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Review of Tasmanian and International Regulatory Requirements for Salmonid Aquaculture

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December 2019

ENVIRONMENT PROTECTION AUTHORITY

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Glossary of Acronyms and Terms

Acronyms	Meaning
AZE	Allowable Zone of Effect
BEMP	Broad-Scale Environmental Monitoring Program
BMP	Benthic Monitoring Program
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DGVs	Default Water Quality Guideline Values
DPIPWE	Department of Primary Industry, Parks, Water and Environment
EMPCA	Environmental Management and Pollution Control Act 1994
EPA	Environment Protection Authority
EQO	Environmental Quality Objectives
EQS	Environmental Quality Standards
ES100	Hulberts Diversity Index
FRDC	Fisheries Research and Development Corporation
H'	Shannon-Wiener Index
IMAS	Institute for Marine and Antarctic Studies
ISI	Indicator Species Index
LMRMA	Living Marine Resources Management Act 1995
MAB	Maximum Allowable Biomass
MTB	Maximum Total Biomass
MFDP	Marine Farming Development Plan
MFPA	Marine Farming Planning Act 1995
MPS	Management Protocol Specification
nEQR	Total Fauna Index
NQI1	Norwegian Quality Index
NSI	Norwegian Sensitivity Index
ROV	Remotely Operated Vehicle
SEPA	Scottish Environment Protection Agency
TAFI	Tasmanian Aquaculture and Fisheries Institute
TFS	Total Free Sulfides
TOC	Total Organic Carbon
TPDNO	Total Permissible Dissolved Nitrogen Output

Terms	Meaning
Adaptive management	A process for refining resource management by learning from management outcomes.
Anaerobic	The absence of oxygen.
Anoxic events	Occurs when a water body becomes completely depleted of oxygen.
Assimilative capacity	The ability of a body of water to receive waste without deleterious effects and damage to biological organisms.
Benthic amelioration plan	A plan to improve the environmental conditions of the seabed.
Benthic footprint	The area on the seabed affected by the fish farming operation.
Best practice environmental management	As defined in Section 4 of the Environmental Management and Pollution Control Act 1994.

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Summary of Comments on EPA (Authority) Report Style Word template

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Number: 1 Author: delvines Subject: Highlight Date: 18/05/2020 7:56:12 PM
Add "Environmental Standard"

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Chronic levels	Are sustained levels of a pollutant that has long lasting effects on the environment.
Cumulative effects	Changes to the environment caused by the combined impact of multiple activities/processes.
Depauperate	Lacking in numbers or variety of species.
Diffuse source	Contamination resulting from the release of waste over a wide area.
Dissolved nutrients	In relation to fish farming, this includes the excretion of ammonia and phosphate.
Environmental indicator	Any parameter of group of parameters indicative of a particular environment or set of environmental conditions.
Environmental compliance	Is to conform to any environmental regulations, laws, regulations, standards, and other requirements to operate.
Environmental Licence	Means an Environmental Licence as granted under Division 9 or Part 3 of the *Environmental Management and Pollution Control Act 1994*
Environmental performance	The performance of an Environmental Licence holder against a set of environmental quality standards outlined in an Environmental Licence.
Environmental quality standards	Is a threshold numerical value or narrative statement to limit environmental disturbance.
Environmental values	The value for a community or society on environmental goods and services.
Emissions	The release of a substance to the environment.
Eutrophication	When dissolved nutrients become enriched in a body of water that stimulates the growth of algae and other aquatic plants that can result in the depletion of dissolved oxygen.
Farm-Zone	A zone that covers the operational part of a marine farming lease.
Husbandry practices	The practice of managing a farm to meet animal health and welfare standards and for optimal animal performance.
Intensive aquaculture	The process of growing marine organisms in high densities with high value supplemental feeding.
Macrobenthic assemblages	Are organisms visible to the naked eye that live on the seabed.
Maerl bed	Is a purple-pink hard seaweed with a brittle skeleton that forms carpets on the seabed.
Metabolic pathways	A series of biochemical reactions that are connected by their intermediates: the products of one reaction are the substrates for subsequent reactions.
Nursery ground	Habitats that enhance the growth and survival of juvenile animals (such as fish).
Opportunistic fauna	An organism with a low level of specialisation that is either capable of adapting to varied conditions, or that gives priority to reproduction over survival.
Organic enrichment	The addition of nutrients from organic matter.
Particulate nutrients	In relation to fish farming, this includes the release of excess feed and the defecation of faeces containing nitrogen, phosphorus and carbon.
Physico-chemical parameters	Are environmental parameters that have physical and chemical properties (for example, Temperature, velocity, pH, dissolved oxygen, turbidity, etc).
Point source	Discharge of waste from a specific, localised source.
Qualitative measurements	Are observations/measurements that do not have a value.
Quantitative measurements	Are observations/measurements that have a value for a particular parameter.
Remediation	The breakdown of any organic matter by the use of processes involving biological organisms.
Reference stations	Are sampling stations that do not experience the same anthropogenic influences to the area being managed. These stations should located in a location that experience similar environmental conditions, so they can be used to benchmark environmental conditions to be achieved.

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Semi-quantitative measurements	Is an approximate measurement, resulting in a measure that is between a qualitative and quantitative result.
Spawning ground	Habitats where reproductive animals (such as fish) go to released and fertilise their eggs.
Spatial delineation	Define the area of interest.
Therapeutants	A medicine given to a fish to treat for an infection, disease or parasite
Threshold	The level or point at which an activity (i.e. fish farming) has exceeded an Environmental Quality Standard.
Visual assessment techniques	The use of divers or remotely operated vehicles to undertake a underwater survey to characterise the environmental condition of the seabed.

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Executive Summary

With an over-arching vision for Tasmania to have the 'most environmentally sustainable salmon industry in the world' the Tasmanian State Government has set a high benchmark, in its *Sustainable Industry Growth Plan for the Salmon Industry*. To better understand this benchmark, the Director, Environment Protection Authority (EPA) has commissioned a review of the existing environmental regulatory practices for salmonid farming with a focus on how Tasmanian regulatory practices compare with those of international salmonid farming jurisdictions. This paper provides information that will inform the development of a new 1environmental Standard' for regulating finfish farming in Tasmania.

Salmonid farming in the Tasmanian marine environment has been operating commercially since the late 1980s. The industry has grown over the past 30 years, with current production exceeding 58,000 tonnes HOG (head on and gutted) of salmonids harvested. In 2018, the salmonid industry provided the State economy with approximately $820 million and directly employed more than 1,800 full time and casual positions. The Department of Primary Industries, Parks, Water and Environment (DPIPWE) formalised an environmental monitoring program for salmonid farming operations in the late 1990s, reviewing and updating the monitoring program in 2004. Underpinning this review and subsequent updated environmental monitoring program was the breadth of local scientific knowledge for Marine Farming Development Plan (MFDP) areas and international knowledge on best practice environmental management.

The current environmental monitoring requirements used by the EPA are derived in part from the 2004 review, and subsequent scientific investigations undertaken by both the Institute for Marine and Antarctic Studies (IMAS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) within and external to the existing MFDP areas. The scientific investigations included but were not limited to, a 'whole-of-ecosystem' assessment of environmental issues for salmonid aquaculture, evaluation of the 'Broad-Scale Environmental Monitoring Program (BEMP)' in the Huon Estuary and the D'Entrecasteaux Channel, and disentangling the effect of finfish farming on the 'health status' of Macquarie Harbour. Given it has been more than 15 years since the last review of the regulatory environmental monitoring program (2004), and the salmon industry has expanded significantly during this time period, it is timely to review the 2fficiency and effectiveness of the current monitoring program in line with 3urrent farm management practices and environmental monitoring tools to protect the environment.

The impacts of salmonid farming on the marine environment are well documented, with the release of dissolved and particulate nutrients interacting directly and indirectly with the surrounding environment. The impact of the dissolved and particulate nutrients on the marine environment may lead to eutrophication of the water column, enrichment of soft and hard substrate habitats, and subsequently changes in the structure and function of marine ecosystems. These can include impacts to habitats that are important for refuge, spawning and nursery grounds for a variety of other organisms. Once impacted by dissolved and particulate nutrients from salmonid farming, restoring the structure and function of marine ecosystems to background conditions can require months to years of rehabilitation through fallowing (i.e. no active fish farming).

Comparative review

This paper outlines international regulatory pr4ctices for monitoring the environmental impacts of farming salmonids in net pens and 5ompares to current regulatory practices in Tasmania. This paper does not attempt to investigate the effectiveness of the respective regulatory regimes, or levels of compliance with them. 6

Across the six key areas identified for this review, environmental regulation in Tasmania generally p7rforms well in an international context.

Compliance and lease management zones 8

For compliance and lease management zones, Tasmania has 10n-form[illegible] established zones where environmental monitoring takes place. These zones cover the 11erational part of the marine farming lease (Farm-Zone), and 35 m from the lease boundary (12owable Zone of Effect – AZE). In addition, monitoring takes place at 13MP stations located beyond the AZE. Other salmonid farming jurisdictions utilise either a

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Number: 1 Author: delvines Subject: Highlight Date: 2/06/2020 6:19:34 AM
A sentence to define what this is specifically would be useful. Presumably a policy document, how is it to be implemented? Also have suggested adding it to the terms list, and perhaps that is all that is required, along with a definition in that table.

Number: 2 Author: deannae Subject: Highlight Date: 2/06/2020 6:20:01 AM
I think that: a) reviewing the efficiency and effectiveness of the present Tasmanian monitoring programme, and b) comparing it to national and international farm management, are two completely different aspects of this review exercise. I think what you are not doing is comparing the effectiveness of the current programme with the effectivness of overseas programmes, which is what this sentence says.

Number: 3 Author: delvines Subject: Highlight Date: 26/05/2020 7:39:08 AM
current international practice?

Number: 4 Author: emman Subject: Sticky Note Date: 26/05/2020 7:40:05 AM
compares international practice to?

Number: 5 Author: emman Subject: Highlight Date: 26/05/2020 7:39:57 AM

Number: 6 Author: emman Subject: Sticky Note Date: 26/05/2020 7:41:15 AM
Use of 'performs' appears to contradict previous sentence - do you mean that environmental regulation is more stringent? Or that it is consistent with? or adopts the best aspects of?

It would be useful to clarify this so the reader knows how to interpret the following points.

Number: 7 Author: emman Subject: Highlight Date: 26/05/2020 7:41:03 AM

Number: 8 Author: delvines Subject: Sticky Note Date: 25/05/2020 8:52:40 AM
Does it matter if they are formal or informal? They are still zones and it makes it confusing without the background to go with this in the summary. Generalised is perhaps a better word.

Number: 9 Author: delvines Subject: Underline Date: 18/05/2020 6:14:52 PM

Number: 10 Author: delvines Subject: Highlight Date: 18/05/2020 6:15:59 PM

Number: 11 Author: deannae Subject: Highlight Date: 2/06/2020 6:21:39 AM
does "the operational part" mean an area defined by the boundary of the surface structures, or the total impact zone? Would be great to have this defined in more detail in the glossary as for AZE for readers who are not familiar with Tassie framework (see next comment)

Number: 12 Author: deannae Subject: Highlight Date: 26/05/2020 7:43:35 AM
I think important to better define this in the glossary.

Author: emman Subject: Sticky Note Date: 26/05/2020 7:47:21 AM
Also it would be useful to clarify (here, or perhaps better in the body of the document) how much of the lease boundary is generally occupied with pens, and how much free space there is, as it stands, I'm not sure what 35m from the lease boundary means in terms of distance from the actual pens. The diagrams below imply that the lease boundary is very close to the edge of the pens.

Number: 13 Author: delvines Subject: Highlight Date: 2/06/2020 6:22:28 AM
not clear if BEMP is just in Tas, or also other jurisdictions? I think only Tas, but need to clarify.

Again, beneficial to describe this term in the glossary. Are all stations beyond the AZE considered BEMP stations? or are there reference stations beyond the AZE that are used for lease-scale monitoring stations, but that are not BEMP stations?

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zone-based or a fixed distance monitoring approach. Both approaches are complementary for regulating environmental compliance.

Selection and number of monitoring stations

In terms of the selection and number of monitoring stations, Tasmanian oversight of Farm-Zone performance relies on less monitoring data than is required in other jurisdictions. The number of monitoring stations beyond the lease boundary have a greater spatial resolution in Tasmania than elsewhere. Additional sampling within the Farm-Zone would enhance current understanding of lease-based effects, while monitoring beyond the AZE to target potential cumulative far-field effects would align with international practice.

Performance based management

For performance based management an adaptive management approach has been used for regulating the environmental performance of salmon farming in Tasmania for the past 20 years. While not formally a tiered environmental monitoring program, the intent has been to be able to measure key environmental indicators using either qualitative, semi-quantitative or quantitative measurements to assess environmental compliance when directed. Tasmania has statutory provisions requiring environmental monitoring to occur at or near peak production, however, this has been discretionary. For the past 5 years, the regulator has required approximately 50% of all environmental monitoring surveys at finfish farms outside Macquarie Harbour to occur at or near peak feed input, while approximately 30% being undertaken during fallowing. ~~In comparison~~ internationally, environmental monitoring is undertaken when the likelihood of impacts from fish farming are at their greatest (i.e. at or near peak production). Formalising and implementing a tiered environmental performance-based monitoring program at or near peak production into the new 'Environmental Standard' to provide a robust and defensible environmental monitoring program, will enable consistency with international practice and provide further security for sustainable growth of salmonid farming in Tasmania.

Environmental indicators and associated thresholds

In terms of environmental indicators and their associated thresholds, Tasmania, has developed visual assessment techniques (from the best available scientific knowledge) using qualitative and semi-quantitative measurements that have been robust and effective on a region-specific basis. Internationally, the use of visual indicators normally only provides additional evidence to support other environmental indicators (e.g. physico-chemical and biological parameters) measured either quantitatively and/or semi-quantitatively against known thresholds. Environmental compliance monitoring in Tasmania, has infrequently undertaken quantitative measurements of key environmental indicators for enrichment over the past 15 years. With the production of salmonids moving into new and more exposed locations along the coast, additional relevant indicators for sensitive and vulnerable habitats (e.g. shallow and deep-water reef communities) have been included into ~~the~~ environmental monitoring ~~program~~. Given the limited scientific knowledge around how these types of habitats respond to dissolved and particulate nutrients from finfish aquaculture, regulating the response requires expert scientific assessment.

Baseline sampling

Similar to farming salmonids in other jurisdictions, baseline sampling for finfish leases in Tasmania collects multiple lines of evidence across various seabed environments and habitat types, including, measuring biological, physico-chemical, and environmental parameters to have a weight of evidence assessment, reflecting best practice.

Management responses, actions and controls

Implementation of appropriate management responses, actions and controls to mitigate the exceedance of environmental thresholds through ~~the initiation of~~ remediation plans are currently part of the Tasmanian regulatory process. However, encouraging Environmental Licence holders to also ~~initiate and~~ implement management actions without the need for formal regulatory direction would be an important element of best practice environmental management.

Recommendations

Over the course of nine meetings, the 'Environmental Standards Working Group', which consisted of 12 scientific and regulatory specialists from the EPA, Marine Farming Branch (DPIPWE), and IMAS at the University of Tasmania, have reviewed and discussed the regulatory information provided in this paper.

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Number: 1 Author: delvines Subject: Sticky Note Date: 2/06/2020 6:22:42 AM
Do you mean zone-based or fixed-distance are complementary with each other, or lease-scale is complimentary in conjunction with a BEMP-style approach? This is not clear.

Number: 2 Author: emman Subject: Sticky Note Date: 26/05/2020 7:48:09 AM
It is not clear why they are complementary - and if they are, should both be used? Or do you want to say that each is effective?

Author: emman Subject: Sticky Note Date: 26/05/2020 7:49:46 AM
(I had assumed that you refer here to the zone-based and fixed-distance approaches being complementary, c.f. Deanna's comment)

Number: 3 Author: delvines Subject: Highlight Date: 18/05/2020 6:17:48 PM

Number: 4 Author: emman Subject: Sticky Note Date: 3/05/2020 12:51:06 PM
It's not clear in what sense you mean 'selection'. would 'position' or 'locations' be clearer terms?

Author: delvines Subject: Sticky Note Date: 18/05/2020 6:25:34 PM
Agree, needs to be more explicit.

Number: 5 Author: delvines Subject: Sticky Note Date: 2/06/2020 6:23:39 AM
Does less monitoring data mean fewer indicators, or less sampling effort? The next sentence or two alludes to sampling effort (stations).

Upate: I see in recommendation 5 it is no. of monitoring stations, so it would make sense to be explicit here.

Number: 6 Author: delvines Subject: Highlight Date: 18/05/2020 6:21:01 PM

Number: 7 Author: delvines Subject: Highlight Date: 25/05/2020 9:03:52 AM
Are the beyond boundary the BEMP ones? Or are they still associated with lease-specific monitoring? If BEMP, just use BEMP, or if additional stations, define "beyond the lease boundary stations" in the glossary.

Number: 8 Author: emman Subject: Sticky Note Date: 26/05/2020 7:51:53 AM
Additional replication? (i.e., an increase in number? this is consistent with the heading, but it could be interpreted as meaning that a greater number of parameters should be measured. "More intensive' or 'better replicated' might be clearer terms

Number: 9 Author: emman Subject: Sticky Note Date: 8/05/2020 9:37:02 AM
Adding sampling locations beyond the AZE...

Number: 10 Author: delvines Subject: Highlight Date: 25/05/2020 9:11:07 AM
This sentence suggests that BEMP programmes (if this is what beyond the AZE is referring to here) that are in place (as mentioned in previous subsection) are not sufficient/in line with interntional practice. I would have thought BEMP monitoring for far-field effects/change was in line with international practice (or better), so im not sure if this is intended. "would" is the key confusing word in that sentence.

Number: 11 Author: emman Subject: Sticky Note Date: 26/05/2020 7:56:15 AM
Not sure that the content of this section matches the heading

Author: deannae Subject: Sticky Note Date: 26/05/2020 7:56:34 AM
Agree, there is discussion around the monitoring timing, the managment response to 'exceedances' at low monitoring 'tiers' and also monitoring indicators. This section may be best to come after those other things are already discussed. Further, does it belong in the comparative review section? There is no explicit comparison provided to national or international context for any of these things here.

Number: 12 Author: delvines Subject: Sticky Note Date: 2/06/2020 6:24:58 AM
Presumably these are the three informal tiers - clarify.

Number: 13 Author: delvines Subject: Highlight Date: 25/05/2020 9:15:47 AM
Inclusion of 'intent' suggests it doesnt work. Is that right?

Number: 14 Author: delvines Subject: Highlight Date: 18/05/2020 6:34:11 PM

Number: 15 Author: delvines Subject: Sticky Note Date: 18/05/2020 6:27:40 PM
At the discretion of whom?

Number: 16 Author: delvines Subject: Highlight Date: 18/05/2020 6:27:31 PM

Number: 17 Author: delvines Subject: Sticky Note Date: 18/05/2020 6:28:49 PM

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zone-based or a fixed distance monitoring approach. Both approaches are complementary for regulating environmental compliance.

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In terms of environmental indicators and their associated thresholds, Tasmania, has developed visual assessment techniques (from the best available scientific knowledge) using qualitative and semi-quantitative measurements that have been 26 bu[illegible]d effective on a region-specific basis. Internationally, the use of visual indicators normally only provides additional evidence to support other environmental indicators (e.g. physico-chemical and biological parameters) measured either quantitatively and/or semi-quantitatively against known thresholds. Environmental compliance monitoring in Tasmania, 27 s infrequently undertaken quantitative measurements of key environmental indicators for enrichment over the past 15 years. With the production of salmonids moving into new and more exposed locations along the coast, additional relevant indicators for sensitive and vulnerable habitats (e.g. shallow and deep-water reef communities) 30 ve been included into 28 ~~e~~ environmental monitoring 29 ~~program~~. Given the limited scientific knowledge around how these types of habitats respond to dissolved and particulate nutrients from finfish aquaculture, regulating 31 e response requires expert scientific assessment.

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32 nilar to farming salmonids in other jurisdictions, baseline sampling for finfish leases in Tasmania collects multiple lines of evidence across various seabed environments and habitat types, including, measuring biological, physico-chemical, and environmental parameters to have a 34 eight of evidence assessment, 33 reflecting best practice.

Management responses, actions and controls

Implementation 35 of appropriate management responses, actions and controls to mitigate the exceedance of environmental thresholds through 36 ~~initiation of~~ remediation plans are currently part of the Tasmanian regulatory process. However, encouraging Environmental Licence holders to also ~~initiate and~~ implement management actions without the need for formal regulatory direction would be an important element of best practice environmental management.

Recommendations

Over the course of nine meetings, the 'Environmental Standards Working Group', which consisted of 12 scientific and regulatory specialists from the EPA, Marine Farming Branch (DPIPWE), and IMAS at the University of Tasmania, have reviewed and discussed the regulatory information provided in this paper.

or, "only being required at fallowing" - which suggests it is at the regulators discretion (required vs. undertaken are very different).

Number: 18 Author: emman Subject: Sticky Note Date: 26/05/2020 7:54:04 AM
'only undertaken' 'predominantly undertaken'?

Number: 19 Author: delvines Subject: Highlight Date: 18/05/2020 6:28:07 PM

Number: 20 Author: delvines Subject: Cross-Out Date: 18/05/2020 6:29:25 PM

Number: 21 Author: emman Subject: Sticky Note Date: 3/05/2020 12:59:45 PM
Not immediately clear how tiered monitoring relates to sampling time

Number: 22 Author: delvines Subject: Highlight Date: 26/05/2020 12:28:09 PM
or in the case of multiple year class stocking, when biological processes are enhanced (warmer).

Number: 23 Author: delvines Subject: Highlight Date: 25/05/2020 9:22:20 AM
This is a long sentence and doesnt quite make sense. Suggest..."Formalising the tiered environmental monitoring program and targeting monitoring to peak production within the new 'Environmental Standard' are two changes that will enable consistency of the current performance based management with present international practice. "

Number: 24 Author: delvines Subject: Highlight Date: 2/06/2020 6:27:43 AM
It would help to know within this section what scale is being discussed; broad scale or lease-scale, or both. It may also help to split into 'old/ existing farming sites' and 'new/proposed farming sites'.

Number: 25 Author: emman Subject: Sticky Note Date: 26/05/2020 7:55:26 AM
How does this statement relate to the statement above that this paper does not investigate effectiveness

Number: 26 Author: emman Subject: Highlight Date: 26/05/2020 7:55:33 AM

Number: 27 Author: delvines Subject: Highlight Date: 25/05/2020 9:27:42 AM
this sounds discretionary. Is it? and at whos discretion? Maybe it relates to those informal tiers of monitoring mentioned earlier? If we are just talking about indicators and thresholds here, how often they are used doesn't really matter does it - Should that fall under a tiered monitoring approach heading instead?

Number: 28 Author: deannae Subject: Cross-Out Date: 25/05/2020 9:30:48 AM

Number: 29 Author: deannae Subject: Cross-Out Date: 25/05/2020 9:30:55 AM

Number: 30 Author: deannae Subject: Highlight Date: 25/05/2020 9:30:34 AM
Have these additional relevant indicators (presumably they are quantitative ones?) been implemented only at the new farming locations as they have been developed?

Number: 31 Author: delvines Subject: Highlight Date: 25/05/2020 9:32:32 AM
Meaning the allowable ecological response? Or a mangement response to ecological changes? I think this means that there are no hard and fast thresholds for those additional relevant indicators, because they require expert opinion in terms of ecological significance or farming attribution etc? I think it could be clearer if this is the case.

Number: 32 Author: delvines Subject: Highlight Date: 2/06/2020 6:28:05 AM
Can this be more explicit? "Baseline sampling characterises broad environmental parameters relating to the biological and physico-chemical seabed (and other?) environments. This is reflective of best practice (internationally?)." Perhaps useful to list those parameters too.

Number: 33 Author: delvines Subject: Sticky Note Date: 18/05/2020 6:48:51 PM
In this context, i am unsure what a weight of evidence assessment means. Does it mean future assessments of change against baseline? i.e. multiple indicators provide a weight of evidence assessment of change?

Author: emman Subject: Sticky Note Date: 26/05/2020 12:29:43 PM
I found this similarly confusing, my comment is: Evidence of what? when it is baseline sampling, and therefore a characterisation? I think your point is that you can then employ a weight of evidence approach to an effects assessment when physical sampling is triggered by visual surveys.

Number: 34 Author: delvines Subject: Highlight Date: 18/05/2020 6:49:33 PM

Number: 35 Author: emman Subject: Sticky Note Date: 3/05/2020 1:09:16 PM
No mention of international practice here?

Number: 36 Author: delvines Subject: Cross-Out Date: 18/05/2020 6:52:06 PM

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Baseline sampling

Similar to farming salmonids in other jurisdictions, baseline sampling for finfish leases in Tasmania collects multiple lines of evidence across various seabed environments and habitat types, including, measuring biological, physico-chemical, and environmental parameters to have a weight of evidence assessment, reflecting best practice.

Management responses, actions and controls

Implementation of appropriate management responses, actions and controls to mitigate the exceedance of environmental thresholds through ~~the initiation of~~ remediation plans are currently part of the Tasmanian regulatory process. However, encouraging Environmental Licence holders to also 37~~tiate and~~ implement management actions without the need for formal regulatory direction would be an important element of 38st practice environmental management.

Recommendations

Over the course of nine meetings, the 'Environmental Standards Working Group', which consisted of 12 scientific and regulatory specialists from the EPA, Marine Farming Branch (DPIPWE), and IMAS at the University of Tasmania, have reviewed and discussed the regulatory 39ormation provided in this paper.

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Number: 37 Author: delvines Subject: Cross-Out Date: 18/05/2020 6:55:31 PM

Number: 38 Author: delvines Subject: Highlight Date: 18/05/2020 6:53:27 PM

presumably this is comparing to international or jurisdication practices? Or otherwise just a nice to have, and world-leading? I agree either way!

Number: 39 Author: deannae Subject: Highlight Date: 25/05/2020 12:10:56 PM

it sounds like this group also reviewed the effectiveness of the current Tassie program as it stands (without international comparison). Perhaps that needs its own section before going into the recommendations that resulted from the overall review.

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Below is a list of recommendations that the working group has established for the future development of the 'Environmental Standard':

2. Utilise a zones concept for the environmental management of Tasmanian finfish leases. The recommended zones are Farm-Zone (Operational area of the marine farming lease extending out to cage edge) and the AZE (extending from the edge of the Farm-Zone and out to 35 m from the lease boundary). Measurements undertaken at locations extending beyond the AZE should be referred to as beyond the AZE.

2a. Maintain the existing outer fixed distance for the AZE, this being set at 35 m from the edge of the lease boundary, while also providing the aquaculture industry with the opportunity to propose an alternative site-specific AZE. To propose a site-specific AZE, it would be expected that state-of-the-art modelling tools (e.g. 3D Hydrodynamic models and particle/nutrient deposition/dispersal models) should be used to demonstrate an acceptable dispersive / depositional footprint for each separate marine farming lease. Before approval and implementation of a site-specific AZE, the EPA may require peer-review for expert evaluation of the modelling work to ground truth the site-specific AZE.

2b. Propose the validation of site-specific AZE over a number of production cycles. If any lines of evidence demonstrate ~~h~~ environmental effect outside of the site-specific AZE, this would trigger a review of attributable causes and appropriate management actions.

3. ~~It is current practice, I~~ suggest that ~~the EPA should~~ establish site-specific monitoring plans in consultation with the 'Environmental Licence' holder to ensure the correct placement of all monitoring stations to assess environmental performance. The use of real-time data (i.e. Doppler current meter data) and modelling tools will be integral in providing additional information regarding current direction and speed, and the potential footprint to aid in the placement of these monitoring stations.

4. Include the selection of representative reference stations at distances appropriate to site-specific environmental forcing (e.g. wave activity, hydrodynamics) when undertaking quantitative AZE sampling to enable suitable comparisons of AZE environmental conditions to background environmental conditions. The sites chosen and the parameters required for quantitative sampling should be determined as part of the baseline sampling program.

5. ~~Consider~~ increasing the number of monitoring stations within the Farm-Zone. This will provide a better understanding of the environmental condition of the near-field environment within the marine farming lease area in-line with international practice.

6. Outline a requirement to regularly review BEMP reports to ensure the appropriateness of the monitoring sites, the parameters used, and the established investigative levels within these programs. Revised water quality guideline values should be provided for use within the new Environmental Standard for all MFDPs across Tasmania to enable site-/region-specific investigative levels to be established to increase the success of protecting ecosystem health.

7. In-line with international practice, undertake all environmental monitoring surveys during the period of peak feed input. As this is the time-period when the load of organic waste is greatest on the seabed, and when environmental impacts on the seabed are likely to occur.

8. ~~Consider~~ conducting regular detailed benthic environmental surveys (e.g. quantitative physico-chemical and biological parameters) across monitoring stations to benchmark environmental performance. The sampling frequency of these detailed surveys should reflect an individual lease's Farm-Zone and AZE environmental performance over successive production cycles.

9. Continue to use existing benthic indicators of organic enrichment (e.g. bacterial mat-forming species, gas bubbling and opportunistic polychaetes) for visual surveys within the Farm-Zone and at AZE monitoring stations. These indicators are globally applied visual indicators for organic enrichment. However, threshold values of these indicators within both the Farm-Zone and AZE require standardisation to reduce potential inconsistencies when assessing and reporting.

10. ~~Consider~~ implementing the video scoring index for environmental condition (established by Macleod and Forbes in 2004) currently being reviewed by IMAS as part of FRDC project 2015-024, as a means to determine environmental performance.

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Number: 1 Author: delvines Subject: Highlight Date: 2/06/2020 6:29:58 AM
General comment on this section is that some recommendations relate to those discussed previously in context of comparative review, but there are some fairly new ones that are introduced with no prior context, so i assume the rationale for those ones have come from somewhere other than the gaps ID'd in the comparative review. I suspect these recommendations also reflect some of the inner learnings and need for improvements identified by people involved in the implementation of the existing framework (regardless of international/other national practice), and if so, this should be stated.

I also wonder if the points from the comparative review section that are also address in the recommendations section area are better discussed under the same heading to improve the flow of this summary. Like: "Monitoring station selection" as a heading, then subheading below that for 'comparative review' and 'recommendations'.

Or categorising this recommendations section within the same category headings as for comparative review.

Also would be helpful if the scale (regional or lease) was specified more explicitly throughout as this becomes confusing but is quite an important distinction.

Number: 2 Author: delvines Subject: Highlight Date: 18/05/2020 6:57:57 PM
earlier, it sounded like this is what already happens. So is the recommendation, rather, to formalise the existing general approach to monitoring zones?

Number: 3 Author: delvines Subject: Highlight Date: 18/05/2020 6:56:56 PM
but these are not the BEMP stations?

Number: 4 Author: delvines Subject: Highlight Date: 2/06/2020 6:31:40 AM
The use of the word propose is confusing here. Is this recommending a method for the validation of AZE zones should be described within the Env. Std? Or, is it recommending that a site-specific zoning validation be a requirement if a lease holder elects a site-specific AZE distance?

Number: 5 Author: emman Subject: Highlight Date: 26/05/2020 9:05:57 AM
'measurable'? or 'unacceptable' environmental effect?

Number: 6 Author: deannae Subject: Cross-Out Date: 25/05/2020 9:43:43 AM

Number: 7 Author: delvines Subject: Cross-Out Date: 18/05/2020 7:47:59 PM

Number: 8 Author: delvines Subject: Cross-Out Date: 18/05/2020 7:48:41 PM

Number: 9 Author: delvines Subject: Highlight Date: 18/05/2020 7:11:53 PM
if it is current practice, then it EPA doesnt need to establish it? Or refer to other international/jurisdictional practices?

Number: 10 Author: delvines Subject: Highlight Date: 26/05/2020 8:04:36 AM
This is the first time this is discussed.

What is the primary intent of this bullet point/having lease-specific monitoring plans? Is it to use better tools to predict monitoring stations at the outset of a lease? Or is the intent here is to have monitoring station placement validated through some mechanism (e.g. 2b(?); feedback of results and adaptive monitoring design) after farms have been operating for xxx time, instead of using predictive tools at the start of the lease then leaving them be? Is this related to the validation (2b above?).

Number: 11 Author: emman Subject: Highlight Date: 26/05/2020 9:05:16 AM
Not sure why real-time is required here - this is a particularly stable characteristic, so occasional surveys should be sufficient

Number: 12 Author: emman Subject: Sticky Note Date: 3/05/2020 1:16:39 PM
does this assume the use of alternative site-specific AZE?

Number: 13 Author: emman Subject: Sticky Note Date: 28/05/2020 9:19:34 AM
Is Reccomendation 4 an elaboration on R3?

Number: 14 Author: emman Subject: Sticky Note Date: 26/05/2020 8:06:31 AM
I'm not convinced that it will provide this better understanding if only visual parameters are measured

Number: 15 Author: delvines Subject: Cross-Out Date: 25/05/2020 10:07:07 AM
These are recommendations, so presumably they will all be considered. I think using this word weakens the recommendation - it suggests

Comments from page 9 continued on next page

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that anything that follows isn't really that important, so as long as you consider it, then thats fine.

Number: 16 Author: emman Subject: Sticky Note Date: 26/05/2020 9:04:43 AM
I think reconsideration of the order of these numbered points might help with interpretation. I would expect an a statement about review of the reports to come toward the end and the monitoring design points to be grouped.

Number: 17 Author: delvines Subject: Highlight Date: 25/05/2020 9:53:41 AM
what is not clear within this summary is the synergy between the lease scale monitoring and the BEMP, and how they feed into state of environment or lease specific reviews of the state of the environment. Perhaps a paragraph on this further up would paint a good picture. Or maybe it is expecting the reader to have a good understanding of these things given it is a Tasmanian document?

Number: 18 Author: delvines Subject: Highlight Date: 2/06/2020 6:33:18 AM
maintain? I'm sure they were appropriate to start with.

Number: 19 Author: emman Subject: Sticky Note Date: 26/05/2020 9:05:23 AM
This recommendation is made under the 'Selection and # of monitoring stations" section, but extends beyond those considerations - and the point would be made more clearly if this were broken into multiple recommendations

Number: 20 Author: delvines Subject: Highlight Date: 18/05/2020 7:24:37 PM
"be at their maximum" (they are likely to occur at other times too!)

Number: 21 Author: emman Subject: Sticky Note Date: 8/05/2020 1:56:20 PM
Would moving 8 to after 10 give a better flow to these points?

And in fact does 8 not relate better to the 'Environmental indicators and associated thresholds' theme?

Number: 22 Author: delvines Subject: Cross-Out Date: 18/05/2020 7:45:18 PM

Number: 23 Author: delvines Subject: Highlight Date: 25/05/2020 9:56:16 AM
how does this fit in to what was discussed previously? Does it mean, "Formalise the requirement for Tier 3 (quantitative) monitoring surveys to benchmark....."? And by doing so addressing the issue that they are at the discretion of the regulator and have not been carried out frequently in the past?

Number: 24 Author: delvines Subject: Highlight Date: 25/05/2020 9:57:15 AM
Consider rewording entire sentence - i think it means "the detailed surveys should encompass sampling stations from the lease holders farm zone and AZE, and these should be sampled at a frequency determined by past environmental performance."

Number: 25 Author: deannae Subject: Highlight Date: 2/06/2020 6:34:43 AM
existing visual indicators of benthic organic enrichment?

Also, how applicable are these indicators to more dispersive farming sites where visual impacts are less likely to manifest? The move to more dispersive coastal areas is one of the reasons for this review, and international literature shows these might no be effective at dynamic sites.

Number: 26 Author: deannae Subject: Highlight Date: 25/05/2020 10:00:49 AM
The use of the term 'visual surveys' is new, so could be interpreted as a separate thing to that discussed earlier in the summary. Presumably visual surveys refers to the qualitative/semi-quantiative compliance surveys presently undertaken as the 'lowest' tier of monitoring under the existing framework?

Number: 27 Author: deannae Subject: Highlight Date: 25/05/2020 10:05:32 AM
This wasnt mentioned in the comparative review, so has come from somewhere else but no background.

Number: 28 Author: emman Subject: Sticky Note Date: 8/05/2020 4:02:34 PM
Is 10 a sub-recommendation of 9?

Number: 29 Author: deannae Subject: Cross-Out Date: 25/05/2020 10:06:03 AM

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11. Maintain existing water quality monitoring associated with salmonid farming should be a priority. Water quality measurements are important rapid determinants of change in a system. Furthermore, consider monitoring water quality at individual leases, and adopting real-time sensor technology to monitor critical water quality parameters at higher temporal resolutions (e.g. turbidity, chlorophyll, oxygen, etc.) at appropriate spatial scale.

12. Consider that the current parameters required for baseline sampling reflect international practice. In addition, recommend the establishment of a robust pre-development time-line of selected water quality, biological, physico-chemical and environmental datasets at sites that are representative of local and regional environments needs consideration. These datasets would aid in establishing site and region-specific indicator guideline values, which would enable better identification of local and broader ecological changes measured during ongoing compliance and broad scale environmental monitoring.

13. Acknowledge and incentivise continued environmental compliance and good environmental performance over consecutive production cycles.

14. Review and align the existing EPA compliance and auditing system with the implementation of the new 'Environmental Standard'.

15. Encourage industry to implement best practice management actions to achieve environmental compliance independent of a regulatory response to ensure long-term environmental sustainability.

The Working Group acknowledges that sound scientific rationale underpin current environmental regulations in Tasmania; however, they also acknowledge that given the expansion and evolution of the salmonid farming industry, environmental monitoring must follow suit. The recommendations made by the Working Group in this paper expand the existing monitoring framework, it also considers contemporary international scientific knowledge and regulatory practices to enhance a progressive monitoring system representing best practice environmental management.

The new Environmental Standard should consist of region-specific, up-to-date biological, and physico-chemical indicators and thresholds for benthic and pelagic environments, together with a more accountable monitoring program, that will ensure environmental monitoring occurs during the time period when the risk for environmental impacts are likely to be at their greatest. This robust approach will ensure that finfish farmers operate within clearly defined 'Environmental Standards' and have the capacity to follow a performance based regulatory system that acknowledges and incentivises operators for consistent environmental compliance and achieving environmentally sustainable farming practices.

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Number: 1 Author: delvines Subject: Highlight Date: 18/05/2020 7:40:19 PM
this recommendation again lacks background and implies the reader has a good understanding of the status quo. Perhaps not important to document scope, but also being explicit on lease vs. regional scale is helpful.

Number: 2 Author: emman Subject: Sticky Note Date: 8/05/2020 1:50:44 PM
As per below, some questions as to the benefits of monitoring at individual leases, c.f. Marlborough water quality BMP..

Number: 3 Author: emman Subject: Sticky Note Date: 8/05/2020 1:58:20 PM
Is there a need to specify here that those scales differ for each parameter?

Number: 4 Author: delvines Subject: Sticky Note Date: 25/05/2020 10:16:02 AM
There are two recommendations here, split them up? Mainly because the second one is quite a large recommendation, esp. compared to the first.

Number: 5 Author: deannae Subject: Cross-Out Date: 25/05/2020 10:14:21 AM

Number: 6 Author: delvines Subject: Highlight Date: 25/05/2020 10:14:41 AM
This is a confusing sentence. Should it just read: "Since they meet international practice, the current baseline sampling requirements should be outlined in the Environmental Standard."?

Number: 7 Author: delvines Subject: Underline Date: 2/06/2020 6:36:02 AM
I think this sentence is recommending collection of baseline data time-series in either proposed farming areas or sentinel monitoring sites near operational or proposed farming areas (is that part of the BEMP?), but i cannot be sure - to clarify. Also, does it relate to the first sentence? i think it is something new, in which case a new point is probably required?

Number: 8 Author: emman Subject: Sticky Note Date: 8/05/2020 1:59:15 PM
how does 'environmental' differ from the 3 previously listed aspects?

Number: 9 Author: delvines Subject: Highlight Date: 25/05/2020 10:16:54 AM
so these 'datasets' are different to lease scale AND BEMP monitoring programmes? Perhaps if they had a name they would be more easy for the reader to untangle from other monitoring programmes/requirements.

Number: 10 Author: emman Subject: Sticky Note Date: 8/05/2020 2:02:54 PM
not sure that 'compliance independent of a regulatory response' exists. Do you not just mean 'good environmental performance' - as in recommendation 13? I suspect 13 and 15 could be combined.

Number: 11 Author: delvines Subject: Cross-Out Date: 18/05/2020 8:02:04 PM
encourage

Number: 12 Author: delvines Subject: Cross-Out Date: 18/05/2020 8:01:31 PM
industry-led

Number: 13 Author: delvines Subject: Highlight Date: 18/05/2020 8:00:54 PM
intervention?

Number: 14 Author: delvines Subject: Cross-Out Date: 18/05/2020 8:04:12 PM
the two are not separate. The expansion of the existing monitoring DOES consider contemporary international scientific knowledge and regulatory practices...

Number: 15 Author: delvines Subject: Highlight Date: 18/05/2020 8:06:48 PM
this is where i would love this term to be defined. Sounds like it will be a very detailed specification of a monitoring and regulatory programme (which sounds great!).

Number: 16 Author: delvines Subject: Highlight Date: 2/06/2020 6:37:41 AM
implies a regular review of the Standard, which would be important to ensure standards are 'good' into the future. Suggest the intent for a regular review is incorporated into the recommendations, or stated somewhere at least.

Number: 17 Author: emman Subject: Highlight Date: 26/05/2020 9:03:41 AM
As you know, it is a huge job to develop thresholds - I wonder if it is setting the standard up for failure, unless the data already exists for setting of thresholds. You may need to go for interim thresholds in some cases? or define pathways for development of thresholds?

Number: 18 Author: emman Subject: Sticky Note Date: 26/05/2020 9:01:28 AM
I wonder if one point that may need to be added is a process for dealing with uncertainty - e.g., establishment of advisory groups etc.

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Background

The publication of this paper is one step in addressing the overarching vision of the Tasmanian State Government that "the Tasmania salmon industry will be the most environmentally sustainable salmon industry in the world, by continuing to improve environmental performance through industry driven innovation coupled with appropriate environmental monitoring and regulation", as outlined in the *Sustainable Industry Growth Plan for the Salmon Industry*. To support this vision and enable the establishment of an Environmental Standard to enhance 1he ~~existing~~ environmental regulation of Salmonid farming in Tasmania, the Environment Protection Authority (EPA) has reviewed the current regulatory practices of salmonid farming in other 2jurisdictions. This paper presents information, that will inform the development of a new 'Environmental Standard' for regulating finfish farming in Tasmania.

The global significance of aquaculture

The production of seafood from aquaculture in 2016 was responsible for 47% of global seafood production (80.4 million tonnes) with an estimated first sale value of approximately USD$232 billion (FAO 2018). Prior to 2016, the per capita consumption of seafood increased from 9.0 kg to 20.2 kg over a 55 year period (FAO 2018), and it is anticipated that this growth in consumption will continue to rise if the availability of seafood also increases. While seafood production from aquaculture has steadily increased since the 1950s, wild fisheries have remained stagnant since the late 1990s (FAO 2018). Currently, the production of fish from aquaculture results in a global production of 80.0 million tonnes, while the total production from wild fisheries is 90.9 million tonnes, of this total 88.5% is for direct human consumption (FAO 2018). In 2016, open-water cage production of Atlantic salmon (*Salmo salar*) exceeded 2.2 million tonnes globally, with Tasmania contributing to approximately 2.5% of global production. Whilst production in Tasmania is relatively small in global terms, in 2018 the Tasmanian salmonid farming industry was the largest seafood sector in Australia, with an estimated farm gate value of AUD$820 million, creating more than 1800 direct/indirect full time equivalent jobs nationally (Anon 2019). However, salmonid farming in Tasmania is not without its challenges. Intensive cultivation of salmonids in net pens and the release of particulate and dissolved wastes (e.g. metabolic by-products, faeces and waste feed) and contaminants (e.g. therapeutants, metals, etc.) are linked to direct impacts on the marine environment.

Known environmental impacts of finfish aquaculture wastes on marine ecosystems

Intensive cultivation of finfish in open-water net pens can result in a wide range of interactions with the marine environment through the release of particulate and dissolved nutrients directly to the surrounding environment (Taranger et al. 2015). Particulate wastes from intensively fed finfish aquaculture are comprised of feed wastage (1-5% of feed used) and faecal material (comprising 12.5% of feed used) (Brooks and Mahnken 2003). Dissolved wastes (e.g. metabolic by-products) released from fed finfish aquaculture have been modelled and comprise nitrogen (3.3% of feed used), phosphorus (0.3% of feed used) and carbon (1.6% of feed used) (reviewed in Wang et al. 2012).

The deposition and accumulation of particulate organic wastes on the seabed are the most documented and well-studied environmental impacts of fish farming. Impacts of these wastes on the marine environment include, but are not limited to, eutrophication (Gowen and Ezzi 1994), enrichment of soft sediment habitats (Holmer and Frederiksen 2007; Norði et al. 2011), and modification of hard substrate habitats (Hamoutene et al. 2015). In addition, fish farming wastes can also impact the structure and functioning of vulnerable/sensitive habitats (Hall-Spencer et al. 2006; Villanueva et al. 2006; Holmer et al. 2008; Terlizzi et al. 2010) that are important habitats/refuges and spawning/nursery grounds for a variety of other marine organisms.

The release of particulate wastes has predominantly occurred over soft sediments, with marked influences on habitat structure and ecological functioning. The accumulation of particulate organic waste alters metabolic pathways in soft sediment ecosystems. When in excess, organic wastes drive anaerobic biogeochemical cycling of the sediments (Holmer and Kristensen 1992; Valdemarsen et al. 2012) and changes the structure and ecological functioning of infauna communities (Kutti et al. 2007; Bannister et al. 2014, Keeley et al. 2014). This ultimately leads to localised organically enriched marine sediments that are

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Number: 1 Author: delvines Subject: Cross-Out Date: 18/05/2020 8:10:26 PM

Number: 2 Author: delvines Subject: Highlight Date: 25/05/2020 10:18:45 AM
define this is nationally and internationally.

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highly modified from background conditions (Woodcock et al. 2019), requiring months to years of rehabilitation through fallowing (i.e. no fish farming activity) to recover to background conditions (Brooks et al. 2004; Macleod et al. 2007; Zhulay et al. 2015; Keeley et al. 2019).

Dissolved and particulate waste released from finfish cages also affects other habitat types across tropical and temperate marine habitats. Although less studied, current evidence suggests that changes to the structure and function of habitats associated with hard bottom substrate types, such as coral reefs (Bongiorni et al. 2003, Villanueva et al. 2006, Huang et al. 2011) and rocky habitats (Hamoutene et al. 2015) can be directly and indirectly linked to the localised release of wastes from finfish aquaculture. Exposure to wastes released from finfish cages can result in: 1) localised modification of seaweeds (Worm and Sommer 2000; Oh et al. 2015); 2) degradation of seagrass beds (Pergent-Martini et al. 2006; Holmer et al. 2008); 3) reduced percentage of live maerl bed cover and altered structure of macrobenthic assemblages (Hall-Spencer et al. 2006; Sanz-Lazaro et al. 2011); 4) displacement of burrowing and suspension feeding macrobenth assemblages in muddy sediments (Wilding et al. 2012); and 5) shifts in the structure of intertidal macrobenthic assemblages (Boyra et al. 2004).

Furthermore, current scientific evidence, albeit limited, suggests that the presence of salmon farm wastes in the marine environment influences the diet of epibenthic macroinvertebrates inhabiting mixed and hard bottom habitats (White et al. 2017; Woodcock et al. 2017 and 2018). Shifts in the feeding (i.e. supplemented feeding on finfish waste) of sea urchins in temperate marine ecosystems can have implications for their distribution, abundance and population structure (White et al. 2018). This observed ecological shift may be the result of a shift in their diet composition that reduces their reproductive fitness and the longevity of sea urchin offspring survival (White et al. 2016 and 2018). This is also relevant for wild fish populations (Fernandez-Jover et al. 2007 and 2011; Dempster et al. 2011) and cartilaginous fish (Gaitan-Espitia et al. 2017; Moreno 2018) that use particulate wastes as an additional diet source. Effects on the fitness and body condition of wild fish populations feeding on aquaculture wastes are documented (Fernandez-Jover et al. 2007 and 2011; Dempster et al. 2011).

Local environmental conditions (water exchange and residence time) are key factors determining the effects of dissolved wastes (e.g. nutrients) on the water quality of coastal marine ecosystems. Dissolved nutrients stimulate primary productivity (e.g. algal growth) and in excess may lead to eutrophication and the outbreak of algal blooms (Liu et al. 2010; Ménesguen et al. 2010; Bužančić et al. 2016). In such circumstances, algal blooms will modify water bodies leading to the deterioration of water quality, through increased turbidity, reduced ecosystem function and services (Nobre 2009). Depending on the algal species, harmful algal blooms (HABs) along the coast have the potential to be physically harmful to finfish species resulting in gill irritation, damage and lesions and in extreme cases may cause anoxic events, and the mortality of a wide variety of marine organisms (Hallegraeff 1993; Anderson et al. 2008; Heisler et al. 2008; Anderson 2014). Three main types of algae responsible for HABs, including cyanobacteria, dinoflagellates and diatoms, and they have the potential of producing biotoxins (e.g. Paralytic Shellfish Toxin, Diarrhetic Shellfish Toxin, Amnesic Shellfish Toxin, and Neurotoxic Shellfish Toxins) that adversely affect human health (Hallegraeff 1993). The effects of dissolved nutrients released from fish farms in Chile, Scotland, the Mediterranean and Norway (Gowen and Ezzi 1994; Soto and Norambuena 2004; Pitta et al. 2006; Husa et al. 2014) have shown low risk of regional eutrophication of water bodies in areas with good water exchange. Elevated nutrients may occur at short distances (< 100 m) from finfish cages (Tsagaraki et al. 2013; Jansen et al. 2016, 2018), and current evidence suggests that this elevation may have an influence on algal community structure on nearby reefs (< 100 m from fish farms), where nutrient indicator algal species can flourish (Oh et al. 2015).

Recently, there has been a greater push to establish new fish farms away from sheltered coastal locations and into more exposed/offshore locations. A general perception when setting up new fish farms in more exposed and deeper locations is that there will be a reduction in environmental impacts through increased dispersal and dilution, reduced deposition and limited accumulation of particulate wastes adjacent to net pens (Holmer 2010). A growing body of evidence suggests that such a shift in farming practices may be less harmful for marine ecosystems in many situations. Monitoring observations under salmon farms in New Zealand with contrasting current flow regimes (high vs. low flow), demonstrated that benthic sediment ecosystems had a greater tolerance to organic enrichment under higher flow conditions compared to low flow conditions. Both biological and physical processes were attributable to reduced impacts under higher flow conditions (Keeley et al. 2013). Studies in the Mediterranean (Maldonado et al. 2005) and Norway

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Number: 1 Author: delvines Subject: Highlight Date: 18/05/2020 8:20:35 PM
does this need to be qualified by the size of the farm? e.g. at some point those environmental gains will likely be offset by intensity of farming.

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(Bannister et al. 2014; Keeley et al. 2019) suggest that intensive farming of finfish in more exposed locations significantly reduces localised impacts on the receiving environment.

Known impact of salmonid farming in Tasmania

Salmonid leases in Tasmania are located in coastal waters, often in sheltered locations with limited exposure to high current velocities (>10 cm s^{-1}) and wave activity. Situated over soft sediment substrates, organic enrichment from fish farms can lead to modified benthic communities, low oxygenated sediments, and the presence of white bacterial mats (i.e. *Beggiatoa* spp.) on the sediment surface (Crawford et al. 2001; Macleod and Forbes 2004; Macleod et al. 2004, 2006, 2007, 2008; Edgar et al. 2005). The response of benthic habitats to organic enrichment is variable, predominantly due to region-specific background environmental conditions. In the west of Tasmania (i.e. Macquarie Harbour), sediments are depauperate of infauna (O'Conner et al. 1996). As such, organically enriched sediments underneath or at the edge of finfish net pens can lead to highly modified conditions, with clear shifts in the abundance, richness and structure of infaunal communities (Ross et al. 2018). The occurrence of large mats of opportunistic polychaetes (i.e. Dorvilleids) and white bacterial mats (i.e. *Beggiatoa* spp.) during peak farming biomass in Macquarie Harbour is common (Ross et al. 2018). Sediment recovery tends to be slow, due to sustained low dissolved oxygen levels in the bottom waters of Macquarie Harbour (Ross et al. 2018). In the south-east of Tasmania (Huon River and the D'Entrecasteaux Channel), the response of soft sediment ecosystems under fish farm leases is dependent on the level of organic enrichment (Edgar et al. 2005). At sites near farm cages, low oxygenated sediments, dominance of opportunistic fauna (e.g. Capitellids and Dorvilleids) and low macrofauna richness are common, while only subtle impacts are detected at or beyond the lease boundary (Edgar et al. 2005). Recovery of sediments and associated macrofauna in the south-east of Tasmania is a function of background environmental state, with locations that have naturally high organic carbon levels (i.e. catchment derived) demonstrating faster recovery trajectories during fallowing than farming locations that are naturally low in organic carbon content (Macleod et al. 2007). Recovery of sediments adjacent to fish farm cages to background conditions in the south-east is likely to require in excess of three years without organic enrichment (Macleod et al. 2004, 2014). Regardless of farming location, universal indicators can be used to demonstrate impacts of organic wastes from fish farms across Tasmania. These indicators include: a) redox potential at the sediment surface, and at 4 cm depth; b) the proportionate abundance of opportunistic polychaetes; and c) the bivalve/mollusc ratio (Edgar et al. 2010). Given the clear evidence of region-specific responses to organic loading, site-specific threshold levels of indicators should be established for each farming region, such as those that have been earlier proposed by Macleod and Forbes (2004).

The effects of dissolved nutrients released from Tasmanian salmonid farms on the water quality of marine ecosystems and its subsequent effects on the ecology and functioning of benthic reef systems in a system wide context has been investigated through a number of scientific investigations in Tasmania. While elevated nutrients have been detected across BEMP study sites in the south-east of Tasmania, nutrient concentrations, ratios and associated phytoplankton abundances have not differed significantly across an 8 year period (2009-2016) (Bell et al. 2017). Despite the presence and stimulated growth of indicator macroalgal species at nearby reefs habitats adjacent to fish farms (up to 100 m from fish farms; Oh et al. 2015), there is currently no documented evidence of broader-scale changes in algal communities on rocky reefs (Valentine et al. 2016) and within intertidal habitats (Crawford and Harwin 2018).

In offshore/exposed locations off the coast of Tasmania (e.g. Storm Bay), there is limited knowledge on the assimilative capacity of marine sediments to organic enrichment and associated elevated nutrients. Evidence presented to date (i.e. from benthic environmental monitoring reports) indicates that the effects of organic enrichment in the vicinity of fish cages is localised, but sporadic, with limited accumulation of organic waste under cages over time. Environmental forcing (e.g. irregular wave activity and current velocities) may increase the dispersal capacity of organic waste into the receiving environment, similar to what has been documented in other salmonid growing regions with strong environmental forcing (Keeley et al. 2013; Keeley et al. 2019). However, the transportation pathway for organic waste is unclear, and further studies (some of which are currently undertaken by IMAS, FRDC 2015-024, FRDC 2016-067, and FRDC 2018-131) are required to ascertain if any broader-scale effects of organic enrichment are occurring.

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Number: 1 Author: emman Subject: Highlight Date: 26/05/2020 9:02:23 AM
poorly oxygenated

Number: 2 Author: delvines Subject: Highlight Date: 18/05/2020 8:22:12 PM
is this still not also the case for Mac Harbour, even if slower response?

Number: 3 Author: delvines Subject: Highlight Date: 25/05/2020 10:19:47 AM
rather: "...without organic inputs from farming?"

Number: 4 Author: delvines Subject: Highlight Date: 25/05/2020 10:22:22 AM
Is this the right place for this recommendation? Suggest it goes in the indicators/thresholds section, leaving only a statement here about the site-specificity of benthic response here.

Number: 5 Author: delvines Subject: Highlight Date: 25/05/2020 10:23:11 AM
"... as follows"?

Number: 6 Author: delvines Subject: Highlight Date: 18/05/2020 8:28:36 PM
sporadic, related to what? Organic inputs, or storm events, or otherwise?

Number: 7 Author: delvines Subject: Highlight Date: 25/05/2020 10:24:16 AM
episodically or sporadically increase?

Number: 8 Author: delvines Subject: Highlight Date: 18/05/2020 8:30:27 PM
what does this mean? The mechanism, or the range of dispersal, or both?

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1 History of Tasmanian salmonid farming environmental regulations

Between 1997 and July 2016, environmental regulation of the salmonid farming industry was implemented by the Marine Farming Branch within the Department of Primary Industries, Parks, Water and Environment (DPIPWE), under the *Marine Farming Planning Act 1995* (MFPA) and the *Living Marine Resources Management Act 1995* (LMRMA). Under the MFPA, 15 Marine Farming Development Plans (MFDPs) were established, of which seven MFDPs were used for salmonid farming. MFDPs contained a range of management controls designed to manage and mitigate potential negative effects of marine farming activities. Marine farming leases (for a specific finfish farm) were located within marine farming zones and required Marine Farming Licences in order to undertake marine farming. Each Marine Farming Licence contained lease-specific environmental standards and monitoring requirements to ensure that marine farming operations were environmentally sustainable. Under statutory requirements at this time, the Marine Farming Licence holder was required to ensure that:

1. There must be no significant visual, physico-chemical or biological impacts at or extending beyond 35 metres from the boundary of the Lease Area.
2. There must be no significant visual impacts within the Lease Area.
3. Where areas are fallowed due to visual impacts, the Lease Area shall not be restocked until the sediments have recovered to the satisfaction of the Director.
4. The licence holder must comply with any written request from the Director specifying waste disposal actions for the purpose of mitigating against any effect on the ecology of the marine environment or nearby shoreline associated with marine farming operations including harvesting, processing of salmonids and the removal of fouling organisms.
5. All fish mortalities arising in connection with marine farming operations must be disposed of in accordance with relevant acts and council by-laws.
6. Levels of antibiotics, or chemical residues derived from farm therapeutic use, present in sediments within or outside the Lease Area, are not to exceed levels specified to the licence holder by prior notice in writing by either the Director or the Chief Veterinary Officer, Tasmania.
7. Prior to any stock being treated with therapeutants, the licence holder must advise the Director, and provide a copy of any medication authority specific to stock treatment that has been issued. The licence holder must comply with requirements to undertake any reasonable residue testing prescribed by the Director.
8. Blood resulting from harvesting of fish must not be released into the marine environment.
9. Black water (defined as all of the components of domestic sewage) from marine farming vessels and structures within the Lease Area, must be either contained and transferred to an approved sewage treatment plant on land, or treated and released into the marine environment using an in situ sewage treatment system that has been approved and licensed by the Director.
10. Grey water (defined as non-industrial wastewater generated from domestic processes such as dish washing, laundry and bathing, excluding water from the toilet) from marine farming vessels and structures within the Lease Area must be managed in such a way as to ensure that the release of the components of domestic sewage are not harmful to the marine environment. Measures may include but not be limited to the use of screens to remove food scraps, the removal of fats and oils prior to washing, and the use of environmentally friendly soaps.
11. The licensee must take all reasonable steps to ensure that no fish, dead or alive of the species authorised by this licence are found outside cages on the Lease Area.
12. Marine farming operations in the Lease Area must not cause the threshold levels listed in Table 1 to be exceeded within the Lease Area.
13. The rolling annual median indicator value for combined compliance region sites, where directly attributable to marine farming operations, must not exceed the indicator limits specified in Table 2 (only applicable to Macquarie harbour).

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Number: 1 Author: deannae Subject: Highlight Date: 25/05/2020 12:26:13 PM
this section contains no information on water column monitoring in Tasmania.

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Table 1. Metal detection levels

Element	Sediment (mg/kg dry weight)	Water column (µg/L)
Copper[1]	270	1.3
Table text	410	15

[1]- Not applicable to Macquarie Harbour

Knowledge of the impacts of finfish farming in Tasmania has been established through a combination of scientific investigations, mandatory lease-scale benthic monitoring programs, and the region-specific BEMPs. The lease-scale benthic monitoring program has been in operation across the State and was formalised in 1997. The initial monitoring program was designed to comply with the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) working definition of monitoring being as 'regular collection, generally under regulatory mandate, of biological, chemical or physical data from predetermined locations such that ecological changes attributable to aquaculture wastes can be quantified and evaluated' (GESAMP 1996). Lease areas have been subjected to a fixed monitoring regime over this time to monitor compliance with management controls specific to benthic impacts. Monitoring on a new lease comprised firstly of a finfish baseline environmental survey', and subsequent on-going monitoring comprising of six monthly finfish video surveys, and triennial finfish monitoring (see DPIPWE 2004 for detailed information on the various monitoring programs).

Table 2. Nutrient detection levels

Indicator	Limit
Ammonia (at 2 metres)	0.033 mg N/L (max.)
Ammonia (at 20 metres)	0.024 mg N/L (max.)
Nitrate (at 2 metres)	0.053 mg N/L (max.)
Oxygen (at 2 metres)	6.82 mg/L (min.)

The last review of the benthic monitoring program established by DPIPWE to assess environmental performance of finfish leases state-wide occurred in 2004 (DPIPWE 2004). The 2004 review, provided an assessment of the historical monitoring records (1997-2003), considerations/recommendations from the research conducted by IMAS (formerly referred to as Tasmanian Aquaculture and Fisheries Institute, TAFI), and logistical issues when conducting surveys. The review documented that the majority of finfish leases operated in shallow locations (14-25 m) over muddy/silty sediments with low current flows (average of 3.34 cm s^{-1}). The review identified that considerable impacts were detectable directly under or in close proximity to stocked cages (usually within 30 m of cage edge); however, the extent of the impacts diminishes quickly with distance from cage. Unacceptable impacts at the compliance points (extending 35 m from the lease boundary) were considered to be low, with only 5% of compliance point monitoring surveys detecting impacts. These impacts were detected visually, through the qualitative video assessments rather than the quantitative sampling of benthic samples at the compliance points. Pen positioning, stocking duration and intensity were identified as the major factors contributing to impacts extending 35 m from the lease boundary. An outcome of the review was the hybridisation of the monitoring program (see DPIPWE 2004 for detailed monitoring information), resulting in weight-of-evidence approach, designed to use predominantly video evidence to detect unacceptable impacts at 35 m beyond the lease boundary. When a non-compliance is detected, a comprehensive benthic triggered survey (sampling of biological and chemical parameters) may then be required to determine the extent of any breaches and if the impact(s) are a result of the marine farming activity. Since 2004, ~~the implementation of~~ benthic triggered surveys have been rarely undertaken in response to non-compliances as the management response is flexible and more often resulted in operations-based management responses (e.g. movement of cages, fallow directions and increased frequency/spatial extent of visual monitoring). When triggered, investigations have been undertaken (e.g. following the observed proliferation of opportunistic polychaetes and increased prevalence of *Beggiatoa* spp. in Macquarie Harbour), this has resulted in commissioned research projects being undertaken by IMAS to conduct ongoing research detailing benthic and water column condition.

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Number: 1 Author: emman Subject: Sticky Note Date: 6/05/2020 6:22:36 AM
The caption of this and the next table are a little confusing, it reads like they are laboratory detection levels, when I think you mean to say they are thresholds (as per Point 12)

Number: 2 Author: deannae Subject: Highlight Date: 25/05/2020 10:32:04 AM
no water column?

Number: 3 Author: deannae Subject: Highlight Date: 25/05/2020 10:32:21 AM
that cover benthic and water column environments?

Number: 4 Author: deannae Subject: Highlight Date: 2/06/2020 6:42:11 AM
the remainder of this section discusses what the lease-scale benthic monitoring looks like, but there is no equivalent information for the BEMPs. Suggest more detail here on the lease-scale monitoring programme at an overview level, and ditto for the BEMP.

Number: 5 Author: deannae Subject: Highlight Date: 25/05/2020 11:58:58 AM
benthic?

Number: 6 Author: delvines Subject: Highlight Date: 19/05/2020 5:34:39 AM
seabed surveys below finfish cages?

Number: 7 Author: delvines Subject: Highlight Date: 19/05/2020 5:35:07 AM
biennial seabed monitoring?

Number: 8 Author: deannae Subject: Highlight Date: 25/05/2020 12:25:45 PM
in the sediments? or for water samples?

Number: 9 Author: delvines Subject: Highlight Date: 25/05/2020 12:01:05 PM
I am not sure what hybridisation means in this context. It seems like a funny word to use to describe the attributes that succeed in the following sentence/s but if it is a DPIPWE term then i guess it is necessary.

Number: 10 Author: delvines Subject: Highlight Date: 25/05/2020 10:26:55 AM
a tiered weight of evidence approach? I.e. the different weights of evidence are the additional tiers of monitoring (as opposed to multiple indicators from a single survey, or something else?)

Number: 11 Author: delvines Subject: Cross-Out Date: 19/05/2020 5:42:09 AM

Number: 12 Author: delvines Subject: Highlight Date: 19/05/2020 5:42:53 AM
i think the word used earlier was discretionary. Is that the same thing that was talked about earlier? Also important to know at who's discretion.

Number: 13 Author: delvines Subject: Highlight Date: 19/05/2020 5:44:37 AM
is this now talking about a different investigation to the triggered surveys? Or do you mean, "The triggered surveys that were undertaken....has resulted in commissioned..."

Number: 14 Author: delvines Subject: Highlight Date: 19/05/2020 5:45:57 AM
might be good to clear up if these are separate to the BEMPs.

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The implementation of the hybridised monitoring approach and environmental standards established by DPIPWE in 2004 satisfied the legislative requirements of the MFPA and LMRMA, and were appropriate for the size of the industry and the farming practices in place at the time of the review. The monitoring approach and environmental standards were modified based on established scientific guidelines (Macleod and Forbes 2004) to ensure that any potential environmental impacts were localised, reversible and short-term (DPIWE 2004). Evaluation of the last nine years (2010-2018) of environmental monitoring data in Tasmania indicates that the impacts of organic enrichment on benthic sediments have remained relatively localised. With the exception of Macquarie Harbour, only 1% of compliance point survey dives (extending 35 m from the lease boundary) have detected the presence of bacterial mats (e.g. *Beggiatoa* spp.) an indicator of organic enrichment, and only one out of 1,421 compliance point survey dives identified gas bubbling following sediment disturbance. In Macquarie Harbour, these statistics increase to 21% of compliance point survey dives (extending 35 m from the lease boundary) detecting the presence of *Beggiatoa* spp., with only one out of 2,003 compliance point survey dives detecting spontaneous gas bubbling from the sediments.

Environmental compliance at the statutory distance of 35 m from lease boundary appears adequate for finfish leases outside of Macquarie Harbour. However, it should be noted that since 2014, 50% of active finfish leases outside of Macquarie Harbour have been monitored for environmental compliance at or near peak feed input (the time period when environmental impacts on an active lease would be most likely to be observed), while approximately 30% being undertaken during fallowing. In addition, only 15% of stocked cages in the aforementioned leases have been monitored during peak production over the same period, reducing the capacity to observe on-lease environmental performance. Limited environmental monitoring during peak production increases the risk that environmental impacts are not detected.

Biomass production in Tasmanian salmonid farming has doubled over the past ten years, with this a shift in farm management practices occurring concurrently. These changes include, 1) establishment of new finfish leases; 2) the expansion/modification of existing finfish leases; 3) expansion to new farming locations; 4) modifying the number and orientation of cages on leases; 5) changes in the sizes of cages; and 6) the use of improved feed and feeding systems to reduce waste feed to the environment. Considering these changes, and with the regulation of the environmental impacts of finfish farming shifting to the *Environmental Management and Pollution Control Act 1994* (see below), it is valid to question whether the existing regulatory framework and environmental monitoring program still reflect best practice in relation to current farm management practices. Therefore, *what changes are required to ensure the environmental monitoring programs operating within the current legislative framework are capturing the potential environmental impacts of a modern and growing salmonid industry*?

Environmental protection framework for finfish aquaculture in Tasmania

In 2016, the EPA took over responsibility for regulating the environmental impacts of salmonid farming. Finfish aquaculture is now subject to the requirements of the *Environmental Management and Pollution Control Act 1994* (EMPCA) which is the primary environment protection and pollution control legislation in Tasmania. It is a performance-based style of legislation, with the fundamental basis being the prevention, reduction and remediation of environmental harm. The focus of EMPCA is on preventing environmental harm from pollution and waste. Additionally, the EPA also refers to the *State Policy on Water Quality Management 1997*, which provides a framework for the development of ambient water quality objectives and the management and regulation of point and diffuse sources of emissions to surface waters (including coastal waters) and groundwater

Objectives of Paper

The main objective of this paper is to review international practice in relation to regulating the environmental impact of cultivating salmonids in net pens and to compare this to current regulation in Tasmania. This review will focus on key aspects regulating the footprint of salmonid farming within the marine environment, particularly with respect to the seabed and water column. This paper covers expert advice and current knowledge on:

- compliance and lease management zones
- the selection and number of monitoring stations

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Number: 1 Author: deannae Subject: Highlight Date: 25/05/2020 12:23:01 PM
From here on out, is this paragraph now referring to the current (rather than previous) review of the Tasmanian framework? Should this not come after the final paragraph of this section, which summarises how much has changed in the industry within this 9yr period?

Number: 2 Author: deannae Subject: Highlight Date: 25/05/2020 12:21:37 PM
The effectiveness of the current Tasmanain framework has been a major consideration of this review, but there is little description of this review in the paper other than just here. It would be good to include a short description of how this part of the review was conducted.

Number: 3 Author: delvines Subject: Highlight Date: 25/05/2020 10:28:09 AM
Does it mean "By contrast, only 15% of leases outside of Macquarie Harbour were monitored at peak production"?

Number: 4 Author: emman Subject: Sticky Note Date: 8/05/2020 2:39:52 PM
This could be stated more clearly, particularly as it becomes an important point in the recommendations.

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 5:51:54 AM
its not clear how this differs from 4) and 5)

Number: 6 Author: delvines Subject: Highlight Date: 19/05/2020 5:50:51 AM
is this the same as 2) ?

Number: 7 Author: delvines Subject: Highlight Date: 19/05/2020 5:51:21 AM
part of 2) ?

Number: 8 Author: deannae Subject: Highlight Date: 25/05/2020 12:24:08 PM
"Legislative framework for environmental protection in Tasmania"?

Number: 9 Author: deannae Subject: Highlight Date: 25/05/2020 12:18:24 PM
as noted earlier, another major objective seems to be reviewing the effectiveness of the Tassie framework.

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- performance based management
- environmental indicators and their associated thresholds
- baseline sampling
- management responses/actions/controls.

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Review of Environmental Management of Salmonid Farming Globally

Compliance and lease management zones

The cultivation of salmonids at an international level has seen the implementation of defined spatial boundaries (i.e. zones) for regulating the environmental performance of finfish farms against defined environmental quality standards (EQS). Globally, jurisdictions regulating the farming of salmonids have adopted different management structures to define spatial boundaries for environmental regulation, driven by variation in husbandry practices/farm management, local environmental conditions, and jurisdiction specific legislative requirements. Regulating the benthic footprint of finfish farms is a widely adopted practice, due to the relative ease of collecting reliable information, with well-established methodologies and scientific understanding of the cause and effects of particulate organic wastes on benthic substrates and associated flora and fauna. On the other hand, regulating for the effects of dissolved nutrients on water quality in marine and estuarine waters has its inherent difficulties (i.e. dilution); capturing spatial and temporal dynamics of interest and attributing causality to aquaculture are significant challenges (Jansen et al. 2016).

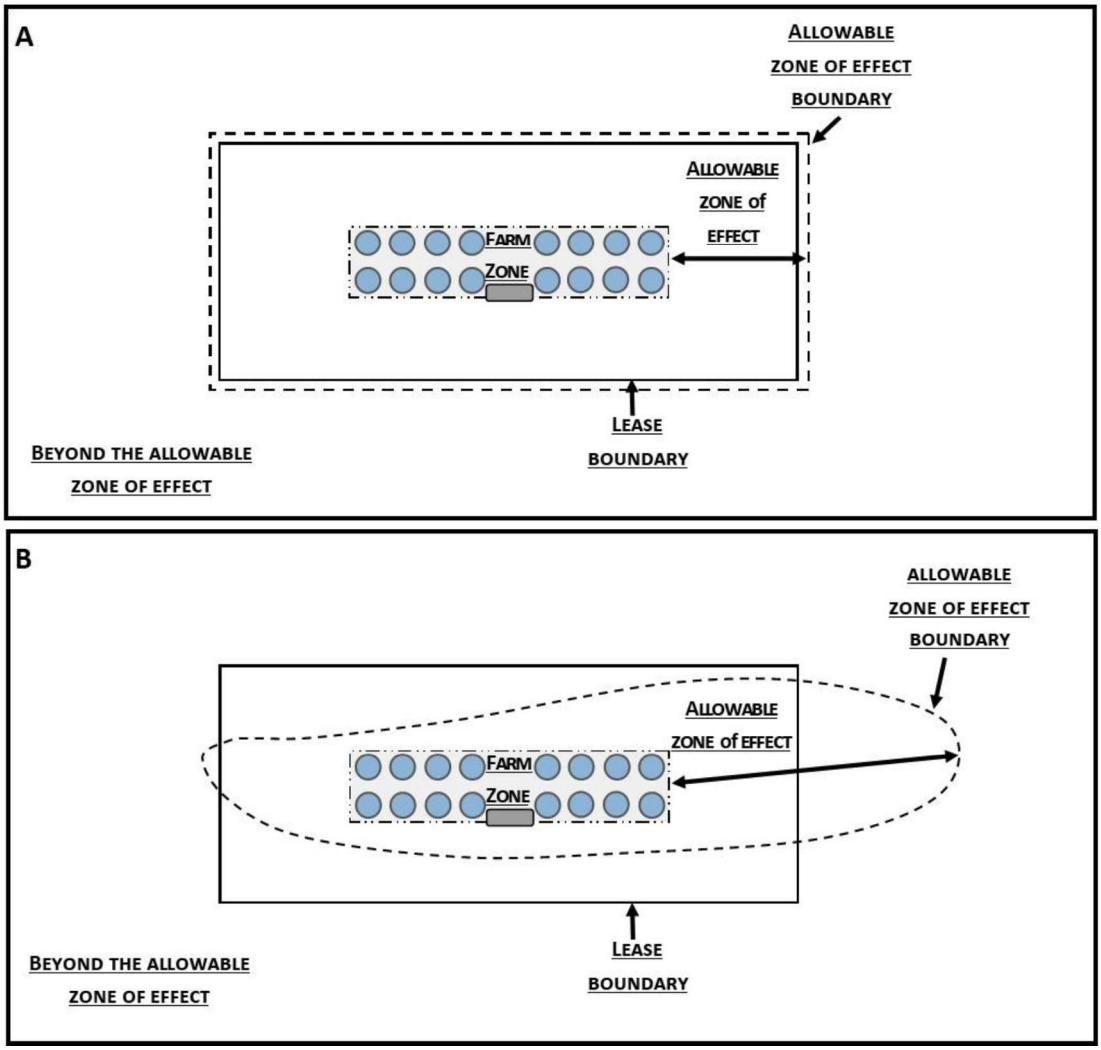

Figure 1. Established zones around two hypothetical farming scenarios. A) The Allowable Zone of Effect, fixed at 35 m from Lease Boundary. B) The site-specific Allowable Zone of Effect predicted using appropriate modelling tools

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Number: 1 Author: deannae Subject: Sticky Note Date: 2/06/2020 6:45:36 AM
yes, going into this section it would help to be armed with a high-level understanding of the Tasmanian framework, which i dont think the previous section provides.

Number: 2 Author: emman Subject: Highlight Date: 26/05/2020 10:05:48 AM
Does it not discuss transect approaches earlier?

Number: 3 Author: emman Subject: Sticky Note Date: 8/05/2020 2:44:07 PM
I'm not sure that dilution is the key issue. Movement and patchiness is the greater problem, combined with the delay in effect (i.e., lag time to see a primary productivity response to enrichment)

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Managing the environmental effects of particulate organic wastes on the seabed varies globally. New Zealand (Keeley et al. 2015a), Norway (NS9410 2016), Scotland (SEPA 2015, 2019), and Tasmania (DPIPWE 2004, Anon 2018b) use a zone type approach to manage environmental effects inside and outside of Salmonid leases. Whilst Ireland (Anon 2011) and Canada (Anon 2012, 2015, 2018a) managed environmental effects at fixed sampling stations along a transect extending beyond the edge of the cage array. The definition of zones vary slightly between countries, but can be expressed broadly as the Farm-Zone, the 'Allowable Zone of Effect' (AZE) and beyond the AZE (Figure 1A). The zone terminology has been simplified for the purpose of this comparative review, making comparison between countries easier to read throughout the review. When referring to Farm-Zone, this is equivalent to 'zone of maximum effect' (New Zealand), 'farm-zone' (Norway), 'cage edge' (Scotland and Ireland), and 'pen sites' (Tasmania). When referring to AZE, this is equivalent to 'outer limit of effect' (New Zealand), 'transition zone' (Norway), 'AZE' or '100 m from cage group' (Scotland and Ireland), and '35 m compliance sites' (Tasmania).

The Farm-Zone encompasses the area bounded by the outer edges of the cages. Farm-Zone monitoring focuses on the severity of the impact of wastes and is included in monitoring programs to ensure that the level of farming activity is proportionate with the biological processes required to assimilate and breakdown the particulate and dissolved nutrients (i.e. the carrying capacity of the ecosystem). The AZE comprises monitoring stations out to a set distance (country-specific) from the cage edge/lease boundary. Environmental monitoring at the AZE focuses on the extent of the diminishing impact and is included in most finfish environmental monitoring programs to ensure the footprint does not exceed an allowable distance from the cage edge/lease boundary. In generalised terms, the AZE is analogous with other effluent 'mixing zones', which is an allocated area where the dilution of pollutants from a point discharge are at chronic levels but do not remain at chronic levels beyond the zone of mixing and the identified environmental values are protected. Beyond the AZE, monitoring programs also encompass sampling for intermediate and broader-scale effects (Figure 1).

Monitoring programs targeting beyond the AZE assume no impact extending outside of the AZE. As such, sampling programs target locations where the likelihood of detecting cumulative effects of dissolved and particulate nutrients high, and focus on habitats that are vulnerable to excessive exposure of dissolved and particulate nutrients derived from aquaculture (Keeley et al. 2015a). To allow determination of localised AZE footprints and monitoring locations for cumulative far-field effects from aquaculture, advanced dispersal modelling tools (e.g. DEPOMOD) are being implemented across different salmon farming countries (e.g. Scotland, New Zealand and Canada) to optimise the placement of site-specific AZE footprints and associated monitoring stations both within and outside the AZE (Figure 1B). In Tasmania, modelling tools (e.g. Connie 3, Maree emulation model) have been increasingly used to inform the aquaculture planning process, regarding point source discharges and cumulative effects (based on agreed assumptions) using sink/source outputs, and to assist with assessing biosecurity risks to aquaculture operations and proposed zones. The use of dispersal modelling tools (e.g. DEPOMOD) are also becoming commonplace within the Tasmanian industry in planning changes to pen locations and production plans.

Unlike the regulation of impacts of organic enrichment on the seabed, regulatory monitoring for impact on water quality is less common across the majority of salmon farming countries globally. In Scotland and Canada, water quality is not part of their normal regulatory environmental compliance monitoring. In Norway and Chile, the collection of water quality measurements (limited to dissolved oxygen) are part of their annual lease management system. However, Norway has a voluntary regional impact-monitoring program, where water quality and seaweed/seagrass habitat mapping are undertaken to assess the regional health of water bodies where fish farming is present. In Ireland, monthly water quality sampling is undertaken as part of their lease management system at the same monitoring stations as the benthic monitoring surveys (Anon 2011). Furthermore, in New Zealand, water-column monitoring has been recommended for finfish aquaculture (Keeley et al. 2015b), with water quality standards and monitoring protocols recently released (Elvines et al. 2019). Monitoring should focus on local-scale water quality issues, while additional sampling beyond the AZE could be integrated for a broader-scale state of the environment monitoring program. In Tasmania, water quality monitoring programs target BEMP stations in various MFDP areas across the State.

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Number: 1 Author: emman Subject: Sticky Note Date: 8/05/2020 3:21:13 PM
Do you intend that 'particulate wastes' is interpreted as explicitly referring to seabed effects? if so, it would be useful to state that.

Number: 2 Author: emman Subject: Sticky Note Date: 6/05/2020 6:56:23 AM
But as per Fig 1 may extend substantially beyond that.

Number: 3 Author: emman Subject: Sticky Note Date: 8/05/2020 3:21:55 PM
and site-specific, and even variable wrt the current flow at the site (i.e., may be shorter cross-current than long-current)

Also is it important to make the point that this approach may only apply to benthic effects, not water column. (as per the comment above, I'm not sure if we are explicit about referring to benthic effects only here)

Number: 4 Author: emman Subject: Sticky Note Date: 6/05/2020 7:00:27 AM
do you mean 'chronic'? i.e., referring to time frame or recurrence, rather than degree?

Number: 5 Author: emman Subject: Sticky Note Date: 8/05/2020 3:22:13 PM
I'm not sure that this statement encapsulates the NZ approach - as per your next sentence the 'intermediate' effects are intended to fall within the OLE/AZE - measurable/significant effects (in the compliance parameter) outside that area are not expected to occur.

If this sentence is intended to serve as an introduction to the next paragraph, it might be useful to re-phrase so it is clear that the effects outside the AZE are not expected

Number: 6 Author: delvines Subject: Highlight Date: 25/05/2020 12:32:13 PM
monitoring in this zone has been mentioned very vaguely each time throughout this document. I still dont have an understanding of what this looks like in Tassie (and if it relates to the BEMP), but presumably this sentence is generalising what it looks like with other countries monitoring programmes? It implies the monitoring outside the AZE is conducted separate to the lease scale monitoring. Is that right? Could benefit from a sentence or two earlier in the document.

Number: 7 Author: emman Subject: Sticky Note Date: 6/05/2020 7:13:51 AM
I don't see how that is demonstrated by Fig 1.

Number: 8 Author: emman Subject: Sticky Note Date: 8/05/2020 3:24:41 PM
referring to water column?

Author: deannae Subject: Sticky Note Date: 25/05/2020 12:48:43 PM
agree that does become confusing. Instead "...detecting cumulative effects **on the seabed** from dissolved and particulate.."

Number: 9 Author: delvines Subject: Highlight Date: 25/05/2020 12:44:33 PM
The fact that these beyond AZE monitoring programmes are monitoring for potential cumulative effects conflicts with the statement that impacts are assumed to not extend outside of the AZE.

Number: 10 Author: deannae Subject: Highlight Date: 2/06/2020 6:47:16 AM
"Is the highest" (in a relative spatial sense)? Or where there is a high likelihood of effects being detected? Two v. different things.

Number: 11 Author: delvines Subject: Highlight Date: 19/05/2020 6:16:20 AM
This reference belongs to the former part of the sentence, but the BMP covers only soft sediments (it appears you are referring to other vulnerable habitats in the second part of the sentence, which are not covered in the NZ benthic BMP?).

Number: 12 Author: delvines Subject: Highlight Date: 19/05/2020 6:27:31 AM
In Marlborough BMP, these are cross-checked with a field mapping exercise later. Not sure if worth mentioning, and also do not think this is a mandatory step for farms outside of this region.

Number: 13 Author: emman Subject: Sticky Note Date: 8/05/2020 3:25:41 PM
And has been taking place for many years

Number: 14 Author: emman Subject: Sticky Note Date: 6/05/2020 7:38:24 AM
Is it worth clarifying that there were extant protocols, the importance of Elvines 2019 is that is signifies a move from local (farm-scale) monitoring to broad-scale (sounds-wide) monitoring. This reflects the lessons for many years of farm-scale monitoring demonstrating that detectable effects of nutrient enrichment are localised, but that cumulative effects are likely to be of greater importance for water column enrichment. DO is more of a local-medium-scale issue

Author: deannae Subject: Sticky Note Date: 25/05/2020 12:54:36 PM
Agree. Also to add that the publication aimed to centralise management and obtain consistency across different farming leases. The history of fish farm water column monitoring in Marlborough is actually listed in the appendix of this document, and as Emma points out, protocols existed but these were lease specific .

Number: 15 Author: emman Subject: Sticky Note Date: 28/05/2020 6:05:39 AM

Comments from page 19 continued on next page

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Managing the environmental effects of particulate organic wastes on the seabed varies globally. New Zealand (Keeley et al. 2015a), Norway (NS9410 2016), Scotland (SEPA 2015, 2019), and Tasmania (DPIPWE 2004, Anon 2018b) use a zone type approach to manage environmental effects inside and outside of Salmonid leases. Whilst Ireland (Anon 2011) and Canada (Anon 2012, 2015, 2018a) managed environmental effects at fixed sampling stations along a transect extending beyond the edge of the cage array. The definition of zones vary slightly between countries, but can be expressed broadly as the Farm-Zone, the 'Allowable Zone of Effect' (AZE) and beyond the AZE (Figure 1A). The zone terminology has been simplified for the purpose of this comparative review, making comparison between countries easier to read throughout the review. When referring to Farm-Zone, this is equivalent to 'zone of maximum effect' (New Zealand), 'farm-zone' (Norway), 'cage edge' (Scotland and Ireland), and 'pen sites' (Tasmania). When referring to AZE, this is equivalent to 'outer limit of effect' (New Zealand), 'transition zone' (Norway), 'AZE' or '100 m from cage group' (Scotland and Ireland), and '35 m compliance sites' (Tasmania).

The Farm-Zone encompasses the area bounded by the outer edges of the cages. Farm-Zone monitoring focuses on the severity of the impact of wastes and is included in monitoring programs to ensure that the level of farming activity is proportionate with the biological processes required to assimilate and breakdown the particulate and dissolved nutrients (i.e. the carrying capacity of the ecosystem). The AZE comprises monitoring stations out to a set distance (country-specific) from the cage edge/lease boundary. Environmental monitoring at the AZE focuses on the extent of the diminishing impact and is included in most finfish environmental monitoring programs to ensure the footprint does not exceed an allowable distance from the cage edge/lease boundary. In generalised terms, the AZE is analogous with other effluent 'mixing zones', which is an allocated area where the dilution of pollutants from a point discharge are at chronic levels but do not remain at chronic levels beyond the zone of mixing and the identified environmental values are protected. Beyond the AZE, monitoring programs also encompass sampling for intermediate and broader-scale effects (Figure 1).

Monitoring programs targeting beyond the AZE assume no impact extending outside of the AZE. As such, sampling programs target locations where the likelihood of detecting cumulative effects of dissolved and particulate nutrients is high, and focus on habitats that are vulnerable to excessive exposure of dissolved and particulate nutrients derived from aquaculture (Keeley et al. 2015a). To allow determination of localised AZE footprints and monitoring locations for cumulative far-field effects from aquaculture, advanced dispersal modelling tools (e.g. DEPOMOD) are being implemented across different salmon farming countries (e.g. Scotland, New Zealand and Canada) to optimise the placement of site-specific AZE footprints and associated monitoring stations both within and outside the AZE (Figure 1B). In Tasmania, modelling tools (e.g. Connie 3, Maree emulation model) have been increasingly used to inform the aquaculture planning process, regarding point source discharges and cumulative effects (based on agreed assumptions) using sink/source outputs, and to assist with assessing biosecurity risks to aquaculture operations and proposed zones. The use of dispersal modelling tools (e.g. DEPOMOD) are also becoming commonplace within the Tasmanian industry in planning changes to pen locations and production plans.

Unlike the regulation of impacts of organic enrichment on the seabed, regulatory monitoring for impact on water quality is less common across the majority of salmon farming countries globally. In Scotland and Canada, water quality is not part of their normal regulatory environmental compliance monitoring. In Norway and Chile, the collection of water quality measurements (limited to dissolved oxygen) are part of their annual lease management system. However, Norway has a voluntary regional impact-monitoring program, where water quality and seaweed/seagrass habitat mapping are undertaken to assess the regional health of water bodies where fish farming is present. In Ireland, monthly water quality sampling is undertaken as part of their lease management system at the same monitoring stations as the benthic monitoring surveys (Anon 2011). Furthermore, in New Zealand, water-column monitoring has been recommended for finfish aquaculture (Keeley et al. 2015b), with water quality standards and monitoring protocols recently released (Elvines et al. 2019). Monitoring should focus on local-scale water quality issues, while additional sampling beyond the AZE could be integrated for a broader-scale state of the environment monitoring program. In Tasmania, water quality monitoring programs target BEMP stations in various MFDP areas across the State.

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As per previous comment - I think work in the Marlborough Sounds has shown that this has limited utility, except for DO. Near-farm nutrient measurements are useful for calibrating models, but not so much for assessing the most important effects.

A similar comment from Deanna: "this is in conflict with the NZ BMP recommendations, the focus is on broad-scale eutrophication and blooms within the system, while localised effects are of less concern. Monitoring in NZ is thus focussed on broader scale change, except where specific info gaps need to be addressed at a local-scale (which would be a dedicated study rather than routine monitoring). In saying this, future monitoring using real-time technology may comprise local scale monitoring - but we are not there yet)."

Number: 16 Author: deannae Subject: Highlight Date: 2/06/2020 6:48:01 AM

first mention of BEMP in this section, but i am under the impression BEMP is also benthic (or sometimes is?).

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Recommendations

Recommendations from the 'Working Group' ~~for consideration during the drafting of the Environmental Standard~~ are that the environmental standard should:

- Utilise a zones concept for the environmental management of Tasmanian finfish leases. The recommended zones are Farm-Zone (Operational area of the marine farming lease extending out to cage edge) and the 'AZE' (extending from the edge of the Farm-Zone and out to 35 m from the lease boundary). Measurements undertaken at locations extending beyond the AZE should be referred to as beyond the AZE.
- Maintain the existing outer fixed distance for the AZE, this being set at 35 m from the edge of the lease boundary, while also providing the aquaculture industry with the opportunity to propose an alternative site-specific AZE. To propose a site-specific AZE, it would be expected that state-of-the-art modelling tools (e.g. 3D Hydrodynamic models and particle/nutrient deposition/dispersal models) should be used to demonstrate an acceptable dispersive / depositional footprint for each separate marine farming lease. Before approval and implementation of a site-specific AZE, the EPA may require peer-review for expert evaluation of the modelling work to ground truth the site-specific AZE.
- ~~Propose~~ validation of all site-specific AZE over a number of production cycles. If any lines of evidence demonstrate an environmental effect outside of the site-specific AZE, this would trigger a review of attributable causes and appropriate management actions.

The selection and number of monitoring sites

Internationally, there is no universal method for calculating the number of monitoring stations for detecting the environmental impacts of wastes from salmonid aquaculture on marine ecosystems. Each country producing salmonids has established their own formula for calculating the number of monitoring stations required.

Norway

In Norway, the number of monitoring stations required for Farm-Zone monitoring is highly dependent on the maximum allowable biomass (MAB) licensed to a specific fish farm. The environmental condition of the site at peak production has no bearing on the number of monitoring stations surveyed. A minimum of eight monitoring stations are required within the lease area (with MAB of 780 tonnes), with one sample collected per station. However, if the MAB exceeds 780 tonnes, then one additional monitoring station is required for every 500 tonnes increase in allowable biomass production (Figure 2). Each monitoring station must be located at cage edge and distributed evenly to cover the active farming area of the lease (NS-9410:2016).

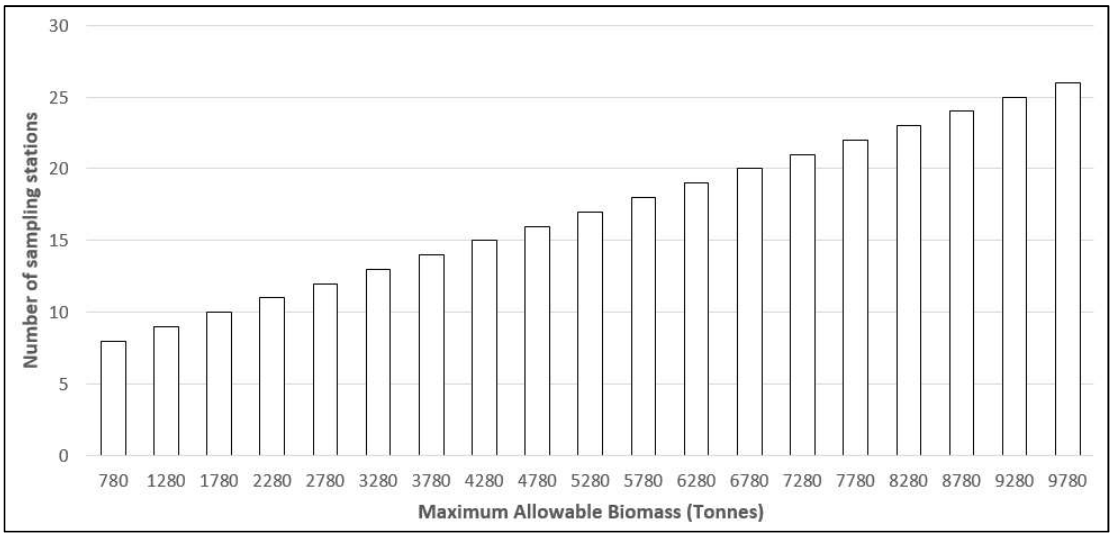

Figure 2. Number of monitoring stations per farm per tonne of MAB in Norway within the Farm-Zone. The line continues with increasing biomass (reproduced from NS-9410:2016)

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 6:26:17 AM
see my earlier comments in summary

Number: 2 Author: emman Subject: Sticky Note Date: 8/05/2020 3:30:00 PM
Are these recommendations equally for seabed and water column?

I'm quite unclear on what is being recommended for the water column.

Number: 3 Author: delvines Subject: Cross-Out Date: 19/05/2020 6:24:20 AM

Number: 4 Author: delvines Subject: Highlight Date: 25/05/2020 12:56:06 PM
seems like this is already well utilised. Formalise?

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 6:25:49 AM
unless a site-specific AZE is established.

Number: 6 Author: emman Subject: Sticky Note Date: 6/05/2020 7:45:25 AM
as a default

Number: 7 Author: emman Subject: Sticky Note Date: 6/05/2020 7:48:19 AM
Is there any expectation that the site specific AZE should cover an equal or smaller area than the default?

Number: 8 Author: delvines Subject: Cross-Out Date: 19/05/2020 6:28:05 AM

Number: 9 Author: deannae Subject: Highlight Date: 25/05/2020 1:20:57 PM
I found this section difficult to get through. I think performance based management / monitoring timing would benefit to come before this, then the reader has a handle on the different Tiers within each countries framework. As it stands, the Tiers of monitoring for each country are described partially, between this section and the next one titled performance based management.

Number: 10 Author: delvines Subject: Highlight Date: 25/05/2020 1:13:31 PM
There is no discussion of water quality monitoring in this section, except as it refers to BEMP in the recommendations.

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The number of monitoring stations for AZE monitoring and the placement of these stations require expert evaluation. Per rule of thumb, positioning of monitoring stations need to be within the area between the Farm-Zone and the outer edge of the AZE, with stations covering the areas with the greatest risk of exposure. The number of stations and the distance of the outermost AZE monitoring station are dependent on the MAB produced on site (Table 3) (NS-9410:2016).

Table 3. Recommended number of monitoring stations and recommended distance from the aquaculture facility to the outermost monitoring station for AZE monitoring on the basis of the MAB in tonnes at the farming location in Norway (reproduced from NS-9410:2016)

MAB at the farming location (tonnes)	Recommended distance from cage edge to the outermost AZE monitoring station (metres)	Recommended number of monitoring stations for AZE
≤ 1999	300	3
2000 to 3599	400	4
3600 to 5999	500	5
≥ 6000	500	6

Scotland

In Scotland, the regulatory framework has recently changed (31 May 2019), and as such, the implementation of site selection and the number of monitoring stations for environmental monitoring vary pre and post regulatory changes.

Prior to May 2019, the number of monitoring stations were dependent on the type of monitoring program (e.g. standard, extended, site-specific) being initiated for the different farming locations. At existing farming sites that have a maximum total biomass (MTB) < 1,000 tonnes, implementation of a 'standard' benthic monitoring program was common. This monitoring program was comprised of samples collected at two stations (cage edge and the edge of the AZE) placed along the pre-dominant current direction and at two reference stations. When there was more than one cage group, with a separation > 100 m, the monitoring stations were located off each cage group. Existing farming sites with MTB > 1,000 tonnes used an 'extended' benthic monitoring program (SEPA 2008a). The 'extended' benthic monitoring program collected samples along two transects in both directions of the prevailing current and at two reference stations. Collection of samples occurred at three stations (cage edge, 25 m and 50 m from cage edge) along each transect. Again, when there was more than one cage group, with a separation > 100 m, the monitoring stations were located off each cage group (SEPA 2008b). At new farming locations, when conditions were suitable (i.e. low re-suspensive conditions) for the use of dispersive modelling tools (e.g. AutoDEPOMOD), predictive site-specific dispersive footprints determined the positioning of monitoring stations (SEPA 2008c). Monitoring stations were: 1) at the edge of the cage group; 2) at the edge of the AZE; 3) at a station 10 m beyond the edge of the AZE; 4) at a station 10 m short of the edge of the AZE; and 5) at two reference stations. At new farming locations, when conditions were not suitable (i.e. highly re-suspensive conditions) for the use of dispersive modelling tools (e.g. AutoDEPOMOD), a fixed monitoring protocol determined the position of the monitoring stations. Monitoring stations were: 1) at the edge of the cage group; 2) at a station 25 m from the edge of the cage group; 3) at a station 50 m from the edge of the cage group; 4) at a station 100 m from the edge of the cage group; and 5) at two reference stations. In summary, prior to May 2019, Scotland's monitoring program focused on establishing farming practices that were in line with the carrying capacity of the ecosystem (SEPA 2008c).

Since 1 May 2019 (the implementation of the new regulatory framework), site selection is focused on sampling both inside and outside of the AZE (Figure 3). A minimum of four transects originating at the edge of pen are required, with two transects orientated along the major axis of the AZE and two along the minor axis. Each transect must extend 50 m beyond the AZE or at least 150 m from the edge of the pen. Along each transect a minimum of seven monitoring stations (with a minimum of 10 m apart) are to be selected with one station located at cage edge, one station at the edge of the AZE, and at least two stations beyond the AZE. When medicated feed is used (e.g. Emamectin benzoate) and the highest predicted

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Number: 1 Author: delvines Subject: Highlight Date: 2/06/2020 6:49:29 AM
its not clear if this design applies to all farms (or just new farms) regardless of farming environment/biomass, nor if DEPOMOD is relied upon to establish transect length/direction post May-19

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concentration period does not correspond to the main monitoring period, then additional surveys for medicine residues must be carried out (Figure 3).

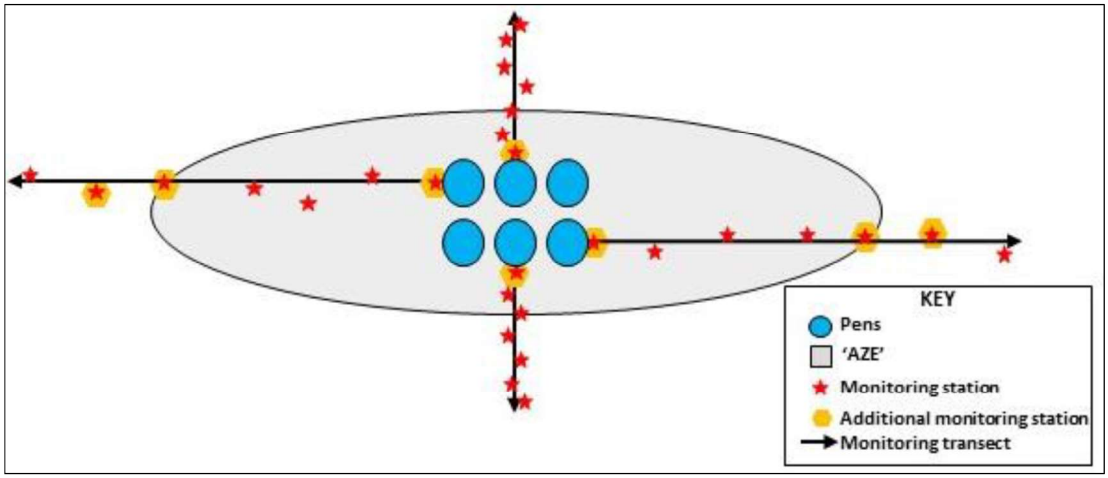

Figure 3. Benthic survey design for new SEPA regulatory sampling requirements for Scottish finfish farms (reproduced from SEPA 2019a)

Ireland

In Ireland, the level of benthic monitoring is determined based on the size of the farm and the average current speeds at the farming location (Table 4). Level 1 monitoring comprises of video observations and grab sampling for redox and sediment organic carbon content, while level 2 monitoring comprises of level 1 monitoring, plus replicate grab sampling for fauna determination. For both monitoring levels, monitoring stations are located at: 1) a minimum of two stations directly beneath the pens; 2) at the edges of the pens; 3) at ~~monitoring stations~~ 10 m, 20 m, 50 m, and 100 m from the net pens along two transects perpendicular to each other; and 4) at a control station (Anon 2011).

Table 4. Recommended number of monitoring stations and recommended distance from the aquaculture facility to the outermost monitoring station for AZE monitoring on the basis of the MAB in tonnes at the farming location in Norway (reproduced from NS-9410:2016)

	Mean current speed (cm/s)		
Tonnage (MT)	**< 5**	**5 – 10**	**> 10**
0 to 499	Level 1	Level 1	Level 1
499 to 999	Level 2	Level 1	Level 1
≥ 1000	Level 2	Level 2	Level 1

Canada

In Canada, during annual (Tier-1) and seasonal (Tier-3) environmental monitoring on the east-coast (e.g. Nova Scotia or New Brunswick), a minimum of two monitoring stations / video transects are required for leases containing a maximum of 200,000 finfish and the number of monitoring stations / video transects increases by one station / transect for every additional 100,000 finfish on the lease. In addition to the minimum required monitoring stations (Table 5), sampling of historic, high impact stations (i.e. stations whose mean sulphide levels have exceeded the EQS) must occur until the environmental impacts decrease to acceptable levels. Triggering of Tier-2 monitoring occurs when EQS are exceeded during Tier-1 and Tier-3 monitoring (Anon 2012, 2018a). Tier-2 monitoring needs to take place within 20 calendar days of the Tier-1 sampling event. Tier-2 monitoring requires:

- Improved spatial delineation of the impacted area. In Nova Scotia, this will include additional monitoring stations located at cage edge for all cages immediately adjacent to the Tier-1 monitoring stations that triggered EQS (Figure 4). In New Brunswick, this will include additional monitoring

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 6:58:13 AM
It isnt clear if this relates to the additional monitoring stations in the legend of Fig3.

Number: 2 Author: delvines Subject: Highlight Date: 2/06/2020 6:49:42 AM
add text around the additional monitoring stations (how is the need for these determined?)

Number: 3 Author: emman Subject: Sticky Note Date: 7/05/2020 6:17:02 AM
Not sure why type of sampling within level is described here when it is not for Scotland, above - I expected to be told that there were different site selection criteria for each level, but that wasn;t the case

Number: 4 Author: delvines Subject: Highlight Date: 19/05/2020 7:02:59 AM
how many?

Number: 5 Author: delvines Subject: Cross-Out Date: 19/05/2020 7:03:09 AM

Number: 6 Author: emman Subject: Sticky Note Date: 7/05/2020 6:19:11 AM
It appears that this is not the right table/caption

Number: 7 Author: emman Subject: Sticky Note Date: 8/05/2020 3:32:52 PM
Not really relevant to selection and number of monitoring sites, so doesn't help with following the reasoning

Number: 8 Author: delvines Subject: Highlight Date: 25/05/2020 1:04:15 PM
or Tier 3, since both can trigger Tier 2?

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stations located at cage edge for the four corner cages and each of the outside cages, and additional monitoring stations between each cage (Figure 4).

- Improved spatial delineation of the zone of influence in Nova Scotia. This will involve monitoring at the outer farm buoys, with no more than 200 m spacing along the outer edge of the cage configuration (Figure 4).

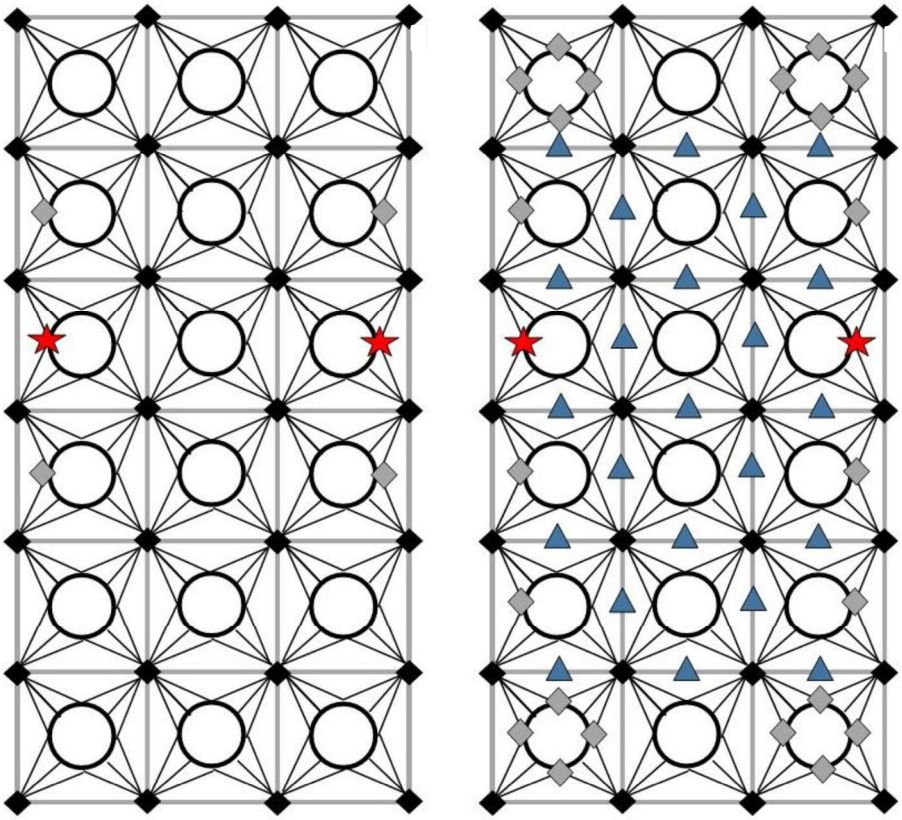

Figure 4. Position of Nova Scotia's (left panel) and New Brunswick's (right panel) Tier-2 monitoring stations in Canada. (reproduced from Anon 2012 and 2018a)
Note: Red stars – Monitoring stations that triggered Tier-2 monitoring. Grey diamonds and blue triangles depict the monitoring stations required for triggered Tier-2 monitoring

Table 5. Number of monitoring stations required for sediment and video sampling on the east coast of Canada (reproduced from Anon 2012, 2018a)

Maximum number of fish within cage site array during production cycle	Number of monitoring stations / video transects[1] (not including reference stations)	Number of samples (3 samples/station for soft bottom sites)
1 – 200,000	2	6
200,001 – 300,000	3	9
300,001 – 400,000	4	12
400,001 – 500,000	5	15
500,001 – 600,000	6	18
600,001 – 700,000	7	21
700,001 – 800,000	8	24
800,001 – 900,000	9	27
900,001 – 1,000,000	10	30

[1]Video surveys are only applicable for Nova Scotia

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Number: 1 Author: emman Subject: Sticky Note Date: 7/05/2020 6:29:11 AM

It would help to state in the caption that these are the minimum requirements. It would also help understanding if this table came before Figure 4, when additional stations are considered - it took me a minute to understand why the same values were applicable to both NBrunswick and NScotia

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 7:13:28 AM

This column is a bit redundant. Just say n=3 per station? Am i missing something?

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Unlike the east coast of Canada, a tiered management approach is not implemented in British Columbia. As such, the number of monitoring stations and frequency of sampling is not a result of fish biomass and/or the abundance of fish in net pens, or a specific environmental enrichment state. Monitoring stations occur along two transects in either direction of the prevailing current at cage edge, 30 m from cage edge and 125 m from cage edge. Sampling is conducted 30 days either side of peak biomass for farms that have a production cycle ending in the complete removal of all fish or at the end of every 24-month period if the production cycle is longer than 24 months (Anon 2015).

New Zealand

In New Zealand, benthic compliance monitoring in the Marlborough Sounds comprises of tiered monitoring program (Table 6). For a single, continuous block of cages in the centre of the lease, five to seven monitoring stations (e.g. farm, AZE and reference) are surveyed dependent on the local flow conditions for the default type 2 annual monitoring. For Type 1 monitoring (the least intensive form of monitoring), two Farm-Zone stations, one to two AZE stations and one reference station are required. Type 3 monitoring (the most intensive form of monitoring) takes place as a repeat of the baseline survey (year 0) and is re-surveyed every five years. The positioning of monitoring stations within the Farm-Zone and AZE is determined on a site-specific basis. For new farming leases, the initial distances should be set based on a predicted benthic footprint using an established depositional model (e.g. DEPOMOD). For established farms, positioning of monitoring stations within the Farm-Zone and AZE are refined based on the observations collected in the Type 3 monitoring conducted after five years of operation. Distances of monitoring stations from cage edge can be specific to transect directions or orientations due to the ~~benthic footprint being dependent on water currents~~ (Keeley et al. 2015a). Indicative distances of monitoring stations from cage edge are provided in Table 7 reflecting ambient water currents with either low or high flows. When fish farms have circular cage configurations on the lease, one Farm-Zone and one AZE monitoring station is required for every three circular cages on the lease, with a minimum of two Farm-Zone monitoring stations per lease. Each lease with multiple circular cages would require multiple reference stations (one near-field and one far-field location).

Table 6. Summary of monitoring frequency and number of monitoring stations for the different tiered monitoring types in New Zealand (reproduced from Keeley et al. 2015a)

Flow	Type 1 – indicator monitoring		Type 2 – Full suite monitoring		Type 3 – Spatial monitoring	
	Low	High	Low	High	Low	High
Total compliance monitoring stations	4	5	5	7	Spatial sampling design varies according to situation	
Farm-Zone stations	2	2	2	3	Design dependent	
AZE stations	1	2	1	2		
Reference stations	1	1	2	2		

Table 7. Indicative distances of monitoring stations from cage edge under different hydrodynamic conditions in New Zealand (reproduced from Keeley et al. 2015)

Monitoring stations	Ambient hydrodynamic condition	
	Low flow	High flow
Farm Zone	Beneath or at edge of pens	Edge of pens, or nearby if area of greatest deposition is offset due to currents
AZE	150 m from edge of pen	200 – 800 m from edge of net pen
Near-field reference	300 – 1000 m away	500 – 1500 m away
Far-field reference	> 1000 m away	> 1500 m away
Cumulative effects reference	Variable, < 1000 m	Variable, < 2000 m

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Number: 1 Author: delvines Subject: Highlight Date: 25/05/2020 1:06:40 PM
While i dont think it belongs in this section (rather, the monitoring timing section) it would be handy to know what the targeted timing is for this. Summer, or defined by some other farming operation/milestone?

Number: 2 Author: emman Subject: Sticky Note Date: 8/05/2020 3:35:16 PM
What you describe here are the BMP requirements,(and in NZ BMP stands for Best Management Practice) - I agree that they are the best ones to consider, but maybe for clarity note that these are only formally adopted at 2 sites. Other sites are still subject to the specific conditions of their consents (which are generally aligned with the BMP, but not exactly the same) The intention is to change the consents so that the BMP is adopted more widely.

Author: delvines Subject: Sticky Note Date: 28/05/2020 6:07:26 AM
Also worth noting that there is no BMP for other farming regions (i.e. Stewart Island), and these are also described in site specific permits case-by-case - i am unsure of how consistent they are with the BMP approach. Ditto for new sites that are not within the Sounds - the BMP would unlikely be automatically applied to these, as the BMP was developed using Marlborough specific site information based on a large existing time series of info (i.e. it represents quite a streamlined approach based on confidence with existing knowledge).

Number: 3 Author: deannae Subject: Highlight Date: 25/05/2020 1:14:41 PM
no water quality context?

Number: 4 Author: delvines Subject: Highlight Date: 19/05/2020 7:21:06 AM
also worth noting that additional stations are elected as part of Type 2 monitoring for areas identified as hotspots, through either modelling or Type 3 'mapping', as you have in Table 7.

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 7:16:24 AM
might be handy to add that it is the routine quantitative monitoring type.

Number: 6 Author: delvines Subject: Highlight Date: 19/05/2020 7:17:51 AM
semi-quantitative

Number: 7 Author: emman Subject: Sticky Note Date: 7/05/2020 6:50:56 AM
The BMP only states that Type 3 is required "Baseline and at year 5, then as necessary..." so not necessarily every 5 years following.

It can also be undertaken at <5yr intervals, e.g., prior to a proposal for a feed increase

Number: 8 Author: deannae Subject: Cross-Out Date: 25/05/2020 1:09:21 PM
distortion of the benthic footprint according to water currents

Number: 9 Author: emman Subject: Sticky Note Date: 7/05/2020 6:52:14 AM
This does not occur - it is mentioned in the BMP to cover possible future approaches

Number: 10 Author: emman Subject: Sticky Note Date: 8/05/2020 3:36:45 PM
There is a new edition of the BMP, from 2019

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Tasmania

In Tasmania, determining the number of mandatory monitoring stations both inside (Farm-Zone) and outside of the lease boundary (AZE) is not undertaken using a precise formula, such as a projection of production biomass, total number of fish, feed input, or the total number of cages stocked for the farming lease. Current Environmental Licence conditions state that within the Farm-Zone a minimum of six monitoring stations are required (the Environmental Licence states that this number may be increased by the regulator), while at the edge of the AZE the number of compliance monitoring stations are site-specific based on the requirements of the EPA. In 2018, outside of Macquarie Harbour, for environmental compliance, on average, 6 Farm-Zone stations (ranging between 5 and 10 cages with the highest feed input for the previous 12 months) and 7 AZE stations (ranging between 5 and 10 stations) were surveyed. Within Macquarie Harbour, the average number of monitoring stations surveyed per lease in 2018 were 6 Farm-Zone stations (top 6 cages with the highest feed input for the past 12 months) and 11 AZE stations (ranging between 4 and 18 stations). If any of the AZE monitoring stations become non-compliant, the Director, EPA may require further video surveys to collect additional environmental information, or other management actions, depending on the degree of non-compliance. Depending on the outcomes of these additional video surveys, the Director, EPA can request a triggered environmental survey (e.g. a repeat of the baseline survey, or other specified sampling) for the collection of both quantitative and qualitative information at the AZE monitoring stations together with a number of reference stations.

In addition to Farm-Zone and AZE monitoring, in some MFDP areas (Huon River and Port Esperance, D'Entrecasteaux Channel, Storm Bay, Tasman Peninsula/Norfolk Bay, and Great Oyster Bay and Mercury Passage, Macquarie Harbour) it is a requirement of all licenced finfish operators to undertake the BEMP. The number of required BEMP monitoring stations vary between the different MFDP areas reflecting the different spatial coverage required to assess broader scale changes in the different farming regions (Table 8).

Table 8. The number of monitoring stations for Broad-scale Environmental Monitoring Program (BEMP) within the different Marine Farming Development Plan Areas in Tasmania

Marine Farming Development Plan Area (MFDP)	Sediment sampling stations	Water quality sampling stations	Other habitat types sampling stations
Huon River and Port Esperance, D'Entrecasteaux Channel	15	15	N/A
Tasman Peninsula and Norfolk Bay	9	9	N/A
Great Oyster Bay and Mercury Passage	7	7	10
Storm Bay	23	28	20
Macquarie Harbour	N/A	11	N/A

The number of required monitoring stations within the farm-zone for Tasmanian finfish leases to those that would be required at a similar feed input level under Canadian (New Brunswick and Nova Scotia) or Norwegian regulations, vary considerably (Figure 5). At 3,000 tonnes maximum feed input, New Brunswick regulations (Canada) would require approximately six sediment-monitoring stations at cage edge, with three replicate samples collected per station (18 observations). The regulations for Nova Scotia (Canada) would require six 50 m video transects from cage edge, in addition to the required six sediment-monitoring stations at cage edge. Under Norwegian regulations, a lease with 3,000 tonnes maximum feed input would require 13 sediment grab monitoring stations, compared to the required six monitoring stations (six individual video observations) in Tasmania. At 9,000 tonnes maximum feed input, Tasmania still only requires six monitoring stations (six individual video observations). However, regulations for New Brunswick (Canada) would require approximately 15 sediment monitoring stations at cage edge, with three replicate samples collected per station (45 observations). For Nova Scotia (Canada) regulations, in addition to the 15 sediment-monitoring stations at cage edge, 15 video transects (50 m) from cage edge would also be required. Under Norwegian regulations, a lease with 9,000 tonnes maximum feed input would require 25 sediment grab monitoring stations. When determining the potential number of monitoring stations required for Tasmanian finfish leases with 12 monthly feed inputs of approximately 3,000 (approx. 24 cages) and 9,000 (approx. 32 cages) tonnes using the New Zealand regulatory approach for the Marlborough sound, then approximately 9 and 1 stations, respectively would be required at both the Farm-Zone and the AZE.

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 7:26:12 AM
Here it would be good context if we knew how they were sampled - video or quantitative?

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 7:29:37 AM
how is this coordinated? do the farmers pay a levy type fee toward a large coordinated monitoring programme administered by independent science body, or do they commission separate sampling for their own broad-scale but lease-specific stations?

Number: 3 Author: delvines Subject: Highlight Date: 19/05/2020 7:47:39 AM
per year?

Number: 4 Author: emman Subject: Sticky Note Date: 29/05/2020 9:53:12 AM
Does this assume circular cages?

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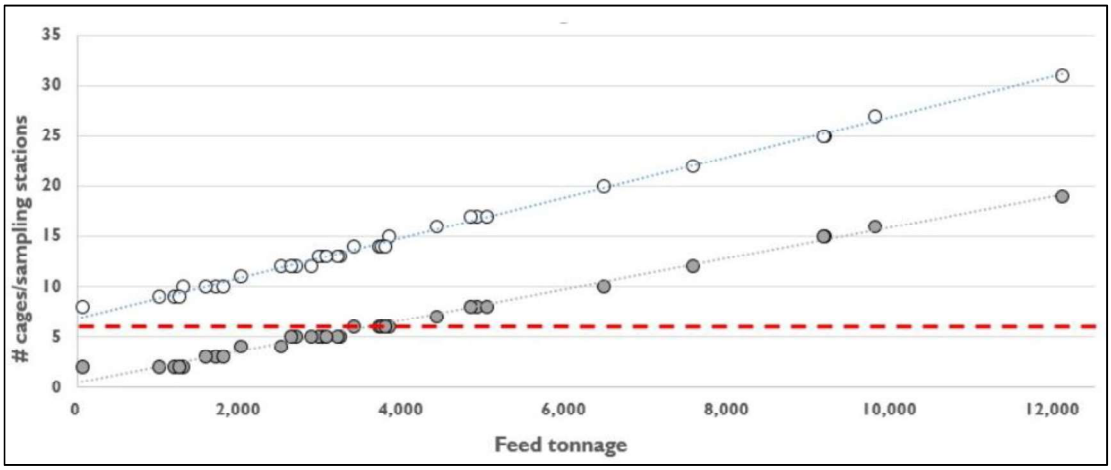

Figure 5 Comparative regression plot of the number of Farm-Zone (e.g. annual cage monitoring stations required for Tasmanian finfish farms stocked between 2016-2018 when applying Tasmanian feed data to current Norwegian (black circles), Canadian (white circles) and Tasmanian (red dotted line) environmental regulations

Recommendations

Site selection and therefore spatial representation of the impacts of salmon farming inside and outside of the lease area is not consistent among countries farming salmonids. For managing Farm-Zone impacts, the approach taken by Canada and Norway, provides the regulator with increased confidence of capturing detailed Farm-Zone effects. Monitoring undertaken by Ireland and Scotland at discrete sampling points along a fixed transect, provides confidence in understanding the extent of impacts from the edge of the Farm-Zone in the main current direction. However, the use of modern dispersal modelling tools (locally validated) being implemented in Scotland, Canada and New Zealand to predict benthic footprints provides the end-user with the capacity to optimise site selection for cost effective environmental monitoring, provided they are not modelling footprints in highly dispersive environments. Typically, Tasmania require fewer monitoring stations at Farm-Zone than what is required under regulation for other jurisdictions farming salmonids. However, AZE and beyond the AZE are generally sampled with greater spatial resolution in Tasmania than elsewhere. In fact, for the BEMP conducted beyond the AZE, the current approach is unique globally, with few other Salmonid farming countries undertaking a detailed BEMP as is undertaken in Tasmania.

Recommendations from the 'Working Group' ~~for consideration during the drafting of the Environmental Standard~~ are that the environmental standard should:

- As is current practice, suggest that the EPA should establish lease-specific monitoring plans in consultation with the 'Environmental Licence' holder to ensure the correct placement of all monitoring stations to assess environmental performance. The use of real-time data (i.e. Doppler current meter data) and modelling tools will be integral in providing additional information regarding current direction and speed, and the potential footprint to aid in the placement of these monitoring stations.
- Include the selection of representative reference stations at distances appropriate to site-specific environmental forcing (e.g. wave activity, hydrodynamics) when undertaking quantitative AZE sampling to enable suitable comparisons of AZE environmental conditions to background environmental conditions. The sites chosen and the parameters required for quantitative sampling should be determined as part of the baseline sampling program.
- Consider increasing the number of monitoring stations within the Farm-Zone. This will provide a better understanding of the environmental condition of the near-field environment within the marine farming lease area in-line with international practice.
- Outline a requirement to regularly review EMP reports to ensure the appropriateness of the monitoring sites, the parameters used, and the established investigative levels within these programs.

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 7:47:22 AM
is the feed tonnage per annum?

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 7:45:49 AM
grey

Number: 3 Author: delvines Subject: Highlight Date: 25/05/2020 1:11:47 PM
is newDEPOMOD not capable of modelling in these types of environments? Is this not being used in Scotland for this purpose? It seems to have the capability to do so.

Number: 4 Author: delvines Subject: Cross-Out Date: 19/05/2020 7:55:07 AM

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 7:55:26 AM
see my comments in the summary

Number: 6 Author: delvines Subject: Highlight Date: 2/06/2020 6:52:21 AM
is this recommendation intended to apply to all sites, even where there is a good understanding of waste dispersal/enrichment (e.g. historically farmed sites with good time series of data?). And what about once that environmental condition is understood reasonably well and changes are not proposed, would sampling effort then reduce?

Number: 7 Author: delvines Subject: Highlight Date: 19/05/2020 8:00:11 AM
Suggest a process for reviewing lease-scale monitoring requirements is also outlined, as these too could become outdated (see previous comment).

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Revised water quality guideline values should be provided for use within the new Environmental Standard for all MFDPs across Tasmania to enable site-/region-specific investigative levels to be established to increase the success of protecting ecosystem health.

Performance based management

Compliance monitoring follows a similar approach internationally. Norway, Scotland, Ireland, Canada, and New Zealand have all adopted a focus on measuring environmental performance at peak production, often employing a tiered performance-based management response linked to the level of impacts observed. The structure of performance-based management is country-specific, with exceedances of environmental quality standards triggering either follow up monitoring, fallowing practices or a reduction in production capacity.

Table 9. Minimum frequency for farm-scale monitoring determined by the environmental conditions in Norway (reproduced from NS-9410:2016)

Location condition	Monitoring frequency
1 – Excellent	With the next maximum load (i.e. peak production)
2 – Good	Pre-stocking and the next maximum load (i.e. peak production)
3 – Poor	Pre-stocking. if pre-stocking investigation gives: • condition 1 – Monitor at next maximum load (i.e. peak production) • condition 2 – Monitor at next half maximum load and at maximum load, or • condition 3 – Monitor at next half maximum load and at maximum load. Production plans modified before next production. If some of the investigations show location condition 4, it is overloaded.
4 – Very Poor	Overloaded, no stocking allowed until conditions reach condition 3, production plans modified before next production.

Norway

In Norway, the frequency of environmental monitoring for Farm-Zone and AZE impacts is based on how impacted the location is (see Table 9 and Table 10). In general, with decreasing environmental condition the frequency of monitoring increases. This approach to monitoring aims to tailor lease performance to the maximum allowable biomass (MAB) produced on a lease, with an aim to achieve optimal carrying capacity of farming locations with respect to benthic performance (NS-9410:2016). If significant changes to the farming operation occur (e.g. increased biomass, shift in operation area, expansion of farming structures), then additional investigations are required by the authorities.

Table 10. Monitoring frequency for AZE monitoring within the AZE and at the outer boundary of the AZE with different environmental condition classifications in Norway (reproduced from NS-9410:2016)

Monitoring station	Environmental condition	Every second production cycle	Every third production cycle
AZE boundary	Excellent or good		X
Within AZE	Poor	X	
	Excellent or good		X

Scotland

In Scotland, the updated regulatory framework (31 May 2019) has modified the national monitoring program. As such, the approach to performance-based management has recently changed. Below is a summary of both pre and post the updated regulatory framework.

Prior to May 2019, the frequency of the national monitoring program for Farm-Zone and AZE was from the date that maximum biomass for the production cycle was first reached until one month after maximum biomass. Ideally, sampling would take place between maximum biomass and one month after maximum biomass, during the period of 1 May to 31 October. Exceeding thresholds of Environmental Quality Standards 'EQS' either as an intensity failure (i.e. non-compliant at cage edge) or as an extent failure (i.e. non-compliant at edge of AZE), triggered additional monitoring and a number of different pre-defined management controls (SEPA 2015).

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 8:00:52 AM
are these only relevant to the BEMP?

Number: 2 Author: delvines Subject: Highlight Date: 25/05/2020 1:22:18 PM
Should the heading of this section be timing of monitoring or monitoring frequency, instead of performance based management? Or perhaps this paragraph needs to be reversed (talk about monitoring timing/frequency penalties as a management response, since they are determined by prior environmental performance?

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If the exceedance was an intensity failure (see Figure 6), additional monitoring was required before the lease reached peak biomass and the farm manager/owner received a formal request to reduce biomass (by 25-50%). If a second intensity failure occurred during the succeeding production cycle, suspension of the farming licence may have occurred to facilitate seabed recovery. Before restocking, pre-stocking monitoring took place to assess seabed recovery. Further directives to reduce biomass and audit monitoring by the regulator would occur (SEPA 2015).

In the case of a first extent failure (see Figure 6), action takes place to determine the reason for the extent failure (e.g. Does the farm require a site-specific AZE if they currently have a default AZE? What are the current husbandry practices? Etc.). Additionally, enhanced monitoring would have been required before the site reached peak biomass to re-assess the AZE prior to the next production cycle. A variation notice would have been issued at the time of the first failure stating that biomass on the lease will be reduced by 25-50% at the beginning of the next production cycle if there is a second consecutive extent failure on the lease. If a second extent failure occurred, the first variation notice served would come into effect. In addition, a second variation notice would be served to further reduce biomass should the next monitoring survey prove to be unsatisfactory. Again, additional monitoring and extended monitoring would be required on the lease, with initiation of audit monitoring by the regulator (SEPA 2015). A third consecutive extent failure would result in the second variation notice served coming into effect. At this stage, a suspension of the lease licence in order to allow recovery of the seabed would occur, coming into effect at the end of the grow-out cycle.

Post May 2019, the regulatory framework in Scotland has been simplified. All monitoring sampling must take place when it is probable that the greatest impact will be observed from the lease (SEPA 2019a). For each production cycle, an estimation of this time period must be presented to the regulator. For a typical production cycle, monitoring must be undertaken within the 30 day period either side of the date that fish biomass on the lease has reduced to 75% of the peak biomass for the final time during that cycle, but must not take place within 14 days of peak biomass (Figure 7) (SEPA 2019a). When medicated feed usage falls outside of the normal monitoring period, additional monitoring for the impacts of medicated feed must be undertaken between 80 – 169 days after the medicated feeding has ceased. SEPA have also introduced additional clauses to regulatory monitoring. The first clause is when environmental monitoring demonstrates that relevant environmental quality standards have been met for two or more consecutive production cycles, and provided that there are no changes to any other conditions within the site permit, the scale of monitoring may be reduced in consultation with SEPA. The second clause is when environmental monitoring demonstrates that relevant environmental quality standards have not been met, SEPA may require that the scale of monitoring be increased. SEPA develops such increases in consultation with the operator (SEPA 2019a).

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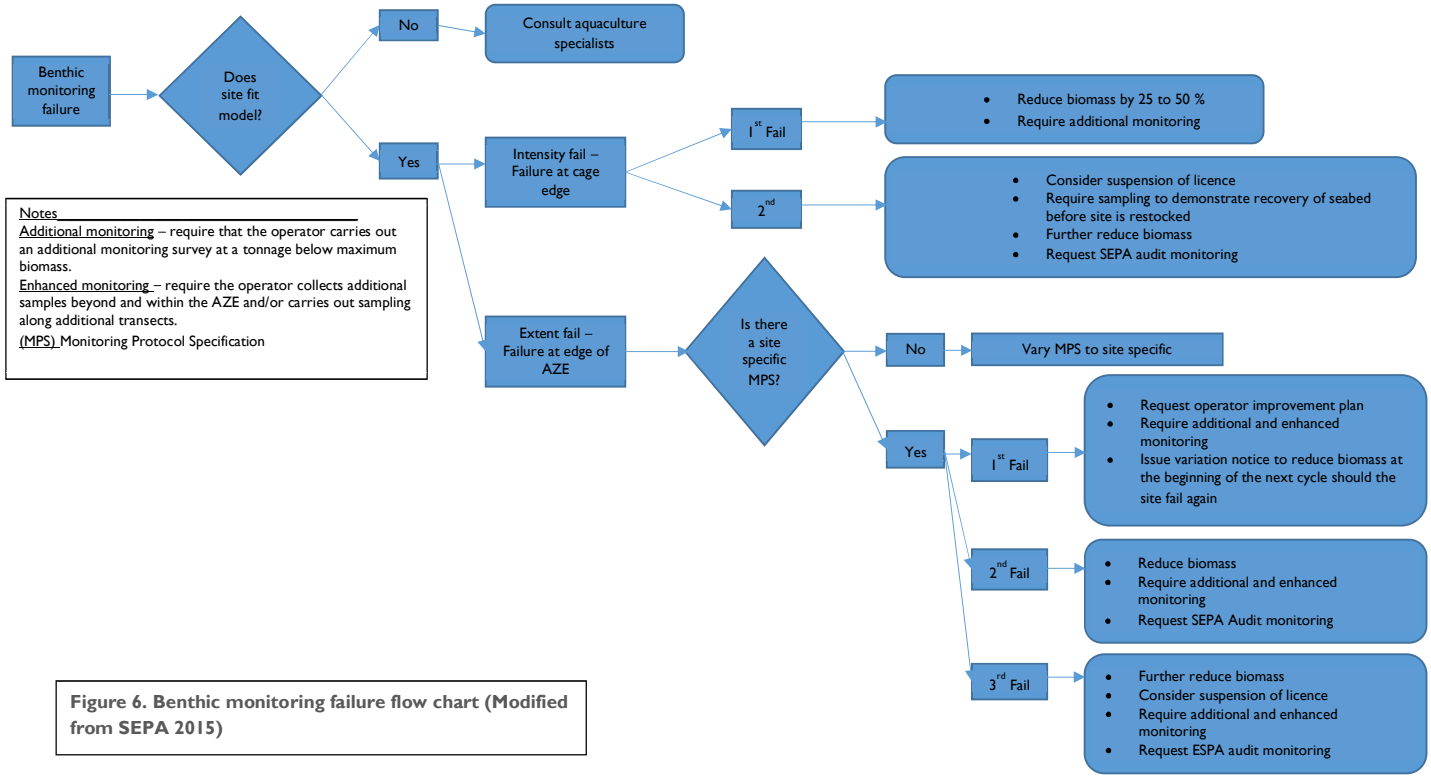

Figure 6. Benthic monitoring failure flow chart (Modified from SEPA 2015)

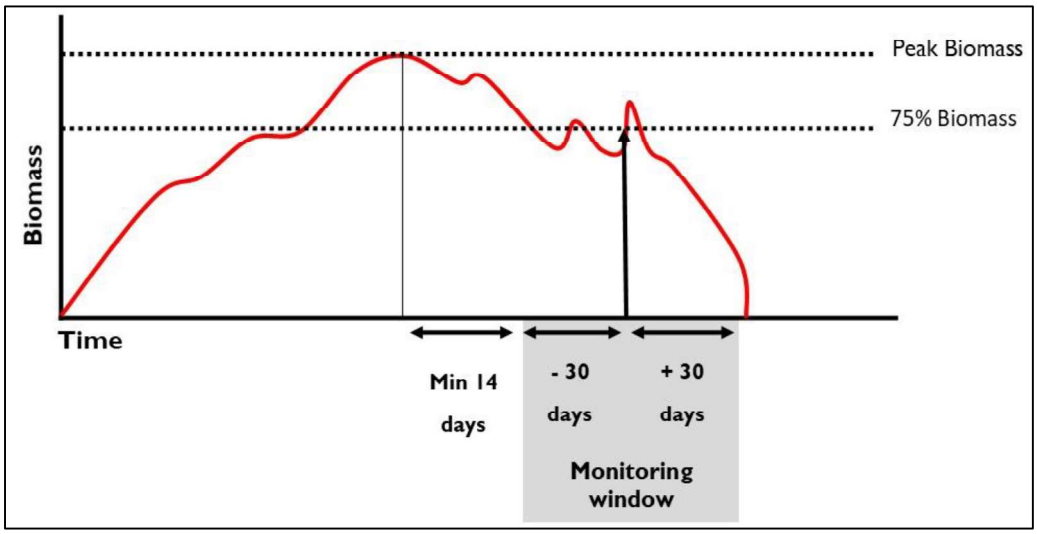

Figure 7. Survey timing window for SEPA environmental monitoring (reproduced from SEPA 2019a)

Ireland

In Ireland, environmental surveys are required to be conducted for each finfish site annually. Environmental surveys are required to be carried out during peak biomass periods or at least within 30 days after end of harvesting of a year class.

Canada

In Canada, the east coast (Nova Scotia and New Brunswick) applies a tiered environmental monitoring system (Tier-1, 2 and 3) for finfish (Anon 2012; 2018a). The frequency of tiered monitoring is annual (Tier-1) and involves a secondary seasonal component (Tier-3) when EQS are triggered. Initiation of Tier-1 monitoring occurs during late summer/early autumn coinciding with peak production. While Tier-3 monitoring occurs during the winter/spring months when weather permits. Tier-2 monitoring is conducted 20 calendar days after the lease has failed either Tier-1 or Tier-3 monitoring events. Failure is determined as a measurement of sulphide concentrations that are ≥ 3000 μm.

For both the east and west coast of Canada, in the case of fish farm leases located over a soft bottom substrate in tidal waters, the owner/operator of the facility must not restock the facility if the EQS in the monitoring standard are exceeded. In the case of aquaculture facilities that are not located over soft bottom substrates, or aquaculture facilities that are located over soft bottom substrates but require visual assessment, the owner/operator of the facility:

- Must not, if the fish farm is located in tidal waters in or adjacent to Quebec, Nova Scotia, New Brunswick, Prince Edward Island or Newfoundland and Labrador, restock the facility if the visual monitoring shows the presence of *Beggiatoa* spp., or similar bacteria, marine worms or barren substrates in more than 70% of the locations specified in the monitoring standard.
- Must not, if the fish farm is located in tidal waters in or adjacent to British Columbia, restock the facility if visual monitoring shows that *Beggiatoa* spp., or similar bacteria or marine worms cover:
    - 10% or more of any four segments of substrate specified in the monitoring standard that are within 100 m to 124 m from the fish containment structure, or
    - 10% or more of two or more contiguous segments of substrate specified in the monitoring standard that are within 116 m to 140 m from the fish containment structure.

On the west coast of Canada (British Columbia), annual monitoring takes place during peak biomass or within 30 days either side of peak biomass for farms that have a production cycle ending in the complete removal of all fish, or at the end of every 24 month period if the production cycle is longer than 24 months. Unlike the east coast of Canada, British Columbia do not implement a tiered management approach. However, fish farm leases are also required to run pre-stocking monitoring prior to fish entry to ensure conditions are suitable for restocking (Anon 2015).

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 8:13:22 AM
this would be nice up front where the tiers are first mentioned (in station location section). On reflection, I wonder if it is worth swapping the monitoring timing, and the monitoring locations around, or combining the two. I did find the monitoring locations section quite hard to get through since it is very knitty gritty and there was no high level explanation up front to set the scene

New Zealand

In New Zealand, benthic compliance monitoring in the Marlborough Sounds is a tiered annual monitoring program (Type 1, 2 and 3; Table 6, Keeley et al. 2015a) coinciding with the period of maximum biological impact. Newly established farms or farms that have undergone significant modifications require Type 2 monitoring (i.e. the default-monitoring program, Keeley et al. 2015a). This monitoring program forms the basis for determining the level of management response required for Farm-Zone and AZE, should triggering of EQS occur. Progression to less intensive monitoring ('Type 1') is contingent on 1) how long the farm has been operational, 2) whether feed levels have significantly increased (> 15%), and 3) what the results of the previous year's annual monitoring were. Type 1 monitoring is the least intensive form. When exceedance of established Type 1 EQS occurs, Type 2 monitoring is initiated and required to be undertaken within 30 days of the initial Type 1 survey. If triggering of EQS under Type 2 monitoring occurs, then the farm manager has up to 24 months to ensure the lease area is environmentally compliant. Type 3 monitoring, the most intensive form of monitoring takes place as the baseline survey (year 0) and is repeated every 5 years.

Tasmania

In Tasmania, implementation of an environmental compliance-monitoring program at Farm-Zone and at the defined 35 m AZE compliance points occurs every 12 months, or in accordance with the stocking and fallowing regime employed on individual marine farms. Detection of significant visual impacts at/or extending beyond 35 m from the boundary of the lease area (e.g. the presence of fish feed pellets, the presence of white bacterial mats, the presence of gas bubbling arising from the sediment, and/or the presence of numerous opportunistic polychaetes), may require the Environment Licence holder to undertake a triggered environmental survey as soon as possible, to provide greater detail on the environmental effects or undertake other remedial activity as determined by the Director, EPA. A triggered environmental survey could be a repeat of the baseline survey or other monitoring as specified by the regulator. This would see the collection of both quantitative and qualitative information from the AZE compliance points, in addition to a number of reference stations and potentially other significant environmental values surveyed as part of the original baseline survey. These surveys are important for informing management responses and controls that need implementation to reduce environmental effects. However, it should be noted that since 2004, the implementation of triggered environmental surveys have been rarely undertaken in response to non-compliances at the 35 m AZE compliance points as the management response is flexible and more often results in operations-based management responses (e.g. movement of cages, fallow directions, increased frequency/spatial extent of visual monitoring, and pre-stocking surveys). Within the Farm-Zone (under cages), the presence of excessive feed dumping and/or extensive bacterial mats, may trigger a fallow direction. However, this is at the discretion of the regulator, it is most likely that a pre-stocking survey is requested. Spontaneous outgassing (gas bubbling) within the Farm-Zone (under cages), triggers a MFDP management control to fallow as soon as practicable. A fallowing direction is on a cage-by-cage basis rather than a whole of lease basis, with the exception of Macquarie Harbour. For farm leases that have triggered a fallowing management response, pre-stocking surveys are mandatory prior to re-stocking fish on site (DPIPWE 2004).

Recommendations

Tasmania has statutory provisions that enable the regulator to require environmental monitoring at or near peak production, however, this is discretionary. In fact, over the past 5 years, the regulator has required 50% of all environmental monitoring surveys at finfish farms outside of Macquarie harbour to be conducted at/or near peak feed input. To increase the likelihood of identifying significant impacts at 35 m from the lease boundary, sampling at or near peak production is paramount. While tiered monitoring provides for a balanced and cost effective approach to environmental monitoring, it can also be used to initiate an effective early warning system to detect environmental harm. In Tasmania, an adaptive management approach has been implemented to identify environmental breaches at the AZE and the Farm-Zone. However, this approach only occurs when significant visual impacts at AZE (e.g. the presence of fish feed pellets, bacterial mats, gas bubbling, or numerous opportunistic polychaetes) and / or Farm-Zone (e.g. the presence of excessive feed dumping, extensive bacterial mats, and spontaneous gas bubbling) are detected. Given that these 'significant visual impacts' constitute major degrading environmental effects as outlined in Macleod and Forbes (2004), formalised tiered environmental compliance-monitoring program should be

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Number: 1 Author: emman Subject: Sticky Note Date: 8/05/2020 3:58:43 PM
Not sure of the rationale for only considering benthic monitoring here?

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 8:19:05 AM
if the results of previous monitoring were compliant

Number: 3 Author: emman Subject: Sticky Note Date: 7/05/2020 2:35:32 PM
(dependent on the degree of non-compliance)

Number: 4 Author: emman Subject: Sticky Note Date: 7/05/2020 2:35:12 PM
As per prev comment, not necessarily repeated every 5 years.

Author: delvines Subject: Sticky Note Date: 19/05/2020 8:23:29 AM
Also can be implemented outside of these bounds ad-hoc.

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 8:23:05 AM
might be worth adding "is usually a spatially intensive survey, but also designed and implemented case-by-case to address site-specific concerns."

Number: 6 Author: delvines Subject: Highlight Date: 19/05/2020 8:24:37 AM
just video/semi quantitative?

Number: 7 Author: deannae Subject: Highlight Date: 2/06/2020 6:58:23 AM
'This' being the triggered environmental survey? Consider including 'triggered environmental survey' to list of terms.

Number: 8 Author: delvines Subject: Highlight Date: 19/05/2020 8:30:42 AM
see earlier comment. who decides on this?

Number: 9 Author: delvines Subject: Highlight Date: 19/05/2020 8:37:05 AM
from here to the end this is a bit confusing and could be clarified.

Number: 10 Author: delvines Subject: Highlight Date: 2/06/2020 6:58:58 AM
i am not sure how this relates to the previous sentence or the discretionary aspect. It implies that the regulator prefers to order the leaseholder to do pre-stocking surveys (presumably after the production cycle is completed?), instead of directing them to fallow a site if conditions below the cages are unacceptable. If the pre-stocking survey is unfavourable, are they mandated to continue the fallow period until conditions are favourable, effectively giving fallow direction by extending it?

Number: 11 Author: delvines Subject: Highlight Date: 19/05/2020 8:35:58 AM
and a pre-stocking survey?

Number: 12 Author: delvines Subject: Highlight Date: 19/05/2020 8:38:46 AM
you mean, is at the discretion of the regulator (otherwise could be read as at the discretion of the lease holder).

Number: 13 Author: delvines Subject: Cross-Out Date: 19/05/2020 8:40:21 AM

dopted that includes an early warning system to inform of possible major degrading environmental effects before they occur.

Recommendations from the 'Working Group' for consideration during the drafting of the Environmental Standard are that the environmental standard should:

- In-line with international practice, undertake all environmental monitoring surveys during the period of peak feed input. As this is the time-period when the load of organic waste is greatest on the seabed, and when environmental impacts on the seabed are likely to occur.
- Consider conducting regular detailed benthic environmental surveys (e.g. quantitative physico-chemical and biological parameters) across monitoring stations to benchmark environmental performance. The sampling frequency of these detailed surveys should reflect an individual lease's Farm-Zone and AZE environmental performance over successive production cycles.
- Acknowledge and incentivise continued environmental compliance and good environmental performance over consecutive production cycles.
- eview and align the existing EPA compliance and auditing system with the implementation of the new 'Environmental Standard'.

Ecological indicators and thresholds

In Norway, the national monitoring program (NS-9410:2016) is based on soft sediment investigations and routine monitoring at efined AZE (rend-C; Table 11, 12, 13) and at Farm-Zone (Trend-B; Table 14). rend-B monitoring includes the collection of qualitative fauna data, measurement of pH and redox, and an assessment of a number of sensory parameters all combined into a score-based classification system that feeds into a lease condition index (see Table 14 for an example of the coring system). This lease condition index is not a specific threshold value, the index score classifies the environmental condition (e.g. very good, good, moderate and poor), which then leads to a specific management response/action depending on the environmental classification. rend-C monitoring includes the collection of quantitative data for sediment chemistry (e.g. otal organic material, total organic carbon, total nitrogen, particle grain size analysis following NS-EN ISO 16665 and ISO 5667-19; and copper – ISO 11885), fauna identification (macrofauna to NS-EN ISO 16665), and hydrographical profiles (following CTD/STD NS-EN ISO 5814). In addition, total phosphorus (following NS-EN ISO 16665 and ISO 5667-19), zinc (following ISO 11885) and tracers including fatty acids and stable isotopes are included. Observations such as bubbling, *Beggiatoa* spp., feed pellets, faeces, and photos of the sediments hould be undertaken and archived. hreshold levels for dissolved oxygen content, sediment chemistry and metals (Table 11), and various macrofauna indices (Table 12) are set based on standard biological conditions for Norwegian coastal waters. Threshold levels have been established for five categories types from category 1 – 'very good' to category 5 – 'very poor'. Overall, environmental condition is based on a total assessment of the environmental parameters collected. Evaluation of fauna data and its reference to environmental condition at the farming zone dictates the frequency of Trend-C monitoring (Table 13, refer to Table 10).

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Number: 1 Author: delvines Subject: Highlight Date: 2/06/2020 6:59:46 AM
formalised, because it already exists? (the problem is it is just too discretionary?)

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 8:43:12 AM
this isnt discussed anywhere that i could see, so might be worth expanding some.

Number: 3 Author: delvines Subject: Highlight Date: 19/05/2020 9:29:28 AM
typo? defined locations within the AZE and farm zone or otherwise?

Number: 4 Author: delvines Subject: Highlight Date: 19/05/2020 9:21:50 AM
i cant see what this means? are the table cross references incorrect?

Number: 5 Author: delvines Subject: Highlight Date: 25/05/2020 1:27:24 PM
I think these terms need explaining up front before they are referred to. 'Trend' is an unusual term and is not intuitive, presumably they are similar to tiers?

Number: 6 Author: delvines Subject: Highlight Date: 2/06/2020 7:01:15 AM
Is this scoring system only for Trend B?

Number: 7 Author: delvines Subject: Highlight Date: 19/05/2020 9:29:58 AM
i am left wondering what Trend-A is.

Number: 8 Author: delvines Subject: Highlight Date: 25/05/2020 1:28:03 PM
wow, this is all done routinely? That is comprehensive!

Number: 9 Author: delvines Subject: Underline Date: 19/05/2020 9:26:43 AM
are?

Number: 10 Author: delvines Subject: Highlight Date: 25/05/2020 1:28:59 PM
i think these 3 sentences could be reversed in order. And consider starting a new paragraph when the topic changes from indicators, to thresholds. Its a bit difficult to digest.

Table 11. Thresholds for environmental 'condition categories' for oxygen in bottom water (Veileder 02:2013), organic carbon and metal concentrations in sediments in Norway (reproduced from Veileder 02:2013 and Veileder M-608:2016)

Source	Parameter	Unit of measure	Environmental 'condition categories'				
			I	II	III	IV	V
			Very good	Good	Moderate	Poor	Very poor
Deep water	O_2 concentration	mg O_2/L	> 6.39	6.39-4.97	4.97-3.55	3.55-2.13	< 2.13
	O_2 saturation	%	> 65	65-50	50-35	35-20	< 20
Sediment	TOC	mg/g	< 20	20-27	27-34	34-41	> 41
	Copper	mg/kg	< 20	20-84	20-84	85-147	> 147
	Zinc	mg/kg	0-90	91-139	140-750	751-690	> 690

Table 12. Overview of threshold values for environmental 'condition categories' for the different fauna indices in Norway (reproduced from Veileder 02:2013)

Index	Environmental 'condition categories'				
	I	II	III	IV	V
	Very good	Good	Moderate	Poor	Very Poor
NQI1	0.82 - 0.90	0.63 - 0.82	0.49 - 0.63	0.31 - 0.49	0 - 0.31
H'	4.8 - 5.7	3.0 - 4.8	1.9 - 3.0	0.9 - 1.9	0 - 0.9
ES_{100}	34 - 50	17 - 34	10 - 17	5 - 10	0 - 5
ISI	9.6 - 13	7.5 - 9.6	6.2 - 7.5	4.5 - 6.1	0 - 4.5
NSI	25 - 31	20 - 25	15 - 20	10 - 15	0 - 10
nEQR	0.8	0.6	0.4	0.2	0

Note: NQI1 – Norwegian quality index; H' – Shannon-Wiener index; ES_{100} – Hulberts diversity index; ISI – Indicator species index; NSI – Norwegian sensitivity index; nEQR – total fauna index

Table 13. Evaluation of fauna samples for monitoring station C1 (Farm-Zone) in Norway (reproduced from NS-9410:2016)

Environmental condition	Requirements
1 - Very good	≥ 20 species of macrofauna (> 1 mm) excluding nematodes in a sample area of 0.2 m^2. None of the species should dominate more than 65% of the total abundance.
2 - Good	5-19 species of macrofauna (> 1 mm) excluding nematodes in a sample area of 0.2 m^2. > 20 individuals excluding nematodes in a sample area of 0.2 m^2. None of the species should dominate more than 90% of the total abundance.
3 - Poor	1 to 4 species of macrofauna (> 1 mm) excluding nematodes in a sample area of 0.2 m^2.
4 - Very poor	No macrofauna (> 1 mm) excluding nematodes in a sample area of 0.2 m^2.

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Number: 1 Author: emman Subject: Sticky Note Date: 7/05/2020 2:43:32 PM
typo here

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Table 14. Trend-B sample sheet (mock numbers filled in to give an example of how the sheet works)

Gr	Parameters	Scoring system	Sample number									Index
			1	2	3	4	5	6	7	8	9	
Bottom type: S (Soft) H (Hard)			S	S	S	S	S	S	S	S	S	
1	Animals	Yes = 0, No = 1	1	1	0	1	0	1	0	0	0	
2	pH	Measured value	6.52	6.52	7.33	6.31	7.35	6.60	7.72	6.41	6.14	
	E_h	Measured value	-143	-105	57	-1.38	-3	-143	-113	-78	-143	
		+ ref. value	217	217	217	217	217	217	217	217	217	
	pH/E_h	From Fig. x	5	5	1	5	2	5	2	5	5	3.89
	Condition sample		4	4	1	4	2	4	2	4	4	
	Condition group 2		4									
			Buffer temp:9.2 °C			Seawater temp: 8.3 °C			Sediment		temp: 8.3 °C	
			pH seawater: 7.52			E_h Seawater: 413 mV					Ref. electrode: 217 mV	
3	Gas bubbles	Yes = 4	4			4					4	
		No = 0		0	0		0	0	0	0		
	Colour	Light/grey = 0			1		0					
		Brown/black = 2	2	2		2		2	2	2	2	
	Smell	None = 0			0		0		0			
		Some = 2	3	2		2		2		2	3	
		Strong = 4										
	Consistency	Compact = 0			1							
		Soft = 2	3	2		3	2	2	2	2	3	
		Loose = 4										
	Grab volume	< 1/4 = 0										
		1/4 – 3/4 =1		1	1		1	1	1	1	1	
		> 3/4 = 2	2			2						
	Thickness of organic waste	0 cm – 2 cm = 0		0	0		0	0	0		0	
		2 cm – 8 cm = 1	1			1				1		
		> 8 cm = 2										
		SUM	15	7	3	14	3	7	5	8	13	
	Corrected total (x 0.22)		3.3	1.54	0.66	3.08	0.66	1.54	1.1	1.76	2.86	1.83
	Condition test		4	2	1	3	1	2	2	4	4	
	Condition group 3		2									
	Average group 2 and 3		4.15	3.27	0.83	4.04	1.33	3.27	1.33	3.38	3.93	2.86
	Average condition		4	4	1	4	2	4	2	4	4	

pH/E_h Index	Corrected total Average value	Condition
< 1.1		1: Very good
1.1 - < 2.1		2: Good
2.1 - < 3.1		3: Moderate
≥ 3.1		4: Poor

Lease condition	3

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 9:28:48 AM
so this is just the farm zone stations?

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Scotland

For Scotland, the strengthened regulatory framework implemented in May 2019 results in a modification to the indicators and associated thresholds from the pre to post-regulatory changes.

Prior to May 2019, the monitoring program established by SEPA covered typical parameters measured for soft sediment habitats and in the past had also included water quality (SEPA 2006). As part of the annual monitoring program, it was a requirement to collect quantitative information on sediment chemistry (redox, organic carbon and medicines), benthic infauna communities, and to undertake a visual assessment of the seabed to identify signs of enrichment (e.g. presence of *Beggiatoa* spp. and/or feed and faecal pellets) (SEPA 2006). Regulatory authorities had established sediment quality criteria (Table 15), but not specifically defined threshold values/enrichment stages or environmental quality standards. Sediment quality criteria do represent clear indications of grossly enriched sediments where SEPA would most likely take action should levels exceed these values.

Table 15. Scottish quality criteria for soft sediments (direct from Macleod et al. in prep)

	Parameters	Within AZE		Outside AZE
Benthos	Number of taxa	< 2 polychaete taxa present		At least 50% of reference station value
	Number of taxa	2 or more replicates with no taxa present		
	Abundance	Organic enrichment polychaetes present in abnormally low densities		Organic enrichment polychaetes must not exceed 200% of reference station value.
	Shannon-Weiner Diversity	N/A		Must be at least 60% of reference station value
	Infaunal Trophic Index (ITI)	N/A		Must be at least 50% of reference station value
Sea Bed	Beggiatoa spp.	N/A		Mats present
	Feed pellets	Accumulations of pellets		Pellets present
Sediment	Teflubenzuron	10.0 mg/kg dry weight/5 cm core applied as an average		2.0 µg/kg dry weight/5 cm core
	Copper	Probable effects: 270 mg/kg dry sediments	Possible effects: 108 mg/kg dry sediment	34 mg/kg dry sediment
	Zinc	Probable effects: 410 mg/kg dry sediment	Possible effects: 270 mg/kg dry sediment	150 mg/kg dry sediment
	Free sulphide	4800 mg kg^{-1} (dry weight)		3200 mg kg^{-1} (dry wt)
	Organic carbon	9%		
	Redox potential	Values lower than -150 mV (as a depth average profile) OR Values lower than -125 mV (in surface sediments 0-3 cm)		

Note: Reproduced from SEPA (2006)

Post May 2019, the new regulatory framework requires the collection of quantitative information for parameters identified to be of high importance for soft sediment habitats, including 1) benthic invertebrates, 2) chemical residues, 3) particle size analysis, and 4) total organic carbon (SEPA 2019a). Within the AZE, licence holders must ensure that wastes do not accumulate to levels that would compromise the biological process needed to breakdown and assimilate them. SEPA use the latest computer modelling to assess whether proposed developments will be able to operate without compromising these processes; and environmental monitoring results to check that the required basic biological standards are being maintained at the edges of the pens of operational sites. Pre-defined environmental quality standards have been clearly stated for benthic invertebrates and chemical residues in the sediments both within and beyond the AZE; however, no guidance has been provided for particle size analysis or total organic carbon (**Table 16**). SEPA

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 9:39:40 AM
to be clear, these sediment quality standards were defined by SEPA, but they were not used as triggers for management action?

Number: 2 Author: emman Subject: Sticky Note Date: 7/05/2020 2:51:18 PM
It seems that some of the criteria are "must be avoided" and some are "minimum standards", which is confusing to follow

Number: 3 Author: delvines Subject: Highlight Date: 19/05/2020 9:41:32 AM
plus they omit a host of other indicators. Why are these two singled out specifically?

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advise that when an appropriate standard has not been supplied, a standard representing equivalent good quality derived using the best available science, including published research and expert advice, will be used. Furthermore, quality standards have not been developed for seabed habitats dominated by large stones, rock or other hard materials. SEPA intend to use visual imagery surveys to assess the condition of these habitats when they lie within the mixing zone of a farm (SEPA 2019b).

Table 16. List of common standards for protecting the seabed (reproduced from SEPA 2019b)

What the standard applies to	Where the standard applies	The type of standard	How the standard is measured	What the standard is
Condition of invertebrate animals living in soft sediments	At mixing zone limit & beyond	Good status standard	Infaunal quality index method[1]	0.64 as minimum value at any time
Most extreme permitted effect of waste deposition on sea bed invertebrate animal communities	In mixing zone	Basic seabed functioning standard	Number of species, and abundance, of the re-worker annelid worms: "AMBI Group V" 1 species[2]; Ophryotrocha species; Boudemos species	A minimum of 2 species with a combined abundance of more than 1000 individuals per m^2
Maximum concentration of infeed sea lice medicine, emamectin benzoate	At mixing zone limit & beyond	Good status standard	ng per kg of marine sediment (dry weight)	12
	In mixing zone	Basic seabed functioning standard	ng per kg	120

[1] – Phillips et al. 2014; [2] – Borja et al. 2000

Ireland

In Ireland, environmental authorities have also established sediment quality criteria as part of the mandatory annual environmental monitoring program (Anon 2008). As with Scotland, these criteria provide a guideline for the regulatory authorities to provide management directives to the fish farms to assess whether the farming activity is environmentally compliant. This information is used to define an appropriate benthic amelioration plan. Key information used to assess sediment quality includes visual observations, bacterial mat coverage, and sediment chemistry (redox and organic carbon) (Table 17). For level 2 sampling, biological samples (infauna indices) are also assessed.

Table 17. Sediment quality criteria applied to Level I benthic surveys in Ireland (reproduced from Anon 2008)

Criteria	Action levels within AZE	Action levels outside AZE
Visual observations	Accumulated feed pellets	Feed pellets present
Bacterial mats	Extensive mats present (> 50% cover)	Patches present
Redox	Values lower than -150 mV (as a depth average profile) Or Values lower than -125 mV (in surface sediments 0-3 cm)	Control values
Organic carbon	100% above control value (averaged within zone)	Control + 25% (averaged within zone)

Canada

In Canada, criteria for managing environmental impacts vary between the various regions of Canada. Nova Scotia use multiple ~~by~~ environmental indicators to meet the 'Environmental Quality Objectives' (EQOs) for oxic classified sediments. These environmental indicators are used to monitor that the environmental

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 9:42:19 AM
assuming this is e.g. grain size and TOC?

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 9:43:46 AM
at Level 1 monitoring?

Number: 3 Author: delvines Subject: Highlight Date: 25/05/2020 1:31:45 PM
are thresholds supplied for these? That was covered off for Scotland but not for Ireland.

Number: 4 Author: delvines Subject: Cross-Out Date: 19/05/2020 9:45:03 AM

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conditions remain 'acceptable' (Table 18) (Anon 2018a). In Quebec, New Brunswick, Prince Edward Island, Newfoundland and Labrador, sulphide measurements are the key focus of the assessment of 'acceptable' condition, with values exceeding 3,000 μm considered unacceptable (Anon 2018c). Furthermore, within these aforementioned regions, where farms are located over hard bottom, visual indicators are monitored to determine whether environmental condition is acceptable. In British Columbia, sulphides are also the main environmental indicator, with sulphide thresholds set as 1,300 μm and 700 μm at 30 m and 125 m from cage edge, respectively. When encountering hard bottom substrates, visual indicators for British Columbia include the presence of *Beggiatoa* spp. and/or marine worm cover (Anon 2018c). Cover of these indicators should not 1) exceed 10% or more of any four segments of substrates specified in the monitoring standard that are within 100-124 m from cage edge; or 2) exceed 10% or more of two neighbouring segments of substrate specified within the monitoring standard within 116-124 or 124-140 m from cage edge.

Table 18 Environmental quality criteria for Nova Scotia (reproduced from Anon 2018a)

Measurement		Sediment classification		
		Oxic	Hypoxic	Anoxic
Physical sampling	Sediment colour	Tan to depth > 0.5 cm	Tan to < 0.5 cm with some black sediments at surface	Surface sediments black
	Microbial presence	No sulphur bacteria present	Patchy sulphur bacteria	Widespread bacterial mats
	Macrofaunal assemblage	Wide array of infauna and epi-fauna	Mixed group of mostly small infauna	Small infauna only
	Sulphide (μm)	< 750 (A) 750 to 1,499 (B)	1,500 to 2,999 (A) 3,000 to 5,999 (B)	> 6,000
	Redox (Eh), mV	100 (A) 100 to -50 (B)	-50 to -100 (A) -100 to -150 (B)	> -150
	Organic matter %	<= reference*	1.5 to 2 X ref.	> 2 X reference
	Porosity %	<= reference*	1 to 10 X ref.	> 10 X reference

New Zealand

In New Zealand, environmental indicators and thresholds are used both qualitatively (Type 1 benthic monitoring) and quantitatively (Type 2 monitoring). Indicator thresholds vary in relation to the type of monitoring that takes place (e.g. Farm-Zone – Zone of Maximum Effect, or AZE – Outer Limit of Effects) (Table 19) (Keeley et al. 2015a). For Type 1 monitoring, Farm-Zone observations for video monitoring are made on the oxic state of the seabed (outgassing + bacterial coverage + macrofauna). Reference to *Beggiatoa* spp. and outgassing are scored relative to their severity of breaching the oxic state of sediments. Scoring of macrofauna can outweigh the scoring of the other parameters, with the presence of heavily enriched macrofauna communities triggering Type 2 monitoring (Keeley et al. 2015a). For Type 2 monitoring, Enrichment State (ES) is used as the indicator for environmental compliance. Various threshold levels are established, with these being indicative of the level of action required and dependent on where sampling takes place (e.g. Farm-Zone vs AZE). Initial action at the Farm-Zone is taken at a threshold of ES >100, which is indicative of very high enrichment; however at the edge of the AZE, initial action is taken if ES conditions are statistically different relative to reference conditions. At an action level that requires destocking, the threshold for ES requires the lower 95% Confidence Interval for overall ES to be 5.6. However, thresholds for enrichment states for the AZE thresholds are set as ≤ 3.0 and the mean ES should not increase more than 0.4 when compared with the previous year (Keeley et al 2015a).

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 9:47:32 AM
in this case, given it is hard substrate, do these indicators replace sulphides, or is there enough deposition that sulphides can somehow be measured? If they replace suphides, are there acceptability criteria for visual indicators, and what are they?

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 9:49:07 AM
apply to BC and other regions in first sentence? if so, combine with first mention of visual indicators.

Number: 3 Author: delvines Subject: Highlight Date: 19/05/2020 1:06:15 PM
i think in this section it is relevant to mention the BMP standards for water column monitoring (thresholds and indicators). ditto in other sections (e.g. management responses), if this review is supposed to cover dissolved waste effects too. While the WQ BMP in NZ doesnt capture all sites (i.e. as is the case with the benthic BMP, some sites are still operating under their old consents), it has been identified as best practice for the Marlborough Sounds region, and eventually farms will fall into alignment with this.

Number: 4 Author: delvines Subject: Highlight Date: 19/05/2020 9:50:16 AM
rapid visual assessment of macrofauna sample

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 10:09:13 AM
and also uses TFS

Number: 6 Author: delvines Subject: Highlight Date: 19/05/2020 9:52:06 AM
The new version 'Type 1 monitoring protocol' that is not yet formally adopted also includes sulphides, but that is more of an FYI since this publication isnt yet widely available.

Number: 7 Author: delvines Subject: Highlight Date: 19/05/2020 10:07:42 AM
Given you are discussing indicators, should probably say something like "raw measurements of sediment chemistry (redox, sulphides), organic content and macrofaunal community indices are used to derive a single score of 'Enrichment Stage' for each sampling station"

Number: 8 Author: delvines Subject: Highlight Date: 2/06/2020 7:04:09 AM
ES is the key indicator used for environmental compliance, but other descriptive indicators also exist.

Number: 9 Author: delvines Subject: Highlight Date: 19/05/2020 9:56:12 AM
peak-of-opportunist conditions may be a more broadly relatable term for ES5 conditions

Number: 10 Author: emman Subject: Sticky Note Date: 8/05/2020 4:08:40 PM
This is currently a matter of some debate, tho use of ES was the intention during the development of standards, this was not always reflected in consent conditions or the BMP - perhaps this is best glossed-over, however, as the iintention is the most useful for the international comparison

Number: 11 Author: delvines Subject: Highlight Date: 19/05/2020 9:57:55 AM
actually, the criteria is that "ES conditions have not changed statistically relative to reference conditions".

Number: 12 Author: delvines Subject: Highlight Date: 19/05/2020 10:04:19 AM
but reduction of inputs can be initiated at non-compliant levels below this.

Number: 13 Author: delvines Subject: Highlight Date: 19/05/2020 10:05:43 AM
Actually, where baseline/background is less than 3.0, the lowest management response level (alert) can be initiated by the statistical test only, regardless of the absolute ES value. I think you have covered this off in the second sentence up, so this last sentence is a little redundant.

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Table 19. Industry operation goals and benthic environmental quality standards (EQS, or Triggers) to be applied based on station-averaged result in New Zealand (reproduced from Keeley et al. 2015a)

	Action level	Monitoring stations	
		Farm-Zone	AZE
Industry operational goal		Overall ES ≤ 5.0	Overall ES < 3.0 (i.e. maintain natural conditions)
EQS for Type 1 monitoring	Type 2	1FS > 1,700 µm Total qualitative score > 6.0 Macrofauna score > 2.0	2FS > 390 µm Total qualitative score > 0
EQS for Type 2 monitoring	Alert	Mean overall ES > 5.0 ≤ 5.3 and 95% CI spans thresholds	A statistically significant increase relative to appropriate reference station(s)
	Minor	Lower 95% CI for overall ES > 5.0 and ≤ 5.3 2 or more replicates with macrofauna virtually absent Bacterial mats visible Obvious spontaneous outgassing	Overall ES ≥ 3.0 AND Mean ES 0.4 higher than previous year, and increase is significant relative to appropriate reference station(s)
	Major	Lower 95% CI for overall ES > 5.3 and ≤ 5.6	-
	Destocking	Lower 95% CI for overall ES > 5.6	-

TFS = Total free sulphides, ES = Enrichment state, CI = Confidence interval

Tasmania

In Tasmania, current benthic environmental indicators included in Environmental Licence conditions for salmon farming have been adopted state-wide based on available science at that time published by Macleod and Forbes (2004). The 'Benthic Monitoring Program' (BMP; DPIPWE 2004) uses 3nnual video surveys (or more frequent, depending on region) as a primary monitoring tool to assess environmental compliance and environmental protection beyond the AZE. Current licencing conditions outline that 4xtensive sediment sampling may be triggered when significant visual impacts are detected (e.g. the presence of fish feed, bacterial mats, gas bubbles or numerous opportunistic polychaetes on the sediment surface) at or extending beyond 35 m from the boundary of the lease. However, environmental indicators of enriched conditions and their associated threshold values adopted in the current Environmental Licences (Table 20) are based on features characterising impact/recovery for soft/muddy sediments in the south-east of Tasmania (Macleod and Forbes 2004). These indicators and thresholds may not be relevant for other substrate types and habitats within and outside of the south-east of Tasmania, or for soft sediments in other regions. Regardless, the indicators and thresholds are used within Environmental Licence conditions universally across the different farming regions of Tasmania (with the exception of opportunistic polychaetes at 35 m compliance sites in Macquarie Harbour).

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 10:08:39 AM
the new BMP version has a flow-specific TFS threshold, so this needs updating.

Author: deannae Subject: Sticky Note Date: 2/06/2020 7:06:04 AM
new values are TFS low-flow = 1700, TFS high flow = 2,400

Number: 2 Author: deannae Subject: Highlight Date: 2/06/2020 7:06:24 AM
this one hasn't changed.

Number: 3 Author: delvines Subject: Highlight Date: 19/05/2020 10:10:43 AM
ie. following MacLeod and Forbes?

Number: 4 Author: delvines Subject: Highlight Date: 19/05/2020 10:11:20 AM
by extensive, do you mean quantitative sediment measurements? or spatially robust, or both?

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Table 20. Current environmental standards for Environmental Licence V1 in Tasmania

Parameters	Monitoring stations	
	1 5 m from lease boundary	Within lease (Farm-Zone)
Visual	Presence of fish feed pellets Presence of bacteria mats Presence of gas bubble (with/or without disturbance) Presence of numerous opportunistic polychaetes (eg. *Capitella* spp., *Dorvilleid* spp.) on sediment surface	Excessive feed dumping Extensive bacterial mats (e.g. *Beggiatoa* spp.) on the sediment surface prior to restocking Spontaneous gas bubbling from the sediment
Physico-chemical	A corrected redox value which differs significantly from the reference site(s) or is < 0 mV at a depth of 3 cm within a core sample A corrected sulphide level which differs significantly from the reference site(s) or is > 250 μM at a depth of 3 cm within a core sample	N/A
Biological	A 20 times increase in total abundance of any individual taxonomic family relative to reference sites An increase at any compliance site of greater than 50 times the total annelid abundance at reference sites A reduction in the number of families by 50% or more relative to reference sites Complete absence of fauna	N/A
Metals*		Copper 270 mg/kg in sediment 1.3 μg/L in water column Zinc 410 mg/kg in sediment 15 μg/L in water column

* - Only required to be measured at leases when specified in individual Environmental Licences

In addition to benthic indicators for Farm-Zone and AZE scale impacts, the 2 EMP is also established in Tasmania to identify system wide changes. Across the state, the BEMP focuses on changes in water quality (Table 21 and 22) and in some of the MFDPs (Great Oyster Bay and Mercury Passage, Huon River and D'Entrecasteaux Channel, Tasman/Norfolk Bay and for Storm Bay) key benthic sediment parameters are also collected, including sediment biota, redox, sulphides, particle size and stable isotopes. Water quality is assessed against site-specific water quality indicator values (Table 21), in MFDPs where they have been established in the relevant Environmental Licences. Where site-specific values are not present, default water quality guideline values (DGVs) have been established by the EPA (2018). DGVs provide a framework for protecting ecosystem values until site-specific investigative values have been determined. In the Huon River and D'Entrecasteaux Channel, 3 road-scale water quality is assessed against proposed non-statutory water quality investigative values to inform regulatory management (Table 22). However, the investigative values of the Huon River, D'Entrecasteaux Channel and Macquarie Harbour require updating, as do those across other MFDP areas where salmon is being farmed. For assessing benthic conditions, significant changes in the measured parameters over time at individual monitoring stations and across monitoring stations ascertain broader-scale changes. Furthermore, other parameters have also been included in BEMP monitoring for some regions including surveying of other habitat types. At Okehampton Bay and Storm Bay, inshore and deep reefs and seagrass surveys have been included to identify changes within these 4 habitats over time. Specific investigative values have not currently been set for this type of data collection.

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Number: 1 Author: emman Subject: Highlight Date: 29/05/2020 4:39:51 PM
These standards permit little chemical change, but substantial biological change, this is the opposite of the NZ situation, where greater weighting is given to biological communities as they indicate the change of interest - ecological functioning. Chemical measures are down-weighted.

I think this should be explicitly addressed and rationale for reliance on chemical indicators given or, better, a recommendation that biological communities are prioritised could be made

Number: 2 Author: delvines Subject: Highlight Date: 25/05/2020 2:29:05 PM
Do all farming areas have BEMPs? or only some of them? If not all, should they as a recommendation?

Number: 3 Author: delvines Subject: Highlight Date: 25/05/2020 2:30:07 PM
what is the response if system change is detected at Level 1, 2 or 3? And what does this mean for salmon farmers within the region? It would be good to get a handle on how the results feedback into management, especially given that it is noteworthy that these BEMPs are reasonably unique to Tassie management framework, and potentially relate to one of your recommendations about baseline time-series monitoring of an area?

Number: 4 Author: emman Subject: Sticky Note Date: 8/05/2020 4:18:23 PM
Should this be a recommendation? (or at least a process for setting standards or incorporating best professional judgement)

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Table 21. BEMP water quality investigative values in Environmental Licence V1 in Tasmania

Parameters	Okehampton Bay	Macquarie Harbour	Tasman/Norfolk Bay
Ammonia (S) µg/L	8.0	33	10.3
Ammonia (B) µg/L	11.0	24	19.3
Total Nitrogen (S) µg/L	324		
Total Nitrogen (B) µg/L	304		
Nitrite/Nitrate (S) µg/L	25.3	53	
Nitrate/Nitrite (B) µg/L	10.6		
Total Phosphorus (S) µg/L	40		
Total Phosphorus (B) µg/L	40		
DRP (S) µg/L	7.0		
DRP (S) µg/L	7.0		
Oxygen (S) mg/L	7.9	6.82	7.4
Oxygen (B) mg/L	7.7		6.9
Chlorophyll mg/m3	1.1	N/A	1.3 (2.61)[1]

[1] – Maximum levels in parentheses

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Table 22 Standard or baseline values proposed for relevant water quality parameters for the Broad-scale Environmental Monitoring Program in the D'Entrecasteaux Channel and Huon Estuary Marine Farming Development Plan Sites (reproduced from Ross and Macleod 2013; Volkman 2009)

Parameters	Standard or baseline			Level 1 (Low Risk)	Level 2 (Moderate Risk)	Level 3 (High Risk)
		Huon Estuary	D'Entrecasteaux Channel			
Nutrients[1] Summer (mg/L)	Surface	0.009	0.006	Summer mean up 25%, or 3 successive annual means > baseline, or mean for any one site +50%	Summer mean up 50%, or 8/10 successive annual means > baseline, or mean for any one site up 200%	Summer mean up 100%, or summer means > 1 µM (~ ANZECC)
	Bottom	0.011	0.009			
Chlorophyll a (µg/L)	Annual	1.4	0.80	Any site: annual mean +100%; or average summer mean +50%	Any site: annual mean +200%; or average summer mean +100%; or average annual mean +50%	Any site: annual mean +400%; or average summer mean +200%; or average annual mean +100%
	Summer	1.7	0.66			
Phytoplankton blooms		7% obs. > 3 x median chl *a*	3.6% obs. > 3 x median chl *a*	% obs. > 3x median rise 50%	% obs. > 3x median rise 100%	% obs. > 3x median rise 200%
Absolute DO	Channel	Mean > 6 ppm		Any 2 channel obs. ≤ 6ppm. Any 2 bay obs. ≤ 5ppm	50% of channel obs. ≤ 6ppm. 50% of bay obs. ≤ 5ppm. Any 2 obs. < 2 ppm.	Channel mean ≤ 6ppm. Bay Mean ≤ 5ppm. Any 2 obs. < 1 ppm.
Absolute DO	Bay	Mean > 5 ppm				
Relative DO		Set at 20th percentile from 1st year of observations		Number of obs. below baseline increases 50%	Number of obs. below baseline increases 100%	Mean falls 10% from baseline (~ ANZECC)
Sediment biota (infauna		First year of sampling		Significant change over time since start of assessments at one or more sites + other relevant indicators	Significant change in multivariate community structure at 1 site since last assessment + other relevant indicators	Significant change in multivariate Community structure at ≥ 2 or more locations since last assessment + other relevant indicators
Sediment chemistry Redox, Sulphides, Metals, Isotopes, Particle size		ANZECC guidelines for metals, and First year of sampling for other parameters		Significant change over time at one site.	Significant change at 2 sites in ≥ 2 indicators. Exceeds ANZECC guidelines for low metal concentrations	Significant change at ≥ 3 sites in ≥ 2 indicators. Exceeds ANZECC guidelines for high metal concentrations

1 – NH4-N ST converted values (total ammoniacal nitrogen); obs. = observations; ppm = parts per million; DO = dissolved oxygen

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Number: 1 Author: deannae Subject: Highlight Date: 25/05/2020 2:31:01 PM
this overview of the BEMP would be beneficial up front of the document in the Tassie historic section.

Number: 2 Author: emman Subject: Sticky Note Date: 8/05/2020 4:19:29 PM
Questionable value in measuring only inorganic N in the far field. - perhaps requires a recommendation

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Recommendations

Multiple key indicators are used to determine enrichment of marine ecosystems across the different salmonid farming jurisdictions. While specific indicators vary between salmonid farming countries, so do their threshold values, which are linked to how the local ecosystems respond. The capacity to implement a tiered approach to environmental monitoring, whereby qualitative and semi-quantitative measurements trigger further quantitative seabed investigations (e.g. taxonomic infauna sampling and sediment chemistry) provides a rapid, robust and cost effective way to assess the status of the marine environment and its response to dissolved and particulate nutrients released from salmonid farming.

Recommendations from the 'Working Group' for consideration during the drafting of the Environmental Standard are that the environmental standard should:

- Continue to use existing benthic indicators of organic enrichment (e.g. bacterial mat-forming species, gas bubbling and opportunistic polychaetes) for visual surveys within the Farm-Zone and at AZE monitoring stations. These indicators are globally applied visual indicators for organic enrichment. However, threshold values of these indicators within both the Farm-Zone and AZE require standardisation to reduce potential inconsistencies when assessing and reporting.
- Consider implementing the video scoring index for environmental condition (established by Macleod and Forbes in 2004) currently being reviewed by IMAS as part of FRDC project 2015-024, as a means to determine environmental performance.
- Maintain existing water quality monitoring associated with salmonid farming should be a priority. Water quality measurements are important rapid determinants of change in a system. Furthermore, consider monitoring water quality at individual leases, and adopting real-time sensor technology to monitor critical water quality parameters at higher temporal resolutions (e.g. turbidity, chlorophyll, oxygen, etc.) at appropriate spatial scales.

Baseline surveys

Baseline sampling is an important tool to provide sufficient background environmental information to assess the potential environmental performance of a new farming lease and to provide adequate data for monitoring environmental changes once production starts.

Norway

In Norway, baseline surveys are mandatory before the establishment of an aquaculture facility within a lease area (NS-9410:2016). Undertaking baseline surveys occurs at both Farm-Zone and at the AZE. Baseline surveys serve as a reference to background conditions and are used as a basis for ecological change compared with investigations undertaken with ongoing production. The baseline survey also provides a basis for deciding on the placement of monitoring stations for environmental monitoring for Trend-B and Trend-C investigations (NS-9410:2016). The parameters used for the baseline surveys in Norway and other countries are outlined in Tables 23 and 24.

Baseline surveys can help optimise orientation and placement of the aquaculture activities based on the spread and accumulation of organic matter. In addition, baseline surveys should include sampling of reference stations that are not included in regular monitoring. Reference stations should be located at least 1 km from the farm in an area with similar bottom type and condition as the area covered by the baseline survey (NS-9410:2016). The reference stations are used to assess if the AZE are significantly impacted by marine farming activity. Baseline surveys may also include natural values mapping (i.e. littoral zone mapping) and mapping of sensitive/vulnerable habitats using remotely operated vehicles and/or towed video (NS-9410:2016).

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 11:32:13 AM
see my earlier comments

Number: 2 Author: delvines Subject: Cross-Out Date: 19/05/2020 11:31:46 AM

Number: 3 Author: delvines Subject: Highlight Date: 2/06/2020 7:08:27 AM
but literature suggests they are less effective in some areas.

Number: 4 Author: emman Subject: Highlight Date: 28/05/2020 6:31:52 AM
The video scoring index has not previously been mentioned, and the regional limitations mentioned above presumably apply.

Number: 5 Author: delvines Subject: Highlight Date: 19/05/2020 11:34:22 AM
again could need to be site or environment specific? assume this is what the IMAS review will be looking at.

Number: 6 Author: delvines Subject: Highlight Date: 19/05/2020 11:38:05 AM
the key aspect here being broadscale?

Number: 7 Author: emman Subject: Sticky Note Date: 29/05/2020 10:02:58 AM
I'm not sure what the rational for the monitoring at individual leases is (unless that info is required for validation of modelling - tho limitation of that are outlined in the NZ BMP Wtr Qual). The BEMP monitoring seems to reflect NZ best practice

Author: delvines Subject: Sticky Note Date: 19/05/2020 11:41:08 AM
Agree. It seems to be a general global consensus that local sampling surveys are of little value (excepting continuous monitoring platforms, which arent quite ready for routine monitoring of all the key parameters relevant to fish farming though this is changing). The key emphasis on this recommendation should rather be on real-time sensor monitoring of water quality (at any scale), rather than consideration of monitoring specific to lease-scale. If lease-scale monitoring is a recommendation, then the rationale for this should be explained, as it doesnt appear to be consistent with the reviewed current practice.

Number: 8 Author: delvines Subject: Highlight Date: 25/05/2020 2:32:50 PM
I have forgotten what these are, so might be good to be reminded or use the same terminology you adopted earlier (Farm-Zone = Trend B, AZE = Trend C?), as you did for NZ?

Table 23. Main sampling categories for baseline surveys across main salmon producing countries

Parameters	New Zealand	Canada	Scotland (old)	Scotland (new)	Norway	Tasmania	Chile
Modelling	X	X	X	X		X[2]	
Bathymetric profile		X		X	X	X	X
Hydrodynamic profile	X	X	X	X	X	X	X
Underwater video surveys	X	X	X	X	X[4]	X	X[4]
Sediment chemistry	X	X	X		X	X	X
Biological analysis	X	X	X	X	X	X	X
Reef surveys	X			X		X[2]	
Water quality	X					X[2]	X
Other features	X	X	X[1]		X	X[3]	X

[1] - For habitats or species of natural heritage interest. [2] - Not a formal requirement prior to the EPA taking over environmental regulation, but increasingly asked for in more recent baseline surveys set by the EPA. [3] - Vulnerable/threatened/protected species, sensitive/ecological valuable habitats. [4] - Only when Hard bottom

Table 24. The main sediment chemistry/Biological measurements collected during baseline surveys across the main salmon producing countries

Sediment chemistry / biology	New Zealand	Canada	Scotland (old)	Scotland (new)	Norway	Tasmania	Chile
Sediment texture	X	X	X			X	
Sediment consistency			X		X		
Sediment colour	X	X	X		X	X	
Redox	X	X	X		X	X	X
Sulphides	X	X				X	X
pH					X	X	X
Particle size	X	X	X	X	X	X	X
Heavy metals	X		X		X	X	
Smell	X		X		X		
Macrofauna	X	X	X	X	X	X	X
Organic content	X	X	X	X	X	X	X
Nitrogen content					X		
Sediment temperature							X
Outgassing		X			X		

Scotland

In Scotland, the recent changes in their regulatory framework (May 2019) have seen a modification in the requirements and implementation of baseline surveys. Presented below are both the pre and post May 2019 survey requirements.

Prior to May 2019, baseline surveys in Scotland included both visual surveys and physical benthic sampling, with new sites requiring both benthic sampling and visual surveys, and only visual observations required at modified sites. Whilst the structure of baseline surveys was set, the forecast production biomass and/or the potential for interactions with areas of natural heritage or other environmental concerns determined the type of monitoring. Baseline surveys were recommended to be undertaken in the summer months (May to October) with sampling intensity differing based on the ~~if~~ baseline survey type (e.g. visual vs benthic and standard vs extended) to be undertaken.

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Number: 1 Author: delvines Subject: Highlight Date: 25/05/2020 2:33:29 PM

I would say that this is collected in NZ, except where the information already exists. Usually, this is done during the surveys that scope the site for a new fish farm development (since it is required by the depositional model). So when it comes to baseline sampling, sufficient data usually already exists.

Number: 2 Author: delvines Subject: Cross-Out Date: 19/05/2020 11:49:31 AM

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- Standard visual baseline survey (SEPA 2008c) was undertaken prior to submission for a new lease or a modified lease, while a site-specific visual baseline survey (SEPA 2008d) was undertaken prior to submission for a new lease or a modified lease to be located within or affecting a marine statutory designated area.

The following criteria were followed for new and modified sites:

- At new leases with no cages, the transect should occur along the centre line of the longest axis of the proposed cage grid and shall also be of sufficient length to extend to the limits of the longest modelled AZE boundary on either end of the cage group. If the greatest width of the AZE was > 200 m then a second transect had to be surveyed at the widest point of the AZE, from one boundary to the other.
- At modified leases, the transect should occur along the line of the longest AZE transect distance, running from the edge of the modified cage group to the edge of the AZE boundary. If the greatest width of the AZE was > 200 m then a second transect had to be surveyed at the widest point of the AZE, from one boundary to the other.
- Along all transects visual observations should be made of the conditions and habitat types on the seabed (see Table 25 for parameters to be observed).

In addition to these requirements, if marine charts identified abrupt changes in depth or the presence of shallow projections, which may indicate reefs or sub-sea cliffs within the AZE boundary for the designated site-specific visual baseline survey, then additional AZE surveys were required to cover the seabed between the cage group and the identified features.

- A benthic, standard baseline survey (SEPA 2008a) was undertaken when the lease did not have prior on-growing and where the maximum biomass was < 1000 tonnes. Samples were taken from two stations, 100 m apart, near the proposed location of the cages. Two reference stations were sampled outside the proposed lease area (ideally 500 – 1000 m away). Physical benthic sampling and visual observations of the seabed were to be undertaken (see Tables 23, 24 and 25 for parameters to be measured).
- A benthic, extended baseline survey (SEPA 2008b) was undertaken when the lease did not have prior on-growing and where the maximum biomass was ≥ 1000 tonnes or leases where there was no prior on-growing and where tonnage applied for was < 1000 tonnes but were situated in an area containing natural heritage or other environmental concerns. Samples were taken along two transects, one down current and one up current with stations at the cage edge, 50 m and 100 m away in both directions. Two reference stations were sampled outside the proposed lease area (ideally 500 – 1000 m away). Physical benthic sampling and visual observations of the seabed were to be undertaken (see Tables 23, 24 and 25 for parameters to be measured).

After May 2019, as part of the pre-application process for new or modification of existing leases the proponent must submit a baseline survey plan to SEPA. This survey plan requires consideration of the regulatory modelling process (SEPA 2019c), which has been developed to inform the predicted AZE around proposed farming locations. Baseline surveys must:

- characterise the seabed in and around a farm's predicted area of impact
- identify any protected habitats or species within that area
- provide an assessment of the existing environmental status of the seabed, including existing impacts, and
- address any potential risks identified in the wider area.

For new locations, the baseline survey is required to survey the area extending the AZE on its major and minor axes by 50 m in all directions, or to a distance of 150 m from the pen edge – whichever is the greatest; and enclosing this extended area (Figure 8A). Within the identified survey area, an initial visual assessment of the seabed must be performed prior to any detailed baseline survey design takes place. To assist this visual assessment, a sampling grid should be applied across the survey area (Figure 8), and the collection of visual survey data may be achieved with either a drop camera at gridline intersections (see Figure 8), or as continuous footage collected along lengthwise gridlines either by towed camera or remotely operated vehicles (ROV) (see Figure 8). The extent of the assessment must be sufficient to identify the

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broad habitat types found within the survey area. Existing habitat data, when available, may be used to determine which grid spacing to apply. The amount of footage required is determined on the available habitat data for the proposed farming area (SEPA 2019a). All visual data requires geo-referencing.

Table 25. Main video survey parameters observed for during baseline surveys across the main salmon producing countries

Video survey parameters	New Zealand	Canada	Scotland (old)	Tasmania
Sediment colour		X	X	X
Seaweed / seagrass cover	X			X[2]
Visibility near cages				X
Variety and density of animals on the seabed	X	X	X	X
Bacterial mats	X	X	X	X
Outgassing	X	X	X	X
1sh feed/Faeces		X	X	X
Flocculent organic material		X		
Rocky reefs	X			X[2]
Other features	X		X[1]	X[2]

Note:[1]- For habitats or species of natural heritage interest. While Norway and Chile recommend doing video surveys when the substrate is hard bottom, there are no defined parameters to record and no established standard for such surveys. [2] - Not mandatory requirements, but being more frequently asked for.

When undertaking the detailed baseline survey, sampling effort must be sufficient to provide an assessment of the status of each habitat type. For identified soft sediment habitats, a sufficient number of monitoring stations (minimum of 5) must be randomly distributed within that area. For soft sediment habitats, grab sampling must be undertaken for measurements of benthic invertebrates, particle size analysis and total organic carbon. When seabed assessments have identified areas that cannot be grab sampled (e.g. hard substrate or priority marine features of conservation value) then these areas must be subject to a more detailed visual survey, with survey requirements determined under consultation with SEPA. To determine the location of monitoring stations within a habitat a semi-probabilistic sampling approach must be applied (Figure 8). Where there is previous use of in-feed medicines within the waterbody and wider area within which the proposed farm is to be sited, then chemical residue samples must also be collected and analysed. Furthermore, where local bathymetry or model outputs identify potential sinks or hotspots of deposition then additional sampling may be required outside of the identified survey area.

For modification of existing sites, licence holders must carry out a baseline survey to assess the capacity of the environment to accommodate an expansion and or modification. The design of this survey can be determined by using existing habitat data.

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 11:54:22 AM
this is an interesting thing to note on a baseline survey. I must say if i encountered this in any of my baseline surveys, i would definitely be noting it.

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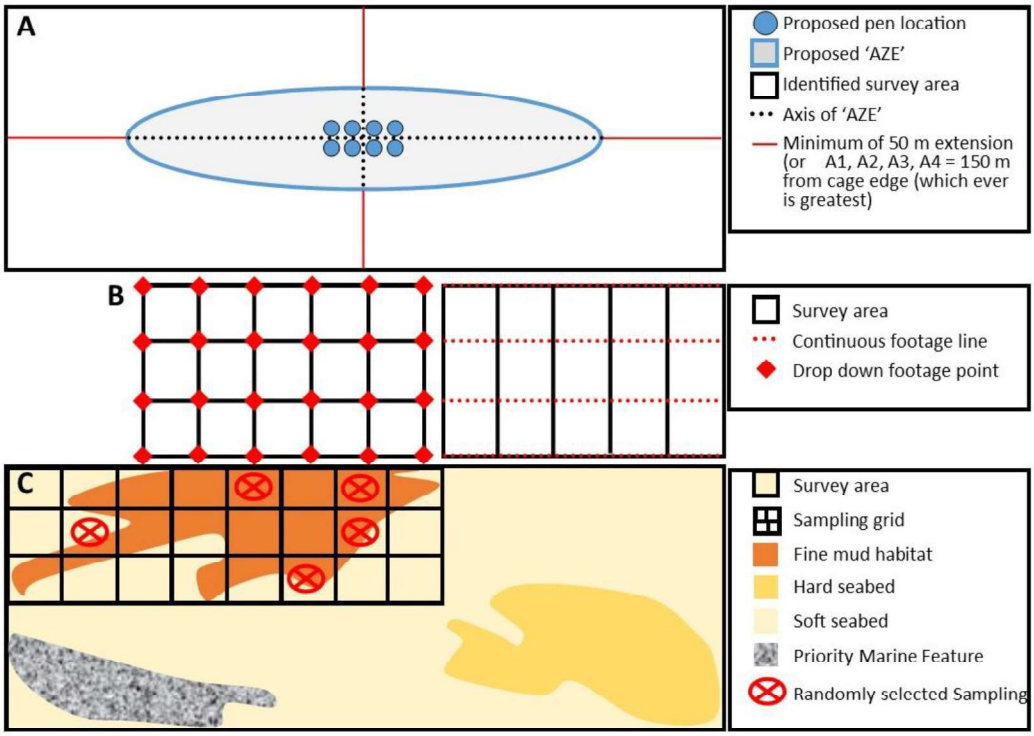

Figure 8. A) Baseline monitoring survey area identifier. B) Drop down and continuous video sampling approaches. C) Semi-probabilistic sampling approach with randomised monitoring stations. (reproduced from SEPA, 2019)

Canada

In Canada, baseline data collection is required for any new site and any significant boundary amendment, or any sites that are being re-activated. Collection of appropriate and complete baseline data is important to help ensure that ongoing environmental monitoring reflects the original data requirements. While the structure of baseline surveys is established at a federal level, there are region-specific variations that are implemented depending on which province (e.g. British Columbia, Québec, Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland or Labrador) the aquaculture facility is located in. Across all regions, baseline surveys are required to sample the same broad suite of parameters (see Table 23) (Anon 2018a).

Across all fish farming locations (with the exception of British Columbia), benthic sampling and visual observations are required to be taken at the centre of the lease and at each corner of the lease boundary. At Québec, Nova Scotia and Prince Edward Island, collection of additional samples takes place between 100-300 m from the edge of the lease boundary in the direction of the dominant current. In addition, sampling at New Brunswick takes place at the end of a 50 m transect from the lease boundary in the dominant current direction (see Table 26 for the number of monitoring stations required to be sampled). In British Columbia, benthic sampling and visual observations are only collected at a minimum of two stations (30 m and 125 m away from the edge of the lease boundary) along two transects that align with the area of greatest predicted impact and with the dominant and sub-dominant current directions. For every 200 m increment in length of the farming structure, additional transects for sampling at 30 m and 125 m stations are required. For a list of parameters for benthic monitoring using either visual and physical sampling approaches see Tables 24 and 25.

Table 26. Number of monitoring stations required for sediment and visual sampling (Nova Scotia and New Brunswick, Canada) (reproduced from Anon 2012, 2018a)

Maximum number of fish on cage array	Number of transects	Number of monitoring stations (excluding ref)	Number of samples per station
1 - 200,000	2	2	6
200,001 - 300,000	3	3	9
300,001 - 400,000	4	4	12
400,001 - 500,000	4	5	15
500,001 - 600,000	4	6	18
600,001 - 700,000	4	7	21
700,001 - 800,000	4	8	24
800,001 - 900,000	4	9	27
900,001 - 1,000,000	4	10	30

Chile

In Chile, baseline surveys are undertaken as part of a preliminary site characterisation. Baseline surveys are undertaken for new farms and/or the expansion of existing farms (Anon 2014). These baseline surveys aim to assess the suitability of a selected location for aquaculture based on the species to be cultivated (e.g. macro-alga or finfish), the type of production (extensive vs intensive), the intensity of production (tonnage), seabed type (e.g. soft, hard and mixed), and the location of production (e.g. lakes, estuaries, rivers, coastal zone). Criteria for baseline surveys are based on eight different aquaculture categories (Anon 2014). Depending on the category that the aquaculture activity falls under, this will determine what type of parameters need to be collected during the baseline monitoring program (see Table 27 for some category examples and the monitoring parameter requirements and Table 23, 24 and 25 for a full list of different parameters sampled in Chile). The number of monitoring stations for baseline surveys are determined based on the size of the lease area (i.e. one station per lease hectare) and should be distributed evenly over the lease) (Anon 2014). In addition, a monitoring station should be located in each corner of the lease sector requested in the licence.

Table 27. Outline of three examples of the eight different types of farming categories and their associated baseline requirements in Chile (reproduced from Anon 2014)

Category	Production type	Tonnage	Seabed type	Location	Depth	Baseline requirements
0	Macroalgae	NA	NA	NA	NA	1) Bathymetry 2) Substrate type
	Extensive (excl. macroalgae)	≤ 1000	Hard, semi-hard		> 60 m	
	Intensive	≤ 50				
3	Extensive	> 1000	Soft	Marine	≤ 60 m	Benthic parameters 1) Bathymetry 2) Substrate type 3) Visual records 4) Particle size 5) pH 6) Redox 7) Temperature 8) Sulphide Water parameters 1) Hydrodynamics 2) Dissolved Oxygen 3) Salinity 4) Temperature
	Intensive	> 50				
	Intensive	> 50				

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 12:00:48 PM
so this is the number of monitoring stations along each transect?

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 12:00:24 PM
is this supposed to read "number of samples in total"? i doubt sampling 30 replicates at each of 10 sampling stations is feasible. I think all that is required if that is the case, is that replication is n=3 at each sampling station, then this column is redundant.

Table 27 (continued). Outline of three examples of the eight different types of farming categories and their associated baseline requirements in Chile (reproduced from Anon 2014)

Category	Production type	Tonnage	Seabed type	Location	Depth	Baseline requirements
4	Extensive	> 1000	Hard, semi-hard	NA	≤ 60 m	Benthic parameters 1) Bathymetry 2) Substrate type 3) Visual records Water parameters 1) Hydrodynamics 2) Dissolved Oxygen 3) Salinity 4) Temperature
	Intensive	> 50				

New Zealand

In New Zealand, baseline monitoring is undertaken where uncertainty exists over the potential effects of a new aquaculture activity or modification of an existing aquaculture activity, particularly where environmental information on the coastal environment is absent or outdated (Keeley et al. 2015a). Under Benthic Monitoring Program (BMP) in New Zealand, baseline surveys are undertaken prior to production occurring at aquaculture locations, and are repeated after five years to provide adequate data for elucidation of the boundary of spatial effects (Keeley et al. 2015b). Specific methods used to conduct these surveys are currently unspecified within the BMP, as a site-specific approach for determining what information is required from baseline monitoring is undertaken in New Zealand; however, baseline monitoring may include the following aspects either as a review of existing data or the collection of new data (Morrisey et al. 2015):

- seabed sampling within lease and immediate vicinity including habitats and communities
- water quality, and
- hydrodynamic conditions.

A list of parameters sampled for compliance monitoring have been included in Tables 23, 24 and 25, reflective of current Type 2 monitoring in Waikato and Marlborough Sounds (Keeley et al. 2015a, b; Morrisey et al. 2015), ~~these would be obvious parameters to be sampled.~~

Tasmania

In Tasmania, baseline surveys are required for any new lease area or any area added to a lease area that increases it by more than 10% (DPIPWE 2004). The baseline surveys consist of multiple parameters including hydrodynamics, seabed conditions and water quality (see Table 23, for a complete list of category parameters sampled) (DPIPWE 2004). Seabed condition is assessed using visual tools (ROV or diver operated see Table 25) and destructive sampling (e.g. grab/core sampling) to measure a number of biological and physico-chemical parameters (Table 24).

For underwater video surveys, internal (inside lease area) and external (outside lease area) spot dives are performed. For external spot dives, a minimum of one upstream and one downstream set of spot dives located parallel to the lease boundary is required. Each set of spot dives consists of a minimum of three spot dives at least 20 m apart, 35 m from the lease boundary. For internal habitat dives, these are done inside the lease area to show habitats within the lease area. The number of habitat dives required would be dependent on the lease area to be surveyed (Table 28). In addition, individual spot dives must be conducted at six control sites (DPIPWE 2004).

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Number: 1 Author: delvines Subject: Highlight Date: 2/06/2020 7:12:00 AM
I think there may be a bit of confusion here. We have two types of surveys: 1) Typically, a site is characterised quite comprehensively by the salmon farmers science provider, prior to them applying for a lease. I would term this the 'site characterisation/scoping survey', which are often too broad-scale to be useful as baseline surveys per se, but they do collect 'baseline' information. 2) 'Baseline surveys' are then undertaken after the lease is granted, but typically before the structures are allowed in the water. A baseline survey therefore targets/ establishes specific sampling stations that are anticipated (or representative of those) to be used for routine monitoring once the farm is operational.

Additional sampling may be added to the 'baseline' sampling programme if there is a large degree of uncertainty around a specific concern, but generally i wouldnt say that is the main purpose of a baseline survey. Information gaps are usually what the site characterisation survey addresses, but in a broader sense (to enable an assessment of what the impacts of a salmon farm might be).

Number: 2 Author: delvines Subject: Cross-Out Date: 19/05/2020 12:14:37 PM
...broad site characterisations are...

Number: 3 Author: delvines Subject: Cross-Out Date: 19/05/2020 12:14:48 PM

Number: 4 Author: delvines Subject: Highlight Date: 19/05/2020 12:15:44 PM
as a basis from which the potential effects of the new aquaculture..... can be assessed, prior to the fish farm or modification being granted.

Number: 5 Author: emman Subject: Sticky Note Date: 8/05/2020 7:53:08 AM
BMP is 'best management practice', i.e., there is a water column and a benthic BMP

Number: 6 Author: delvines Subject: Highlight Date: 2/06/2020 7:12:20 AM
i would say that the approach is pretty generalised in NZ, but is subject to the types of habitats present within the farm area.

Number: 7 Author: delvines Subject: Highlight Date: 19/05/2020 12:20:31 PM
but for farm sites operating under the BMP, the minimum requirement is implicit in the Type 2 monitoring requirements.

Number: 8 Author: delvines Subject: Highlight Date: 25/05/2020 2:35:41 PM
Note that Type 2 monitoring only covers soft sediment, and doesnt include reef and water column parameters. Reef monitoring, however, is an important aspect of seabed monitoring in NZ, at least in Marlborough and primarily at dispersive sites.

Number: 9 Author: delvines Subject: Highlight Date: 19/05/2020 12:31:48 PM
Do you mean baseline information? Definitely alot of parameters in those tables are collected for baseline and site characterisation, but not used for compliance monitoring under Type 2. It would be easier to list the compliance monitoring parameters, and i am happy to provide this.

Number: 10 Author: delvines Subject: Highlight Date: 2/06/2020 7:13:13 AM
FYI, Waikato currently has no fish farming, it was something that was investigated some time ago. Though there is still some chatter about this going ahead, it is probably not a good case study for this purpose. Our other active farming regions outside oft he Marlborough Sounds are Banks Peninsula (Akaroa Harbour), and Steward Island (Big Glory Bay), which are both comparatively small farming areas with only one company operating in each.

Number: 11 Author: delvines Subject: Cross-Out Date: 19/05/2020 12:28:57 PM
and these would be a focus of soft sediment baseline sampling.

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Table 28. Number of internal habitat dives based on lease area

Lease area to be surveyed (Ha)	Number of habitat dives
0-5	2
6-10	4
11-20	6
21-40	8
41-100	10
101-200	20
201-300	30

For sediment chemistry, single undisturbed sediment cores are collected from each of the video spot dive sites to undertake a visual assessment, measure redox and sulphide concentrations and subsample for particle size analysis. For organic content and metal analysis, single sediment cores are also to be collected from each of the video spot dive sites for analysis. Benthic fauna analysis is undertaken using single grabs (collected as a 'set' of three replicate grabs) from each of the external video spot dive sites (outside of the lease area). These cores are collected as a 'set' of three replicates (n=3). This approach was adopted from advice from TAFI (See Crawford et al. 2002) to provide an optimised spatial spread of sites along the boundary whilst still collecting replicate samples from more or less homogenous sedimentary habitats. Reef surveys and threatened species, introduced species and sensitive habitat surveys are undertaken where reefs and hard substrate areas are potentially affected.

Recommendations

Across salmonid farming regions internationally, the collection of biological and physico-chemical data, supported with detailed localised oceanographic and bathymetry data are important data to assess a site's assimilative capacity. Furthermore, the use of visual sampling tools (e.g. ROVs and drop cameras) to assess the conditions of the seafloor and to survey the receiving environment to determine the presence of sensitive and/or vulnerable habitats or habitats of ecological importance is highly valuable. However, the use of visual sampling tools to assess environmental condition of the seabed should be first validated with traditional biological/physico-chemical data before relying solely on visual tools. Once characterised, this information is available as a benchmark from which changes in the receiving environment (due to the dispersal and accumulation of organic wastes from caged aquaculture) can be assessed by comparison with ongoing monitoring results.

Recommendations from the 'Working Group' for consideration during the drafting of the Environmental Standard are that the environmental standard should:

- Consider that the current parameters required for baseline sampling reflect international practice. In addition, recommend the establishment of a robust pre-development time-line of selected water quality, biological, physico-chemical and environmental datasets at sites that are representative of local and regional environments needs consideration. These datasets would aid in establishing site and region-specific indicator guideline values, which would enable better identification of local and broader ecological changes measured during ongoing compliance and broad scale environmental monitoring.

Management responses, actions, and controls

Norway

In Norway, management responses to non-compliances are written into the national environmental monitoring standards (NS-9410:2016), while management directives follow Norwegian law (Aquaculture regulations section 35). With worsening environmental conditions (conditions 2 - 3) identified using the Trend-B monitoring survey (see Table 9), the standard management action is to increase the frequency of monitoring (Table 29). When environmental conditions remain at poor condition, then modification of production plans occur before the next production cycle. If environmental conditions are at Level 4 (i.e. very poor), then the management response is that no stocking is allowed until the environmental conditions reach Level 3 (i.e. poor), and production plans should be modified to reduce environmental impacts. If over successive production cycles the environmental surveys continue to show unacceptable

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Number: 1 Author: deannae Subject: Highlight Date: 25/05/2020 2:36:28 PM
see my comments in summary

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environmental conditions, the Directorate of Fisheries, in consultation with the county governor's environmental department, may decide to decommission the site. For Trend-C monitoring, if environmental surveying identifies conditions at the 'AZE-scale' to be poor, then this triggers additional intensive seabed monitoring to identify attribution (Table 29).

Table 29. Management response/actions for different levels of environmental conditions on the seabed in Norway (modified from Macleod et al. in prep)

Investigation	Environmental condition	Management response (MR)/ Management action (MA)/Management controls (MC)
Trend-B monitoring survey (Farm-Zone)	Excellent	MR – Monitor at next peak production.
	Good	MR – Monitor at pre-stocking and next peak production.
	Poor	MR – Monitor at pre-stocking. If pre-stocking survey gives: • condition 1: MR – Monitor at next peak production • condition 2: MR – Monitor at next half maximum and at maximum load, or • condition 3: MR – Monitor at next half maximum load and at maximum load. MA – modify production plans prior to next production
	Very Poor	MA – No pre-stocking allowed until conditions reach condition 3. MA- Modify production plans prior to next production. MC – Decommissioning of the farming site.
Trend-C monitoring survey ('AZE scale')	Poor condition at outer edge of AZE	MR – Undertake additional monitoring to reveal the extent of the poor conditions and if the conditions are attributable to the farming activity or if they are natural conditions.
	Poor condition at stations within AZE	

Scotland

In Scotland, the regulatory framework has recently changed (May 2019). This change has resulted in strengthening of SEPA's enforcement action by creating an enforcement function, which will proactively drive improvements in compliance. SEPA will introduce a quality assurance scheme that will involve auditing the way environmental samples are collected, analysed, and reported. In addition, the environmental performance at pen scale and cumulative effects on the wider environment will also be audited. This will provide SEPA with greater confidence regarding impacts associated with the farming activity, enabling enforcement action to be taken if necessary. Action to be taken could include re-setting permit limits and reducing the size of the farm or making a report to the public prosecutor.

Prior to May 2019 implementation of management responses / management actions would follow environmental seabed compliance surveys. If environmental conditions were satisfactory, no further action was likely to occur, apart from contacting the responsible person and noting the outcomes of the surveys as part of the compliance assessment. On identification of a borderline classification, while still a passing condition, the responsible person would be informed of the environmental condition to ensure that they had the opportunity to make appropriate site husbandry modifications so that the farm continued to achieve environmental compliance. If assessment of environmental conditions was deemed unsatisfactory, this suggested that the emissions exceeded the site's carrying capacity. The responsible person for the farm would be contacted and informed of the site's performance and given an opportunity to adopt mitigation measures that would lead to improved conditions onsite before further regulatory action is taken.

In Scotland, there were two types of environmental compliance failures (intensity and extent), and these were managed differently (Table 30; SEPA 2015). For intensity failures, this meant that the biomass of farmed fish exceeded the carrying capacity of the near-field local environment (i.e. failure at cage edge). Failure at this level automatically incurred a reduction in biomass and additional monitoring. For a second intensity failure at the same location, the worst case scenario was that there could have been a

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management action to suspend the farming licence until conditions warrant further activity on the lease (Table 30; SEPA 2015). For extent failures, this meant that established environmental triggers were exceeded at the extent of the AZE (Table 30). This type of failure automatically incurred additional monitoring, with mitigation plans likely to be requested by authorities. However, successive extent failures resulted in a management action of reduced biomass and initiation of environmental auditing, while it was expected that additional operational monitoring would be undertaken (Table 30; SEPA 2015).

Table 30. Management response/actions for different levels of environmental conditions on the seabed in Scotland (modified from Macleod et al. in prep)

Environmental condition	Management response (MR)/ Management action (MA) /Management controls (MC)
Intensity fail (cage edge)	1st Failure • MA – Reduce biomass and undertake additional monitoring. 2nd Failure • MR – Undertake monitoring to assess recovery before restocking. • MA – Consider licence suspension / further biomass reductions prior to re-stocking. • MC – SEPA audit monitoring.
Extent fail (edge of AZE)	If monitoring not using site-specific AZE – Site-specific AZE should be established prior to next production. Where a site-specific AZE is in place: 1st Failure • MR – Undertake additional monitoring before peak biomass – extend beyond. standard + 10 m AZE to determine extent of impact. • MA – Develop improvements / mitigation plan. 2nd Failure • MR – Undertake additional (enhanced) monitoring. • MA – Reduce biomass. • MC – SEPA audit monitoring. 3rd Failure • Same as 2nd Failure.

Ireland

In Ireland, the Coastal Zone Management Division of the Department of Agriculture, Fisheries and Food, requires a finfish licensee to submit a Benthic Amelioration Plan within 30 days of a reported breach of sediment quality criteria. The aim of the Benthic Amelioration Plan is to achieve an acceptable benthic standard in the licensed area as soon as possible. The plan may include:

- Cage by cage feed waste control plan with follow up monitoring. If benthic conditions do not improve, further reductions in feed inputs will be required until a follow up environmental report indicates acceptable conditions.
- Provide for movement of all production cages coupled with a 5% reduction in production tonnage over the next production cycle. When production cages are moved, the impacted area from the reported site must continue to be monitored annually until a subsequent environmental report indicates acceptable conditions.

In addition to these conditions, the Department of Agriculture, Fisheries and Food reserves the right to prescribe specific remedial action in any particular case in the light of the relevant benthic monitoring report.

New Zealand

In New Zealand, there are currently five levels of management actions to accompany varying degrees of non-compliance (Table 31; Keeley et al 2015a). Farms that are implementing Type 1 environmental monitoring and exceed established environmental trigger levels have immediate requirements to undertake Type 2 monitoring. Should Type 2 monitoring identify that environmental conditions have exceeded set

operational environmental triggers, one of the other four action levels will be initiated. Triggered management responses increase in complexity with increasing organic enrichment of the environment. Triggering minor and major action levels leads to the development of action plans to mitigate seabed enrichment within 24 months after first detection. If after the 24 month period no benthic improvement is observed, or where the lease classification exceeds 5.6, destocking is triggered as a last resort (Table 31).

Table 31. Management response/actions for different levels of environmental conditions on the seabed across various provinces in New Zealand (modified from Macleod et al. in prep)

Action level	Site classification / triggers		Management response (MR)/ Management action (MA)
	Zone of max. effect	Outer limit of effect	
Type I monitoring	TFS[1] > 1700 μm Qualitative score > 6.0 Macrofauna score > 2.0	Overall ES < 3.0 (natural state)	MR – Triggers Type 2 monitoring.
Alert	Highly enriched: Mean ES > 5.0 to ≤ 5.3 (95% CI span thresholds	A statistically significant increase relative to reference station(s)	MR – Plan how the farm intends to reduce seabed enrichment.
Minor	Highly enriched: Lower 95% CI for overall ES > 5.0 to ≤ 5.3 Two or more replicates with macrofauna virtually absent Bacterial mats visible Spontaneous outgassing	ES ≥ 3.0 Mean ES 0.4 higher than previous year Increase is significant to reference stations	MR/MA – Plan and initiate response to reduce seabed enrichment within 24 months – 20 day reporting period. MR/MA – More drastic responses will be requested if 12-month follow up, indicates seabed conditions have not improved. MR/MA – Initiate regular Type I monitoring prior to next major restocking to inform the stocking level for the 12-month period leading in to the monitoring survey at the end of the 24-month period.
Major	Highly enriched: Lower 95% CI for overall ES > 5.3 to ≤ 5.6	None	MR/MA – Same as the minor action level, however it will need to be more significant as appropriate to the enrichment stage.
Destocking	Highly enriched: Lower 95% CI for overall ES > 5.6 Non-compliance after 24-month period has been issued	None	MA – Stock must be removed and the site fallowed until seabed conditions meet EQS. 4 months to comply or at the end of the current production cycle. MA – Develop appropriate stocking plan to ensure site will meet EQS for future surveys.

[1]-Total free sulphides

Canada

In Canada, degrading environmental conditions around fish farming activities initiates management responses/management actions relative to the level of impact reported (Table 32; Anon 2012, 2018a). In New Brunswick and Nova Scotia, low levels of environmental deterioration triggers additional/more intensive environmental monitoring. Increasing environmental degradation leads to further management actions/responses including reviewing site farming practices, modifying harvest/farm scheduling, and third party auditing (Anon 2012, 2018a). Where extreme deterioration to the environment occurs, farms are required to work closely with environmental regulators to develop mitigation strategies to resolve poor environmental performance. For British Columbia and other locations on the east coast of Canada, should environmental conditions exceed appropriate trigger levels, re-sampling and potentially fallowing of locations until conditions are appropriate for re-stocking would be the main management responses/actions (Anon 2012, 2018a).

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Number: 1 Author: delvines Subject: Highlight Date: 2/06/2020 7:14:42 AM
action levels are pre-defined for exceedance at the cage edge (only). This has actually caused some problems recently.

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 12:48:17 PM
might be worth noting that exceedance of the EQS at the edge of the AZE (i.e. an 'extent' exceedance) can only trigger up to a minor management response (i.e. fix it within 24 months).

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Table 32. Management response/actions for different levels of environmental conditions on the seabed across various provinces in Canada (modified from Macleod et al. in prep)

Province	habitat	Site classification / Triggers	Management response (MR)/ Management action (MA)
Nova Scotia		Oxic A	MA – If site remains 100% oxic for 2 production cycles, then compliance sampling is required only every 2nd year at the peak of production.
		Oxic B	
		Hypoxic A	MA– Submit an updated mitigation plan to address poor environmental performance.
		Hypoxic B	MR – Conduct more intensive monitoring. MA – Submit an updated mitigation plan to address poor environmental performance.
		Anoxic	MR – Conduct more intensive monitoring. MA – Work closely with regulators to establish suitable mitigation plan to resolve poor environmental performance.
New Brunswick		Oxic A	No MR or MA to consider – continue operation as planned.
		Oxic B	
		Hypoxic A	MR – Undertake detailed data analysis and review 1) staff training, 2) equipment maintenance and 3) site cleaning practices.
		Hypoxic B	MR– Conduct more intensive environmental monitoring. MR – Conduct internal audit of site operations. MA – Modify harvesting schedule and review and adjust site setup / pen orientation. MA – No onsite equipment or net cleaning.
		Hypoxic C	MR – Conduct even more intensive environmental monitoring. MR/MA – Thorough site review, third party external audit of site operations. MA – Modify harvesting schedule and reduce biomass ASAP over degraded parts of site. MA – No onsite equipment or net cleaning. MA – Regulator instructions for site operation practices (e.g. modify harvest schedule and/or biomass on site).
		Anoxic	MA – Work closely with regulators to establish suitable mitigation plan to resolve poor environmental performance (e.g. harvest program, fallowing program, increased monitoring, future limitations to production).
AAR: British Columbia	Soft substrate	1300 μm sulphide (30 m from cage edge)	If conditions are as such MR – Re-sampling of sites. If re-sampling confirm exceedance MA – Sites must not be re-stocked.
		700 μm sulphide (125 m from cage edge)	
	Hard substrate	Presence of *Beggiotoa* spp. (or similar) or marine worm cover ≥ 10% of 4 segments of substrate within 100-124 m of cages ≥ 10% of 2 contiguous segments within 116-124 m or 124-140 m	If conditions are as such MA – Sites must not be re-stocked.

Table 32 (continued). Management response/actions for different levels of environmental conditions on the seabed across various provinces in Canada (modified from Macleod et al. in prep)

Province	habitat	Site classification / Triggers	Management response (MR)/ Management action (MA)
AAR: East Coast	Soft substrate	3000 μm sulphide (30 m from cage edge)	If conditions are as such MR – Re-sampling of sites. If re-sampling confirm exceedance MA – Sites must not be re-stocked.
	Hard substrate	Presence of *Beggiotoa* spp. (or similar) or marine worms in > 70% of the monitoring stations	If conditions are as such MR – Re-sampling of sites.

Chile

In Chile, management of non-compliance is quite straight forward when controlling for environmental degradation. The environmental conditions are assessed as either aerobic (oxic) or anaerobic (anoxic). As a management action, restocking of the fish farms cannot happen if the environmental conditions are anaerobic; as such, the farm manager must fallow the lease until the environmental conditions are assessed as aerobic. A formal management response is that the farmer must also be able to demonstrate that the farm will not result in anaerobic conditions for a least another whole production cycle is complete (Anon 2001).

Tasmania

In Tasmania, the regulation of salmon farming has been a changing landscape since the late 1990s. Current Environmental Licences contain specific conditions and MFDPs prescribe management controls to mitigate environmental impacts associated with marine farming operations. Assessment of the environmental sustainability of salmon farming operations is based on scientific knowledge established by IMAS since the late 1990s.

In the MFDPs (see Anon 2018d for MFDPs), a number of key environmental management controls are used for regulating the carrying capacity and counteracting anoxic conditions, including:

1. There must be no significant visual, physio-chemical or biological impacts at or extending 35 metres from the boundary of the lease area, as specified in the relevant marine farming licence.
2. Lessees must ensure that farmed areas are fallowed as soon as practicable after bubbles of hydrogen sulphide and/or methane gasses form in the sediment and rise to the surface without physical disturbance of the seabed.
3. The Director, EPA, may, from time to time, determine the total permissible dissolved nitrogen output (TPDNO), within specified periods, attributable to licensed finfish marine farming operations for a specified area.
4. The Director, EPA may from time to time, using whatever information the Director, EPA considers appropriate, determine the maximum permissible biomass of finfish that may be stocked within the area covered by this plan or any other specified area within the plan area.

In addition, other management controls are stipulated in the various MFDPs to ensure environmental compliance including:

1. Lessees must comply with the environmental monitoring requirements for collection, analysis and reporting as specified in the relevant marine farming licence (Now the Environmental Licence).
2. The maximum permissible stocking density of salmonid fish is set at fixed levels of 25 or 15 kg/m3 depending on the MFDP.
3. Finfish nets must be at least 1 metre clear of the seabed at low tide under normal growing conditions.
4. All chemical use must comply with the requirements of the *Agriculture and Veterinary Chemicals (Control of Use) Act 1995*.

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5. Lessees must dispose of wastes from: harvesting; processing of produce; and removal of fouling organisms, in a manner that the Secretary is satisfied will not cause an unacceptable effect on the ecology of the marine environment or nearby shorelines.
6. Lessees must ensure that Black and Grey Water resulting from the servicing of marine farming operations is not released into the marine environment unless otherwise authorised.

In 2004, the hybridisation of the Tasmanian 'Finfish Farming Benthic Monitoring Program' established management responses/actions for the AZE (35 m beyond the lease boundary) and the Farm-Zone (lease area). The current weight-of-evidence approach uses predominantly video evidence to detect unacceptable impacts at 35 m beyond the lease boundary. When a non-compliance is detected, the management response/action required may be to initiate a comprehensive benthic triggered survey (sampling of biological and chemical parameters) to determine the extent of any breaches and if the impact(s) are a result of the marine farming activity. Alternatively, other remedial activity may also be required as determined by the Director, EPA. Remedial activity may and has included fallowing of the nearest fish cage, up to fallowing of an entire lease, based on compliance site visual impacts. Since 2004, the implementation of benthic triggered surveys have been rarely undertaken in response to non-compliances as the management response is flexible and more often resulted in operations-based management responses (e.g. movement of cages, fallow directions and increased frequency/spatial extent of visual monitoring). When triggered investigations have been undertaken (e.g. following the observed proliferation of opportunistic polychaetes and increased prevalence of *Beggiatoa* spp. in Macquarie Harbour), this has resulted in commissioned research projects being undertaken by IMAS to conduct ongoing research detailing benthic and water column condition.

Within lease area monitoring, the detection of significant visual impacts under or at cage edge could trigger a management response for fallowing individual cages. In this case, the fallowed cages are not allowed to be restocked until pre-stocking surveys identify that the sediments have recovered to the satisfaction of the Director, EPA. Depending on the severity of the detection of significant visual impacts, this may trigger additional lease area monitoring as determined by the Director, EPA, which may identify additional areas requiring fallowing.

Recommendations

One of the key management responses/actions resulting from a triggered event is the requirement for increased monitoring (i.e. investigative monitoring), and if environmental thresholds are exceeded, the subsequent establishment of remediation plans to enable farming locations to avoid ongoing breaches of environmental compliance regulations. The implementation of a tiered approach has provided farmers in Canada, Norway and New Zealand with an early warning system, helping to ensure responsible farming of lease areas, with the opportunity to mitigate unwanted impacts and achieving sustainable fish production and future development potential. Furthermore, biomass reduction is being implemented across a number of countries (depending on environmental performance) to ensure farms are farming at the environment's carrying capacity. Licence suspensions and/or forced destocking or fallowing are also target mitigation strategies when environmental performance is poor.

Recommendations from the 'Working Group' for consideration during the drafting of the Environmental Standard are that the environmental standard should:

- Encourage industry to implement best practice management actions to achieve environmental compliance independent of a regulatory response to ensure long-term environmental sustainability.

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Number: 1 Author: delvines Subject: Highlight Date: 19/05/2020 12:55:40 PM
this is all a repeat of somewhere earlier. Can it be summarised just to the relevant bits? I think all it really needs to say is that the management actions have been at the discretion of the regulator, favouring management actions like fallowing over resampling responses (if that is correct based on earlier comment).

Number: 2 Author: delvines Subject: Highlight Date: 19/05/2020 12:56:26 PM
is this relating to general practice elsewhere?

Number: 3 Author: delvines Subject: Highlight Date: 2/06/2020 7:18:02 AM
Although the tiered management action levels when operating at the Type 2 monitoring level sometimes includes additional sampling, it might also be worth noting that Type 1 monitoring level in NZ has never actually been used, since they have not yet met the criteria to use it (i.e. doesnt appear to be a strong enough incentive, and it is worth farmers risking non-compliance if they are able to produce more fish). I think that attitude is probably company-specific.

Number: 4 Author: emman Subject: Sticky Note Date: 8/05/2020 4:47:30 PM
I'm not sure where this paragraph is going - it doesn't seem to lead to recommendations. Perhaps the point needs to be made clearly in this section that current controls/actions seem to be working well in Tasmania, and therefore only an increase in voluntary good environmental practice remains to be instituted?

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Conclusions

The regulation of environmental performance of salmonid farms in Tasmania has been ongoing since 1998. During this period, DPIPWE has reviewed the regulatory performance, supporting adaptive farm management practices in step with the expansion of the industry and available scientific knowledge. Given it has been more than 15 years since the last review of the regulatory environmental monitoring program (2004), and the salmon industry has expanded significantly during this time period, it is timely to review the efficiency and effectiveness of the current monitoring program in line with current farm management practices and environmental monitoring tools to protect the environment.

This paper outlines the approaches undertaken globally for environmental regulation of salmonid farming. Information presented in this paper provided an overview of the current approaches taken to regulate the footprint and environmental impacts of particulate organic wastes and dissolved nutrients on marine and estuarine ecosystems. The paper demonstrates that environmental monitoring is a function of: 1) the local environment; 2) the goals of the environmental monitoring program; and 3) country's scientific bias of selecting indicators to measure and document the environmental performance/impact of fish farms on marine and estuarine ecosystems against a swath of documented indicators to detect organic enrichment from aquaculture.

The Working Group acknowledges that sound scientific rationale underpin current environmental regulations in Tasmania, however, they also acknowledge that given the expansion and evolution of the salmon farming industry, environmental monitoring must follow suit. The recommendations made by the Working Group in this paper expand the existing monitoring framework, but also considers current international scientific knowledge to further enhance a progressive monitoring system.

The new Environmental Standard should consist of region-specific, up-to-date biological/physico-chemical indicators and thresholds, together with a more accountable, transparent monitoring program, that will ensure environmental monitoring is implemented during the time period when potential environmental impacts are likely to be at their greatest. This robust approach will ensure that finfish farmers operate within clearly defined Environmental Standards and have the capacity to follow a performance based regulatory system that rewards operators for consistent environmental compliance. The Environmental Standard should enable sustainable regulation and potential for further development, while protecting the community values identified for Tasmanian water bodies.

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Number: 1 Author: deannae Subject: Sticky Note Date: 25/05/2020 2:40:31 PM
see my earlier comments where the wording is the same as the summary at the front.

Number: 2 Author: emman Subject: Sticky Note Date: 8/05/2020 4:49:07 PM
I'm not sure that the scientific basis was outlined here? There is some references to scientific literature, but I think this review is based on international practice rather than science. There is an assumption (or knowledge!) that this practice is based on science, but the science isn't explicitly presented in the document.

Author: deannae Subject: Sticky Note Date: 25/05/2020 2:43:09 PM
Does it mean 'bias', as in, Canadas monitoring and farm management is biased toward their selection of sulphides as their sometimes sole indicator? As opposed to countries who manage using for example, biological indicators?

Number: 3 Author: deannae Subject: Underline Date: 26/05/2020 12:13:35 PM
very long sentence

Number: 4 Author: emman Subject: Sticky Note Date: 8/05/2020 4:49:34 PM
As per the above, is it 'scientific knowledge' or 'practice' you are detailing here?

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Number: 1 Author: emman Subject: Highlight Date: 28/05/2020 5:47:29 AM
The division of the references into Guidelines, Reports, and Scientific articles is unhelpful when attempting to look for source literature.

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Appendix

The 'Environmental Standard' Working Group

The 'Environmental Standard' working group was established to provide expert advice and support for reviewing the environmental standards for salmonid cage culture globally and comparing these to Tasmania. The working group consisted of twelve marine/environmental experts working across the EPA Tasmania (Raymond Bannister, Stephen Gallagher, Greg Dowson, Mark Churchill, Kate Hoyle, Kate Duttmer and David Horner), the Marine Farming Branch (Eric Brain and Graham Woods) and the Institute for Marine and Antarctic Studies (Jeff Ross, Catriona Macleod and Flora Bush). The group participated in nine meetings undertaken between 21 May 2018 to 5 March 2019 to discuss six key 'Terms of Reference (ToRs)', which related to the establishment of the new 'Environmental Standard' for regulation of salmon farming in Tasmania.

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