Fisheries New Zealand
Tini a Tangaroa

Best practices and technologies available to minimise and mitigate the interactions between finfish open ocean aquaculture and seabirds

New Zealand Aquatic Environment and Biodiversity Report No. 272

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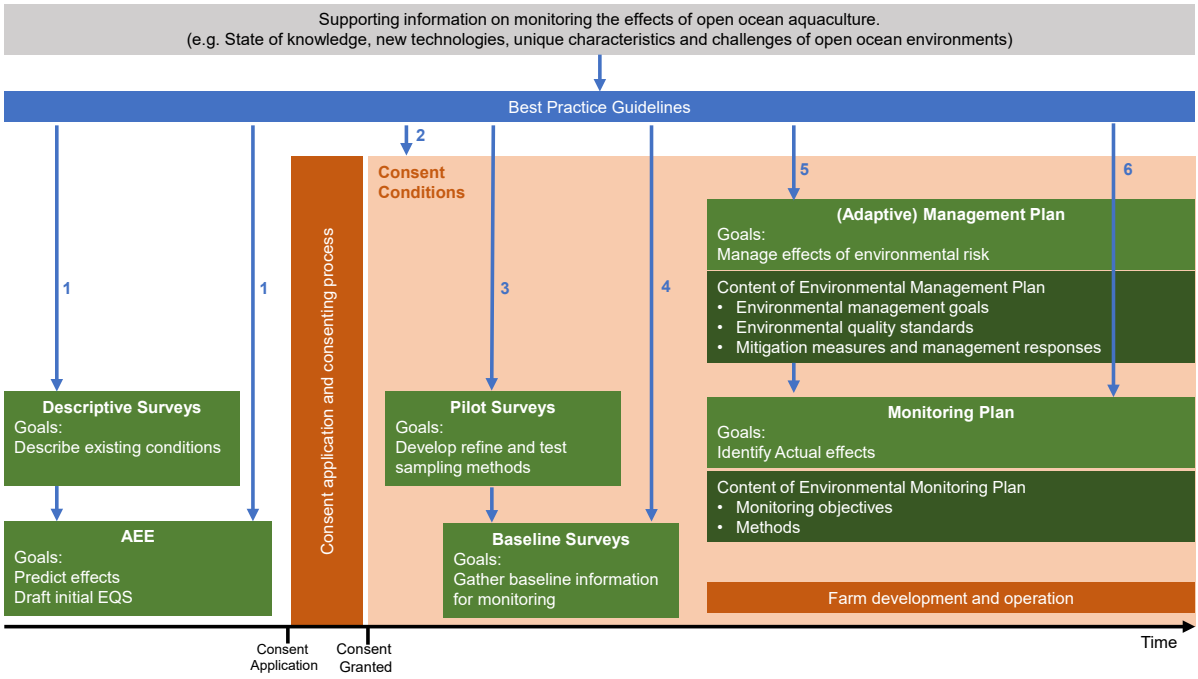
CORRECTION: This report was updated, in late October 2021, with a revised Table 2.

PREAMBLE

At Fisheries New Zealand we work to ensure New Zealand has world leading finfish farming practices which are environmentally, economically, socially, and culturally sustainable. The Government's Aquaculture Strategy has a goal of $3b in annual sales by 2035 and development of an open ocean finfish aquaculture industry is a key priority. Towards this goal of supporting sustainable open ocean finfish aquaculture, best practice guidelines for managing the effects of open ocean finfish farming on marine mammals, seabirds, water quality, and the benthic environment have been developed.

The guidelines for open ocean finfish farming ('the Guidelines') have been created to assist in the preparation of consent applications as well as inform consent conditions and decisions that will mitigate adverse environmental effects. The diagram below sets out the role of these guidelines in supporting OOA management under the Resource Management Act 1991.



1. The Guidelines inform the preparation of the Assessment of Environmental Effects (AEEs) by: (a) describing potential effects and (b) Outlining the specific information required for designing monitoring plans.
2. The Guidelines support the development of consent conditions by (a) Recognising that monitoring and management aspects may need to be adapted over time. (b) Promoting the development of Management Plans that enable the necessary flexibility in data collection and analysis.
3. The Guidelines provide assistance for planning pilot surveys to test sampling approaches.
4. The Guidelines inform the development of baseline surveys and monitoring programmes. Baseline information can be derived from descriptive surveys or existing reliable information sources.
5. The Guidelines support the development of Management Plans by (a) Identifying the content required to link monitoring to effects management: and (b) Providing considerations for the development of Environmental Quality Standards (EQSs).
6. The Guidelines support the development of Monitoring Plans (EMOPs) by providing technical guidance for monitoring effects and advice on how this can be implemented.

For seabirds and marine mammals, the Guidelines focus on mitigation of interactions through site selection, design, and operation of farm infrastructure. For benthic and water quality, mitigation of impacts is driven by the need for careful site selection and adaptive management practices that maintain acceptable environmental conditions within consented boundaries.

Because open ocean aquaculture is at an early development stage in New Zealand, carefully designed monitoring programmes will be required to assess the effectiveness of mitigation measures. The Guidelines therefore consider the range of monitoring options that may be appropriate in open ocean environments.

Effective monitoring will inform structural or operational improvements that deliver better environmental outcomes over time. The flexibility to evolve both monitoring and farming practices will be essential given the lack of New Zealand and international experience with open ocean aquaculture (OOA).

Guideline development process:

- Literature reviews were commissioned on the effects of open ocean aquaculture on **seabirds and marine mammals**. These provided a starting point for developing best practice guidelines. Following this, the Aquatic Environment Working Group and the Aquaculture Working Group (chaired by Fisheries New Zealand) provided peer review of the first and second drafts of this document.
- Fisheries New Zealand commissioned a report focused mainly on benthic effects of open ocean aquaculture overseas. This included several case studies from Norway regarding water quality effects. A technical working group was formed to discuss issues and develop guidelines for **benthic and water column effects** given the range of options available for monitoring and management of these effects.
- **Guidelines will be reviewed as needed** based on growing knowledge, so they can be improved. Considering this is the early days of open ocean aquaculture in New Zealand (and elsewhere), it is envisaged the initial review cycles will be relatively short with a backstop of 5 years from the development of the farms, or as required (e.g., if monitoring data and results are significantly different from anticipated).
- **Further research** is required into the effects of open ocean aquaculture upon the marine environment. In addition to known information gaps, research needs will be identified and documented as part of the guideline development and review process. These can then input to any ongoing or future Fisheries New Zealand research planning or prioritisation processes such as the proposed Aquaculture Innovation Plan and the proposed Aquaculture Strategy and Investment Roadmap, currently under development.

Factors to consider when reading and applying the Guidelines:

- Fisheries New Zealand is leading (with input from other government agencies) a process of considering options **for a future regulatory framework for open ocean aquaculture**. This future **open ocean aquaculture regulatory framework will take into consideration** concurrent regulatory change including the Biosecurity Act review, marine protected areas reform, and particularly the review of the Resource Management Act with a new Natural and Built Environment Act and Strategic Planning Act.
- While this regulatory framework may lead to recommended changes for any new farms proposed, **these guidelines are expected to remain relevant under any future regulatory framework.** The guideline review process can be used to manage required adaptations. Although we describe these guidelines within a Resource Management Act context, they are technical guidelines that will remain relevant under any regulatory framework.
- For the purpose of developing guidelines, **open ocean aquaculture is defined as "aquaculture outside of semi-enclosed bays and harbours or other sheltered locations around mainland New Zealand and larger offshore islands".** This definition

includes the existing applications[1,2,3] at the time of publication of this document. Future applications are likely to be for areas that are at least as exposed as those in the existing applications. The process of considering different options for management frameworks for open ocean aquaculture may lead to a more precise definition of open ocean aquaculture. If so, that definition will be evaluated for adoption into these guidelines. Furthermore, although 'open ocean' is likely to contain areas considered non-dispersive (e.g., weak hydrodynamic regimes) (Bennett et al. 2020), we have assumed that only dispersive open ocean environments will be targeted for finfish farming and, thus, the guidance focuses on these environments.

Further guideline development will occur, for example:

- An approach to comprehensive biosecurity management for aquaculture is in the process of being developed. Officials advised Ministers in mid-2021 on recommendations to improve the management of aquaculture biosecurity, both marine (including open ocean) and land based.
- **Navigation issues** will continue to be considered under future regulatory frameworks. Fisheries New Zealand will continue to engage with Maritime New Zealand to ensure we meet our national and international obligations to provide for safe navigation.
- **Engineering guidelines** have been identified as a lower priority for government. This may be revised in the future.
- The development of guidelines for managing **shark or any other environmental interactions** with open ocean aquaculture has been identified as a lower priority for government. This may be revised in the future.

Mat Bartholomew

Director, Aquaculture, Fisheries New Zealand

[1] Blue Endeavour, New Zealand King Salmon.
[2] Hananui, Ngāi Tahu, and Project South, Sanford.
[3] Project East, Sanford.

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Gaskin, C.[4]; Milardi, M.[5]; Cumming, S.[5] (2021). Best practices and technologies available to minimise and mitigate the interactions between finfish open ocean aquaculture and seabirds.

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At Fisheries New Zealand, we work to ensure New Zealand has world-leading finfish farming practices which are environmentally, economically, socially, and culturally sustainable. The Government's Aquaculture Strategy has a goal of $3b in annual sales by 2035, and development of an open ocean finfish aquaculture industry is a key priority.

Within these guidelines, open ocean aquaculture (OOA) is defined as "aquaculture outside of semi-enclosed bays and harbours or other sheltered locations around mainland New Zealand and larger offshore islands". We have assumed that only dispersive open ocean environments will be targeted by industry, and the guidance is focused on these areas.

The purpose of these guidelines is to inform the sustainable development of open ocean finfish farming in New Zealand by providing robust and practical guidance for minimising and mitigating effects on seabirds. These guidelines are intended to inform the development of Environmental Management Plans (EMOPs) and related processes under the Resource Management Act 1991 (RMA) to ensure that minimising and mitigating effects on seabirds is well integrated into the consent management framework. Associated RMA processes include the design of baseline surveys, assessments of environmental effects (AEE) preparation, writing or review of consent conditions, and design of adaptive management processes.

These guidelines focus on mitigation of interactions through site selection, design, and operation of farm infrastructure. Because open ocean aquaculture is at an early development stage in New Zealand, carefully designed monitoring programmes will be required to assess the effectiveness of mitigation measures.

The main effects that need to be addressed include:

- **attraction or avoidance**, because marine farm structures represent a new physical, visual, or acoustic obstruction that seabirds may choose to ignore, investigate, or avoid. Attraction might alter natural foraging and passage patterns and potentially lead to interactions and also to incidents.
- **interactions** with farm structures**,** defined as events when a seabird makes physical contact with the farm structure, which may lead to
- **incidents** that cause injury (e.g., rope cut, abrasion), collision, entrapment, or entanglement (live or fatal) of a seabird.

Mitigation options include:

- Discourage activities that could attract seabirds to the farm.

[4] Northern New Zealand Seabird Trust.
[5] Fisheries New Zealand.

- Minimise artificial lighting, where and when possible, to reduce attraction of prey fish and predators.
- Utilise strategies for feeding rates and feeding systems, to minimise attraction of seabirds.
- Avoid un-tensioned and/or loose ropes, lines, or nets on farms at all times.
- Consider the line diameter and colour to ensure lines are visible to seabirds in flight.
- Consider the use of predator-resistant materials in the construction of farms.
- Adopt a range of non-lethal or non-injurious bird deterrents, where necessary, to dissuade birds from roosting.
- Minimise predator exclusion nets, or design and manage nets (including surface nets) to minimise the likelihood of entrapment.

Undoubtedly there is potential for negative interactions between seabirds and open ocean aquaculture facilities. Such interactions are occasionally recorded for inshore aquaculture in New Zealand. Avoiding these effects for the threatened, endangered, and protected species in particular is critical. This document provides recommendations for management and mitigation actions that will greatly reduce the potential for OOA to impact on seabirds.

1. INTRODUCTION

Seabirds have evolved from several different taxonomic groups. Common to all is that they spend some part of their life cycle feeding at sea. This separates seabirds from shorebirds (waders) that feed in the littoral zone[6] or on shorelines and from species that regularly roost at sea such as ducks and swans. Seabirds have water resistant feathering (from oils in the preen gland) that enable them to fully immerse in salt water. They have webbed feet that allow them to swim in water and can readily become airborne off the water. Most seabirds have short legs and powerful wings or flippers, all have bills with sharp hooks, points, or filters which enable them to catch fish, cephalopods, crustaceans, and zooplankton. Lastly, seabirds can drink saltwater and have physiological adaptations for removing excess salt (Taylor 2000).

A total of 145 seabird species occur within New Zealand's Exclusive Economic Zone, including species breeding outside the region. New Zealand hosts 95 breeding species, 37 of which are endemic (i.e., breeding nowhere else in the world), totaling about 14 million breeding pairs. A large proportion of the seabirds breeding in New Zealand are highly migratory species which disperse to exclusive economic zones (EEZs) of other countries and international waters following breeding, mostly in the Pacific Ocean, but also moving into the South Atlantic Ocean and Indian Ocean. These include all albatrosses, most shearwaters and petrels, and also some penguins.

Species that regularly gather in large numbers, whether to feed or for other purposes, do so in areas that usually coincide with specific oceanographic features where the biological productivity is high. For albatrosses and petrels and shearwaters, foraging areas are not always close to their breeding sites and could be hundreds or even thousands of kilometres away. The at-sea distributions of several species of seabirds have been investigated by Fisheries New Zealand, e.g., under project PRO2019-10, and could serve as an indication of seabird ranges around New Zealand (Peatman et al. in prep.).

The guidelines presented in this report take into account the diverse foraging and feeding behaviours of seabirds, highlighting their capability to detect potential food sources across large areas of the open ocean environment and around marine structures (including vessels). Because of New Zealand's diverse seabird avifauna and the new situation of locating finfish aquaculture in open ocean areas, there is little to no direct data on the type and magnitude of potential interactions in this environment. Seabirds could potentially be attracted through smell, sound, and sight to open ocean finfish farms, and they could try to exploit the farm resources with a consequent risk of interaction.

Seabirds that feed in association with fish schools (flock feeding) feed on the krill and small fish that the schools drive to the surface and could be attracted to fish presence in the cage especially during feeding time. Seabirds utilise a range of senses (sight, smell, sound) to detect prey at sea (olfactory attraction). This is most marked in prions and petrels, which could be attracted to farms by the smell of fish and feed. Fish in pens, particularly smolt, could be attractive prey to visual predators like gannets and terns if visible when flying above and could drive birds to plunge dive towards the pen. Penguins, shags, shearwaters, and petrels can pursue prey underwater and these behaviours could carry a risk of entanglement or entrapment, resulting in drowning if the birds cannot escape. Some species such as penguins and shags forage diving near the seafloor, and fish farms have been known to affect the seafloor near the farm, even though this effect is less likely in the high-energy open ocean environment. Terns, gulls, shags, and even gannets roost in large numbers between feeding bouts, and farm structures could provide new roosting opportunities, increasing the risk of interactions.

Some petrels are active at night and could be attracted to farm lights and interact with structures less visible at night. In general, seabirds are very likely to be attracted to and investigate any discards and

[6] The littoral zone is usually defined as the near shore area where sunlight penetrates to the seafloor.

debris (natural or otherwise). Key knowledge gaps are also identified, and future research to address these gaps are recommended in the future research section.

Undoubtedly there is potential for negative interactions between seabirds and open ocean aquaculture facilities. Such interactions are occasionally recorded for inshore aquaculture in New Zealand. Avoiding these effects for the threatened, endangered, and protected species in particular is critical. However, by following the recommendations for management and mitigation actions discussed below, the risk of offshore aquaculture in New Zealand impacting marine mammals can be greatly reduced.

2. SEABIRD GUIDELINES

The Seabird Guidelines ('the Guidelines') are focused on reducing the likelihood of seabirds being attracted to finfish open ocean aquaculture structures, thus minimising interactions. The guidelines are designed to mitigate the possible consequences of any interaction by reducing the significance of any resulting effects.

The Marine Mammal Guidelines (Clement et al. 2021) for open ocean aquaculture were developed alongside the Seabirds Guidelines. Within these two sets of Guidelines there are some examples of tensions: e.g., in the Seabird Guidelines it is recommended that operators "reduce the extent of structures above water in the farm design, to minimise seabird attraction, wherever possible", whereas in the Marine Mammal Guidelines it is recommended that any predator exclusion nets should "where practicable, extend 2–3 m above the sea surface (e.g., jump fences) around any surface pens". Any tension between guidelines will need to be resolved on a case-by-case basis in management plans. The Guidelines are not absolute; operators will have to ascertain, when preparing an assessment of effects, which effect should take precedence and draft their management plans accordingly. This is expected to vary on a site-by-site basis, based on the species present in the area (e.g., marine mammals might be of more concern than seabirds in a given area or for a type of farming, and thus lead to a different prioritisation of management).

2.1 Types of effects that require management / monitoring

Northern Seabird Trust produced the first draft of the Guidelines using a recent literature review on the interactions of seabirds with open ocean aquaculture by Connor-McClean et al. (2020), as well as current information from New Zealand inshore aquaculture and overseas open ocean experiences.

This review highlighted the main effects that need to be addressed, including:

- **attraction or avoidance**—marine farm structures, farm waste, and associated vessels may represent a new physical, visual, or acoustic obstruction that seabirds may choose to ignore, investigate, or avoid. Attraction might alter natural foraging and passage patterns and, potentially, lead to interactions and also to incidents.

Attraction may increase the risk of interaction with the structure, whereas avoidance may exclude seabirds from part of their habitat. Some factors such as lighting, the presence of dead fish, or underwater noise have been identified as potentially attracting seabirds to farm structures and increasing risk of interaction, and the Guidelines aim to minimise and mitigate these factors.

- **interactions** with farm structures—interactions occur when a seabird makes physical contact with the farm structure (e.g., roosting), which may lead to **incidents** that cause injury (e.g., broken wings) or entanglement (live or fatal) of a seabird. These terms are used throughout the document and in the tables of guidelines below.

Nets have been identified as the main factor increasing injury and entanglement risk for seabirds, so the Guidelines aim to minimise this risk. e.g., by ensuring nets are taut and/or have a certain mesh size. Farm waste has also been identified as a potential risk factor in open ocean operations.

The Guidelines are designed to:

- minimise or mitigate the attraction (or avoidance) of seabirds to open ocean finfish farms, e.g., attraction and disorientation from farm and vessel lights or noise at night, in adverse weather or at times when seabirds are very hungry and competing for prey or following prey that might aggregate close to the farm;
- minimise or mitigate interactions between the farm structures and seabirds, including roosting or sheltering on structures, and opportunistic feeding;
- minimise or mitigate incidents, e.g., collision or entanglement with in-water predator and fish pen nets, above-water bird netting, structures, and vessels.

2.2 Approach to guideline development and legislative framework

The Guidelines are focused on the main effects discussed above and are intended to define best practices and technologies to minimise and mitigate adverse effects of open ocean finfish aquaculture on seabirds. Several of these guidelines are intentionally general, particularly for aspects where little or no knowledge exists to suggest how seabirds will react to aquaculture structures, gear, and technology in an open ocean environment. New Zealand has not yet implemented a seabird monitoring framework to assist in developing evidence-based mitigation actions and/or guidelines for open ocean finfish aquaculture, so these guidelines are mainly a product of current scientific literature and expert knowledge. It is expected that further development of the guidelines might be needed when new evidence becomes available.

The main statute protecting seabirds in New Zealand is the Wildlife Act 1953. With the exception of black-backed gulls (*Larus dominicanus*), all seabirds breeding within New Zealand are either fully or, for a few seabirds, partially protected under the Wildlife Act 1953 and its amendments. Seabirds that visit New Zealand waters, but do not breed in New Zealand, are also covered under the Wildlife Act 1953. Under this Act, seabirds are considered protected species and it is an offence to 'take' (which includes among others, disturb, harass, injure, or kill) a seabird without a permit. It also gives defence for accidental or incidental injury or death (e.g., while fishing or carrying out other activities) provided all such events are reported to the Department of Conservation (DOC). These guidelines are intended to help ensure the statute protection is met in relation to open ocean aquaculture.

Most other regulatory requirements fall under national resource management legislation, including the Resource Management Act 1991 (RMA), the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (and associated regulations), and the New Zealand Coastal Policy Statement 2010. Regional coastal plans and regional policy statements established under the RMA may also have provisions relevant to seabird populations and/or their habitats.

2.3 Interaction between the Guidelines and the Resource Management Act 1991

Practitioners, i.e., regional councils, can use the Guidelines to assist processes under the RMA in one of three ways:

- Information generated because of implementing the planning and siting guidelines (Table 1) may be suitable for subsequent inclusion in regional coastal plans, such as significant seabird colonies on land or important foraging habitats. These types of areas could, for example, be shown on plan maps and require any applicant to carefully consider how they would avoid, remedy, or mitigate risk of entanglement.

- The Guidelines provide a source of guidance for councils in processing and making decisions on consent applications for offshore aquaculture. For example, if a proposed aquaculture site is near significant seabird colonies, then reasoning for selecting that location and an appropriate management plan should be provided for a relevant consent application
- The Guidelines for management and monitoring (Tables 2 and 3) could inform the development of proposals that outline potential consent conditions, and then be used by applicants and councils during the consent process as a basis for discussion of conditions. Management of effects of activities under the RMA is typically approached through a combination of consent conditions and management and monitoring plans. Consent needs to be both certain and enforceable. Therefore, when using the guidelines, a balance should be drawn between those that might be suitable to include as consent conditions, those that could inform or form part of management plans, and those that sit outside the resource consent process. Consent applicants should consider these guidelines while preparing consent applications and discuss particulars of specific sites and approaches with councils during the application development process. Discussions between councils and applicants should continue throughout the processing of an application.

Table 1: Planning and siting guidelines to minimise and mitigate the risk of interactions between seabirds and open ocean finfish aquaculture in New Zealand.

Principle	Guidelines
Minimise location overlap	Farm proposals should create a site-specific list and description of seabirds likely to be found in the surrounding area, including their threat classification and a list of potential effects, and their likelihood and consequences.
	Farm siting should strive to minimise direct proximity to known significant colonies and known important foraging habitats.
	Site selection should aim to minimise spatial overlap with range-restricted species' home ranges.
Minimise interaction risk through farm design	Reduce the extent of structures above water in the farm design, to minimise seabird attraction and roosting opportunities, wherever possible.
	Design farm structures to reduce roosting opportunities, where practical.

Table 2: Management guidelines to minimise and mitigate the risk of adverse effects on seabirds from open ocean finfish aquaculture in New Zealand. [Continued over the page]

Principle	Guidelines
Increase awareness	Increase seabird awareness through provision of seabird identification information to farm operators.
Management plan	Develop customised seabird management plans addressing protocols to minimise interactions with the species likely to be in each area, defining monitoring and reporting requirements, and providing for entanglement response actions. Plans should include an appropriate review period (e.g. three years).
Minimise attraction to farms	Consider twine diameter and colour to ensure visibility of nets to seabirds both above and underwater. Cover pens with nets (top nets) to reduce the visibility of fish activity within them. The amount of feed and dead fish that are accessible outside the nets is limited by: • utilising strategies for feed rates and feeding systems, to minimise attraction of predators and their prey; • removing dead fish from pens as soon as reasonably practical and storing them in a manner that does not attract predators. Discourage activities that could attract seabirds to the farm (e.g., fishing). Utilise strategies for feeding rates and feeding systems, to minimise attraction of seabirds. Minimise artificial lighting, where and when possible, to reduce attraction of prey fish and predators by: • using downward pointing, shaded light sources within fish pens as part of fish husbandry; • reducing the use of lights on farm structures to the minimum required for health and safety of farm workers and navigation, where practical; • minimising the need for service vessels to be active in the area at night, where practical. Minimise above-water and underwater noise generation by: • regularly maintaining all equipment and vessels (e.g., lubrication and repair of winches and generators); • ensuring that all noise suppression equipment, such as mufflers and ventilation baffles, are maintained in good working order; • minimising disturbance of seabirds from boat traffic and farm operation noise, where practical. Adopt net de-fouling protocols that minimise food provision to birds.
Minimise and mitigate entanglement risk	Improve predator-resistant materials in net construction and maintain tautness of the top net to deter birds roosting and minimise the risk of entanglement (i.e., to avoid feet and legs being caught in the mesh).

	Adjust mesh sizes of top and underwater nets to minimise entanglement risk. Mesh sizes are recommended (6 cm), but these may not be suitable for small-bodied species such as diving petrels and some shearwaters (see Supplementary Table 1). Where anti-predator nets are installed, they should: • completely enclose all structures to be protected; • be spaced from pen nets by a distance sufficient to avoid entrapment and designed so that fish pen and predator net gear do not touch in all tidal and sea conditions where practicable; • be maintained under tension and taut; • have a mesh size that minimises a predator's ability to penetrate the net with its head, flippers, or wings (note a potential conflict with Marine Mammal Guidelines); • be kept well-maintained (e.g., holes repaired as soon as possible). Where necessary, dissuade birds from roosting by adopting a range of non-lethal or non-injurious bird deterrents that can be used randomly (see e.g., Parker 2017).
Appropriate maintenance and replacement schedules	Follow standard and regular maintenance inspections and replacement schedules, particularly after any significant storm events, to ensure: • no marine wildlife is entangled in or has entered the farm; • nets/pens and lines are well maintained (e.g., holes repaired as soon as feasible) and kept taut.
Minimise interaction with marine debris	Minimise potential for loss of rubbish or structural and gear debris from farms through a waste management plan that could include, for example: • collecting or retrieving waste, and retaining it in secure storage (especially in higher wind conditions); • mitigating the loss of debris through scuppers; • maintaining farm infrastructure regularly, to minimise breakages or loss of equipment overboard.
Minimise pathogens and parasites transfer	Minimise build-up of guano (seabird droppings) deposits on structures.
Minimise pest and predator transfer	Ensure best practice techniques on the support vessel so that pests (animals and plants) are not transported to farms, with the potential to swim or wind disperse onto nearby pest free islands where they could impact seabirds (e.g., DOC Pest-free Certification, AQNZ A+ sustainable aquaculture, BAP certification, Aquaculture Stewardship Council).
Review of management practices, protocols, and procedures	Run regular independent reviews of the effectiveness of the management plan in managing and mitigating the adverse effects on seabirds.

Table 3: Monitoring guidelines to minimise and mitigate the risk of adverse effects on seabirds from open ocean finfish aquaculture in New Zealand.

Principle	Guidelines
National monitoring framework	Make data available to any future government-led national database, with standardised reporting requirements across the open ocean aquaculture sector to collectively gather and make use of New Zealand-wide seabird monitoring data and record all incidents in open ocean aquaculture.
Baseline and farm construction monitoring (Level 1)	Develop a baseline monitoring programme lasting for at least a year, to understand presence and density of seabirds in the proposed area, prior to and during farm development. Multiple surveys at different times of the year might be required, depending on species breeding times. Establish and collect standard parameters, regardless of methods used, to model potential interaction rates (e.g., number of seabird individuals adjusted for observation effort within a particular area).
Farm monitoring (Level 2)	Develop monitoring and reporting protocols using existing farm management processes and equipment (e.g., video monitoring or passive acoustic systems) to monitor seabird interactions and incidents, once the farm is operating. This should last for the first year of operation and cover all seasons. Report interactions and incidents to DOC, including: • recorded, categorised, and quantified interactions/incidents, for the first year of operation; • footage and/or photographs where available; • reporting on protected seabird injuries and mortalities as required under the Wildlife Act 1953. Target monitoring of seabird interactions during periods potentially at higher risk of interaction (e.g., overlap between species presence/activity and farm operations) and during each stage of farm development.
Solution Monitoring (Level 3)	If level 2 monitoring identifies a significant interaction or increased risk, increase monitoring effort (e.g., use real-time farm monitoring systems, passive acoustics, etc.) to assess: • seabird behaviour around farms; • cause and duration of attraction; • type and outcomes of interactions. Investigate attraction factors and identify mitigation solutions of seabird interactions are commonplace and/or results in entanglements.

2.4 Structure of seabird monitoring guidance

Understanding and adequately mitigating adverse effects of open ocean finfish aquaculture farms will not be possible without baseline and standardised seabird monitoring across this industry sector. These guidelines propose three levels of monitoring that could be implemented with any new finfish farm proposal (see Table 3). Depending on the outcomes of the various levels, monitoring can be modified and tailored to best address the concerns at each site.

In the first instance (Level 1), one year of baseline monitoring is required at the proposed open ocean aquaculture site. Most level 2 and 3 monitoring is expected to be undertaken by existing remote farm operational systems, because it is assumed that a large portion of day-to-day operational monitoring at open ocean finfish farms will be undertaken remotely. It is envisaged that the monitoring approach will be developed in consultation with scientists, and that monitoring will be operated and maintained by the consent holder, as specified in the resource consent and audited by the council. These approaches are reliant upon farm operators maintaining protocols and are part of the regulatory consent compliance that can be enforced by councils.

The consent holder will also be in the unique position to assess the significance of these interactions and develop solutions more effectively, while gathering much needed data on the knowledge and research gaps identified below, which would serve to refine and develop future guidelines.

3. FUTURE RESEARCH REQUIREMENTS

There are significant knowledge gaps concerning almost all seabird species, their marine habitat preferences, and the probability of risk arising from open ocean finfish aquaculture farms in New Zealand. With the move to locate aquaculture farms in open ocean waters, where an increase in the diversity and abundance of species is likely, future research should also focus on the seabird species utilising these new areas. Fisheries New Zealand will look to prioritise the delivery of these research needs as soon as possible.

3.1 Seabird populations

- Detailed information on the time-specific distribution, abundance, and critical habitats is lacking. There have been few dedicated systematic seabird surveys at sea. Most data used in assessments have been derived from eBird, which for seabirds are mostly limited to observations from ferries (Cook Strait, Foveaux Strait), and seabird watching trips (Hauraki Gulf, Marlborough Sounds, Kaikōura, Rakiura/Stewart Island). Reports from Fisheries New Zealand observers have also been used, but these are limited to areas where vessels are fishing and by the rate of observer coverage. Exceptions are the research into King shag foraging, and the movement tracking of yellow-eyed and Fiordland crested penguins (Foveaux Strait), Gibson's, Antipodean, Buller's, white-capped, and Salvin's albatrosses (from breeding colonies on Snares, Auckland, and Bounty islands, respectively), and black petrel and flesh-footed shearwater, as well as preliminary tracking for Buller's shearwater, fluttering shearwater, fairy prion, common diving petrel, Australasian gannet, and little penguin (Hauraki Gulf).
- To address this knowledge gap, dedicated seasonal seabird surveys are needed in potential open ocean farm zones, to identify whether seabirds are actively foraging/feeding or passaging through the areas.
- Surveys are required for seabirds that breed within the vicinity of proposed ocean marine farm zones to establish baseline populations and study sites to determine trends—relevant for species with limited foraging ranges during breeding (e.g., penguins, some petrels, shags, gulls, and terns).
- More support for population studies on threatened species with wider foraging distributions will be important because these are likely to be the primary seabirds in contact with open ocean marine farms.

3.2 Seabird Interactions

- Although there has been an increase in research into aspects of seabird biology in recent years, there remain significant gaps in the knowledge of diet and feeding behaviours, including nocturnal feeding and if and how this affects risk to seabirds from open ocean farming. Investigating the foraging ecology of seabirds is especially challenging given their wide-ranging movements and the practical difficulties of obtaining unbiased information on their feeding behaviour and diet.
- It is well-known that physical structures in the water column tend to aggregate fish around them, and several studies have shown the importance of fish pen aquaculture structures as Fish Aggregation Devices (FADs). Further attraction can be derived from the presence of fish, fish feed, and lighting.
- It is possible, albeit unlikely, that open ocean finfish aquaculture could change the diet for some species, and this would need further investigation. The effects of submerged lighting on zooplankton and bait fish have not been examined in an open ocean situation in New Zealand and would also be an important area of future research.
- Research into potential mitigation methods for open ocean structures including appropriate mesh sizes, thickness, and visibility.

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6. SUPPLEMENTARY MATERIAL

Supplementary Table 1: Body sizes for selection of New Zealand seabirds which dive in pursuit of prey where available. Head is the circumference (diameter) of the head, Body is the circumference (diameter) of the body at the shoulders, Span is the wing or flipper span. Note: circumference measurements are from live birds. Wingspan measurements are from Heather & Robertson (2000).

Species	Head (cm)	Body(cm)	Span (cm)	Diving behaviour
Eudyptes pachyrhynchus Fiordland crested penguin (also *Eudyptes robustus* Snares crested penguin)				Flipper propulsion
Megadyptes antipodes Hoiho (Yellow-eyed penguin)				Flipper propulsion
Eudyptula minor Little (Blue) penguin				Flipper propulsion
Procellaria parkinsoni Black petrel			115	Wing propulsion (wings flexed, not fully open), also feet
Puffinus carneipes Flesh-footed shearwater (also *Puffinus griseus* Sooty shearwater)			FFS: 99–107 SS: 94–105	Wing propulsion (wings flexed, not fully open), also feet
Puffinus bulleri Buller's shearwater	12 (5)	25(8)	97–99	Wing propulsion (wings flexed, not fully open), also feet
Puffinus assimilis Little shearwater (also *Puffinus gavia* Fluttering Shearwater and *Puffinus huttoni* Hutton's Shearwater)	6 (3)	20 (6)	LS: 58–67 FS: 76 HS: 72–78	Wing propulsion (wings flexed, not fully open), also feet
Pelecanoides urinatrix Common diving petrel (also *Pelecanoides whenuahouensis* Whenua Hou diving petrel)	8 (3)	16.3 (5)	33–38	Wing propulsion (wings flexed, not fully open), also feet
Morus serrator Australasian gannet	30	31.5	170–200	Wing propulsion (wings flexed, not fully open), also feet
Phalacrocorax varius Pied shag			110–130	Feet propulsion, wings held closed to body
Stictocarbo punctatus Spotted shag			91–99	Feet propulsion, wings held closed to body