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Guidance for identifying appropriate water quality, benthic, and hydrodynamic effects monitoring for non-fed aquaculture in the Waikato region

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Pisces Consulting

Coastal and marine environmental services

Guidance for identifying appropriate water quality, benthic, and hydrodynamic effects monitoring for non-fed aquaculture in the Waikato region

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4 October 2023

Prepared for Waikato Regional Council

Summary

Purpose and scope

This document provides practical guidance for consent holders, science providers, and Waikato Regional Council (WRC) to identify appropriate monitoring of water quality, benthic, and hydrodynamic effects of non-fed aquaculture, such as shellfish spat catching and on-growing, and seaweed farming. These effects are generally well understood and are of relatively low risk to the coastal environment.

The monitoring framework is designed for the general scale and type of non-fed aquaculture present in the Waikato CMA at the time of preparing the guidance but anticipates an increased scale of seaweed aquaculture. For marine farms outside this scope the guidance will still be informative but may not provide a complete set of monitoring requirements.

This guidance is not intended to be prescriptive. Instead, it provides a framework for identifying appropriate monitoring in the context of local environmental characteristics and sensitivities, and the nature and intensity of predicted effects from the marine farm.

This guidance can be used at any stage of a resource consent for non-fed aquaculture, including:

- To identify appropriate monitoring for a new commercial marine farm and develop a (draft) environmental monitoring plan (EMOP) to be submitted with a resource consent application for a new marine farm.
- To identify appropriate monitoring as part of a monitoring review, for example a review of the EMOP or consent conditions stipulating monitoring requirements.
- To support the identification of appropriate monitoring for a change or addition to an existing marine farm, such as a farm extension or change of species.
- To identify appropriate monitoring (within the confines of the applicable planning provisions) where an existing marine farm is seeking a renewal of its resource consent.

This guidance is non-statutory. While the monitoring framework presented in this guidance identifies monitoring 'requirements', in a resource consent compliance context, these represent recommendations only. Also, for existing consents to avoid any concerns or doubt, the existing consent conditions always prevail. Site- or farm-specific circumstances may require deviation from the identified monitoring requirements. The monitoring framework applies primarily to the identification of new or review of monitoring requirements for commercial aquaculture. Considerations for non-commercial and multi-trophic aquaculture as well as farm extensions are also provided.

Monitoring framework

The monitoring framework presented in this guidance ensures that monitoring is focussed on relevant environmental change and avoids monitoring environmental change that is associated with ecologically inconsequential or minor adverse effects, or effects that are, in the relevant environmental context, generally considered positive, for example because the environmental change represents an increase in biodiversity or remediates nutrient enrichment.

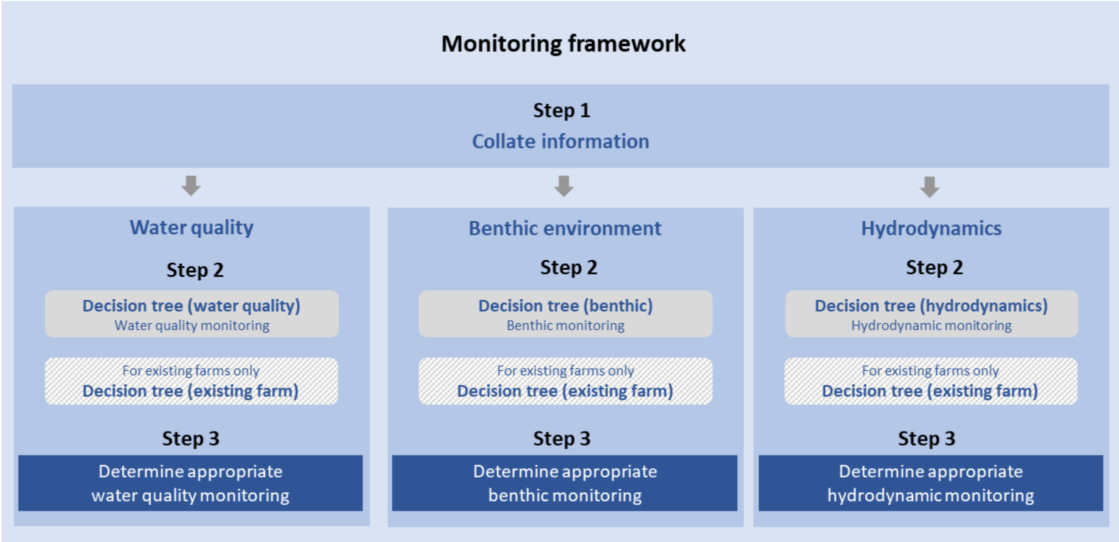
It is expected that for some marine farms applying this guidance will not identify any monitoring requirements, while for others a subset of all potential monitoring requirements discussed in this guidance will apply. Due to the nature of sites where aquaculture is enabled in the Waikato Coastal

Marine Area (CMA), it is unlikely that the full suite of potential monitoring requirements will be applicable to a single marine farm.

A central aspect of the framework is the review of monitoring requirements over time to ensure that monitoring is responsive to improved knowledge. There is a general expectation that monitoring requirements for a marine farm decrease over the duration of consent as actual individual and cumulative effects of the farm are better understood and thus require less or no further monitoring.

The monitoring framework is structured around potential adverse water quality, benthic, and hydrodynamic effects of non-fed aquaculture relevant to the Waikato CMA that have been identified from the scientific literature. These potential effects:

1. **Effects on water quality**
    - **WQ1**: Depletion of phytoplankton through filtration or competition for nutrients to levels at/or below those inducing adverse changes to the food web.
    - **WQ2**: Nitrogen reduction to levels below those required for natural populations of primary producers such as phytoplankton and wild marine macroalgae and plants.
2. **Effects on the benthic environment**
    - **B1**: Adverse effects on benthic features (taxa, areas, habitats, ecosystems, vegetation types, routes, and ecological corridors) specified in NZCPS Policy 11 or identified as ecologically significant in the operative or proposed Waikato Regional Coastal Plan (WRCP).
    - **B2**: Adverse effects on benthic infaunal communities from organic enrichment of sediments.
    - **B3**: Smothering of, or other adverse effects of ecological concern on, benthic habitats, flora, or epifauna communities due to biodeposition, biofouling or crop drop-off.
    - **B4**: Adverse effects on benthic flora or fauna sensitive to light reduction from shading of the seabed by farm structures or crop.
    - **B5**: Leaching of chemical contaminants from treated timber structures.
3. **Effects from changes in hydrodynamic conditions**
    - **H1**: Changes in current, wave, and/or flushing dynamics that adversely impact nationally or regionally significant surf breaks or cause environmental or ecological changes of concern.



Applying the monitoring framework requires three steps:

Step 1: Collate information

The first step in the monitoring framework is collating location- and farm-specific information, including marine farm set-up, water column and benthic characteristics, and predicted effects.

Step 2: Identify the appropriate potential effects to be monitored

Under the second step the potential effects to include in monitoring are identified. Three decision trees[1] (water quality, benthic, and hydrodynamic monitoring; shown below) guide through a series of questions that combine farm- and location-specific information with the existing knowledge and Waikato-specific experience on non-fed aquaculture effects and environmental sensitivities.

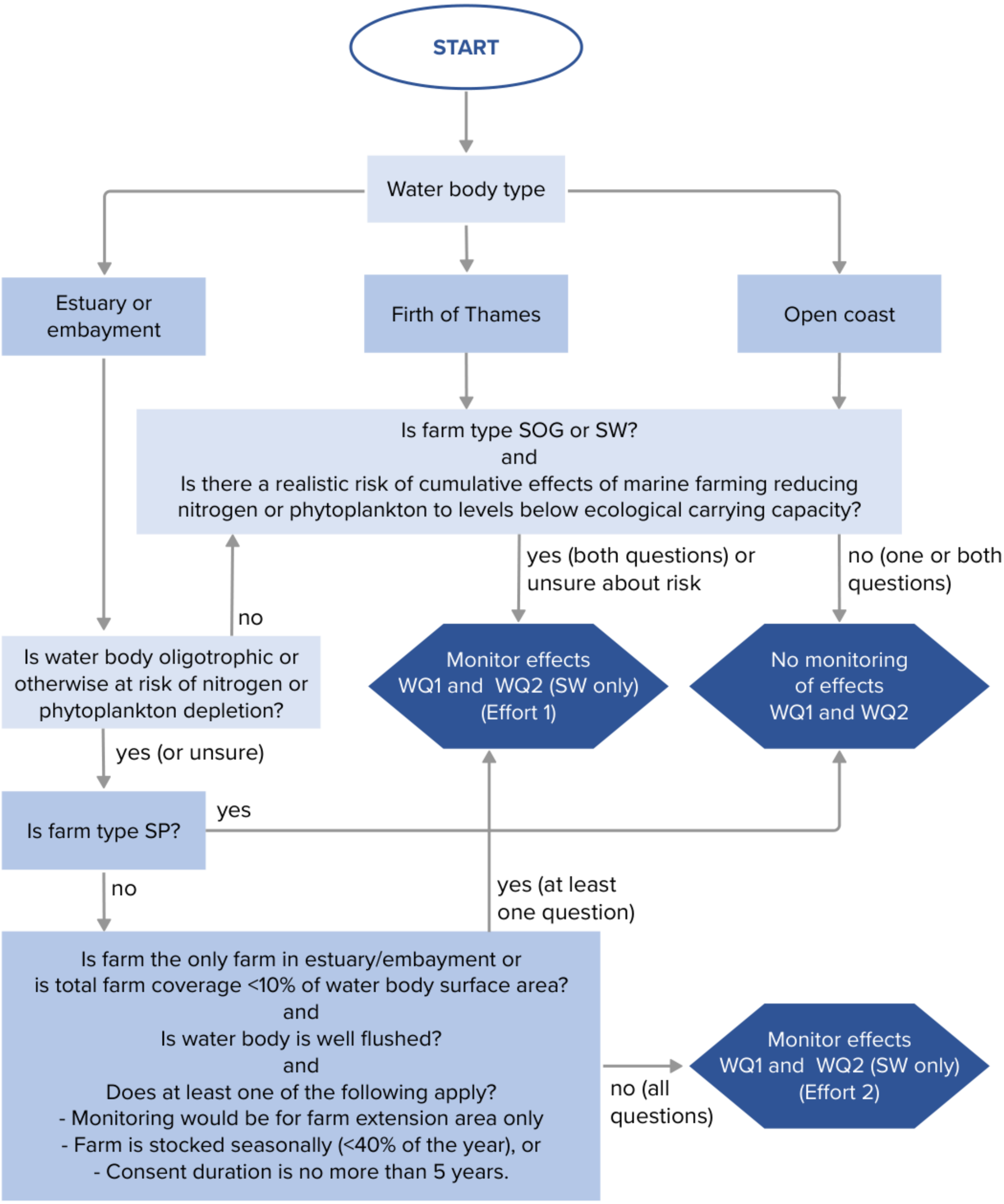
Step 3: Determine appropriate monitoring

In the final step of the monitoring framework, appropriate specific monitoring requirements are determined, including indicators, sampling and analysis methods, monitoring frequency and reporting.

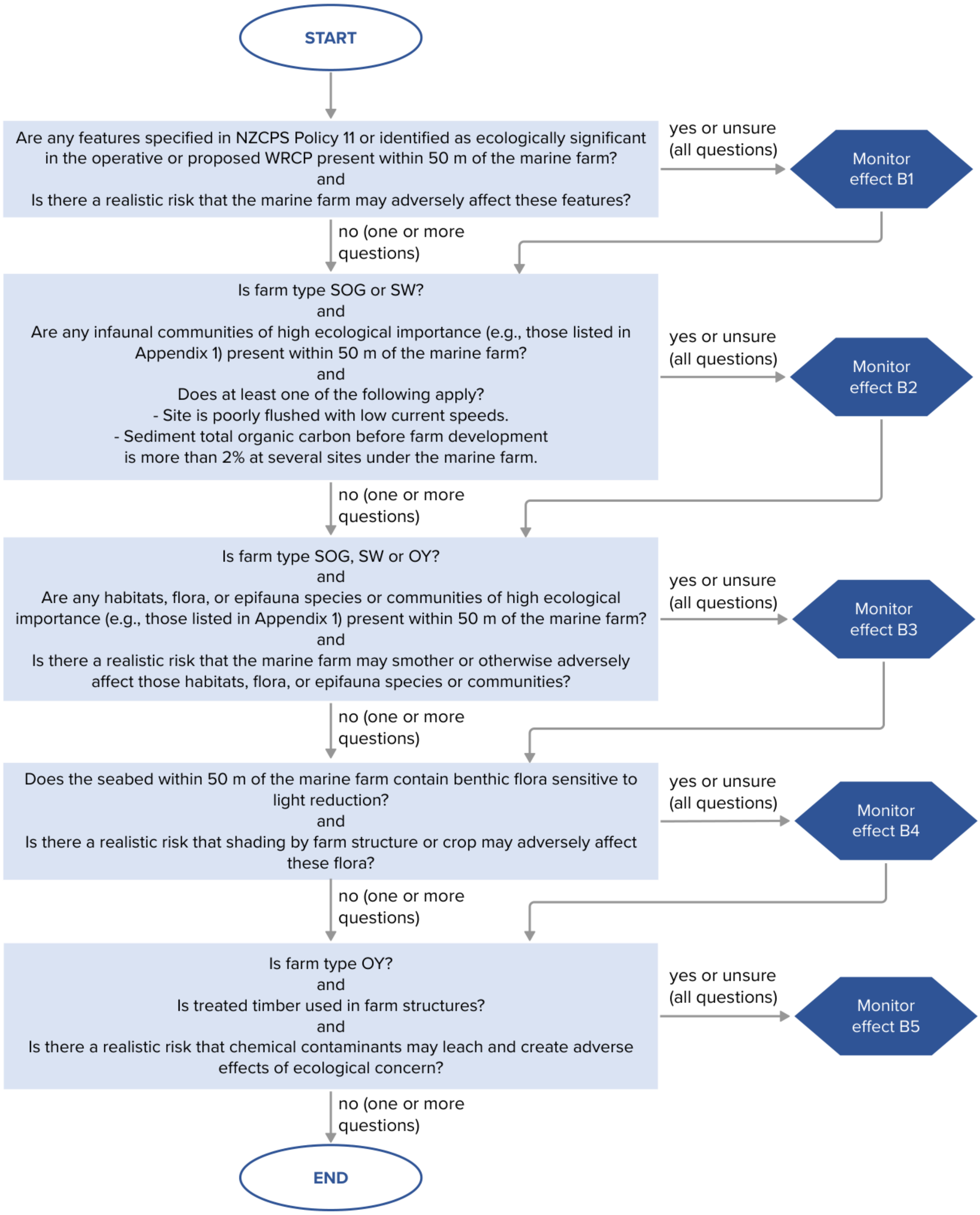
[1] The following acronyms are used in the decision trees: SOG (subtidal shellfish on-growing), SP (spat catching), OY (oyster farming), SW (seaweed farming), NZCPS (New Zealand Coastal Policy Statement), WRCP (Waikato Regional Coastal Plan). Effort 1 and 2 denote monitoring effort. The use the decision trees is explained in this guidance.

Decision trees for identifying appropriate potential effects to be monitored

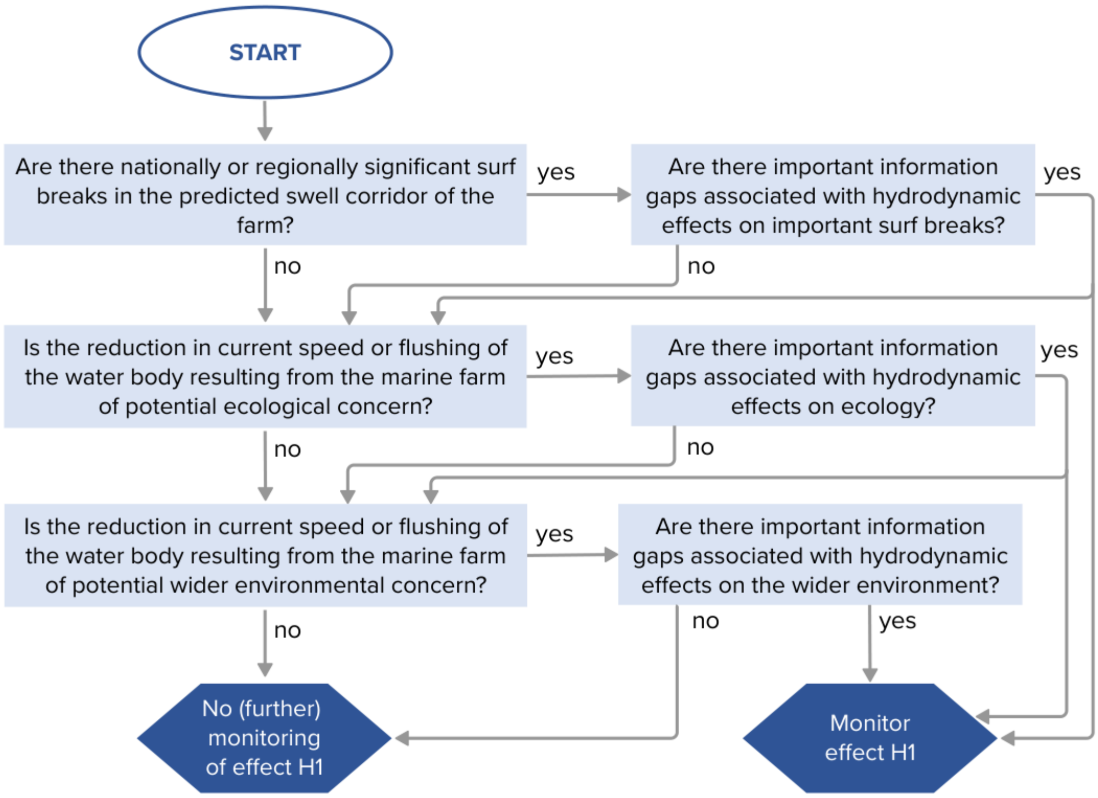
Water quality monitoring



Benthic monitoring



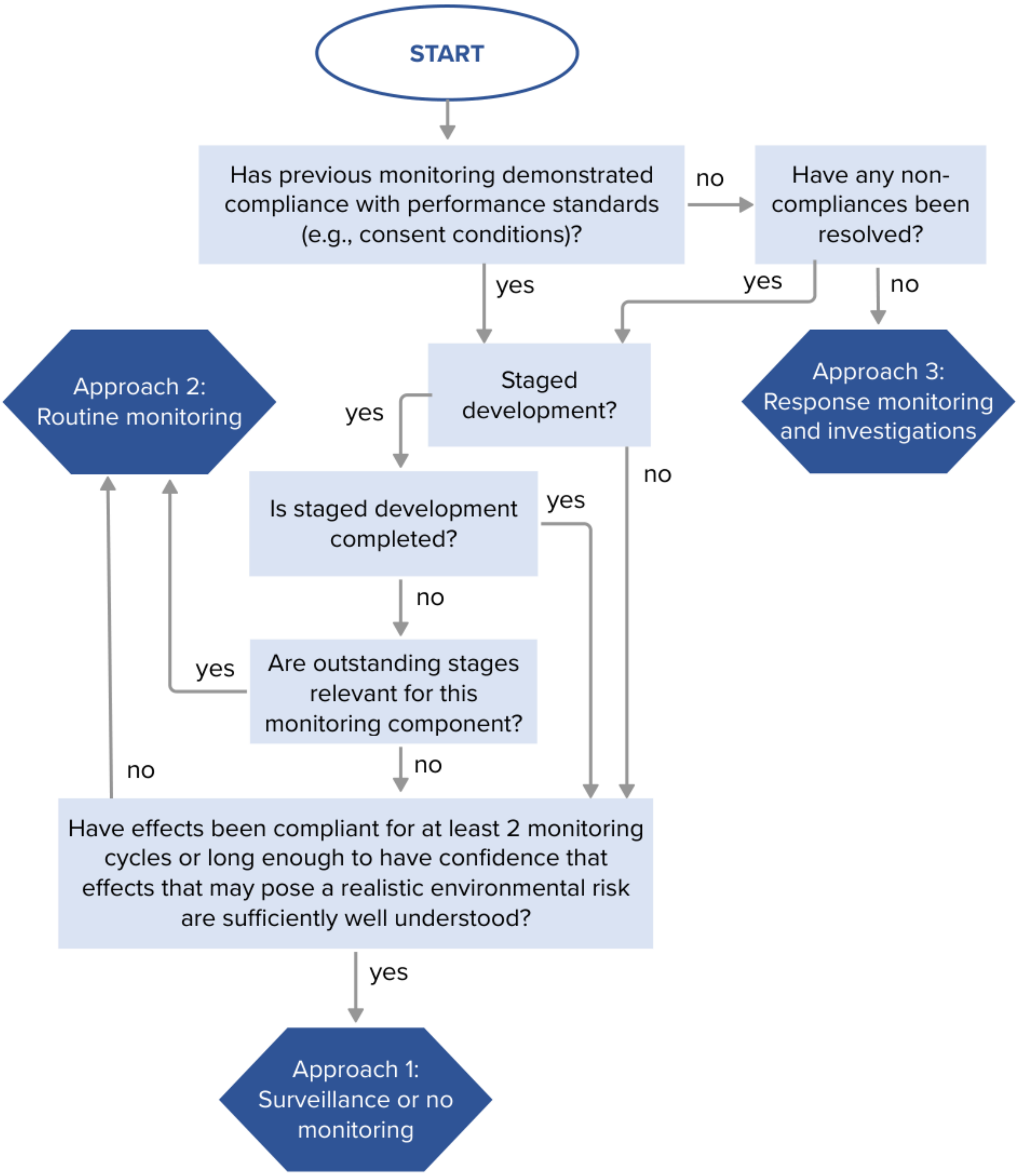
Hydrodynamic monitoring



Applying the monitoring framework to existing farms

If the monitoring framework is applied to an existing consented marine farm, for example during the review of a monitoring programme, the farm's monitoring and compliance history and development state needs to be considered. For existing farms an extra step is therefore required within the monitoring framework. For each type of monitoring being reviewed (i.e., water quality, benthic, and/or hydrodynamic monitoring) the decision tree below assists with determining whether the overall monitoring approach should be surveillance or no monitoring, routine monitoring or response monitoring and investigations.

For existing consented marine farms identified monitoring recommendations may be more or less comprehensive than those stipulated in the existing consent conditions. If consent conditions require monitoring that is not identified as necessary under the framework it may be possible to monitor at a reduced effort. In these situations, an applicant may consider applying for a variation of their consent condition(s). If applying the framework during a review of monitoring requirements identifies recommendations that are more comprehensive than those stipulated in consent conditions, compliance needs for the marine farm would not change under the existing consent and the corresponding monitoring would not be necessary.


START
Has previous monitoring demonstrated compliance with performance standards (e.g., consent conditions)?
no
Have any non-compliances been resolved?
yes
yes
no
Approach 2: Routine monitoring
Staged development?
Approach 3: Response monitoring and investigations
yes
no
Is staged development completed?
yes
no
yes
Are outstanding stages relevant for this monitoring component?
no
no
Have effects been compliant for at least 2 monitoring cycles or long enough to have confidence that effects that may pose a realistic environmental risk are sufficiently well understood?
yes
Approach 1: Surveillance or no monitoring

Developing the monitoring programme

The framework provides a process for identifying monitoring requirement 'from scratch'. While working through the three decision trees, potential effects are considered and either included or excluded in the derived monitoring programme. For water quality monitoring, recommended monitoring effort is also identified. For benthic and hydrodynamic monitoring this needs to be determined on a case-by-case basis.

Specific recommendations for monitoring of the identified potential water quality, benthic, and hydrodynamic effects that require monitoring are then derived from tables that combine effects to be monitored, monitoring effort, and, for existing farms, outcomes of considering monitoring history and farm development progress.

The monitoring framework can incorporate comprehensive baseline data, but it is also applicable in situations where baseline data is limited or uncertain. The decision trees provide options for information gaps; generally, they result in a more comprehensive monitoring programme due to the uncertainties typically associated with information gaps. A summary of the baseline data recommended for applying the monitoring framework is provided in the table below.

Data/information	Type of monitoring and applicable effect(s)		
	Water quality	Benthic	Hydro-dynamic
Baseline data required or recommended for using decision trees			
Estimated trophic state of water body (specifically, whether oligotrophic or at risk of phytoplankton or nitrogen depletion)	✓ (WQ1, WQ2)		
Total area covered by existing marine farms in water body	✓ (WQ1, WQ2)		
Size (area) of the water body	✓ (WQ1, WQ2)		
Current speeds and flushing characteristics of water body	✓ (WQ1, WQ2)	✓ (B2)	
Benthic habitats, epifauna and infauna communities, and benthic flora within ~50 m of the marine farm		✓ (B1, B2, B3, B4)	
Sediment total organic carbon content under marine farm		✓ (B2)	
Presence of important surf breaks in predicted swell corridor of farm			✓ (H1)
Presence of ecosystem components in the water body sensitive to reductions in current speed or flushing			✓ (H1)
Coastal processes in the water body sensitive to reductions in current speed or flushing			✓ (H1)
Baseline data recommended to inform appropriate monitoring design			
Sufficient understanding of spatial and temporal variability in the indicators to be monitored to: • Inform selection of monitoring sites, including reference sites • Inform sampling effort • Inform statistical approach for detecting farm effects, including evaluation of appliable limits and thresholds	✓ (All)	✓ (All)	
Sufficient understanding of flow, substrate, habitats, slope, and depth of farm site and surrounding environment to inform selection of suitable reference site(s).		✓ (All)	
Sufficient understanding of the factors influencing the likely time of the year when farm effects have greatest biological impact to inform decisions on the time of monitoring.		✓ (All)	

Application to example scenarios

The guidance provides three example applications of the monitoring framework to hypothetical marine farm scenarios:

Scenario 1: A new longline mussel farm in a well-flushed embayment;

Scenario 2: A new intertidal oyster farm in a sheltered intertidal area of estuary; and

Scenario 3: A 1 ha longline mussel farm extension in an open coast environment.

For each example, the marine farm set-up and environmental context are described and the process of working through the respective decision trees and identifying the specific components of monitoring, including monitoring review, are explained.

These examples illustrate how to use the monitoring guidance and demonstrates how to identify appropriate monitoring proportionate to the intensity of predicted effects and the site-specific nature and sensitivity of the receiving environment.

These examples also highlight that many potential effects are not recommended to be included in monitoring. The approach to identifying appropriate monitoring allows for monitoring requirements to change over time, in most cases justifying reductions in monitoring effort over the duration of consent, including partial or complete cessation of monitoring components.

While it does not directly apply to assessments of environmental effects (AEEs), this guidance can inform AEEs by identifying potential water quality, benthic, and hydrodynamic effects of relevance to a planned marine farm.

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1 Introduction

1.1 Scope and purpose of this guidance

This non-statutory guidance provides practical guidance for consent holders, science providers, and Waikato Regional Council (WRC) to identify appropriate monitoring of water quality, benthic, and hydrodynamic effects of non-fed aquaculture, such as shellfish spat catching and on-growing, and seaweed farming. These effects are generally well understood and are of relatively low risk to the coastal environment.

The monitoring framework used to identify monitoring requirements described in this guidance ensures that monitoring is focussed on relevant environmental change and avoids monitoring environmental change that is associated with ecologically inconsequential or minor adverse effects, or effects that are, in fact, generally considered positive, for example because the environmental change represents an increase in biodiversity or remediates nutrient enrichment.

Whether monitoring is required generally depends on the sensitivity of the receiving environment, the nature and intensity of predicted effects, and the level of uncertainty in effects predictions. Monitoring provides information on environmental change generated by the presence and/or operation of the marine farm, which enables an assessment of the actual effects of the marine farm and robust decision-making on effects management and monitoring review.

The purpose of this guidance is to support the development of targeted, effective, and efficient water quality, benthic, and hydrodynamic monitoring programmes that:

1. Have a clearly defined purpose and clear monitoring objectives.
2. Are relevant and proportionate to the intensity of predicted effects and the site-specific nature and sensitivity of the receiving environment without being unnecessary onerous.
3. Focus on detecting effects that are:
    a. Uncertain but pose a realistic environmental risk;
    b. Potentially unacceptable; and
    c. Required to be monitored to assess limits or thresholds in consent conditions or to inform adaptive management.
4. Enable management responses to be taken in response to monitoring results.
5. Are underpinned by current knowledge on the potential effects of and the sensitivities of the environment to non-fed aquaculture relevant to the Waikato Coastal Marine Area (CMA).
6. Recognise that monitoring requirements change over time, which, in most cases, justifies reductions in monitoring effort over the duration of consent, including partial or complete cessation of monitoring components.

This guidance is not intended to be prescriptive. Instead, it provides a framework for identifying appropriate monitoring in the context of local environmental characteristics and sensitivities, and the nature and intensity of predicted effects from the marine farm. At the same time, it is designed to be applicable when information is limited.

It is expected that for some marine farms applying this guidance will not identify any monitoring requirements, while for others a subset of all potential monitoring requirements discussed in this guidance will apply. Due to the nature of the Waikato CMA, it is highly unlikely that the full suite of potential monitoring requirements will be applicable to a single marine farm.

A central aspect of the framework is the review of monitoring requirements over time to ensure that monitoring is responsive to improved knowledge, e.g., knowledge derived from consent-related or State of the Environment (SOE) monitoring, or scientific research. There is a general expectation that monitoring requirements for a marine farm decrease over the duration of consent as actual individual and cumulative effects of the farm are better understood and thus require less or no further monitoring.

1.2 When to use this guidance

This guidance can be used at any stage of a resource consent for non-fed aquaculture, including:

- To identify appropriate monitoring for a new commercial marine farm and develop a (draft) environmental monitoring plan (EMOP) to be submitted with a resource consent application for a new marine farm.
- To identify appropriate monitoring as part of a monitoring review, for example a review of the EMOP or consent conditions stipulating monitoring requirements.
- To support the identification of appropriate monitoring for a change or addition to an existing marine farm, such as a farm extension or change of species.
- To identify appropriate monitoring (within the confines of the applicable planning provisions) where an existing marine farm is seeking a renewal of its resource consent.

This guidance also assists with identifying baseline data requirements for monitoring. Furthermore, while it does not directly apply to assessments of environmental effects (AEEs), this guidance can be used to inform AEEs by identifying potential water quality, benthic, and hydrodynamic effects of relevance to a planned marine farm.

Some considerations for identifying monitoring requirements for non-commercial and multi-trophic aquaculture are also provided.

1.3 Considerations of monitoring requirements stipulated in consent conditions

The monitoring framework provides a process for identifying monitoring requirement 'from scratch'. As part of the process, all potential effects that may need to be monitored (described in section 2) are considered and either included or excluded in the derived monitoring programme. If the framework is applied to an existing consent, it is possible that identified monitoring requirements are different from those stipulated in consent conditions. To avoid any concerns or doubt: existing consent conditions always prevail.

The monitoring framework is designed for the general scale and type of non-fed aquaculture present in the Waikato CMA at the time of preparing the guidance but anticipates an increased scale of seaweed aquaculture. For marine farms outside this scope the guidance will still be informative but may not provide a complete set of monitoring requirements.

If consent conditions (or other consent compliance documents) require monitoring of potential effects that are not identified as necessary under the framework, the respective potential effects need to be included in the monitoring framework, but it may be possible to select a low monitoring level and reduced monitoring effort. However, if limits, thresholds, or other monitoring-related compliance requirements are stipulated in consent conditions, care needs to be taken to ensure the appropriate monitoring data is collected. Alternatively, it may be worth considering applying for a variation of the respective consent condition(s).

1.4 Structure of this guidance document

This guidance document is structured as follows:

- Section 2 provides a summary of potential adverse water quality, benthic, and hydrodynamic effects of non-fed aquaculture that underpin the monitoring framework.
- Section 3 describes the monitoring framework used to identify water quality, benthic, and hydrodynamic monitoring requirements and provides brief considerations for special cases, specifically non-commercial aquaculture, species diversification, multi-trophic aquaculture, and farm extensions.
- Section 4 describes baseline data required for applying the monitoring framework and monitoring programme design.
- Section 5 provides guidance for preparing an EMOP.
- Section 6 presents example applications of the monitoring framework to hypothetical marine farm set-ups.

2 Potential adverse effects of non-fed aquaculture that may require monitoring

2.1 The role of potential adverse effects in identifying appropriate monitoring

The monitoring framework presented in this guidance is structured around potential adverse effects[2] of non-fed aquaculture relevant to the Waikato CMA. This section describes these effects and relevant contextual information that underpinned the design of the monitoring framework introduced in section 3.

As explained earlier, it is highly unlikely that all effects described in this section will need to be monitored and the monitoring framework assists with identifying effects that are relevant and thus appropriate for inclusion in a specific monitoring programme. The examples shown in section 6 demonstrate that in typical non-fed marine farm set-ups only few potential effects require monitoring.

2.2 Potential adverse water quality, benthic, and hydrodynamic effects of non-fed aquaculture

Potential adverse water quality, benthic, and hydrodynamic effects have been identified from the scientific literature, focussing on national and Waikato CMA-specific publications, including Ministry for Primary Industries (2013a), Keeley (2013), Plew (2013), Stenton-Dozey (2013), Forrest et al. (2015), and Clark et al. (2021), as well as a recent review by Giles (2021) and publications cited within. This document does not provide a full literature review but includes citations where appropriate to support statements made.

[2] Unless otherwise specified, the term ‘potential effect’ in the remainder of this document refers to ‘potential adverse effect’.

The potential effects underpinning the monitoring framework are:

1. Effects on water quality
    - WQ1: Depletion of phytoplankton through filtration or competition for nutrients to levels at/or below those inducing adverse changes to the food web.
    - WQ2: Nitrogen reduction to levels below those required for natural populations of primary producers such as phytoplankton and wild marine macroalgae and plants.
2. Effects on the benthic environment
    - B1: Adverse effects on benthic features (taxa, areas, habitats, ecosystems, vegetation types, routes, and ecological corridors) specified in NZCPS Policy 11 or identified as ecologically significant in the operative or proposed Waikato Regional Coastal Plan (WRCP).
    - B2: Adverse effects on benthic infaunal communities from organic enrichment of sediments.
    - B3: Smothering of, or other adverse effects of ecological concern on, benthic habitats, flora, or epifauna communities due to biodeposition, biofouling or crop drop-off.
    - B4: Adverse effects on benthic flora or fauna sensitive to light reduction from shading of the seabed by farm structures or crop.
    - B5: Leaching of chemical contaminants from treated timber structures.
3. Effects from changes in hydrodynamic conditions
    - H1: Changes in current, wave, and/or flushing dynamics that adversely impact nationally or regionally significant surf breaks[3] or cause environmental or ecological changes of concern.

Table 1 provides monitoring-related information on these potential effects relevant to the Waikato region. Most potential effects only apply to a subset of non-fed aquaculture types, and this is indicted in the second column of Table 1. For example, potential effect WQ1 (Depletion of phytoplankton through filtration or competition for nutrients) only applies to subtidal shellfish on-growing (SOG) and seaweed farming (SW). Whether monitoring is required for a specific subtidal shellfish on-growing or seaweed farm depends largely on site-specific environmental conditions and farm-specific considerations and is determined by applying the monitoring framework presented in section 3 of this guidance. However, for oyster farming (OY) or spat catching (SP), there is never a need to monitor potential effect WQ1 because it is well known that these types of marine farming have negligible effects on phytoplankton or nutrient levels, irrespective of site-specific environmental conditions.

Table 1 describes known conditions under which monitoring is unlikely to be required and conditions that indicate monitoring may be required. This information aims to assist with determining farm-specific monitoring requirements and underpins the monitoring framework presented in section 3. For example, it is unlikely that monitoring of potential effects WQ1 and WQ2 is required in water bodies known to be mesotrophic or ecosystems at risk of nutrient enrichment (eutrophication) because in these ecosystems the level of phytoplankton reduction caused by shellfish or the level of nutrient

[3] Nationally and regionally surf breaks are identified in Atkin and Mead (2016).

uptake by farmed seaweed is known be small and is generally considered to have positive consequences on the water body by alleviating eutrophication risk.

For each potential effect, a description of the environmental change to be measured through monitoring is described. It is important that the environmental characteristics (typically referred to as indicators) measured are appropriate for robustly detecting and quantifying the magnitude of environmental change directly related and relevant to the potential effect. Whenever possible, indicators should be easily measurable following standard methods and be cost-effective options for achieving required outcomes.

Monitoring objectives suggested in Table 1 are intended to provide specific goals for monitoring that support a focussed and effective monitoring approach. Monitoring objectives should describe monitoring goals in clear and measurable terms that can be evaluated through monitoring results, stipulating specific limits or thresholds if possible and ecologically meaningful. If monitoring objectives have been met, it is recommended that monitoring requirements are reviewed as it may be appropriate to discontinue monitoring or reduce monitoring effort.

Finally, Table 1 provides some general comments relevant to the potential effects, including under which conditions the effects may be considered negligible or ,in fact, positive, and thus do not need to be monitored within a consent-related monitoring programme.

2.3 Potential environmental changes typically of low concern and not required to be monitored

Additional environmental changes to those described above have been raised in relation to specific marine farms and/or in scientific studies as potential adverse effects of non-fed aquaculture. Most were raised in the beginnings of large-scale mussel farm developments in New Zealand. These environmental changes include:

- Dissolved oxygen reduction in the water column due to enhanced organic enrichment from mussel farming;[4]
- Nutrient enrichment due to mussel nitrogen release;[5]
- Exacerbation of harmful algal blooms (HAB) through nitrogen release by mussels;[6] and

[4] Broekhuizen et al., (2002) stated that oxygen depletion within the water column is generally considered unlikely in shellfish aquaculture operations. This view has been strengthened over time and a reduction in dissolved oxygen is typically not considered a relevant potential effect of non-finfish aquaculture.

[5] Changes in water column nitrogen typically rapidly manifest as changes in phytoplankton because nitrogen tends to be the element limiting primary production (Broekhuizen et al., 2002). Primary producers, such as phytoplankton, are the most immediate sink for dissolved nutrients and more appropriate for monitoring to assess carry-on effects of increases in nutrient concentrations instead of monitoring nutrients directly (Forrest et al., 2015).

[6] Harmful algal blooms (HABs) represent a particular risk in mussel growing waters (including a risk to aquaculture operations) and at times questions arise on whether mussel farming is contributing to HABs. HABs can be a natural phenomenon. Although such blooms may be influenced by seawater nutrient concentrations, there is no evidence in to indicate that mussel farming in New Zealand causes or exacerbates HABs (Ministry for Primary Industries, 2013a).

- Changes in zooplankton communities, including copepods, fish and invertebrate eggs and larvae.[7,8]

Based on current scientific information and the nature of the Waikato CMA, it is unlikely that non-fed aquaculture in the Waikato CMA would cause these environmental changes, but, if it would, it is unlikely that associated effects would be of ecological concern. For these reasons, these environmental changes are not included in the monitoring framework.

If applicable to a specific marine farm, such atypical adverse effects and associated monitoring requirements would be identified during the consenting process. As for all aspects of monitoring, requirements stipulated in consent conditions prevail over those identified in this non-statutory guidance.

2.4 Cumulative effects

Cumulative effects of marine farms can occur from multiple stressors of the same type (e.g., multiple mussel farms in one bay) or from the interaction of different stressors (e.g., changes in phytoplankton caused by a seaweed farm, sediment run-off from land, and climate change). In the context of other stressors affecting coastal ecosystems, effects from non-fed marine farming are generally benign.

Addressing cumulative effects is inherently complex and challenging. Cumulative effects can operate on different spatial and temporal scales and monitoring cumulative effects requires broad-scale (e.g., regional) and long-term approaches. While most people broadly understand the concept of cumulative effects, widely accepted or standardised approaches to measuring and monitoring cumulative effects are not available.

WRC acknowledges that cumulative effects monitoring is generally not required on a single non-fed marine farm-scale basis. However, where multiple farms are in close proximity or specific cumulative effects have been identified as being of ecological concern during the consenting process, cumulative effects monitoring may be required. In these instances, monitoring requirements would need to be identified on a case-by-case basis.

For most non-fed marine farms in the Waikato CMA, cumulative effects monitoring will not be required. For this reason, cumulative effects monitoring is not included in this guidance.

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[7] Mussels most effectively extract medium sized phytoplankton (c. 52–100 µm; Safi and Gibbs, 2003) from the water column. Overseas observations and an experimental study showing mussels can extract particles as large as 600 µm (Zeldis et al., 2004) have raised speculations, but no direct evidence, that farmed mussels can alter the species composition of zooplankton (including copepods, fish and invertebrate eggs and larvae) in the medium to longer term (Stenton-Dozey, 2013). Based on modelled predictions, Broekhuizen et al. (2004) concluded that it would be unlikely that 3,600 ha of proposed mussel farms in the Wilson Bay Marine Farming Zone and the western Firth of Thames would induce anything more than subtle changes in the production or standing stock of the zooplankton community.

[8] Where mussel farms are sited over fish spawning grounds there would likely be at least some degree of uptake of fish eggs by farmed mussels, but the true vulnerability of fish eggs and larvae to predation by mussels and the rate or quantity of uptake is unknown (Ministry for Primary Industries, 2013b). It is noted that the uptake of fish eggs is an effect on wild fish stocks, which is out of scope of this guidance.

Table 1. Potential water quality, benthic, and hydrodynamic effects of non-fed aquaculture relevant to the Waikato Coastal Marine Area (CMA) that may require monitoring. For each potential effect this table shows marine farm types the effect applies to (column 2), farm- and site-specific conditions under which monitoring is unlikely to be required (column 3), conditions under which monitoring may be required (column 4), a description of the environmental change to be measured through monitoring (column 5), suggested monitoring objectives (column 6), and background information (row below). References to 'trigger value' or text in square brackets are placeholders for farm- or consent-specific triggers (e.g., limit or threshold, comparison to reference/baseline conditions, or qualitative descriptor) or respective policy wording. Information provided in columns 3, 4, and 7 underpins the monitoring framework presented in section 3 of this guidance. Marine farm types are as follows: OY = Intertidal oyster farming, SOG = Subtidal shellfish on-growing, SP = Spat catching, SW = Seaweed farming. Other acronyms used are: AEE = assessment of environmental effects, NZCPS = New Zealand Coastal Policy Statement.

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
Effects on water quality					
WQ1: Depletion of phytoplankton through filtration or competition for nutrients to levels at/or below those inducing adverse changes to the food web	SOG, SW	Mesotrophic water bodies or ecosystems at general risk of nutrient enrichment (eutrophication). Well flushed water body. Low density of non-fed marine farms in water body. The AEE has not identified this potential effect to be of ecological concern.	Filtration capacity of bivalves is high relative to residence time of water body. Oligotrophic water body or water body at or approaching its ecological carrying capacity in terms of phytoplankton depletion.	Changes in phytoplankton (chlorophyll-*a*) at impact sites compared to reference sites.	To assess whether chlorophyll-*a* reduction through [filtration (for SOW)/competition for nutrient levels (for SW)] is no greater than [enter trigger value].
Background information on potential effect WQ1	The potential for localised phytoplankton depletion hinges on the filtration capacity of bivalves relative to the residence time of water in the estuary as longer residence times give suspension-feeders more opportunity to remove particles (Dumbauld et al., 2009).[9] Phytoplankton removal can have adverse effects if it reaches or exceeds the ecosystem's ecological carrying capacity (Dumbauld et al., 2009, Keeley et al., 2009).[10] Phytoplankton are the basis of all marine food webs and depletion effects could therefore have consequences throughout the marine ecosystem; however, measuring changes to the food web beyond phytoplankton is beyond the scope of consent monitoring.				

[9] This relationship is complicated however, not only by estuarine hydrography, but also because phytoplankton population growth, not just grazing, influences density, particularly if phytoplankton are supplied with readily available nutrients released by the grazers themselves or by anthropogenic sources (Dumbauld et al., 2009).

[10] The carrying capacity can be qualitatively examined by comparing the clearance rate for a given species, the densities at which they are farmed, the trophic state and flushing characteristics of the water column (Keeley et al., 2009).

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
	Ecological carrying capacity concerns can be informed by considering current relative to historic filter feeder densities (Dumbauld et al., 2009; Bastien-Daigle et al., 2007). Furthermore, Newcombe and Broekhuizen (2018) suggested that rising sea temperatures may have played a role in declining phytoplankton levels in Pelorus Sound. Potential changes to the carrying capacity over the duration of consent in response to rising sea temperatures and phytoplankton uptake by farmed filter feeders may therefore require a periodic (~5-10 yearly) review of monitoring requirements. In ecosystems at risk of nutrient enrichment (eutrophication), the removal of phytoplankton by farmed oysters and mussels can improve water quality (Dumbauld et al., 2009; Fulford et al., 2007; Stenton-Dozey and Broekhuizen, 2019).				
WQ2: Nitrogen reduction to levels below those required for natural populations of primary producers such as phytoplankton and wild marine macroalgae and plants	SW	Mesotrophic water bodies or ecosystems at risk of nutrient enrichment (eutrophication). Well flushed water body. Low density of seaweed farms in water body. The AEE has not identified this potential effect to be of ecological concern.	Predicted nitrogen uptake of seaweeds is high relative to residence time of water body. Oligotrophic water body/low ecosystem ecological carrying capacity for additional seaweed. Large-scale seaweed farms.	Changes in dissolved nitrogen at impact sites compared to reference sites.	To assess whether dissolved nitrogen reduction through uptake by cultured seaweed is no greater than [enter trigger value].
Background information on potential effect WQ2	At a sufficiently large scale and high density, nutrient depletion by farmed seaweed could have undesirable effects on the wider ecosystem if nutrient levels are reduced below that required for natural populations of primary producers, particularly if seaweed farms are located in areas that are naturally nutrient poor or have limited water exchange (Clark et al., 2021; Keeley et al., 2009). When coastal waters are eutrophic (excessively high in nutrients), removal of nutrients could improve water quality (Clark et al., 2021). As discussed in Clark et al. (2021), several studies have shown that seaweed aquaculture has minimal effects on dissolved nitrogen (see references within). Potential changes to the carrying capacity over the duration of consent may trigger the need for a periodic (~5-10 yearly) review of monitoring requirements.				
Effects on the benthic environment					
B1: Adverse effects on benthic features (taxa, areas, habitats, ecosystems, vegetation types, routes, and	All	It is known or highly likely that no features (taxa, areas, habitats, ecosystems, vegetation types, routes, and ecological corridors) specified in NZCPS Policy 11 or identified as	Known or probable presence of features (taxa, areas, habitats, ecosystems, vegetation types, routes, and ecological corridors) specified in NZCPS Policy 11 or identified as ecologically	Changes in features (taxa, areas, habitats, ecosystems, vegetation types, routes, and ecological corridors) specified in NZCPS Policy 11 or identified as ecologically significant in the operative or	Depending on the features (potentially) present, select one or several of the following: • To assess whether the marine farm causes adverse effects on features (taxa, areas, habitats, ecosystems,

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
ecological corridors) specified in NZCPS Policy 11 or identified as ecologically significant in the operative or proposed Waikato Regional Coastal Plan (WRCP)		ecologically significant in the operative or proposed WRCP that are sensitive to effects from non-fed marine farming are present below the farm structure. The AEE has not identified this potential effect to be of ecological concern.	significant in the operative or proposed WRCP under or near the farm structure.	proposed WRCP representing adverse effects under or adjacent to the marine farm.	vegetation types, routes, and ecological corridors): o specified in NZCPS Policy 11(a) or (b); or o identified as ecologically significant in the WRCP that are greater in intensity than [specify the effects intensity not allowable under the respective policy].
Background information on potential effect B1	While it is desirable to compare monitoring result against quantitative trigger values, it is acknowledged that these may not be available for benthic features specified in NZCPS Policy 11 or identified as ecologically significant in the operative or proposed WRCP. In this instance, expert judgement will be required to interpret the monitoring objective.				
B2: Adverse effects on benthic infaunal communities from organic enrichment of sediments	SOG, SW	It is known or highly likely that no benthic infauna of ecological importance that are sensitive to effects from non-fed marine farming are present below the farm structure. Benthic environment largely unstressed with low background organic carbon, low macrofauna diversity, and low macrofauna abundance. Dispersive site. The AEE has not identified this potential effect to be of ecological concern.	Known or probable presence of infauna of ecological importance (e.g., those listed in Appendix 1) and sensitive to organic enrichment resulting from non-fed aquaculture under the marine farm. Site is poorly flushed with very little predicted (or measured) dispersal of biodeposits. Organically enriched sediment (defined as total organic carbon before farm development in the upper range or above typical levels, which in the eastern Waikato CMA is >~2%;	Changes in benthic infauna community structure reflecting adverse effects of ecological concern, including loss of ecologically important species or ecological function.	To assess whether the marine farm causes organic enrichment that reflects adverse effects of ecological concern. Enrichment effects of ecologically concern are defined as (select one): • [indicator(s)] value of [enter trigger value(s)] at [specify distance from farm boundary or location]; or • an [increase/decrease] in [indicator(s)] value of [enter trigger value(s)] at impact compared to reference sites.

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
			Morrisey et al., 2016) at several sites under the [proposed] marine farm).		
Background information on potential effect B2	Sediment enrichment under mussel farms can lead to a displacement of sensitive, including large-bodied, infauna (e.g., heart urchins, large bivalves) that provide important ecosystem function. In sediments that are low in infauna abundance and diversity, organic enrichment from non-fed marine farms has been shown to enhance infauna diversity and productivity in the Waikato region and the Marlborough Sounds and a possible re-establishment or 'substitution' of biodiversity and ecosystem services lost through anthropogenic ecosystem degradation, thus creating environmental change, which can be considered ecologically beneficial (e.g., Morrisey et al., 2016; Stenton-Dozey and Broekhuizen, 2019). Infauna species richness and density under mussel farms can also be improved by structure created by dropped mussel shell, an effect observed under one part of a mussel farm off eastern Waiheke Island (Wong and O'Shea, 2011). The spatial extent of organic enrichment depends on the local current regime. It is typically limited to within 50 m of farm structures (Keeley, 2013). Using a highly sensitive method, changes to seabed sediments were observed up to 25-100 m away from the Wilson Bay Marine Farming Zone Area A (described in Forrest et al., 2015). While it is desirable to compare monitoring result against quantitative trigger values, it is acknowledged that these may not be available for benthic infauna species. In this instance, expert judgement will be required to support the interpretation of monitoring results.				
B3: Smothering of, or other adverse effects on, benthic habitats, flora, or epifauna communities due to biodeposition, biofouling or crop drop-off	SOG, SW, OY	It is known or highly likely that no benthic habitats or epifauna or flora of high ecological value and sensitivity to adverse effects from biofouling or crop drop-off are present below farm structure. The AEE has not identified this potential effect to be of ecological concern.	Known or probable presence of habitats, flora, or epifauna of ecological importance (e.g., those listed in Appendix 1) and sensitive to drop-off from non-fed aquaculture within 50 m of the marine farm.	Change in benthic habitats, flora, or epifauna communities under and adjacent to the marine farm reflecting adverse effects of ecological concern, including loss of ecologically important species.	To assess whether biodeposition, biofouling or crop drop-off causes changes in benthic habitats, flora, or epifauna communities that reflect adverse effects of ecological concern. Effects of ecologically concern are defined as (select one): • [indicator(s)] value of [enter trigger value(s)] at [specify distance from farm boundary or location]; or • an [increase/decrease] in [indicator(s)] value of [enter trigger value(s)] at impact compared to reference sites.

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
Background information on potential effect B3	Live mussels, shell material and associated fouling biota typically settle beneath mussel longlines. High biodeposition and drop-off may have adverse effects on benthic habitats, flora, and epifauna. Because shellfish farms generally avoid rocky habitats as they are known or presumed to be more sensitive to deposition, scientific knowledge of the effects of mussel farm deposition on rocky habitats and other sensitive biogenic habitats is limited (Ministry for Primary Industries, 2013a). Mussel-culture derived benthic reefs attract mobile surface-dwelling scavengers, detritivores, and predators, such as starfish and sea cucumbers (Stenton-Dozey and Broekhuizen, 2019); however, the extent of such aggregations varies significantly between sites (Ministry for Primary Industries, 2013a). The spatial extent of biodeposition, biofouling or crop drop-off depends on the local current regime but is typically limited to within 50 m of farm structures (Keeley, 2013). Dense shell accumulation is typically confined within 10 m of farm structures (Ministry for Primary Industries, 2013a). While it is desirable to compare monitoring result against quantitative trigger values, it is acknowledged that these may not be available for benthic habitats, flora, or epifauna. In this instance, expert judgement will be required to interpret monitoring results.				
B4: Adverse effects on benthic flora or fauna sensitive to light reduction from shading of the seabed by farm structures or crop	All	It is known or highly likely that no benthic flora or fauna sensitive to light reduction are present under the farm structure. Crop density and surface coverage of farm structures and crop provides open space for sunlight to penetrate. Poor water clarity and/or relatively deep water. The AEE has not identified this potential effect to be of ecological concern.	Known or probable presence of benthic flora or fauna) sensitive to light reduction under the farm structure. High water clarity and/or relatively shallow water. Crop density and surface coverage of farm structures and crop impedes light penetration.	Change in benthic flora or fauna under the marine farm reflecting adverse effects of ecological concern, including loss of high value species.	To assess whether shading from farm structures or crop causes changes in benthic flora or fauna that reflect adverse effects of ecological concern. Shading effects of ecologically concern are defined as (select one): • [indicator(s)] value of [enter trigger value(s)] under the farm; or • an [increase/decrease] in [indicator(s)] value of [enter trigger value(s)] at impact compared to reference sites.
Background information on potential effect B4	Shading by farm structures or crop may reduce the amount of light reaching the seafloor, with potential implications for the growth, productivity, survival and depth distribution of benthic flora or fauna sensitive to light reduction, including primary producers (macroalgae, seagrass, microphytobenthos) and organisms with photosynthetic symbionts (e.g., some sponges and anemone species). For mussel farms, shading is generally not a major consideration but could conceivably arise if farms were located in environments where important primary producers were abundant directly beneath the farm structures (Keeley, 2013). Shading effects are conceivably of most importance where				

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
	oyster or mussel farms are placed across habitats in environments of relatively high water clarity, and in locations where other ecological effects (especially those from sedimentation and biodeposition) are minimal (Keeley et al., 2009). Oyster cultivation on longlines with more open space between lines has been shown to cause little reduction in eelgrass density and cover with eelgrass metrics generally scaling directly with oyster density (Dumbauld and McCoy, 2015; Skinner et al 2014; Rumrill and Poulton, 2004). Shading effects can effectively be mitigated through appropriate farm placement and spacing between longlines (Keeley et al., 2009). While it is desirable to compare monitoring result against quantitative trigger values, it is acknowledged that these may not be available for benthic flora or fauna sensitive to light reduction. In this instance, expert judgement will be required to interpret monitoring results.				
B5: Leaching of chemical contaminants from treated timber structures	OY	Moderately to well-flushed environments. The AEE has not identified this potential effect to be of ecological concern.	Poorly flushed environment. Existing high contaminant levels. Known or probable presence of benthic species with high sensitivity to contaminants.	Increase in or detection of chemical contaminant concentration at locations expected to be most impacted.	To assess whether chemical contaminant concentrations are above permitted levels [enter trigger value(s)].
Background information on potential effect B5	The levels of contaminants resulting from treated timber are normally well below regulatory standards and are far below concentrations which would cause ecological concern (Ministry for Primary Industries, 2013a).				
Effects from changes in hydrodynamic conditions					
H1: Changes in current, wave, flushing dynamics and/or stratification that adversely impact nationally or regionally significant surf breaks or cause environmental or ecological changes of concern	All	Well flushed water body. Low density of non-fed marine farms in water body. No nationally or regionally significant surf breaks and no identified environmental or ecological changes of concern resulting from potential change in hydrodynamic conditions. The AEE has not identified this potential effect to be	Nationally or regionally significant surf breaks are present in swell corridor of the farm. Predicted reduction in currents, flushing of water body, or changes in stratification patterns of potential ecological concern, e.g., in relation to phytoplankton dynamics. Predicted reduction in currents or flushing of water body of potential	Changes in [currents/waves/stratification] and spatial extent of these changes outside the marine farm, and/or Changes in ecological or environmental features as a consequence of changes in hydrodynamic conditions.	To assess whether the marine farm is causing changes in [currents/waves/stratification/ecological feature/environmental feature] greater than permitted change [enter trigger value] at [specify distance] m beyond the farm boundary.

Potential effect	Applicable farm type	Conditions unlikely to require monitoring	Conditions that may require monitoring	Environmental change to be measured	Suggested monitoring objective associated with this effect*
		of ecological or wider environmental concern.	environmental concern, e.g., changes in benthic substrate due to modified bottom water currents. Farm structures cover large proportion of water body.		
Background information on potential effect H1	Marine farms can modify hydrodynamic conditions through the presence of structures and crop. The scale of hydrodynamic effects depends on the size and layout of the farms and their location (Ministry for Primary Industries, 2013a). Farm structures can reduce current speeds but also locally increase current speed due to accelerations of flow around or beneath farmed areas (Plew, 2013). The presence of marine farms may affect water residence times or stratification, which subsequently may affect biological processes (Ministry for Primary Industries, 2013a). At the typical current densities of mussel farms in New Zealand, hydrodynamic effects are of little ecological relevance; however, the risk of effects increases with increasing densities (Ministry for Primary Industries, 2013a). Mussel farm structures can dissipate wave energy and a wave 'shadow' of reduced wave energy may extend beyond the farmed areas, potentially leading to changes in sediment transport, beach erosion and replenishment and changes in habitat for species that have acclimatised to wave conditions (Ministry for Primary Industries, 2013a; Plew, 2013). A commonly raised concern in relation to potential changes in the wave climate in New Zealand is the potential impact on surf breaks. Surf breaks of regional significance have been identified by Atkin and Mead (2016). None are located in the Firth of Thames or along the west coast of the Coromandel Peninsula, but 38 surf breaks of regional significance are located along the Waikato eastern and western coastlines. While some degree of wave dampening will occur for any mussel farm structure with surface or near surface components, the effects are likely undetectable for small farms or in sheltered areas (Ministry for Primary Industries, 2013a; Plew, 2013). The physical effects on hydrodynamic conditions will persist for the duration that the structures and crop are in place, but recovery will be nearly immediate on removal of all structures (Ministry for Primary Industries, 2013a). Monitoring may focus on the consequences of changes in hydrodynamics of concern (e.g., surf breaks, seagrass beds) instead of hydrodynamics conditions near the farm; however, this requires careful consideration of natural variability and other factors influencing the monitored features.				

* These monitoring objectives illustrate how objectives could be worded but different wording may be appropriate for specific marine farms. Ideally, monitoring objectives should include quantitative descriptors of acceptable or unacceptable environmental conditions or change, which are to be assessed through monitoring. However, while this is desirable, it is acknowledged that quantitative descriptors may not be available, especially for benthic monitoring. In that instance, expert judgement will be required to interpret monitoring results.

3 Framework for identifying appropriate monitoring

3.1 Overview

The monitoring framework is effectively an arrangement of Table 1 (potential effects of non-fed aquaculture) into three decision trees, one each for water quality, benthic, and hydrodynamic monitoring, that are applied to specific farm set-ups and local environmental conditions. The monitoring framework has three steps, which are described below and illustrated in Figure 1.

Step 1: Collate information

The first step in the monitoring framework is collating location- and farm-specific information, such as culture species, farm location, water and benthic environment characteristics, and predicted effects. This information is needed to work through decision trees in Step 2.

Step 2: Identify the appropriate potential effects to be monitored

The second step is where decisions are made on which potential effects to include in monitoring. Three decision trees (water quality, benthic, and hydrodynamic monitoring) guide through a series of questions that combine farm- and location-specific information with the existing knowledge and Waikato-specific experience on non-fed aquaculture effects and environmental sensitivities described in Table 1. The outcome of this process is a list of potential effects that are appropriate to monitor and, for decision tree (water quality) also the recommended monitoring effort. The decision trees combine known broad-scale environmental characteristics of the Waikato CMA, such as the different flushing dynamics of estuaries, the Firth of Thames, and the open coast, location-specific characteristics derived from baseline data, such as the presence (or absence) of sensitive benthic habitats and species, and marine farm-specific information. For existing marine farms, an extra step is required to consider monitoring history and farm development progress.

Step 3: Determine appropriate monitoring

In the final step of the monitoring framework, appropriate specific monitoring requirements are determined, including indicators, sampling and analysis methods, monitoring frequency and reporting. This step combines the identified potential effects, monitoring effort, and baseline data. For the revision of monitoring requirements of existing marine farms, this step also considers the monitoring history and farm development progress.

The three steps of the monitoring framework are described in detail in the remainder of this section and example applications to hypothetical marine farm set-ups are provided in section 6.

The framework applies primarily to the identification of monitoring requirements for commercial aquaculture. It can be applied to new farms or review of monitoring requirements and is suitable for the range types of farms and locations currently used for non-fed marine farming in the Waikato CMA. Site- or farm-specific circumstances may require deviation from the identified monitoring requirements. Considerations for non-commercial and multi-trophic aquaculture as well as farm extensions are provided in section 3.7.

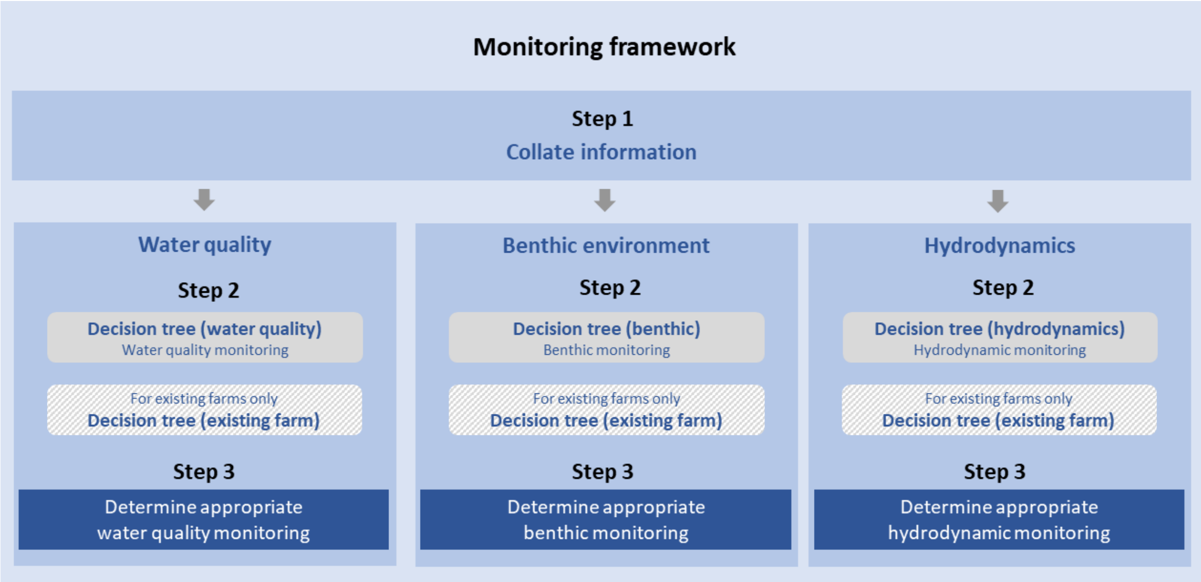


Figure 1. Illustration of the monitoring framework used to identify appropriate water quality, benthic, and hydrodynamic monitoring.

3.2 Applying the monitoring framework to existing marine farms

If monitoring requirements are reviewed for existing farms, previous monitoring needs to be considered. For example, if previous monitoring of phytoplankton has generated a good understanding of phytoplankton depletion and no substantial further farm development is planned, there should be no need to continue monitoring. On the other hand, if despite previous monitoring potential effects that may pose a realistic environmental risk are not yet well-understood, it may be necessary to continue routine monitoring.

For existing farms, an extra step is therefore required within the monitoring framework. The decision tree shown in Figure 2 (decision tree (existing farm)) assists with this step. For each type of monitoring being reviewed (i.e., water quality, benthic, and/or hydrodynamic monitoring), it determines whether the overall monitoring approach should be:

- Monitoring approach 1: Surveillance or no monitoring;
- Monitoring approach 2: Routine monitoring; or
- Monitoring approach 3: Response monitoring and investigations.

Decision tree (existing farm) in Figure 2 indicates that, if a farm has previously been monitored, monitoring results indicated compliance with respective requirements (e.g., consent conditions), and no further farm development is planned, it is likely that either surveillance monitoring will be sufficient, or it may be appropriate to discontinue monitoring completely (Approach 1). In the context of the monitoring framework, surveillance monitoring aims to 'keep an eye' on some key environmental indicators that, if changed, may indicate a need to increase monitoring effort.[11] If there are unresolved non-compliances from past monitoring, situation-specific response monitoring or

[11] For the purpose of this guidance, surveillance monitoring means the periodic measurement of environmental components that, if modified in certain ways and/or at or above a certain amount, would indicate an environmental effect of the monitored marine farm that is unexpected and of ecological concern.

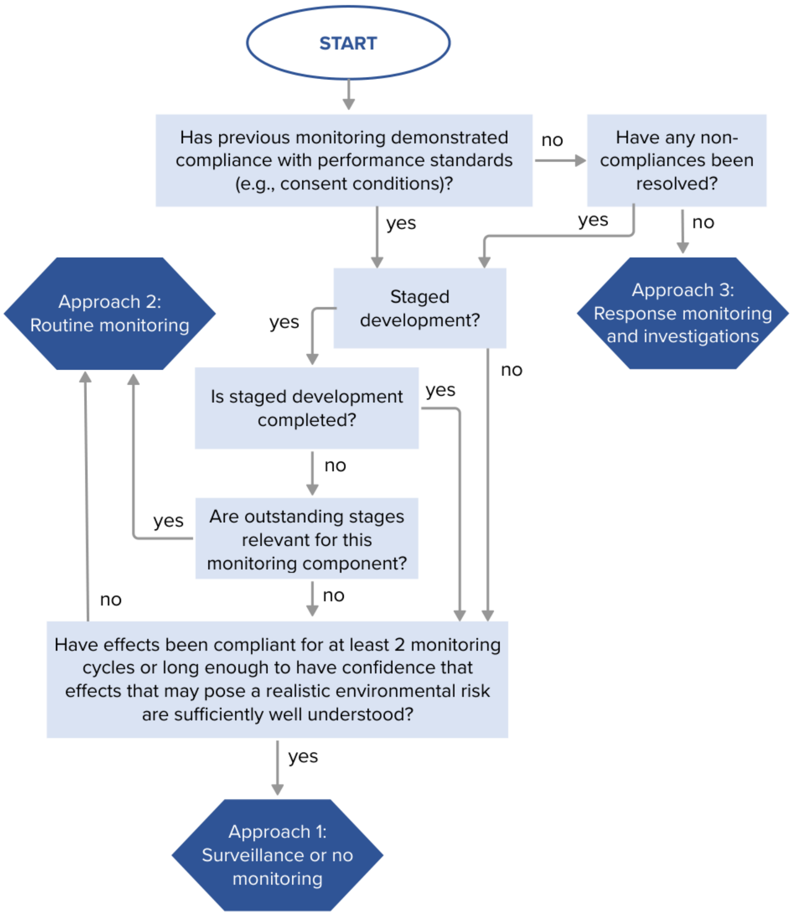


Figure 2. Decision tree (existing farm) used to determine the overall water quality, benthic, or hydrodynamic monitoring approach for an existing farm based on its monitoring history and development progress if this guidance is used to inform a review of monitoring requirements.

investigations may be required (Approach 3). If there have been no recent non-compliances but further development is expected to impact water quality, the benthic environment, or hydrodynamic processes in a way that may cause or intensify effects that pose a realistic environmental risk and are not sufficiently well understood, it may be appropriate to continue with routine monitoring (Approach 2). The outcome of this additional step or existing farms feeds into step 3 of the monitoring framework as described in sections 3.4.2 (water quality effects monitoring), 3.5.2 (benthic effects monitoring), and 3.6.2 (hydrodynamic effects monitoring).

3.3 Step 1: Collate information

Information used under the monitoring framework relates to culture species, marine farm structure (size, surface coverage of farm structures and crop), characteristics of the water body, number and size of other marine farms in the water body, location-specific benthic conditions, including the presence of ecologically significant benthic species, and predicted water quality, benthic, and hydrodynamic effects of the marine farm. If monitoring has previously been carried out at the marine farm,

Step 1
Collate information

Culture species and farm structure
Number/size of other marine farms
Water body characteristics
Benthic conditions
Predicted effects
Monitoring history

monitoring results and the outcomes of previous environmental compliance assessments are also required.

The more relevant information is available for applying the monitoring framework, the more likely it is to achieve a simple and effective monitoring programme. This is because uncertainty generally results in a more precautionary, and thus comprehensive, approach to monitoring. The exact nature of the information requirements becomes apparent when stepping through the decision trees in Step 2.

The AEE, baseline data[12], and supporting technical reports are important sources of information as they contain core information on the proposed (or existing) marine farm, environmental characteristics, and predicted effects. A robust AEE will assist in applying the monitoring framework as it should have followed a similar process for identifying relevant effects and utilised the same (or similar) data and information as is required under this guidance. Baseline data will provide important information on environmental characteristics, including temporal and spatial variability and location-specific features.

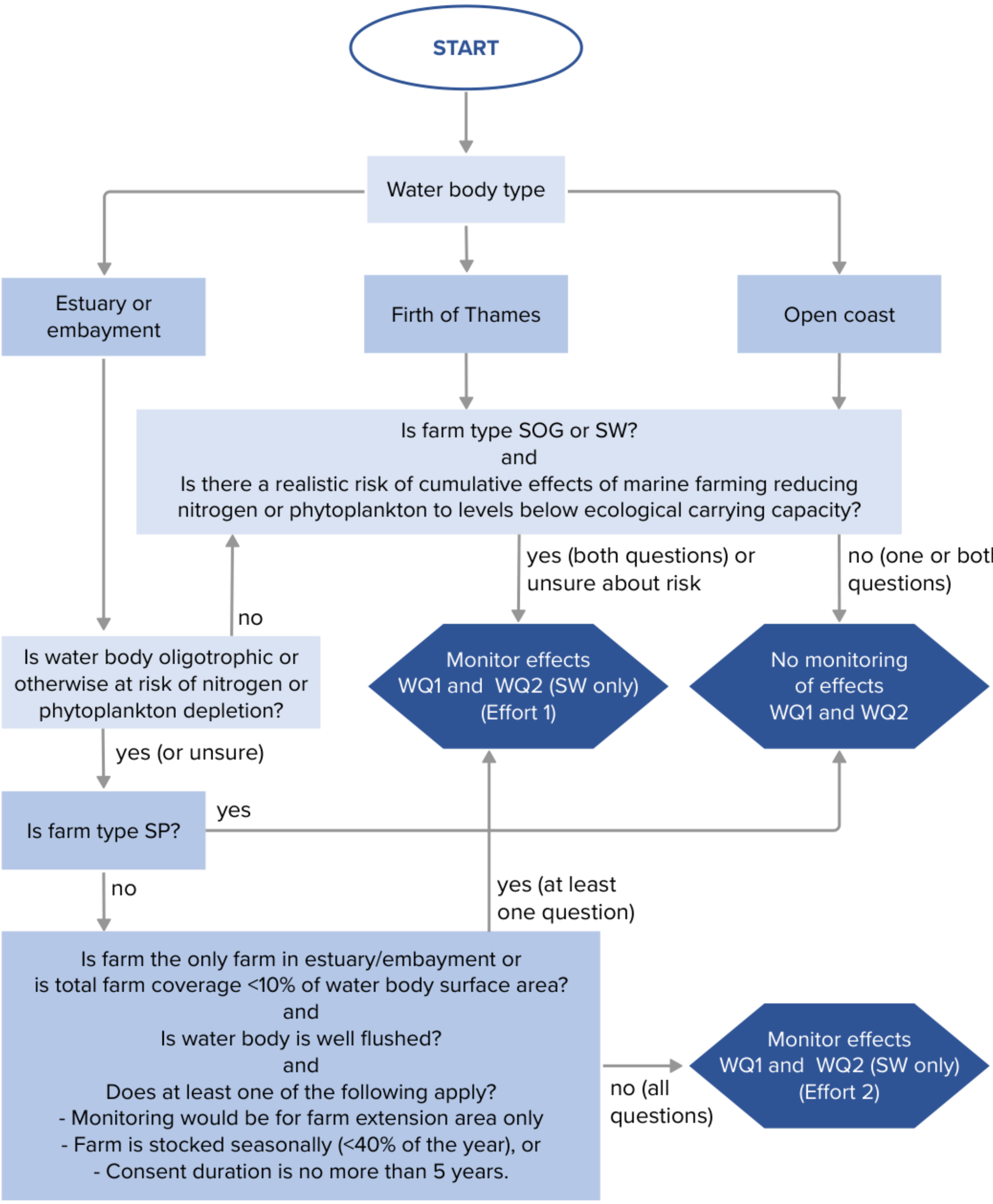
If the AEE has already been completed, monitoring recommendations may have already been made within it and this guidance can be used to confirm and/or refine those recommendations. If the AEE is still in draft, this guidance can be used to identify monitoring recommendations to include in the AEE. For existing farms, the original AEE may no longer reflect current scientific knowledge and it will be important to consider new scientific information and potential environmental change since the time of the original AEE when applying the monitoring framework.

Additional useful information may be available in form of technical reports held by WRC[13] or from SOE monitoring results[14]. In most instances the decision trees used in Step 2 provide options for dealing with information gaps. If critical information is missing, additional baseline data may be required before monitoring can commence.

Once a marine farm is operational, monitoring programmes can be further refined based on monitoring results and, depending on the monitoring design, baseline data may become less critical for the interpretation of monitoring results over time. Furthermore, not all monitoring requires environmental baselines. For example, some monitored indicators are compared to reference conditions or toxicity thresholds, without the need for baseline data.

This guidance is applicable to situations where comprehensive baseline data is available as well as situations with limited baseline data. Working through the monitoring framework will determine whether there are gaps in baseline data or whether sufficient data is available to finalise the monitoring design. Section 4 provides a more specific summary of baseline data requirements.

[12] See glossary for a definition of baseline data. For the purpose of this guidance, baseline data refers to any data describing environmental baseline conditions, independent of its source and whether it was collected before or after consenting.
[13] https://www.waikatoregion.govt.nz/services/publications/ (filter by category 'coastal')
[14] https://www.waikatoregion.govt.nz/environment/coast/coast-monitoring/

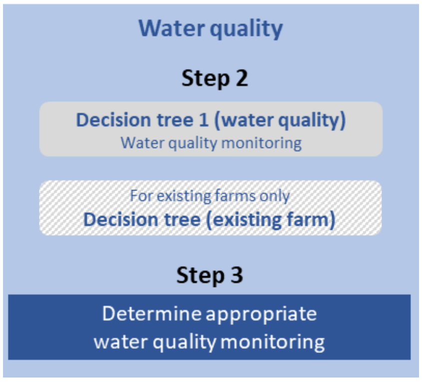


WQ1: Depletion of phytoplankton through filtration or competition for nutrients to levels at/or below those inducing adverse changes to the food web.

WQ2: Nitrogen reduction to levels below those required for natural populations of primary producers such as phytoplankton and wild marine macroalgae and plants.

Figure 3. Decision tree (water quality) for identifying potential water quality effects requiring monitoring and associated monitoring effort, developed based on the effects-specific information in Table 1. The term 'total farm coverage' refers to the total area of non-fed marine farms in the water body, including the one being assessed. Monitoring under Effort 2 is generally more comprehensive than under Effort 1. SP: Spat catching, SOG: Subtidal shellfish on-growing, SW: Seaweed farming, OY: Intertidal oyster farming.

3.4 Steps 2 and 3: Water quality effects



3.4.1 Step 2: Identify appropriate potential effects to be monitored and monitoring effort

The decision tree shown in Figure 3 ('decision tree (water quality)') is used to identify which potential water quality effects (WQ1 and/or WQ2, as described in Figure 3 and Table 1) should be include in monitoring and what monitoring effort (Effort 1 or 2) is likely most appropriate.

The factors determining appropriate effects to be monitored and appropriate monitoring effort are described in Table 1. They include the type of water body, specifically its flushing characteristics, the proportion of the water body covered by non-fed marine farms, whether it is at risk of nitrogen or phytoplankton depletion, the size and type of the marine farm monitoring is developed for, and operational factors that influence the environmental impact, such as seasonal operation and short consent duration. By stepping through the decision tree, water quality effects are either included or excluded.

For the purpose of applying decision tree (water quality) in Figure 3, water bodies are classified into estuaries and embayments, open coast, and the Firth of Thames (Figure 4).

3.4.2 Step 3: Determine appropriate water quality monitoring

Table 2 presents specific water quality monitoring recommendations derived from applying decision tree (water quality) in Figure 3. This table provides guidance for a range of monitoring programme components, including indicators, monitoring sites, sampling and data analyses, and reporting. Suggested wording for monitoring objectives is provided in Table 1. In general, monitoring under Effort 2 is more comprehensive than under Effort 1. Location- or farm-specific circumstances may require or justify deviations from these recommendations.

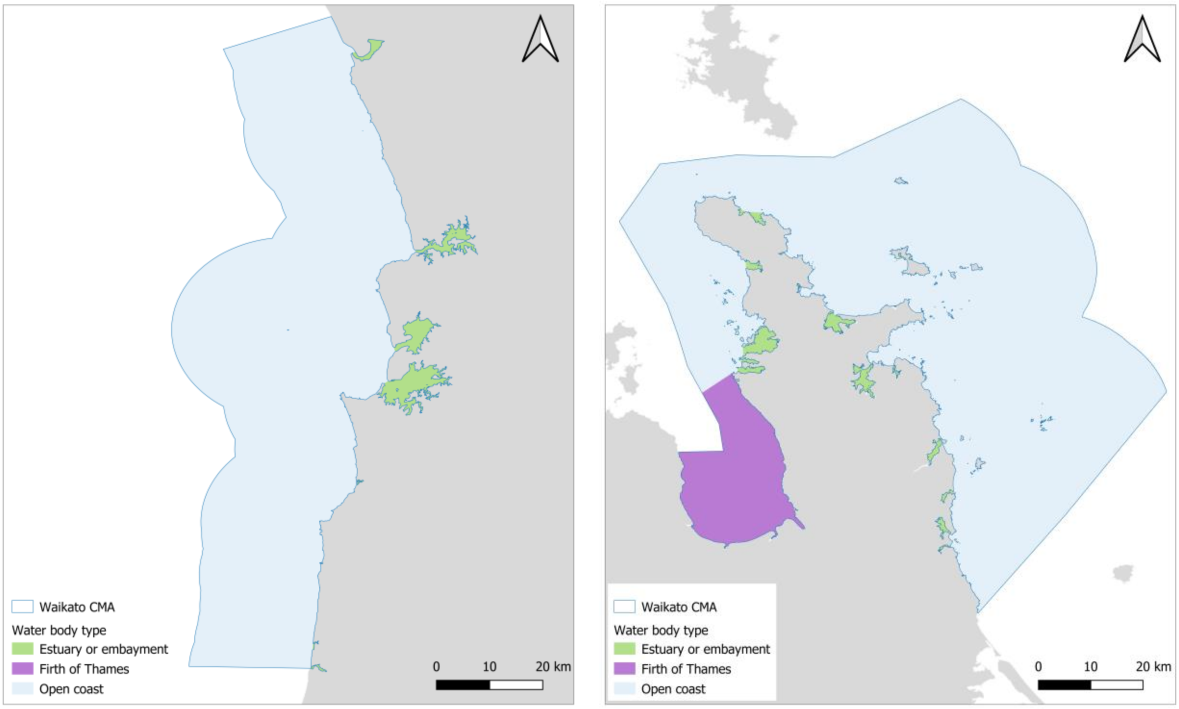


Figure 4. Classification of water bodies in the western (left) and eastern (right) Waikato CMA into 'estuary or embayment', open coast, and the Firth of Thames for the purpose of applying decision tree (water quality) in Figure 3.

Table 2. Specific recommendations for water quality monitoring of potential effects WQ1 and WQ2. Effects to include and monitoring effort are derived from the application of decision tree (water quality). Monitoring under Effort 2 is generally more comprehensive than under Effort 1. Recommendations shown across columns apply to Effort 1 and 2. Additional recommendations for existing farms are shown in the bottom row. Effects WQ1 and WQ2 are explained in Figure 3 and Table 1. DIN: dissolved inorganic nitrogen.

	Monitoring programme component	Effort 1*		Effort 2*	
		Recommendation	Effect	Recommendation	Effect
New farm	Monitoring objectives	See suggested wording in Table 1	All	See suggested wording in Table 1	All
	Indicators to measure	Chlorophyll-*a* Temperature, Salinity	All	Chlorophyll *a* Water clarity (total suspended solids) Temperature, Salinity	All
		DIN	WQ2	DIN	WQ2
	Monitoring sites	One potential impact site representing site of maximum effect, two reference sites.	All	Number and locations of potential impact sites proportional to farm size and expected impact. Two or more reference sites.	All
	Sampling depth	Surface water only. For chlorophyll-*a* and DIN, collect depth-integrated samples (over a depth range appropriate for the site-specific water depth). Sampling depth should be consistent among monitoring sites.			All
	Sampling frequency	2-monthly	All	Monthly	All
	Duration and review	2-years, then review monitoring	All	Ongoing but review monitoring every 5 years	All
	Replication	No replication	All	No replication	All
	Method considerations	If chlorophyll-*a* is measured using in-situ fluorometry, appropriate calibration and verification is required.			All
	Data analysis	Calculation of phytoplankton (chlorophyll-*a*) and nitrogen reduction relative to changes measured at reference sites, taking into considering natural background concentration gradients.			All
	Reporting frequency	2-yearly	All	Annually	All
Existing farm **		Approach 1: Surveillance or no monitoring • Discontinue monitoring Approach 2: Routine monitoring • Monitoring as for new farms (Effort 1) Approach 3: Response monitoring and investigations • Requires case-by-case determination	All	Approach 1: Surveillance or no monitoring Options include: • Monitoring as for new farms (Effort 1), review after 2 years to decide if suspension or discontinuation is appropriate • Suspend monitoring for 5 years, then monitor for 2 years as for new farms (Effort 2) before reviewing again • Discontinue monitoring (potentially review after 5 years) Approach 2: Routine monitoring • Monitoring as for new farms (Effort 1 or 2) Approach 3: Response monitoring and investigations • Requires case-by-case determination	All

* Derived from decision tree (water quality) in Figure 3.

** Derived from decision tree (existing farm) in Figure 2.

For existing marine farms, the bottom row in Table 2 provides additional considerations for implementing the overall approach for water quality monitoring derived from decision tree (existing farm) in Figure 2. For example, if applying decision tree (existing farm) to water quality monitoring indicates that Approach 1 ('Surveillance or no monitoring') is appropriate and decision tree (water quality) identifies effect WQ1 should be included in monitoring at Effort 2, expert judgement will be required to determine whether it is most appropriate to monitor effect WQ1 at Effort 1 for two years and then review, suspend monitoring for a period of time before monitoring for 2 years, or discontinue monitoring entirely with the potential to review after 5 years. There would be an expectation for monitoring reviews to consider whether it is appropriate to suspend or discontinue monitoring.

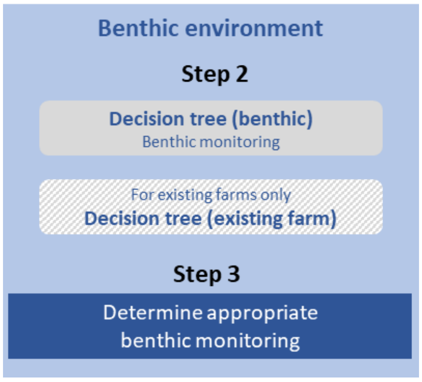
In addition to the specific recommendations listed in Table 2, the following general guidance applies to water quality monitoring:

- Chlorophyll-*a* concentration should be measured as a proxy of total phytoplankton biomass. Unless identified as a component of response monitoring or investigations, it is unlikely that phytoplankton species and community structure would need to be monitored.[15]
- Monitoring data can be influenced by a range of factors unrelated to the marine farm. For example, river inflows may result in a reduction of chlorophyll-*a* concentration, which may inadvertently be interpreted as chlorophyll-*a* reduction from mussel filtration. While it may not be strictly necessary to monitor these variables, helps determine whether any measured environmental change was caused by the marine farm. Two important factors identified in this guidance are salinity and temperature, which are both included as indicators in Table 2.
- The monitoring design must be appropriate to enable a reliable detection of the effects to be monitored and, if applicable, a reliable evaluation of limits or thresholds.
- If comparisons to baseline data or reference sites are required, natural spatial and temporal variability in indicator values need to be carefully considered.
- Reference sites should be placed at locations considered 'outside the influence of the farm'. Sites located in the 'usually upstream of the residual flow' direction are useful reference sites. Ideally, reference sites should be beyond the extent of the tidal ellipse; however, this may not be practicable in small water bodies. Information on water quality at potential reference site locations may be available from WRC SOE monitoring.[16]
- Laboratory analyses must be conducted at facilities that exhibit good laboratory practice according to standard methods, preferably by accredited laboratories. Detection limits must be appropriate for the required data analysis and compliance assessments.

[15] Supporting this general guidance is that long-term water column monitoring around mussel farms in the Wilson Bay Marine Farming Zone has shown no changes in the relative proportion of diatoms, flagellates or ciliates over an eight-year period, thus alleviating concerns by demonstrating that there were no changes to the long-term composition of phytoplankton communities (Ministry for Primary Industries, 2013a; Stenton-Dozey, 2013).
[16] https://www.waikatoregion.govt.nz/environment/coast/ecosystem-health/estuarine-water-quality/

- Discrete water quality sampling and measurement (chlorophyll-*a*, DIN, and salinity[17]) should be carried out in general accordance with the 'NEMS Coastal Water Quality'[18] as far as practicable.[19]

3.5 Step 2 and 3: Benthic effects



3.5.1 Step 2: Identify appropriate potential effects to be monitored and monitoring effort

The decision tree shown in Figure 5 (decision tree (benthic)) is used to identify which potential benthic effects should be included in monitoring. As described in Table 1, factors influencing these decisions include the species to be farmed, presence or absence of ecologically valuable benthic species, communities, or habitats, level of existing enrichment, and hydrodynamic characteristics of the farm site. Examples of ecologically valuable benthic species, communities, and habitats are listed in Appendix 1.

By stepping through decision tree (benthic) in Figure 5, benthic effects recommended to be included in monitoring are identified. Effects not included do not require monitoring because, as summarised in Table 1, based on scientific knowledge and experience with marine farming under the respective farm- and site-specific conditions, there is sufficient confidence that effects will not be of ecological concern and therefore do not require monitoring. Reviews (~5-yearly) will be appropriate in some instances to enable a reassessment of monitoring requirements in light of new scientific information. Where decisions cannot be made with certainty due to missing information (indicated by option 'unsure'), a precautionary approach is likely appropriate, which would require the respective monitoring to be included. This approach ensures that monitoring is proportionate to the ecological significance, intensity, and uncertainty of predicted effects in the context of local environmental sensitivities.

For benthic effects monitoring, the appropriate monitoring effort needs to be determined on a case-by-case basis. An important consideration for determining appropriate monitoring effort is the robustness of baseline data. Gaps or uncertainties in baseline data could be addressed by requiring a higher effort for the initial phase of benthic monitoring. After the initial phase (e.g., the initial monitoring survey), the need for and effort of ongoing monitoring could be reviewed. Other considerations for determining the monitoring effort are described in the next section.

3.5.2 Step 3: Determine specific benthic monitoring recommendations

Table 3 presents specific benthic monitoring recommendations derived from applying decision tree (benthic) in Figure 5. Suggested wording for monitoring objectives is provided in Table 1. This table provides guidance on a range of monitoring programme components, including indicators, monitoring sites, sampling method, timing, and frequency, and reporting for a more comprehensive (Effort 2) and a less comprehensive (Effort 1) monitoring design. The decision on which monitoring effort is most appropriate needs to be made on a case-by-case basis, taking into considerations

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[17] Salinity may also be sampled in the field using sensors.

[18] National Environmental Monitoring Standards (NEMS) Water Quality Part 4 of 4: Sampling, Measuring, Processing and Archiving of Discrete Coastal Water Quality Data; accessible at https://www.nems.org.nz/documents/water-quality-part-4-coastal-waters/.

[19] It is acknowledged that the NEMS Coastal Water Quality is designed for SOE monitoring. Following the NEMS is useful and desirable but may come at an unwarranted expense. As described in the NEMS: "while sampling for [monitoring consented activities] is not specifically addressed in this document, much of the guidance around field measurements, water sample collection and handling, and data management are applicable […]. This Standard therefore provides a normative reference for most discrete water quality sampling and measurements carried out in coastal waters across New Zealand".

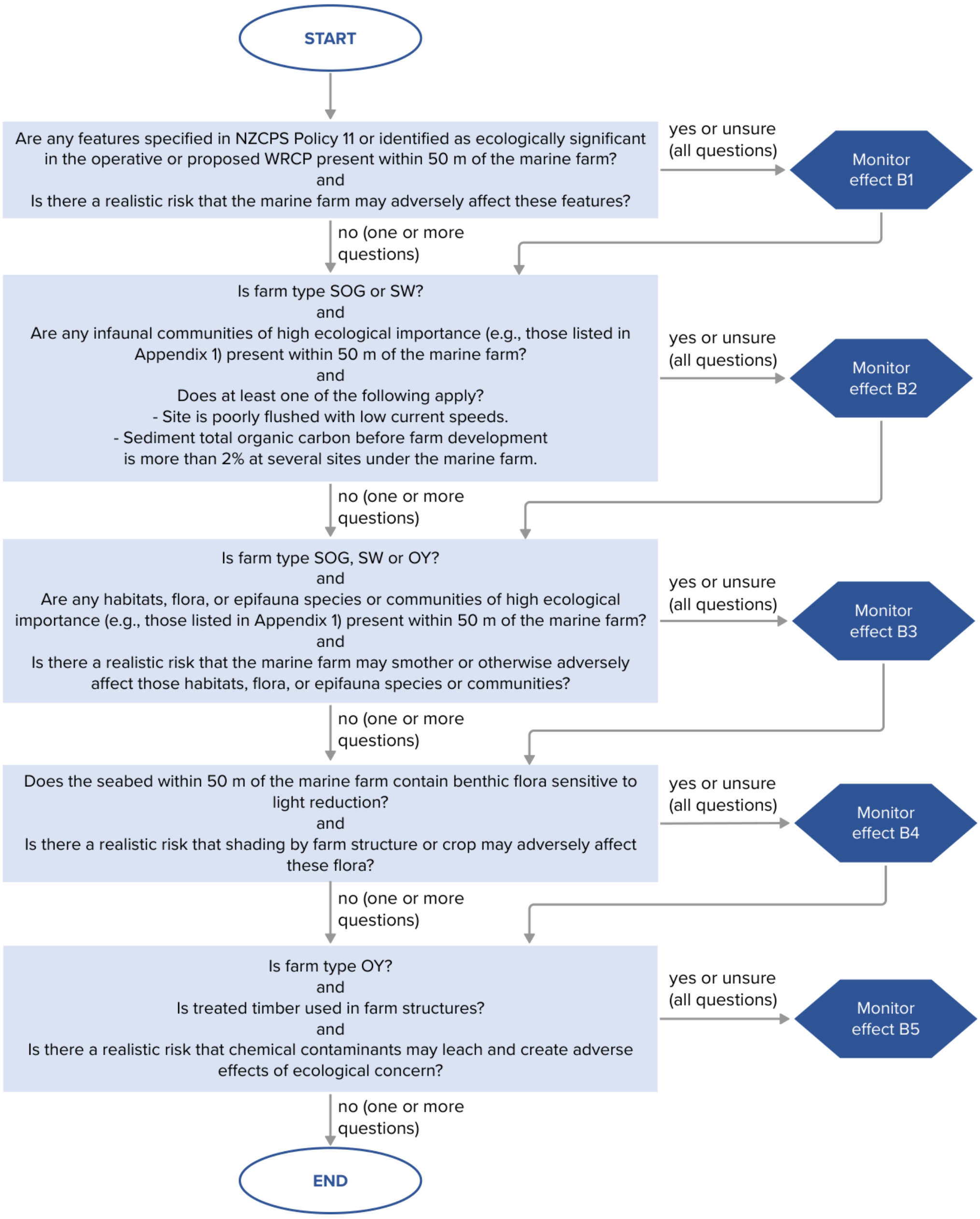
factors such as the ecological values potentially affected, the level of environmental risk, and the reversibility of potential effects.

For existing marine farms Table 3 provides additional considerations for implementing the overall approach for benthic monitoring derived from decision tree (existing farm) in Figure 2. For example, if applying decision tree (existing farm) to benthic monitoring indicates that Approach 1 ('Surveillance or no monitoring') is appropriate, expert judgement will be required to determine whether the identified benthic effects should be monitored once at Effort 1 (i.e., one monitoring survey) followed by a review to decide if suspension or discontinuation is appropriate, whether monitoring should be temporarily suspended (with a possibility to resume monitoring or discontinue), or whether monitoring should be discontinued entirely.

Benthic baseline data is required to implement some recommendations in Table 3 and the additional benthic monitoring guidance listed below. For example, information on natural variability is required to determine reference site locations and appropriate replication.

In addition to the specific recommendations listed in Table 3, the following general guidance applies to benthic monitoring:

- Monitoring 'sites' may be 'areas', especially for visual assessments, which are typically carried out over a specific area (defined by size or habitat type, e.g., macroalgal bed) or along a transect, rather than a single location. The number and location of potential impact sites depends on the type and distribution of benthic habitats and species to be monitored, as well as natural variability.
- As much as practicable, reference sites/areas should be located in areas with comparable flow, substrate, habitat characteristics, slope, and depth to potential impact sites. The placement of reference sites should anticipate planned future development stages, if applicable.
- The monitoring design must be appropriate to enable a reliable detection of the effects to be monitored and, if applicable, a reliable evaluation of limits or thresholds.
- If comparisons to baseline data or reference sites are required, natural spatial and temporal variability in indicator values need to be carefully considered.
- Laboratory analyses must be conducted at facilities that exhibit good laboratory practice according to standard methods, preferably by accredited laboratories. Detection limits must be appropriate for the required data analysis and compliance assessments.



B1: Adverse effects on benthic features (taxa, areas, habitats, ecosystems, vegetation types, routes, and ecological corridors) specified in NZCPS Policy 11 or identified as ecologically significant in the operative or proposed Waikato Regional Coastal Plan (WRCP).

B2: Adverse effects on benthic infaunal communities from organic enrichment of sediments

B3: Smothering of, or other adverse effects of ecological concern on, benthic habitats, flora, or epifauna communities due to biodeposition, biofouling or crop drop-off.

B4: Adverse effects on benthic flora or fauna sensitive to light reduction from shading of the seabed by farm structures or crop.

B5: Leaching of chemical contaminants from treated timber structures.

Figure 5. Decision tree (benthic) for identifying potential benthic effects requiring monitoring, developed based on the effects-specific information in Table 1. Unless effects are explicitly identified, they do not need to be monitored. SP: Spat catching, SOG: Subtidal shellfish on-growing, SW: Seaweed farming, OY: Intertidal oyster farming.

Table 3. Specific recommendations for benthic monitoring of potential effects B1-B5. Monitoring under Effort 2 is generally more comprehensive than under Effort 1. Recommendations shown across columns apply to Effort 1 and 2. Additional recommendations for existing farms are shown in the bottom row. Effects B1-B5 are explained in Figure 5 and Table 1.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Monitoring programme component</th><th colspan="2">Effort 1*</th><th colspan="2">Effort 2*</th></tr>
<tr><th>Recommendation</th><th>Effect</th><th>Recommendation</th><th>Effect</th></tr>
<tr><td rowspan="12">New farm</td><td>Monitoring objectives</td><td>See suggested wording in Table 1</td><td>All</td><td>See suggested wording in Table 1</td><td>All</td></tr>
<tr><td rowspan="4">Indicators to measure (also see derived indicators under 'data analysis' below)</td><td>Infauna (identified to lowest practical taxonomic level)</td><td>B1, B2</td><td>Infauna (identified to lowest practical taxonomic level)</td><td>B1, B2</td></tr>
<tr><td>Sediment total organic matter content</td><td>B2</td><td>Sediment total organic matter content</td><td>B2</td></tr>
<tr><td>Relevant specific benthic flora or fauna species, habitats, or other features identified as being potentially affected</td><td>B1, B2, B3, B4</td><td>Relevant specific benthic flora or fauna species, habitats, or other features identified as being potentially affected</td><td>B1, B2, B3, B4</td></tr>
<tr><td>Concentration of relevant chemical contaminant in sediment</td><td>B5</td><td>Concentration of relevant chemical contaminant in sediment</td><td>B5</td></tr>
<tr><td>Monitoring sites</td><td>Representative potential impact site(s), one reference site</td><td>All</td><td>Number and locations of potential impact sites proportional to farm size and expected impact. Two or more reference sites.</td><td>All</td></tr>
<tr><td>Sampling frequency</td><td>5-yearly but considerations described for Effort 2 also apply.</td><td>All</td><td>Annually to 3-yearly but dependent on habitat type and severity of potential ecological consequence. The interval between monitoring surveys in complex habitats needs to be large enough to allow for change to manifest but small enough to detect effects of high ecological importance early so that effective management action can be taken.</td><td>All</td></tr>
<tr><td>Sample collection methods</td><td colspan="3">Methods for sample collection will depend on the habitat and the sample being collected. In soft sediments, sample collection is likely most suitable using a van Veen grab deployed from a boat. In habitats containing hard structures, van Veen and similar grab sampling methods are unlikely to be appropriate. If sample collection is required, diver collection is likely to be the best collection method.</td><td>All</td></tr>
<tr><td>Visual sampling methods</td><td colspan="3">Video transects (ideally fixed start/end points) can provide a broad overview of habitat and species and may be used to help assess spatial extent of habitat (e.g., measure patch size/density) or counts of conspicuous larger or rarer organisms for density measures. By contrast, still images (e.g., quadrats) provide for higher resolution analyses that might be required for some indicators of habitat quality (e.g., percentage cover, density of inconspicuous or small organisms, size of individuals). Seabed footage and images could be collected by divers, towed video, drop camera (with attached quadrat frame), or remotely operated vehicle with imaging attachment(s).</td><td>B1-B4</td></tr>
<tr><td>Replication</td><td colspan="3">The appropriate number of replicate samples or other data depends on sampling design, natural variability, and the level of environmental change that needs to be detectable.</td><td>All</td></tr>
</table>

Table 3 contd.

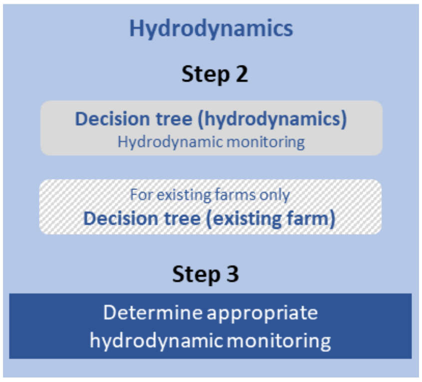
	Monitoring programme component	Effort 1* Recommendation	Effort 1* Effect	Effort 2* Recommendation	Effort 2* Effect
New farm	Timing of sampling	Monitoring of organic enrichment of soft sediments should target the period of highest biological impact, which is typically between January and March. The time when effects on epifauna and habitats other than soft sediments manifest are less understood and may not align with the period of highest temperature or deposition. For example, recruitment patterns may be of high relevance to the manifestation of effects. The timing of sampling therefore needs to be determined on a case-by-case basis.			B1-B4
New farm	Data analysis	Centred on the relevant specific benthic flora or fauna species, habitats, or other features identified as being potentially affected, monitoring will likely include comparing indicators of species presence, community composition, habitat quality, ecological functioning, and/or spatial extent between potential impact and reference sites. Infauna community composition should be examined using univariate and multivariate analysis. Univariate indices may include taxa richness, total abundance, Margalef's diversity index, Pielou's evenness, and Shannon–Wiener diversity index, but indices need to be determined on case-by-case basis. To assess epifauna and habitat quality, monitoring of key species could involve tracking taxa-specific density (e.g., number per square metre), biomass, percentage cover, and population size structure (of habitat forming organisms).			B2
New farm	Reporting frequency	After each sampling	All	After each sampling	All
Existing farm**		Approach 1: Surveillance or no monitoring Options include: • Monitoring as indicated for new farms (Effort 1), review after next monitoring survey to decide if suspension or discontinuation is appropriate • Temporarily suspend monitoring (skip one or multiple monitoring survey), then monitor again once at Effort 1 before reviewing again to potentially discontinue monitoring at that point • Discontinue monitoring Approach 2: Routine monitoring • Monitoring as indicated for new farms (Effort 1 or 2) Approach 3: Response monitoring and investigations • Requires case-by-case determination			

* For benthic monitoring the appropriate monitoring effort needs to be determined on a case-by-case basis taking into considerations factors such as the ecological values potentially affected, the level of environmental risk, and the reversibility of potential effects.

** Derived from decision tree (existing farm) in Figure 2.

3.6 Step 2 and 3: Hydrodynamic effects

3.6.1 Step 2: Identify appropriate potential effects to be monitored and monitoring effort



The decision tree shown in Figure 6 (decision tree (hydrodynamics)) is used to identify whether hydrodynamic effects monitoring is necessary. Hydrodynamic effects are different to water quality and benthic effects because in most cases the potential concern is not the change in hydrodynamic conditions itself but is related to the consequence of this change on surf breaks, ecology, or the wider environment. This is reflected in the decision tree, which focusses on these consequences.

Changes in hydrodynamic conditions can typically be predicted with relatively high confidence; however, the consequences of these changes on ecology or the wider environment are more difficult to predict. Therefore, the decision on whether hydrodynamic monitoring is required is strongly influenced by the understanding and potential severity of potential consequences. This can create challenges for identifying appropriate monitoring of hydrodynamic effects as well as the selection of appropriate monitoring approaches.

The factors determining appropriate hydrodynamic monitoring are described in Table 1 and include the presence of nationally or regionally significant surf breaks in the swell corridor of the marine farm, the potential of adverse consequences on ecology or other environmental features, and the scale of marine farm coverage of the water body.

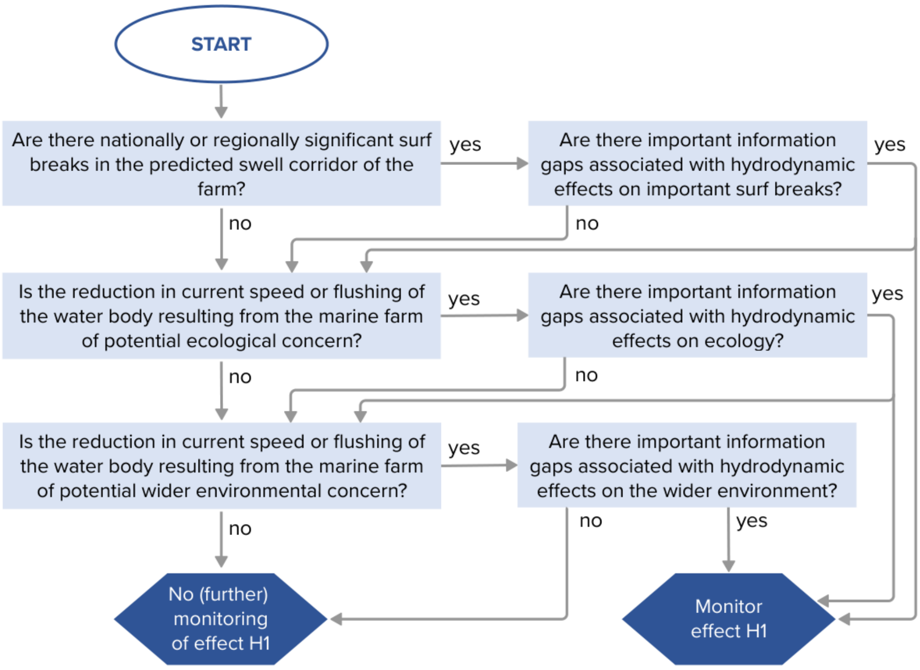
Because hydrodynamic effects generally don't change once a farm is in place (unless there is substantial additional development or change in farm structure or crop that results in different physical interactions with water flow), ongoing hydrodynamic monitoring is typically not required or useful. Instead, hydrodynamic effects monitoring is often more akin to an investigation. If hydrodynamic conditions or the ecological or wider environmental consequences of changes in hydrodynamic conditions display high temporal variability, are uncertain, or are predicted to change over time, ongoing hydrodynamic monitoring (likely at low frequency) may be necessary, but only if there is a realistic environmental risk that warrants the monitoring effort required to undertake hydrodynamic monitoring.

If hydrodynamic monitoring is required, it may be more meaningful and effective to monitor the consequence of changes in hydrodynamic conditions directly instead of changes in hydrodynamics, providing monitoring results can be linked to the marine farm. For example, if there are concerns that changes in current flow due to the presence of an intertidal oyster farm may result in increased mud retention and subsequent adverse effects on a shellfish bed, it may be more appropriate to monitor changes in grain size or shellfish instead of current flow around the farm. Such monitoring would likely be incorporated in the benthic monitoring programme. In this instance, while hydrodynamic conditions are unlikely to change once the farm is in place, the change in grain size (potential increased muddiness) and effects on the shellfish bed (potential loss) may occur gradually over time and ongoing routine monitoring may be appropriate. Because of these complexities, the decision tree for hydrodynamic monitoring does not identify specific hydrodynamic effects to be monitored but simply assists in determining whether hydrodynamic monitoring is required or not.

A careful balance needs to be struck between ensuring that hydrodynamic monitoring assesses potential environmental change of concern and maintaining a direct causal connection to the marine farming activity. The bar for requiring hydrodynamic monitoring is high because of the generally low level of concerns associated with non-fed aquaculture, the complexity in hydrodynamic and related ecological and coastal processes, and the resulting large monitoring effort required to obtain robust and meaningful monitoring data.

3.6.2 Step 3: Determine specific hydrodynamic monitoring recommendations

Hydrodynamic monitoring may aim to establish the nature and intensity of direct hydrodynamic effects or focus on the consequence of changes in hydrodynamic conditions on environmental or ecological characteristics, e.g., changes in phytoplankton dynamics due to reduced flushing of the water body, or changes in benthic substrate due to modified bottom water currents. The range of potential monitoring methods is therefore wide. For this reason, only general recommendations for hydrodynamic monitoring are provided in Table 4 and specific requirements need to be identified on a case-by-case basis. If hydrodynamic monitoring is reviewed for existing farms, Approach 1 (derived from decision tree (existing farm) in Figure 2 represents 'no monitoring'. This is because under the conditions reflected under Approach 1, the hydrodynamic effects are well known and not expected to change in a way that would give rise to concerns.



H1: Changes in current, wave, and/or flushing dynamics that adversely impact nationally or regionally significant surf breaks or cause environmental or ecological changes of concern.

Figure 6. Decision tree (hydrodynamics) for identifying whether hydrodynamic effects monitoring is necessary, developed based on the effects-specific information in Table 1.

Table 4. General recommendations for hydrodynamic monitoring.

	Monitoring programme component	Recommendation
New farm	Monitoring objectives	See suggested wording in Table 1
New farm	Indicators to measure	Depending on the effects or consequences of concern, focus on indicators of hydrodynamic conditions and/or indicators of the consequence of changes in hydrodynamic conditions, e.g., sediment composition or ecological ecosystem components potentially affected. Indicators of hydrodynamic conditions may include: • Tidal regime (current speed and direction) • Wave conditions (wave height, period, and direction) • Sea surface height (elevation) • Residual water movement • Temperature and salinity stratification Indicators of the consequence of changes in hydrodynamic conditions may include: • Benthic habitat or species potentially adversely affected • Sediment grain size as indicator of potential change in sediment composition
New farm	Monitoring sites/areas*	Fixed instruments (such as current meters, wave gauges, and Acoustic Doppler Current Profilers [ADCP]) are deployed at locations of interest (e.g., sites of potential concern) or along transects from the farm to determine the spatial extent of effects. Transect line surveys can be made using a boat mounted ADCP.
New farm	Survey duration*	Instruments need to be deployed sufficiently long to cover the range of relevant hydrodynamic conditions (tidal, wind, wave and stratification). The deployment period is typically between six and eight weeks.
New farm	Timing of surveys*	The timing of surveys is important because of the seasonality in hydrodynamic conditions. The appropriate time of the year needs to be determined on case-by-case basis.
New farm	Analysis*	Monitoring may involve calculation/modelling of flushing characteristics or other hydrodynamic characteristics and processes. For assessments of change over time, consistency of (numerical) approaches is critical due to the lack of routine methods.
New farm	Reporting frequency*	After each survey
Existing farm**		Approach 1: Surveillance or no monitoring • No monitoring Approach 2: Routine monitoring • Case-by-case determination, consider guidance for new farms Approach 3: Response monitoring and investigations • Requires case-by-case determination

* Applies to monitoring of hydrodynamic conditions. For monitoring indicators of the consequence of changes in hydrodynamic conditions, appropriate monitoring methods need to be identified on a case-by-case basis.
** Derived from decision tree (existing farm) in Figure 2.

3.7 Special cases

3.7.1 Non-commercial aquaculture

Due to the potentially wide range of non-commercial marine farming operations, no specific guidance for monitoring is provided for this category. For some non-commercial aquaculture, monitoring will not be necessary (e.g., a low impact/risk short-term marine farming activity) but in some instances quite comprehensive monitoring may be required (e.g., if the marine farming activity involves new species with potentially large or uncertain effects). The guidance provided in this document will likely be useful for informing decisions on appropriate monitoring; however, specific requirements will need to be determined on a case-by-case basis.

3.7.2 Species diversification and multi-trophic aquaculture

The potentially broad scope of species diversification and multi-trophic aquaculture also precludes the provision of specific guidance for monitoring. As for non-commercial aquaculture, the guidance provided in this document will likely be useful for supporting decisions on monitoring; however, specific requirements will need to be determined on a case-by-case basis.

3.7.3 Farm extensions

For farm extensions existing monitoring and baseline information from the parent farm will be valuable (and necessary) for identifying appropriate monitoring. Existing information from the parent farm generally reduces the need for monitoring of the farm extension. However, benthic effects may differ between the parent farm and farm extension and there may be a need to consider cumulative effects from the extension area.[20]

Due to the small size of the extension area in proportion to the parent farm, it is highly unlikely that a farm extension would triggers the need for water column or hydrodynamic monitoring.

The need for benthic monitoring should be assessed by applying decision tree (benthic) in Figure 5 as the benthic environment in the extension area may contain ecologically valuable and sensitive species, in which case benthic monitoring of the extension area would be appropriate.

Monitoring of the extension area should be aligned with monitoring of the existing farm.

If applying the framework during a review of monitoring requirements identifies recommendations that are more comprehensive than those stipulated in consent conditions, this outcome would not change the compliance needs for the marine farm.

4 Baseline data recommendations for monitoring design

Under this guidance baseline data is used to inform the following processes:

- Working through the three decision trees (water quality, benthic, and hydrodynamic) shown in Figure 3, Figure 5, and Figure 6; and
- Determining specific aspects of monitoring programme design, including monitoring sites, sampling design, and sampling effort.

Environmental baseline data is an important component of monitoring. Fit-for-purpose baseline data allows monitoring to focus on specific aspects and areas of potential ecological concern only. Furthermore, if effects are sufficiently well understood and environmental characteristics permit, fit-

[20] It is noted that this type of cumulative effect is different from the cumulative effects discussed in section 2.4.

for-purpose baseline data provides confidence to make decisions that no monitoring is required or that a reduced level of monitoring suffices.

Baseline data needs vary and in some instances baseline data may not be required. The monitoring framework incorporates existing scientific knowledge, which means that some decisions can be made without any farm-specific scientific data. For example, for most small- medium-scale non-fed marine farms located in the open coast environment, water quality monitoring will not be required because it is known that potential effects on phytoplankton and nitrogen are negligible. As a consequence, typically no baseline data associated with the respective effects will be needed. On the other hand, to identify benthic monitoring requirements, targeted benthic baseline surveys will generally be required to determine whether ecologically significant and potentially sensitive benthic species are present in areas predicted to be affected by the marine farm.

Gaps in baseline data may be identified while working through the decision trees and/or while designing the monitoring programme. It may be possible to fill some information gaps from information held by the consent applicant or other information sources, such as SOE monitoring, scientific publications, or monitoring results of near-by marine farms.[21] Some information gaps may also be addressed by taking a more precautionary approach to monitoring, i.e., by including monitoring of potential effects for which information is incomplete or uncertain until monitoring results have provided the required information. The decision trees under the monitoring framework provide options for dealing with information gaps; generally resulting in a more comprehensive monitoring programme.

However, some information gaps may require additional baseline data. In these instances, baseline surveys are required before the before monitoring programme can be finalised and monitoring of effects can commence.

A summary of baseline data underpinning the decision trees and monitoring programme design is provided in Table 5. This summary should be read in conjunction with the respective detailed information provided in sections 3.4 (water quality effects), 3.5 (benthic effects), and 3.6 (hydrodynamic effects). Specific baseline data requirements and therefore baseline survey design requirements need to be identified on a case-by-case basis.

[21] See section 3.3 for an overview of potential information sources.

Table 5. Summary of baseline data recommended for applying the decision trees and additional guidance for identifying appropriate water quality, benthic, and hydrodynamic effects monitoring.

Data/information	Type of monitoring and applicable effect(s)		
	Water quality	Benthic	Hydro-dynamic
Baseline data required or recommended for using decision trees			
Estimated trophic state[22] of water body (specifically, whether oligotrophic or at risk of phytoplankton or nitrogen depletion)	✓ (WQ1, WQ2)		
Total area covered by existing marine farms in water body	✓ (WQ1, WQ2)		
Size (area) of the water body	✓ (WQ1, WQ2)		
Current speeds and flushing characteristics of water body	✓ (WQ1, WQ2)	✓ (B2)	
Benthic habitats, epifauna and infauna communities, and benthic flora within ~50 m of the marine farm		✓ (B1, B2, B3, B4)	
Sediment total organic carbon content under marine farm		✓ (B2)	
Presence of important surf breaks in predicted swell corridor of farm			✓ (H1)
Presence of ecosystem components in the water body sensitive to reductions in current speed or flushing			✓ (H1)
Coastal processes in the water body sensitive to reductions in current speed or flushing			✓ (H1)
Baseline data recommended to inform appropriate monitoring design			
Sufficient understanding of spatial and temporal variability in the indicators to be monitored to: • Inform selection of monitoring sites, including reference sites • Inform sampling effort • Inform statistical approach for detecting farm effects, including evaluation of appliable limits and thresholds	✓ (All)	✓ (All)	
Sufficient understanding of flow, substrate, habitats, slope, and depth of farm site and surrounding environment to inform selection of suitable reference site(s).		✓ (All)	
Sufficient understanding of the factors influencing the likely time of the year when farm effects have greatest biological impact to inform decisions on the time of monitoring.		✓ (All)	

[22] There will generally be no need for a comprehensive scientific assessment of trophic state. An expert assessment will likely be sufficient for determining whether the water body is oligotrophic or at risk of chlorophyll-*a* or nitrogen depletion, for example by relying on SOE monitoring or scientific literature.

5 Preparing an environmental monitoring plan (EMOP)

The purpose of an EMOP is to describe how monitoring will be carried out and how the actual effects of the marine farm will be assessed. An EMOP should provide clear instructions to those planning and carrying out the monitoring and a clear description of how limits and thresholds or other monitoring-related compliance conditions will be evaluated. Draft EMOPs can be prepared before a consent is granted. EMOPs can only be finalised once consent conditions are finalised.

An EMOP should provide the necessary contextual information for monitoring, such as farm set up and basic operational information. The EMOP should also briefly describe the pertinent history of the marine farm and, if monitoring has been conducted prior to the preparation of the EMOP, a brief history of monitoring at the farm site. The EMOP needs to describe any monitoring requirements, monitoring objectives, monitoring sites, indicators, sampling and analysis, reporting, and EMOP review.

General recommendations for EMOPs include:

- The EMOP should provide a clear purpose for all aspects of monitoring. This should provide confidence that the programme is fit-for-purpose (targeted, effective, and efficient) and will assist with potential future requests to change monitoring requirements.
- There should be clear monitoring objectives. Suggestions for monitoring objectives for all potential effects discussed in this guidance are provided in Table 1.
- There should be sufficient detail on what data will be collected, how it will be analysed and interpreted, and how compliance requirements will be evaluated.
- Information should be accurate, unambiguous, and suitable for all audiences, including marine farmers, WRC consent staff, and scientific experts.
- The EMOP should clearly state the date of publication and the document version.
- Raw data should be submitted in spreadsheet format with the monitoring reports and allow for re-analysis of data by WRC to confirm reported monitoring results.

More specific recommendations and considerations are provided in Table 6.

Table 6. Recommendations and considerations for the preparation of an Environmental Monitoring Plan (EMOP).

EMOP content	Recommendations and considerations
Description of the marine farming activity	Relevant aspects of the marine farming activity, including farmed species, farm layout, and basic operational information, such as production cycles and seasonality of operation, if applicable.
History of the marine farm	Briefly describe the pertinent history of the marine farm, such as the commencement of operation, changes in farmed species, farm layout or extensions. If monitoring has been conducted prior to the preparation of the EMOP, a brief history of monitoring at the farm site should be provided.
Compliance standards, trigger values, and other monitoring requirements stipulated in consent conditions or other documents	The EMOP should describe any monitoring requirements stipulated in consent conditions or other documents, any compliance requirements to be informed by monitoring (compliance standards), and, if applicable, the staged development or other aspects of the adaptive management approach relevant for monitoring. If monitoring requirements were strongly influenced by the AEE (e.g., if monitoring aims to validate model predictions), the respective aspect of the AEE should also be described. Compliance standards typically include limits or thresholds or descriptive standards for the comparison or evaluation of monitoring results, including conditions under which response actions are to be taken. Compliance standards may be specified in consent conditions or other documents related to the marine farm, such as environmental management plans. The EMOP should specify how monitoring results will be analysed to evaluate whether compliance standards are met and what response actions will be taken in the event that they are not met.
Monitoring objectives	Monitoring objectives should be clearly stated to enable the results of monitoring to be assessed in terms of environmental objectives. Monitoring objectives should be specific, quantifiable, and practicably achievable based on environmental characteristics, resource availability, and sensitivity of methods. They should reflect the potential effects identified through the monitoring framework provided in this guidance and, if applicable, any relevant compliance standards. This guidance provides monitoring objectives that can be tailored for specific marine farms (Table 1). Some monitoring objectives may remain unchanged over the duration of consent, while others may need to be reviewed over time to ensure they remain relevant in the context of wider environmental change or improvements in knowledge.
Monitoring sites	A map of monitoring sites should be provided. The characteristics and rationale for all monitoring sites should be described and a justification for the suitability of reference sites should be provided.
Indicators (or parameters)	There should be a rationale for all indicators with a direct link to monitoring objectives.
Frequency and timing of monitoring	The frequency and timing of monitoring should be described along with the reasons why they were chosen.
Sampling (sample collection and visual) and analysis methods, including statistical approaches	Procedures and protocols for sampling and analyses, including those for sample collection, storage, and transport, statistical data analysis, and quality control, should be described. Procedures and protocols for the gathering, analysis, calibration (if applicable), and quality control of data collected electronically, including video, still imagery, in situ sensors, should be described.
Reporting	Reporting requirements for monitoring reports should be described, including which results to present, how compliance standards are to be assessed and compliances and non-compliances reported, raw data to be listed, and timing of reporting.
EMOP review	Most EMOPs are reviewed over the duration of consent. Reviews ensure that monitoring remains relevant in light of new data collected through monitoring or obtained from other sources, such as SOE monitoring or research projects.

6 Example applications of the monitoring framework

This section provides example applications of this guidance to three hypothetical marine farm set-ups:

Scenario 1: A new longline mussel farm in a well-flushed embayment

Scenario 2: A new intertidal oyster farm in a sheltered intertidal area of estuary

Scenario 3: A longline mussel farm extension (1 ha) in an open coast environment

The purpose of these examples is to illustrate how to use the monitoring guidance and to demonstrate how it facilitates the identification of appropriate monitoring that is relevant and proportionate to the intensity of predicted effects and the site-specific nature and sensitivity of the receiving environment. These examples also highlight that, for these relatively common marine farm set-ups, many potential effects described in this guidance are not identified as requiring monitoring.

For each example scenario, the marine farm set-up and environmental context are described and the process of working through the respective decision trees is illustrated and explained. Answers to questions in decision trees are illustrates as follows:

- ✓ = yes,
- ✗ = no, and
- ? = unsure.

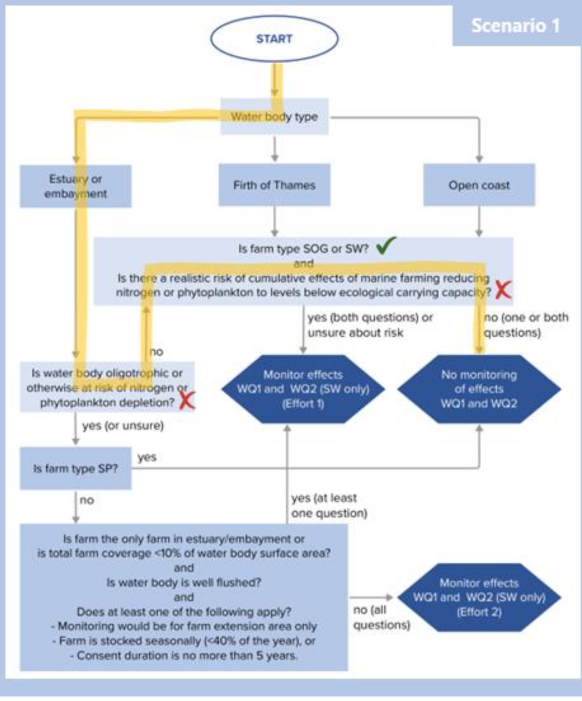
Where answering one of multiple questions is sufficient to determine the next step in a decision tree, only that single answer is provided. This is appropriate and realistic as in such instances the subsequent questions are not relevant for determining monitoring requirements.

The following acronyms are used in the scenario decision trees: OY = Intertidal oyster farming, SOG = Subtidal shellfish on-growing, SP = Spat catching, SW = Seaweed farming, WQ1-WQ2 = potential water quality effects as explained in Table 1, B1-B5 = potential benthic effects as explained in Table 1, H1 = potential hydrodynamic effects as explained in Table 1, NZCPS = New Zealand Coastal Policy Statement, WRCP = Waikato Regional Coastal Plan.

Scenario 1 **New longline mussel farm**	• Well-flushed embayment receiving river inflow from Coromandel catchment, known to contain moderate nutrient loads • Sandy seafloor • Typical benthic infauna communities and sediment organic carbon levels • Macroalgal bed under part of the farm and adjacent to it; spacing of lines minimises shading so that is not expected to adversely affect macroalgae • Rocky reef associated with macroalgal bed • No light-sensitive benthic flora and fauna or other ecologically valuable species • No regionally or nationally significant surf breaks nearby • No specific water quality, benthic, or hydrodynamic effects of ecological concern identified during consenting • One other mussel farm in embayment, combined size of both farms <10% of embayment surface area

Appropriate water quality monitoring

- None
- There would be no need to review water quality monitoring needs over the duration of consent

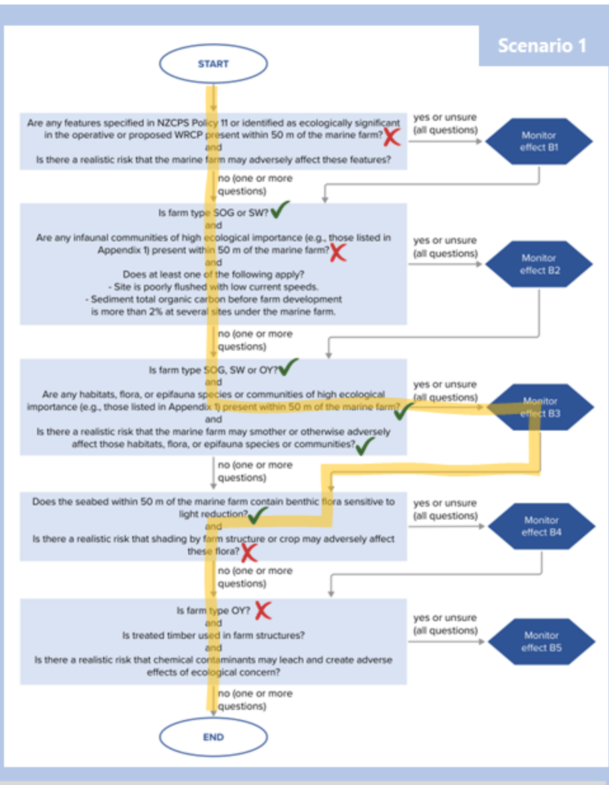


Appropriate benthic monitoring

Monitoring of the macroalgal bed and rocky reef to assess whether biodeposition, biofouling or crop drop-off causes changes that reflect adverse effects of ecological concern (potential effect B3). Monitoring effort 1 would likely be considered appropriate as the macroalgae and rocky reefs are not of ecological significance.

The monitoring approach would likely comprise:

- 5-yearly surveys of parts of the macroalgal bed and rocky reef potentially adversely affected using visual sampling methods.
- A comparable macroalgae-rocky reef assemblage in similar conditions (water depth, distance to shore, current speeds) would be used as a reference area.
- Monitoring should be reviewed after 2-3 surveys to evaluate whether monitoring effort can be reduced, or monitoring can be discontinued completely.



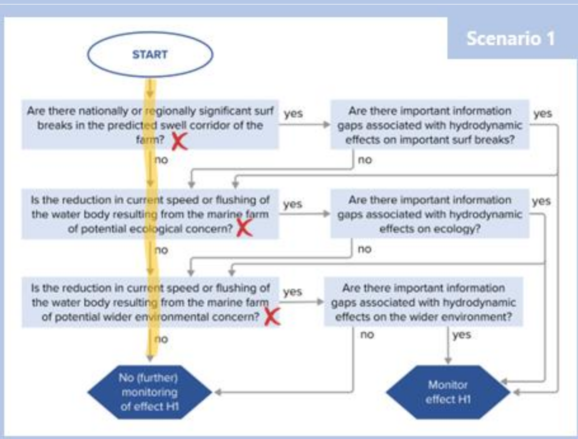
The monitoring review process would be as follows:

1. Has previous monitoring demonstrated compliance with compliance standards set out in conditions? Assuming it has:
2. Will there be further farm development of the part of the farm that may impact the macroalgal bed? If not:
3. Is there confidence that the effects of the farm on the macroalgal bed and rocky reef are sufficiently well understood? If adverse effects (if any detected) have been generally consistent and/or predictable among surveys, it could reasonably be concluded that effects are well understood.

In these circumstances, and providing actual effects are as or less than expected, the monitoring approach could be changed from routine to surveillance monitoring with surveys being reduced in frequency to 10-yearly. If the next survey demonstrates no greater effects than the previous one, monitoring could possibly be discontinued completely.

Appropriate hydrodynamic monitoring

- None
- There would be no need to review water quality monitoring needs over the duration of consent



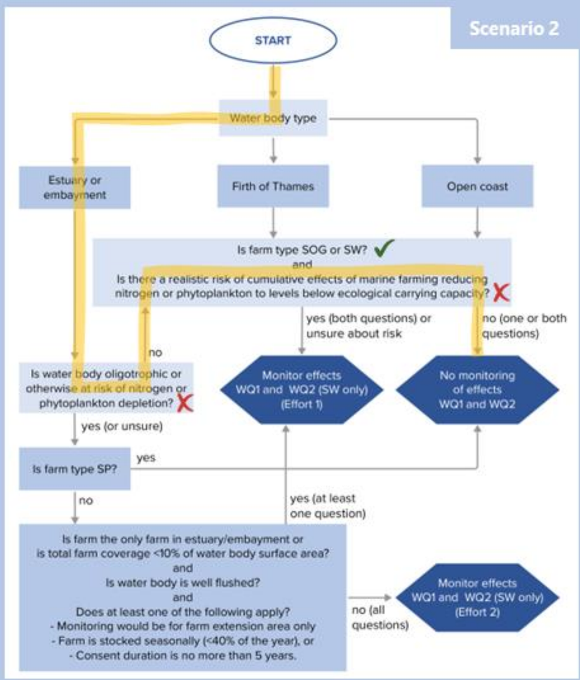
Scenario 2

New intertidal oyster farm

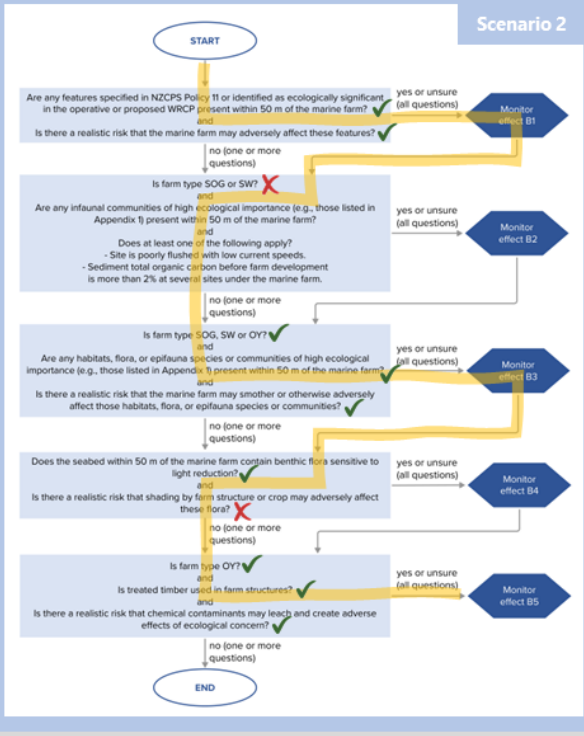
- Small (<3% of estuary surface area) intertidal oyster farm
- Farm structure made from copper-chrome-arsenate (CCA) treated timber
- Sheltered intertidal area of estuary
- Estuary catchment comprises mix of urban development, farming, forestry, and native bush
- Farm is within 30 m of a seagrass bed
- Muddy substrate
- Typical benthic infauna communities and sediment organic carbon levels
- No benthic species of high ecological value
- Elevated baseline arsenic and copper levels in sediment at the proposed site
- No nationally or regionally significant surf breaks nearby
- No specific water quality, benthic, or hydrodynamic effects of ecological concern identified during consenting
- No existing marine farms in the estuary

Appropriate water quality monitoring

- None
- There would be no need to review water quality monitoring needs over the duration of consent



Appropriate benthic monitoring



Monitoring of the seagrass bed to assess:

1. Whether the marine farm causes adverse effects on seagrass that are greater than those allowed under NZCPS Policy 11 or under WRCP policies related to features identified as ecologically significant in the operative or proposed WRCP;
2. Whether biodeposition, biofouling or crop drop-off causes changes in the seagrass bed that reflect adverse effects of ecological concern (potential effect B3); and
3. Whether sediment chemical contaminant concentrations are elevated by leaching from the timber structure above permitted levels (likely default guideline values, DGV, specified in ANZG (2018), potential effect B5).

The first two monitoring objectives would likely be combined into one objective, assessing monitoring results against specific limits denoting thresholds to unacceptable levels of change in seagrass bed extent and/or condition.

Monitoring effort 2 would likely be considered appropriate because of the high ecological value of seagrass beds and uncertainties in scientific understanding of biodeposition effects on seagrass. For effect B5 monitoring effort 1 would likely be sufficient, however, overall monitoring effort 2 would apply.

Monitoring of effect B4 (light sensitive seagrass bed) would probably not be required because of the low likelihood of shading effects of an intertidal farm beyond the farm structures.

The monitoring approach would likely comprise:

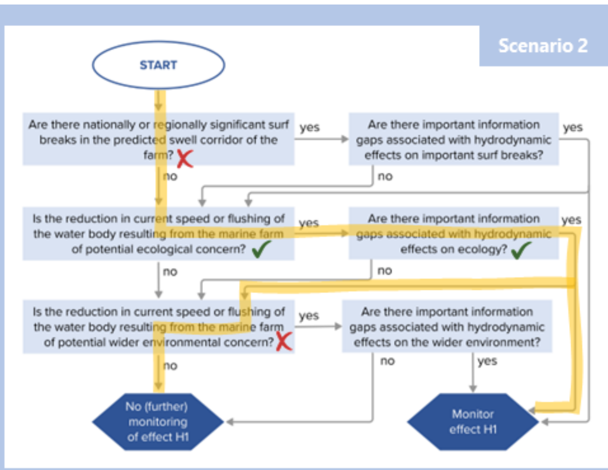
- A robust baseline survey of the seagrass bed (focussing on the area potentially affected by the oyster farm) unless one has already been conducted.
- Initially annual surveys of the seagrass bed (or part of the seagrass bed potentially adversely affected) using visual sampling methods (while the guidance suggests 3-yearly, the ecological value of seagrass would likely be a factor warranting deviation from the general guidance resulting in more stringent monitoring, e.g., an annual survey at a specific time of the year).
- A seagrass bed in similar environmental conditions (water depth, distance to shore, current speeds) would be used as a reference area (or, if no separate seagrass bed exists, a part of the seagrass not expected to be impacted by the farm could be used as a reference area).
- At the same time of seagrass surveys, sediment sampling at representative locations near timber poles for analysis of copper, chromium, and arsenic and comparison to DGV.
- Monitoring should be reviewed after 2-3 surveys to evaluate whether effort can be reduced.

The monitoring review process would be as follows:

1. Has previous monitoring demonstrated compliance with compliance standards set out in conditions? Assuming it has:
2. Will there be further farm development of the part of the farm that may impact the seagrass bed or sediment chemical contaminant levels? If not:
3. Is there confidence that the effects of the farm on the seagrass bed and sediment chemical contaminant levels are well understood? It is unlikely that this could be concluded after only 2-3 years. However, there may be sufficient confidence to support a reduction in monitoring frequency. It is likely that effects on sediment chemical contaminants will be sufficiently well understood after this period of time and this component of monitoring may be discontinued.
4. In these circumstances, the monitoring approach would remain routine monitoring of the seagrass bed, but surveys could be reduced in frequency to 3-yearly. If after another 2-3 surveys effects have not increased in intensity, further reductions in frequency, e.g., to 5-yearly, could be supported.

It is unlikely that monitoring of the seagrass bed would ever be completely discontinued.

Appropriate hydrodynamic monitoring



Monitoring of the seagrass bed to assess whether:

- Changes in the flow of currents caused by the presence of the marine farm structure and crop results in changes in sediment dynamics (e.g., retention of fine sediment under and near the farm structure) that adversely affects the seagrass bed adjacent to the farm.

The monitoring approach would likely focus on monitoring sediment grain size (for the purpose of identifying whether the farm has resulted in a retention of fine sediment) and the seagrass bed directly (for the purpose of identifying ecological change of concern) instead of monitoring change in hydrodynamic conditions. These monitoring components would be incorporated into the benthic monitoring programme. Annual monitoring would likely be considered appropriate to obtain sufficient data points for examining trends over time in sediment grain size composition. Hydrodynamic monitoring needs should be reviewed at the same time as benthic monitoring needs.

The monitoring review process would be as follows:

1. Has previous monitoring demonstrated compliance with compliance standards set out in conditions? Due to the likely high uncertainty around expected effects on changes in sediment grain size composition and subsequent effects on the seagrass bed, it is likely that compliance standards would be qualitative. Assuming that, based on expert judgement, it is concluded that standards are met:
2. Will there be further farm development of the part of the farm that may impact the seagrass bed?

   If yes and further development may affect the seagrass bed, it is unlikely that monitoring would be changed to ensure consistency in the monitoring data set and thus maximise the likelihood that adverse effects would be detected.

   If not: Considerations would include whether there is confidence that he effects of the farm on changes in sediment grain size distribution and resulting effects on the seagrass bed are well understood. As described for the benthic monitoring review, it is unlikely that after only 2-3 years it would be possible to conclude that effects are well understood. As also outlined under benthic monitoring, it is possible that monitoring frequency is reduced over time, but it is unlikely that monitoring of grain size and the seagrass bed would ever be completely discontinued.

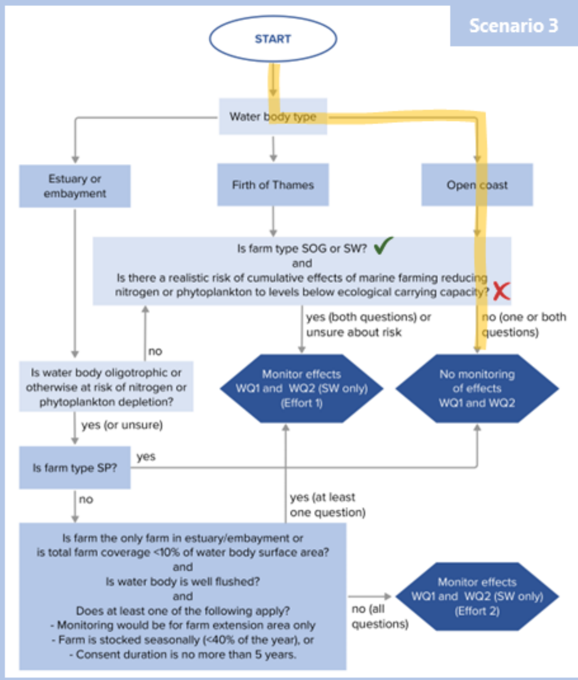
Scenario 3

Longline mussel farm extension (1 ha)

- Three km off the Waikato west coast in 30 m water depth (open coast)
- Seafloor dominated by sandy/muddy substrate and low benthic infauna diversity, apart from a ~20 m x 20 m area with coarse substrate
- Limited information available on epifaunal community associated with coarse substrate
- Coarse substrate and epifauna community unlikely to fall under NZCPS Policy 11(a) descriptors and unlikely to be ecologically significant under the WRCP
- Policy 11(b) descriptor(s) may be met for area of coarse substrate and marine farm in extension area could be managed to ensure effects are no greater than those allowed under Policy 11(b)
- No nationally or regionally significant surf breaks nearby
- No specific water quality, benthic, or hydrodynamic effects of ecological concern identified during consenting

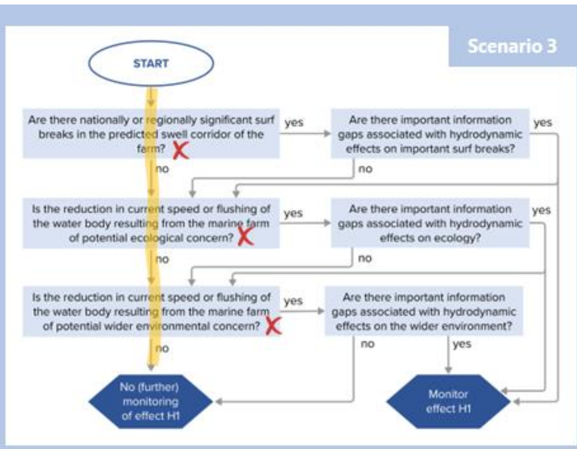
Appropriate water quality monitoring

- None
- There would be no need to review water quality monitoring needs over the duration of consent

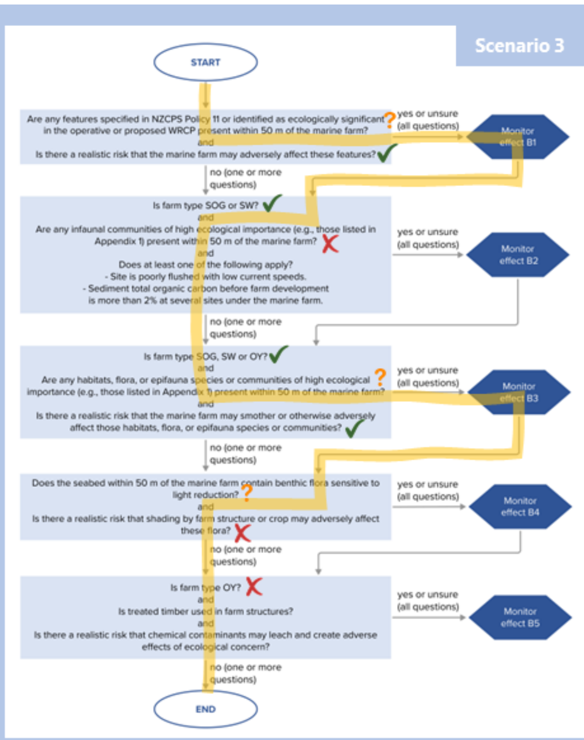


Appropriate hydrodynamic monitoring

- None
- There would be no need to review water quality monitoring needs over the duration of consent



Appropriate benthic monitoring



Prior to farming in the extension area, a baseline survey would be required to determine whether the area of coarse substrate falls under NZCPS Policy 11(b). A robust description of baseline conditions will also be required for interpreting monitoring results. This will be particularly important because it is unlikely that a comparable substrate and epifauna community can be found in a reference area.

If Policy 11(b) applies, performance indicators for monitoring will be set to match requirements of the NZCPS and monitoring will likely be more frequent than outlined below and at effort 2.

If Policy 11(b) does not apply, monitoring of the coarse substrate and associated epifauna community will aim to assess whether biodeposition, biofouling, or crop drop-off causes changes in the composition or condition of the habitat or epifauna community that reflect adverse effects of ecological concern (potential effect B3). Effort 1 would likely be appropriate, with monitoring as follows:

- 5-yearly surveys of the substrate and epifauna community, likely using visual sampling methods.
- A focus on describing and assessing the composition and condition of the epifauna community compared to baseline conditions with grain size sampling to assess changes in substrate.
- Reviewed of monitoring after 2-3 surveys to evaluate whether monitoring effort can be reduced, or monitoring can be discontinued completely.

Monitoring of the extension area should be integrated with existing monitoring of the parent farm (if any). It may be appropriate to review the monitoring approach of the parent farm at the time of the farm extension application to achieve best alignment of monitoring.

The monitoring review process would be as follows:

1. Has previous monitoring demonstrated compliance with compliance standards set out in conditions? Assuming it has:
2. Will there be further farm development of the part of the farm that may impact the coarse substrate and epifauna community? If not:
3. Is there confidence that the effects of the farm on the epifauna community are well understood? If adverse effects (if any detected) have been of low intensity and not caused any measurable degradation of the epifauna community, it could reasonably be concluded that effects are well understood.

In these circumstances, the monitoring approach could be changed from routine to surveillance monitoring with surveys being reduced in frequency to ~10-yearly. If the next survey demonstrates no greater effects than the previous one, monitoring could possibly be discontinued.

7 Review of this guidance

This guidance, including the decision trees of the monitoring framework, will be reviewed periodically as more information on the receiving environment and/or the effects of non-fed marine farming in the Waikato CMA becomes available. This ensures that the processes used to identify appropriate monitoring continues to be informed by current knowledge.

8 Glossary and acronyms

Actual effect	An environmental effect that has been measured (observed) after commencement of the activity. Actual effects are typically measured through environmental monitoring.
AEE	Assessment of environmental effects.
Baseline conditions	Condition of the receiving environment before being affected by the marine farm. Baseline conditions include the biological, chemical, and physical characteristics of the water column and benthic environment and hydrodynamic conditions, including spatial and temporal variability.
Baseline data	Data describing environmental baseline conditions i.e., environmental conditions prior to an area being affected by the marine farm. Baseline data can be obtained from a wide range of sources, including baseline surveys conducted before or after consent is granted. For the purpose of this report, no distinction is made between baseline data collected through descriptive surveys, baseline surveys, or other information sources.
Benthic flora	Algae and plants living on the seabed.
Biogenic habitat	Habitat formed by living or dead plants or animals in sufficient density and extent that their three-dimensional structure or interaction with the substrate provides substantive ecosystem services such as shelter, protection, and resources for at least one phase of the lifecycles of other marine organisms. Examples include kelp forests, rhodolith beds, coral structures, bryozoan thickets, sponge gardens, tubeworm fields, and horse mussel beds. It is noted that this definition is broader than the definition of biogenic habitat in the NES-MA.
CMA	Coastal Marine Area.
Commercial aquaculture	Aquaculture that is undertaken with the primary purpose of producing aquaculture products for sale.
Compliance standard	Quantitative or qualitative descriptors of environmental conditions or levels of environmental change that denote maximum allowable environmental change or that, if reached or exceeded, trigger some management action. In this guidance, quantitative compliance standards are referred to as limits and thresholds. Compliance standards are stipulated in consent conditions or other compliance documents. Water quality, benthic, and hydrodynamic monitoring results are typically compared to compliance standards to evaluate the environmental performance of the marine farm.
Cumulative effect	As defined in the RMA, any cumulative effect which arises over time or in combination with other effects, regardless of the scale, intensity, duration, or frequency of the effect. Cumulative effects can arise from multiple stressors of the same type (e.g., multiple mussel farms) as well as the interaction of different anthropogenic and natural stressors.

Ecological carrying capacity	For the purpose of this guidance defined as the ability of the water body to maintain the ecosystem in its natural, original, or healthy state, acknowledging that this state is difficult to define.
EMOP	Environmental monitoring plan.
Epifauna	Animals living on the surface of the seabed or attached to submerged objects, aquatic animals, or aquatic plants.
Fed-aquaculture	The farming of any aquatic organism that involves the discharge of feed into the coastal marine area and includes finfish farming.
Hydrodynamic conditions (or hydrodynamics)	The state and dynamics of currents, sea level, and surface waves. In coastal waters, the main hydrodynamic processes generating hydrodynamic conditions are wind-induced and tide-induced waves, and tide-, wind-, density- and wave-induced currents.
Indicator	A measurable or quantifiable characteristic of the environment. Some indicators can be directly measured (e.g., water column chlorophyll-*a*), while others are calculated from measurements and, in some instances, other information (e.g., phytoplankton depletion, benthic infaunal community health indicators).
Infauna	Animals living in the sediment.
Limits and thresholds	Quantitative descriptors of environmental conditions or levels of environmental change. Limits and thresholds are specific types of compliance standards, i.e., values stipulated in consent conditions (or other compliance documents) that denote maximum allowable environmental change or that, if reached or exceeded, trigger some management action.
Monitoring	Systematic repeat measurements, periodic analysis, and reporting of change in the receiving environment. In this guidance, the term is used to refer to consent-related monitoring that focusses on environmental change caused by marine farms, in other words, the actual effects of marine farms.
Monitoring framework	The 3-step framework for identifying appropriate water quality, benthic, and hydrodynamic monitoring presented in this guidance.
Monitoring report	A report prepared periodically to describe the result of monitoring carried out over a specific period of time.
Non-fed aquaculture	Farming of any aquatic organism that does not involve the discharge of feed into the coastal marine area and therefore excludes finfish farming.
NZCPS	New Zealand Coastal Policy Statement 2010.
Open coast	Defined in Figure 4 of this guidance document as the area outside estuaries and embayments and the Firth of Thames.
Potential impact site	Monitoring site that may be impacted by the marine farm. Potential impact site locations are informed by monitoring objective. For example, if a monitoring objective aims at measuring maximum phytoplankton depletion, a potential impact station may be located at the centre of a marine farm. However, if a monitoring objective aims at measuring the effects of shell drop off on sensitive benthic habitats near the farm, potential impact stations may

	be located along a transect from the farm boundary to the sensitive benthic habitat.
Potential effect	An environmental effect that may occur but has not been measured or predicted for a specific activity, e.g., marine farm (for distinction from 'actual' or 'predicted').
Predicted effect	An environmental effect that is predicted to occur but has not yet been measured (for distinction from 'actual' or 'potential' effect).
Realistic risk	For the purpose of using the decision trees presented in this guidance means that the likelihood of the respective effect and/or environmental outcome of concern occurring is more than a theoretical possibility or mere speculation; there must be a plausible cause and effect relationship between the marine farming activity and the respective adverse effects/environmental outcome.
Reference site	A monitoring site that is located in an area expected not to be impacted by the monitored activity. Reference sites should be in an area with similar natural environmental conditions (e.g., water depth, substrate, flushing) as the impact sites and (as much as practicable) unimpacted by other stressors.
RMA	Resource Management Act 1991.
Rocky reef	Means the exposed hard substrate in the CMA formed by geological processes (including cobbles equal to, or greater than, 64 mm across, boulders, and bedrock but not including sand or gravel) and includes marine species associated with the reef. This definition is consistent with the definition of 'reef' in the Resource Management (National Environmental Standards for Marine Aquaculture) Regulations 2020 (NES-MA).
SOE monitoring	State of the Environment Monitoring.
Surveillance monitoring	For the purpose of this guidance means the periodic measurement of environmental components that, if modified in certain ways and/or at or above a certain amount, would indicate an environmental effect of the monitored marine farm that is unexpected and of ecological concern.
WRC	Waikato Regional Council.
WRCP	Waikato Regional Coastal Plan.

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Appendix 1: Examples of benthic species, communities, and habitats of ecological importance

Table A1-1. Examples of benthic species, communities, and habitats of ecological importance that may be sensitive to organic enrichment and/or drop-off from non-fed aquaculture. The presence, density, and/or condition of these ecologically important features may trigger the need for monitoring. Modified from Davidson et al. (1999) and incorporating information on biogenic habitats from Anderson et al. (2019). Anderson et al. (2019) is also recommended as a resource for more information on biogenic habitats, their ecological values and how they may be adversely affected. Additional references are provided in the table.

Species, community, or habitat	Description and examples
Anthozoa	Sea anemones and corals
Atrina zelandica	Horse mussel (also see 'beds of large shellfish').
Austrovenus stutchburyi	Cockle
Beds of large shellfish	Anderson et al. (2019) defines shellfish beds as the occurrence of large shellfish in densities of ≥ 30% cover over an area of 100 m^2 or more, or where catches contribute 30% or more by weight or volume in a single dredge tow or grab sample. Key species are robust dog cockles (*Tucetona laticostata*), horse mussels (*Atrina zelandica*), New Zealand scallops (*Pecten novaezelandiae*), and green-lipped mussels (*Perna canaliculus*),
Biogenic habitats	Including but not limited to those listed in this table. Biogenic habitats vary in their sensitivity to organic enrichment and/or drop-off from non-fed aquaculture, which needs to be considered when determining monitoring requirements.
Bryozoans (colonies or thickets)	Including *Arachnopusia unicornis*, *Cellaria immersa*, *Celleporaria agglutinans*, *Cinctipora elegans*, *Diaperoecia purpurascens*, *Galeopsis porcellanicus*, *Galeopsis grandiporus, Hippomenella vellicate*, *Hornera robusta*. Bryozoan colonies range in size through five orders of magnitude from 0.2 mm to 2 metres in size. Anderson et al. (2019) define bryozoan beds (or thickets) as habitats where frame-building bryozoan species dominate (at least) square metres of seafloor.
Callorhinchus milii	Elephant fish embryo
Cerianthus sp.	Burrowing anemone
Epigonichthys hectori	Lancelet
Galeolaria hystrix	Subtidal calcareous tubeworm.
Glycymeris spp.	Dog cockles (also see 'beds of large shellfish').
Hydroids	Including tree hydroid *Solanderia ericopsis.*

Important infauna communities	Infauna communities providing ecosystem functions that contribute in a meaningful way to the health or recovery of the surrounding ecosystem, including diverse community containing large keystone species.
Kelp forests	Brown algae belonging to the order Laminariales (or true kelps) or Fucales (or seawracks), including *Carpophyllum spp*., *Ecklonia radiata, Macrocystis pyrifera,* and *Durvillaea spp*.. Anderson et al. (2019) define kelp forests as either a monospecific or mixed-species stand of mature brown algae from the orders Laminariales and Fucales that form complete canopy cover with > 4 adult plants per m^2.
Lenormandia chauvini, *Rhodomenia* spp.	Red algae
Macoalgal meadows	Including green algae *Caulerpa flexilis*, *Ulva spp*., *Codium spp*., red algae *Adamsiella chauvinii*, *Stenogramma interruptum*, *Gracilaria truncata*, *Rhodophyllis spp*., *Asparagopsis spp*., *Rhodymenia spp*., and filamentous genera as *Ceramium* and *Polysiphonia sensu lato*. The kelp *Ecklonia radiata* can also grow in meadows. Anderson et al. (2019) define macroalgal meadows as stands of one or more key species growing over sand, shell or cobble substrates which may or may not be attached to substrata, and which provide greater than ≥35% cover over an area of ≥10 m^2 in seabed imagery (e.g., towed video). Also see D'Archino et al. (2019).
Neothyrus lenticularis *Magasella sanguinea* *Waltonia inconspicua*	Lamp shells
Non-calcareous tubeworm fields	Anderson et al. (2019) define non-calcareous tubeworm fields as areas of contiguous cover or mosaics of higher density tubeworm patches interspersed by bare sediment, where tubeworms (and any attached epifauna) cover >500 m^2 of seafloor, or contribute at least 25% of the weight or volume of the catch from towed sample gear, or occur in two successive samples collected by point sampling gear. Key species are wire-weed/Tarakihi-weed, *Spiochaetopterus* and *Phyllochaetopterus spp*, *Acromegalomma* worms, *Acromegalomma suspiciens*, *Euchone spp*. and *Owenia petersenae*.
Paphies australis	Pipi
Pecten novaezelandiae	Scallop (also see 'beds of large shellfish').
Rhodoliths (individual or bed)	Free-living, calcified red algae. Anderson et al. (2019) define rhodolith beds as free-living coralline thalli (individual rhodoliths) that occur on the seabed in greater than ≥10% cover, or a single occurrence of a rhodolith species in a towed or point sample.
Rocky reef	

Salt marsh vegetation	Rushes/sedges
Sea pens (individuals or fields)	Colonial marine cnidarians in the order Pennatulacean. Anderson et al. (2019) define sea pen fields (or sea whip fields) by two or more individuals per m^2 in seabed imaging surveys or two or more specimens collected using towed gear,
Sponges (especially sponge gardens)	Including *Aaptos*, *Ecionemia elata*, *Axinella spp.*, *Callyspongia spp.*, *Cinachyra spp.*, *Crella spp.*, *Dendrilla rosea*, *Iophon spp.*, *Ircinia spp.*, *Polymastia granulosa*, *Raspalia spp.*. Anderson et al. (2019) define sponge gardens as occurring on the seabed in greater than ≥25% cover over an area of 100 m^2 or more, or where sponge specimens contribute to ≥20% of the volume of the catch from towed sampling gear, or ≥25% of the volume in a successive grab samples.
Triostrea chilensis	Dredge oyster
Uncommon sediment type	Well sorted sand/gravels
Zostera capricorni (formerly referred to as *Z. novazelandica* and/or *Z. muelleri*)	Seagrass. Most valuable at densities forming beds or meadows. Anderson et al. (2019) defines seagrass meadows as areas of continuous/dominant (>60%) plant cover within an area of 10,000 m^2 or more and notes that areas smaller than this are more appropriately referred to as seagrass patches.