	S	B	Y	Y	Metric could inform about the financial viability of fishing in the Gulf, but would likely also be influenced by other factors. Would need to account for vessels fishing across multiple areas. Metric could be calculated for each different fishing method.	H
Proportion of a fishing trip that is actively fishing	Y	Y	E	Y	U	G	Y	U	Would inform about ease or difficulty of fishing. May not be possible to calculate when boats leave and return to port. Likely influenced by a number of variables which need better understanding.	M
% of stocks that reach catch limits	Y	Y	E	Y	N	B	Y	Y	Would inform about ease or difficulty of fishing. Likely influenced by a combination of variables such as management efficiency and the economics of fishing which need better understanding. Stocks not aligned with QMAs	L
Key Attribute: Socio-economic value of fishery components (commercial wellbeing)										
Number of vessels fishing in the Hauraki Gulf									Described in commercial effort section above	
Commercial fisher average wages relative to other sectors	Y	Y	D	Y	S	B	Y	Y	Metric informs about commercial fisher wellbeing from the perspective of relative wages. Not possible to estimate average wages for just the Hauraki Gulf. Would also require fishing company cooperation.	L
Customised commercial fisher wellbeing survey	Y	S	N	S	S	B	S	U	Metric would inform about commercial fisher wellbeing across the full range of stressors they face. Survey would need to be reconducted frequently, so potential cost implications. Survey design could be informed by FirstMate work. Survey results will always be somewhat subjective.	M
Number of FirstMate Hauraki Gulf based clients	Y	Y	E	Y	S	B	S	N	Metric informs about wellbeing of fishers via self referral to FirstMate. Would need to be paired with number of vessels metric above. Other stress factors not specific to Gulf would also influence this metric.	H
Key Attribute: Socio-economic value of fishery components (recreational value)										
Snapper and kahawai recreational CPUE-at-length									Discussed under Fish population Focal Component	
Number of species caught per fishing trip (other than snapper and kahawai)	Y	Y	E	Y	U	D	Y	U	Metric informs about the value recreational fishers obtain by catching a range of fish species. Data is available through ongoing boat ramp creel surveys and is of high public interest.	H
Recreational rock lobster CPUE (number or weight of lobsters per hour fished)	Y	Y	E	Y	Y	L	Y	Y	Metric informs about recreational fisher experience relevant to rock lobster. Data from CRA 2 creel survey.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Scallop effective spawning stock biomass (survey)									Discussed under Fish population Focal Component	
Large intertidal shellfish density (survey)									Discussed under Fish population Focal Component	
Total amount of recreational fishing effort	Y	Y	E	Y	N	G	Y	Y	From National Panel Survey and creel surveys. In a general sense total recreational effort would represent how important recreational fishing is to society (and also potentially as a pressure metric), but somewhat unclear what this metric informs (it can also be influenced by a variety of variables such as weather, socioeconomics, other entertainment options etc...).	H
Customised recreational fisher attitudes and values survey	Y	Y	N	S	U	G	S	U	Would provide a broader understanding about recreational fisher values which could provide context for other parts of the indicator framework. Survey results are always somewhat subjective.	M
Key Attribute: Socio-economic value of fishery components (customary value)										
Number of customary authorisations issued	Y	Y	E	S	N	G	S	U	Most reliable component of customary permit data. Metric could inform about level of engagement with fishery management, but also species abundance and likely other factors (i.e., this metric is influenced by multiple factors). Directionality also not clear. Potential issues with data confidentiality (even if data is aggregated across the Gulf) that need to be clarified.	M
Customary authorisation catch rates	Y	Y	D	Y	N	G	Y	U	As above, but catch data associated with customary permits is poorly reported.	L
Snapper and kahawai recreational CPUE-at-length									Discussed under Fish population Focal Component	
Large intertidal shellfish density (survey)									Discussed under Fish population Focal Component	
Iwi/community monitoring									Not assessed here, but monitoring conducted under projects such as "Pou rāhui, pou tikanga, pou oranga: reigniting the mauri of Tīkapa Moana and Te Moananui-ā-Toi" could have great utility	W
Customary fisher attitudes and values survey	Y	Y	N	S	S	G	S	Y	Would provide a broader understanding about customary fisher values which could provide context for other parts of the indicator framework. Survey results are always somewhat subjective. Similar to "Tangata whenua attitudes and values associated with Fisheries Management (as measured by a survey questionnaire)" metric described in Desired Outcome 3 below.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Socio-economic value of fishery components (edibility)										
Shellfish condition	N	Y	N	S	Y	L	Y	U	Shellfish condition responds to seasonal cycles, so not relevant to fishery management actions.	L
Heavy metal concentrations in sediments									Already discussed under Pollution status variables Key Attribute	
Safeswim number of days unsafe to swim	Y	S	E	Y	S	L	Y	U	Safeswim makes water quality predictions for a range of Hauraki Gulf locations using wastewater and rainfall monitoring combined with models of tide, wind and sunlight. Metric could serve as a proxy for shellfish edibility, and could be presented at an individual beach or aggregated spatial level. Link to actual shellfish edibility unclear. Similar to Faecal bacteria (E. coli and Enterococci) concentrations, and swimmable days metric under the Pollution status variables Key Attribute.	M
Number of days shellfish harvesting closed due to biotoxins	S	Y	E	Y	Y	L	Y	Y	Metric could inform about edibility from the perspective of contamination from biotoxin blooms. Monitoring of biotoxins occurs, but the frequency of biotoxin contamination is unrelated to pollution or other managed stressors.	H
Number of days shellfish harvesting closed due to bacteria levels	Y	Y	E	Y	Y	L	Y	Y	Metric could inform about edibility from the perspective of contamination from animal faeces associated bacteria. Shellfish harvesting closures based on modelling data from shellfish farm locations, but could inform about the level of closure for nearby recreational harvesting. Heavily connected to rainfall, but catchment specific faecal load information regularly updated.	H
Key Attribute: Implementation of management & monitoring (spatial)										
% of Hauraki Gulf where fishing is prohibited	Y	Y	E	Y	Y	G	Y	Y	Statement of fact indicator describing the % of Gulf where certain activities are/are not allowed.	H
% of Hauraki Gulf where the seafloor is protected	Y	Y	E	Y	Y	G	Y	Y	Statement of fact indicator describing the % of Gulf where certain activities are/are not allowed.	H
% of the Hauraki Gulf where Ahu Moana management measures are in place	Y	Y	E	Y	Y	G	Y	Y	Statement of fact indicator describing the % of Gulf where certain activities are/are not allowed.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Key Attribute: Implementation of management & monitoring (fish stocks)										
% of stocks above soft limit	Y	Y	E	Y	Y	B	Y	Y	Metric informs about the level of sustainability of fish populations in the Gulf. It is already reported by FNZ and would inform about the quality of fishery management. Ignores stocks with unknown status, but see below. Population units assessed wont align with Hauraki Gulf. Would need to exclude nominal fisheries or report on something like the top 20 fisheries.	H
% of stocks with unknown status	Y	Y	E	Y	Y	B	Y	Y	A useful supplement to metric above that describes the proportion of stocks with unknown status. Population units assessed wont align with Hauraki Gulf. Would need to exclude nominal fisheries or report on something like the top 20 fisheries.	H
Average coefficient of biomass variation across stocks	Y	Y	E	Y	N	B	Y	Y	Biomass variation averaged over last 10 years could inform about the quality of assessments, however, biomass can vary due to factors unrelated to fishery management. Would only apply to stocks with assessments. Population units assessed wont align with Hauraki Gulf.	L
% of Hauraki Gulf fish stocks with level 1 or 2 assessments	Y	Y	E	Y	Y	B	Y	Y	Informs about the quality of assessments. Potentially duplicitous of the metrics above. Population units assessed wont align with Hauraki Gulf. Would need to exclude nominal fisheries.	M
Average number of years since last stock assessment was conducted	Y	Y	E	Y	N	B	Y	Y	Metric informs about quality of assessments by describing how up to date they are. Frequency of assessments not always related to biomass though. Would also only apply to stocks with assessments. Population units assessed wont align with Hauraki Gulf.	L
% of Hauraki Gulf fish stocks that have catch limit reviews or with new science information	Y	Y	E	Y	S	B	Y	Y	Metric informs about quality of assessments by describing frequency of review and input of new information. Similar to above, such a metric not always related to biomass, but has the advantage of applying to stocks without assessments. Population units assessed wont align with Hauraki Gulf.	M
Intrinsic vulnerability of landings	Y	S	E	Y	Y	B	Y	Y	A cost-effective metric that informs about overall vulnerability of landings (uses life history characteristics to provide a score for each species that is weighted by landings) and is already used elsewhere.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
% of stocks with Hauraki Gulf management settings	Y	Y	E	Y	Y	G	Y	U	Metric informs about the effectiveness of management in the Hauraki Gulf specifically. However, Hauraki Gulf specific management settings will mostly be applied through spatial fishery restrictions, which are already covered above.	L
% of stocks with localised depletion concerns	Y	Y	D	S	Y	D	Y	U	Spatial distribution metrics are covered in Fish population Focal Component. However, more detailed localised depletion metrics for a wider range of species would require fine scale monitoring. Community based BRUV monitoring could be an option.	M
Key Attribute: Implementation of management & monitoring (compliance)										
Number of inspections	Y	Y	E	Y	Y	D	Y	U	A cost-effective metric derived from fishery officer interviews that can inform about compliance effort from existing sources (FNZ compliance dash board). Specific spatial aspects (e.g., HPA inspections) could be created if needed. Includes recreational and commercial inspections.	H
% non-compliance	Y	Y	E	Y	Y	D	Y	U	As above, but informs about the level of compliance.	H
% of fishing events (or harvest) with cameras	Y	Y	E	Y	Y	G	Y	U	FNZ are developing indicators that combine observer and camera coverage to report on. Indicator could be split by fishing method (or for selected harvested species).	H
% of camera footage selected for review	Y	Y	E	Y	Y	G	Y	U	Informs about the level of commercial compliance effort in relation to cameras. Supplementary metric to the above because not all footage is reviewed. Further, review of camera footage is targeted, so number may seem lower than true level of effectiveness.	H
Number of non-compliant events per day from camera footage	Y	Y	E	Y	N	B	Y	U	As above, but informs about the level of compliance.	M
Key Attribute: Fishing pressure										
Catch to biomass ratio	Y	S	E	Y	Y	B	Y	Y	A standardised metric describing fishing pressure, but only possible for stocks that have a biomass estimate. This could be constrained to highly caught species for which there is good information e.g., snapper and rock lobster.	M
Total catch (also split by fishing method and sector)	Y	Y	E	Y	Y	G	S	Y	A non-standardised metric describing fishing pressure that can be broken down by sector and method and is available from existing sources. Could be expressed relative to TAC.	M
Number of vessels fishing in the Gulf									Discussed under Socio-economic value of fishery components Key Attribute	

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Total recreational fishing effort									Discussed under Socio-economic value of fishery components Key Attribute	
Fishing intensity by commercial method	S	Y	E	Y	S	D	Y	Y	Intensity is an effort metric standardised by the area of the Gulf where a particular method can be used. Intensity metrics could be easily calculated from existing information but would need to be generated for each method and could be produced for different subareas of the Gulf. Could be somewhat duplicitous of effort metrics above.	M
Aggregated area of seabed contacted by trawl and dredge gears	Y	Y	E	Y	S	D	Y	Y	A metric of high public relevance that informs about the level of seabed contact. An existing project produces this established metric annually, but would require estimation of Hauraki Gulf as its own area. New analysis method would be needed to included Danish seine.	H
Weight of undersized fish released	Y	Y	E	Y	S	G	S	Y	A metric that informs about undersize fish bycatch discards. Non-QMS bycatch not able to be quantified as cannot be observed from cameras and observer coverage is too low. Undersized fish weight is likely to be influenced by recruitment pulses, so not clear what this metric really communicates.	M
Desired Outcome: Inclusive and integrated participation in fisheries governance										
Focal Component: Tangata whenua										
Proportion of Hauraki Gulf iwi or hapū represented at Hauraki Gulf wide fisheries wananga and hui	Y	S	D	S	N	G	U	N	This indicator is intended as a metric of tangata whenua engagement across the Hauraki Gulf with fisheries management. The meetings may include working groups, special management area meetings, fisheries stock reviews and research meetings. Although the representation of iwi at fisheries hui could be used as an indicator, it is also likely to reflect the subject matter of the hui, internal capacity, and resourcing. By having a metric that measures the proportional representation of hapu/iwi rather than the number of representatives this could cancel out some of the capacity artifacts. It will be difficult to use attendance as a measure of success for the co-management of fisheries in the Hauraki Gulf without also pairing this with measures of satisfaction with fisheries management and any specific capacity and resourcing concerns iwi have.	M

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Number or area of Hauraki Gulf in voluntary customary fishery closure	Y	Y	E	Y	S	G	Y	U	A metric that provides insight into both the level of concern surrounding fisheries and fisheries management locally but also the facilitation, resourcing and engagement of tangata whenua with fisheries management in their rohe based on local values and issues. This metric describes the use of voluntary customary closures such as rāhui, whereas the metric below describes fishery closures through Section 186A of the Fisheries Act 1996. Although these closures are local management tools, data for the total area within the Hauraki Gulf should be easily gathered. Interpretation of this metric could be difficult, because while it will likely be influenced by engagement with fishery management, it will also be influenced by fish population abundance.	H
Number or area of customary fishery closures through Section 186A of the Fisheries Act	S	S	E	Y	S	D	U	N	Similar to the metric above, but reflects the use of Section 186A of the Fishery Act 1996 to seek closures. Comparison of these two customary closures metrics could be insightful, but again potentially driven by multiple factors.	M
Number of customary authorisations issued									Discussed above under the Socio-economic value of fishery components (customary value) Key Attribute. Potential issues with interpretation and data confidentiality.	
Number of responses to calls for submissions from FNZ by hapu and iwi	S	Y	E	Y	S	G	Y	N	This indicator is intended as a metric of tangata whenua engagement across the Hauraki Gulf with fisheries management. Although this is a straightforward measure with high quality data, the indicator may not be able to accurately inform tangata whenua engagement with fisheries management in the Hauraki Gulf. The Crown is obliged to engage and co-develop fisheries management decisions prior to the proposals going for submission, therefore the level of submissions from iwi post co-development is likely to be low.	M

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Tangata whenua attitudes and values associated with fishery management	Y	Y	N	S	S	G	S	Y	Although participation metrices go some way to indicating tangata whenua engagement with fisheries management, this specific indicator will measure the attitudes of tangata whenua towards processes, resourcing and relationships regarding fisheries management in the Hauraki Gulf. Participation may vary due to capacity and resourcing rather than engagement. Surveys should be designed to capture values and changes in attitudes and could use scaled metrices like rubrics or multi-choice questions. The attitudes and values questions could be guided by the work and indicators developed in the 'Mana Moana' workstream. It will be important to deliver the surveys kanohi ki te kanohi at least in the first instance to increase engagement and uptake. The development of this survey may require input from social scientists. Similar to Customary fisher attitudes and values survey in Socio-economic value of fishery components (customary value) Key Attribute above.	H

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Focal Component: Community										
Number of responses to calls for submissions from FNZ by community members	S	Y	E	Y	S	B	Y	U	This indicator is intended as a metric of community and public engagement with fisheries management across the Hauraki Gulf. This is a straightforward and easy to interpret metric for which historical, existing and future data can be mined. The most significant challenge will be isolating data for the Hauraki Gulf as many fisheries management decisions and reviews are at stock levels which may be wider than the Hauraki Gulf itself. There may be value in interpretation of the positive and negative feedback and the proportion of responses from persons located within the Hauraki Gulf even if the proposal or stock is wider than the Hauraki Gulf.	M
Community attitudes and values towards Fisheries Management as measured by a survey questionnaire	Y	Y	N	S	S	G	Y	Y	Although participation metrics go some way to indicating public engagement with fisheries management, participation may vary due to capacity and resourcing rather than engagement and this indicator will measure the attitudes of the public with processes, resourcing and relationships in regard to fisheries management in the Hauraki Gulf. Surveys should be designed to capture values and changes in attitudes and could use scaled metrics like rubrics or multi-choice questions. These surveys could be circulated to existing community groups or as part of responses to fisheries submissions.	H
Number of multi-stakeholder fisheries advisory groups active in the Hauraki Gulf	Y	S	D	N	N	G	U	Y	A metric of government regard for community input into fisheries management. The number of groups and their active participation into fisheries management may be hard to measure as Government may not always be involved in these groups. The groups formed for the special management areas in the Hauraki Gulf may be one example of groups and participation by the public. These groups may be short lived or focussed on specific issues that do not apply across scales relevant to the Hauraki Gulf.	L

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
Focal Component: Government										
Average number of years since last update for Hauraki Gulf fisheries indicators	Y	Y	E	S	S	G	Y	Y	Metric intended to understand Government commitment to work toward EBFM in the Hauraki Gulf. A cost-effective indicator that could be updated annually by reviewing when each indicator was last reviewed. Similar to Average number of years since monitoring for key components of the Hauraki Gulf Fishery plan metric discussed below under Implementation of management and monitoring of the Hauraki Gulf Fisheries Plan.	M
Proportion of fisheries projects that are multiagency or with local Government	Y	Y	D	Y	Y	G	Y	U	This metric is intended to measure the collaboration between FNZ and other agencies such as DOC, Ministry for the Environment, Councils, other Government ministries and not for profit agencies. This indicator may also secondarily report on the investment of other agencies in fisheries management in the Hauraki Gulf. Defining what fisheries projects are, and then conducting accounting to apportion Hauraki Gulf component would need some thought, and would likely be time consuming.	H
Number of interagency fisheries publications and research outputs for the Hauraki Gulf	Y	S	N	Y	U	G	Y	U	A simple metric that is intended to measure the results and outputs of collaboration between FNZ and other agencies such as DOC, Ministry for the Environment, Councils, other Government ministries and not for profit agencies. Online searches for authoring institutions and agencies, funders or acknowledgements could be used.	M
Use of local and indigenous knowledge in fishery management	S	N	N	S	U	B	N	Y	Although the incorporation of local and indigenous ecological knowledge is incredibly important for fisheries management, as a standalone indicator this is a subjective measure that will be difficult to quantify. Other indicators such as attitudes and values surveys, funding of community and hapu led projects, multi-stakeholder meetings and advisory groups may be more appropriate and measurable metrics to understand how well FNZ is incorporating local and indigenous knowledge in fisheries management.	L

Indicator	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Overall rating
FNZ funding for community based fisheries management groups, projects and research in the Hauraki Gulf	Y	S	N	S	Y	G	S	U	A metric to measure investment by Government in community participation and facilitation of fisheries management. While this data will exist, there would be work involved in the extraction (from ministry and organisation management budgets and employment apportioning) and interpretation of the relevant information specific to the Hauraki Gulf.	L
Resourcing allocated to build tangata whenua fisheries management capacity by FNZ	Y	S	N	S	Y	G	S	Y	A metric to measure investment by Government in tangata whenua participation in fisheries management (and Government ability to meet their treaty obligation). Currently, there is no strategic data collection and while the information exists there would be work involved in the extraction and interpretation of the relevant data specific to the Hauraki Gulf. This data would need to be extracted from employment and budget information across ministries and organisations which decreases the availability and efficiency scores.	H
Additional component: Implementation of management and monitoring of the Hauraki Gulf Fisheries Plan										
Government operational budget ($) associated with each component of the Hauraki Gulf fishery plan	Y	Y	E	S	Y	G	Y	Y	A metric designed to inform about Government investment in the Hauraki Gulf Fishery Plan. An exercise to apportion funds (management budgets and Full Time Equivalent positions) relevant to the Hauraki Gulf would need to be conducted, but this is potentially the simplest implementation metric.	H
Average number of years since monitoring for key components of the Hauraki Gulf Fishery plan	Y	Y	E	S	S	G	Y	Y	A metric designed to inform about the frequency of monitoring related to the Hauraki Gulf Fisheries Plan, which would need to focus on key components. Monitoring frequency may not be standardised (on a needs basis). Similar to Average number of years since last update for Hauraki Gulf fisheries indicators in Government Key Attribute above.	M
% of management actions achieved (from FNZ annual operational plan for the Gulf)	Y	Y	E	Y	Y	G	S	Y	A metric designed to inform about 'follow through' on Government commitments using a traffic light approach to document the level of achievement for FNZ annual operational plan actions. Will be somewhat subjective.	H

Appendix 3

Traffic light approach evaluation of potential ngā tohu – indicators (against evaluation criteria) relevant to the Hauraki Gulf fishery system and mana moana.

Ngā Tohu	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Recommendation
Ngā Pou: Ngā Hapori – Community Mobilisation										
Community Awareness	Y	S	Y	Y	Y	U	U	U	Data sets that indicate community awareness and engagement with fishery governance and understanding of EBFM.	H
EBFM for Mana Moana	Y	S	D	S	S	B	Y	Y	Data and associated indicators that measure the effectiveness and impact of EBFM.	M
Locally led approaches	Y	Y	N	Y	Y	L	Y	U	The number of community led practices and research projects being undertaken around the Hauraki Gulf.	M
Partnering with communities and iwi	Y	Y	Y	N	Y	B	Y	U	Data pertaining to the level of partnership between the Government and iwi and hapū.	H
Inter-generational planning	Y	S	N	S	S	U	U	U	Data that will be informative to understanding progress towards longitudinal outcomes, actions, and decision making for future generations.	H
Ngā Pou: Ngā Kaihāpai - Stewardship & Advocacy										
Customary take	Y	S	Y	Y	Y	U	U	U	The MMAG highlighted the need for more data pertaining to customary take	H
Customary permits	Y	S	Y	Y	Y	L	U	U	Customary permit issuers need more information and data to aid with issuing permits.	M
Ahu Moana	Y	Y	N	Y	Y	L	Y	N	Useful to know where, who, and how many Ahu Moana sites there are and the status of different ecosystem traits within those Ahu moana.	L
Governance structures	Y	Y	Y	Y	Y	B	Y	U	Data pertaining to the resourcing, capability and capacity building of mana moana, which could potentially be reflected through the number of roles they occupy across the fisheries system.	H
Kaitiaki (professional and voluntary roles)	Y	N	D	S	S	B	U	U	The number of people (professional and voluntary) that facilitate kaitiakitanga in the Hauraki Gulf.	L
Ngā Pou: Ngā Putea – Investments & innovations										
Investments in iwi, hapū, and whānau led research and innovations	Y	S	N	Y	Y	Y	B	U	Amount of funding into Māori-led research and kaupapa in the Hauraki Gulf.	H
Investments from central and regional government	Y	Y	P	Y	Y	B	Y	Y	Amount of investment from central and regional government into Māori-led kaupapa.	H
Funding requirements – what is needed and how much	Y	N	N	Y	S	B	U	U	An indicator that reflects a break-down of costs to achieve effective EBFM for mana whenua.	M
Funding opportunities	Y	N	N	Y	S	B	U	U	Data that shows what funding avenues are available to mana moana.	M
The Māori Economy	Y	S	N	S	Y	Y	Y	U	Data that highlights all commercial activities in the Hauraki Gulf including opportunities for mana moana to enhance outcomes for their own iwi and hapū led economies.	H

Ngā Tohu	Relevance	Simplicity	Data availability	Practicality & cost-effectiveness	Specificity & sensitivity	Spatial scale	Quality	Comparability	Comments	Recommendation
Ngā Pou: Ngā Ture – Policy and legislation										
Regulatory framework of the Hauraki Gulf	Y	N	E	Y	Y	B	Y	U	Information and data describing the regulatory frameworks that exist around the Hauraki Gulf.	H
Legal enablers for Mana moana	Y	N	E	Y	Y	B	Y	U	Indicators that identify and highlight the legal pathways and opportunities for mana moana to express rangatiratanga through existing law and policy.	H
Optimising future policy enactment	Y	S	D	Y	Y	B	U	U	Relevant data sets to quantify policy amendments and developments for mana moana.	M
Cultural impact assessments	Y	S	D	Y	Y	B	U	U	Relevant data sets to inform cultural impact assessments in the Hauraki Gulf. Data could be extracted from assessments conducted as part of resource consent applications.	M
Operating outside of the regulatory framework	Y	N	D	S	S	B	U	U	Data pertaining to means by which activities and undertakings are facilitated outside of the regulatory framework (i.e., lobbying etc.).	L