ASC Farm Standard

TWG Recommendations to ASC for Revised Criterion 2.7 - Water Quality

Requirements - Lentic & Lotic Receiving Waters

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Contact information:

Aquaculture Stewardship Council
Daalseplein 101, 3511 SX Utrecht
The Netherlands
+31 30 239 31 10
www.asc-aqua.org

Glossary of terms and acronyms

AC: Assimilative capacity
AMA: Area-based Management Association
AZE: Allowable Zone of Effect
BOD: Biological oxygen demand
Chl-a: Chlorophyll-a
DO: Dissolved oxygen
DPSIR: Driver, Pressure, State, Impact, Response (OECD framework indicator categories)
FW: Fresh water
HAB: Harmful algal bloom
HRT: Hydraulic residence time – also referred to as flushing time
IOE: Farm nutrient input-output efficiency management
Lentic: an aquatic ecosystem with standing or slow flowing water such as a lake, pond, or reservoir
Lotic: an aquatic ecosystem with rapidly moving water
RW: Receiving water
RWFA: Receiving water farm afar (sample station out with a downstream mixing zone)
RWFE: Receiving water (farm) effluent outfall point (formally RWFO)
RWRP: Receiving water reference point (unimpacted upstream sample station)
SD: Secchi-disk depth (measure of water transparency)
TAG: Technical advisory group (ASC)
TN: Total nitrogen
TP: Total phosphorous
TSI: Trophic Status Indicator
TSS: Total suspended solids
TWG: Technical working group (ASC)
VR: Variance Request (ASC procedure for mitigation requests re. indicator non-compliance)
WFD: EU Water Framework Directive
WUM: Waterbody Unit of Management
WQ: Water quality

Background

This document details recommendations to ASC arising from the Water Quality (WQ) Technical Working Group (TWG) review meetings held between June 2021 and December 2022. The TWG was tasked by ASC to revise the current approach in the ASC Standards and *recommend water quality indicators that collectively reflect and address risks from aquaculture in all major production systems*[1] *that discharge into different water types*[2]; reflecting the latest scientific knowledge and current best practices within the aquaculture industry.

Recommendations address eutrophication impacts associated with nutrient enrichment originating from feed or fertiliser inputs[3], pond or channel dredging, or other husbandry and harvest activities identified as being 'at risk' e.g., net cleaning, blood-release. Effluents of primary concern are those directly released from culture systems and from any post-culture water treatment systems. Requirements do not apply to fully closed systems (with no receiving water effluents of any kind) or to systems that are net nutrient sinks.

Initial discussions resulted in three separate recommendation reports for production systems discharging to (i) lakes and reservoirs[4] (ii) flowing fresh waters and (iii) saltwater environments. The TWG went on to propose a more fundamental categorisation of receiving waters according to their nutrient retention potential based on hydraulic residence time, to differentiate between still/ slower flowing (**'lentic'**) from faster flowing (**'lotic'**) systems.

In this revised approach requirements for (freshwater or saline) **lentic systems**, commence with an assessment of baseline enrichment/trophic status and which nutrients are likely to be limiting or co-limiting. A more precautionary approach is adopted for **lotic systems** at risk of episodic impacts linked to high seasonal variability in flow conditions. Riverine headwaters with lower flow and low background nutrient concentrations are likely to be particularly sensitive.

Saline environments: Phosphorus is known to be a major cause of eutrophication in temperate freshwater lakes; highly oligotrophic systems being most sensitive. But eutrophication has also increased in many coastal marine ecosystems since the 1970's, correlated with tremendous increases in nitrogen pollution. Hitherto regulators assumed controls on eutrophication in lakes and coastal waters should be focussed on [P] control as the limiting nutrient, due to the presence nitrogen-fixing cyanobacteria. However, in most estuaries and coastal waters with salinities exceeding 6–8‰, planktonic, nitrogen-fixing cyanobacteria (NFC) do not occur as their growth is limited by factors other than [P], whilst these controls on NFC growth are relaxed in off-shore waters (Howarth and Pearl 2008). There is now a strong consensus on the need to control both nitrogen and phosphorus to manage estuarine and coastal as well as freshwater eutrophication.

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[1] Major production systems are cages, suspended/off-bottom, in or on-bottom and land-based (point-discharge systems, e.g. ponds, raceway, flow-through and RAS).

[2] Water types were marine, brackish, and freshwater. Other interacting abiotic factors including hydraulic residence-time, energy conditions and water temperature profile are further key determinants of nutrient fate.

[3] Requirements will also cover acute nutrient loading episodes e.g., from net-cleaning, blood water release, dewatering of solids settlement systems, water exchange during harvests.

[4] Although reservoirs are man-made systems constructed for primary utility functions (e.g., irrigation, hydro-electric, water supply) they can also support other important ecosystem functions and services. Under this context, and for the purpose of this document, when lakes are mentioned, they shall also encompass reservoirs.

Rationale and Intent of the Criterion

Rationale: Eutrophication and its consequences are amongst the most serious environmental problems facing humanity today (Stephen et al 2015). Excessive inputs of nitrogen (N) and phosphorus (P) profoundly alter the composition and functioning of freshwater and marine ecosystems, leading to shifts from long-lived macro-algae to bloom-forming toxic algae and other nuisance species. Water quality impacts, particularly oxygen depletion (hypoxia) can then kill sensitive fish species with cascading effects on entire aquatic ecosystems and overall loss of biodiversity at local and regional scales. The general deterioration of water quality may also preclude water use by other industries and communities.

The release of nutrients (N & P) and particulate matter (TSS) from fed and fertilised aquaculture systems can contribute to eutrophication and other impairments to water quality (e.g., taste and odour problems). The severity of these effects is contingent on many factors including depth and location of the waterbody as well as nutrient inputs from other natural and anthropogenic sources.

Aquaculture contributions to eutrophication can be limited by ensuring nutrient loads in farm effluents do not have excessive localised impacts e.g., through oxygen depletion, or cumulatively exceed the assimilative capacity of the wider waterbody. Various in-farm measures can also reduce nutrient loading by limiting the amount of N and P released per unit of production.

The indicators have been developed to identify the nutrient retention capacity of the receiving water body and the susceptibility of at-risk water bodies to additional nutrient inputs. Where relevant, additional assimilative capacity assessment and coordinated area management efforts are required, to reduce the rate of change and prevent shifts in trophic status.

Intent: To assess and minimise risk that nutrients and suspended solids released from a farm negatively impact the receiving water body and adversely affect associated ecosystem structure and function.

Scope

Current ASC water quality indicators aim to minimise the negative impacts of anthropogenic eutrophication in sensitive aquatic ecosystems resulting from 'waste' nutrients originating from aquaculture feed and (pond) fertiliser inputs in faeces, waste feed and as metabolic by-products.

- Requirements should be limited to fed and/or fertilised aquaculture systems including cages or land-based systems (hereafter respectively referred to as systems with '**diffuse'** and '**point'** sources of effluents) discharging to freshwater brackish or marine environments including lakes, reservoirs, streams, rivers, canals, estuaries, lagoons, marine in- and off-shore locations – and sub-systems including embayments and irrigation systems.

In lotic systems derogations on specified water quality requirements should be allowed where:

a. Extensive systems act as (net) nutrient sinks
b. Background [TSS] are naturally very high e.g., alluvial delta river systems AND/OR
c. Flow rates are extremely high

In lentic systems derogations on specified water quality requirements should be possible where:

d. Secchi depth (SD) measurements indicate ultra-oligotrophic status and no progressive deterioration.

- Extensive farms may also release nutrient bearing effluents through periodic dredging of ponds or channels and may come under scope of these requirements, where not subject to other derogations e.g., as net nutrient sinks in alluvial river deltas.
- Focus should be on managing impacts within defined functional boundaries e.g., loosely following the 'waterbody unit of management' (WUM) approach set out in the EU Water Framework Directive[5].

Considering the cumulative nature of eutrophication and the lentic-lotic categories described above, four working sub-criteria were framed as follows – the fourth sub-criterion being added to support more coordinated monitoring and management actions at a landscape level:

Sub-criterion 1 'Landscape' level pressures, states, and impacts (lentic systems): to address cumulative sectoral aquaculture eutrophication pressures and impacts, based on the trophic status (state) and assimilative capacity of lentic waterbodies with higher nutrient retention characteristics.

Sub-criterion 2 Farm level pressures and impacts (lentic and lotic systems)**:** to address more localised eutrophication pressures and impacts at farm level in lentic and lotic waterbodies.

Sub-criterion 3 Farm level nutrient Input-Output 'management' (IOE; lentic and lotic systems): limiting nutrient inputs and outputs to mitigate ecological impacts.

Sub-criterion 4 Area based management (lentic systems): collective sectoral responses to cumulative pressures and impacts at landscape (water body unit of management: WUM) level.

DPSIR Framework: These 'sub-criteria' and their higher order 'principles', correspond with elements of an *extended* 'DPSIR' (*Driver*), Pressure (e.g., limiting nutrient concentration), State (e.g., trophic status), Impact (e.g. [chl-a,], [DO]), Response (e.g., nutrient management) framework first proposed for development of environmental indicators by the Organisation for Economic Cooperation and Development (OECD)[6]. Figure 1 illustrates how the four revised sub-criteria proposed above could be operationalised within this evidence-based framework incorporating an iterative feed-back/ improvement cycle based on causal interdependencies between these elements.

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[5] The Water Framework Directive (WFD) requires preparation, implementation & review of River Basin Management Plans (RBMP) on a 6-year cycle. River Basin Districts (RBD) and the WFD Waterbodies are important spatial management units (regularly used in catchment management studies), See Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No 2 Identification of Water Bodies. (https://circabc.europa.eu/sd/a/655e3e31-3b5d-4053-be19-15bd22b15ba9/Guidance%20No%202%20-%20Identification%20of%20water%20bodies.pdf)

[6] https://www.grida.no/resources/8124, https://www.fao.org/3/w4745e/w4745e08.htm

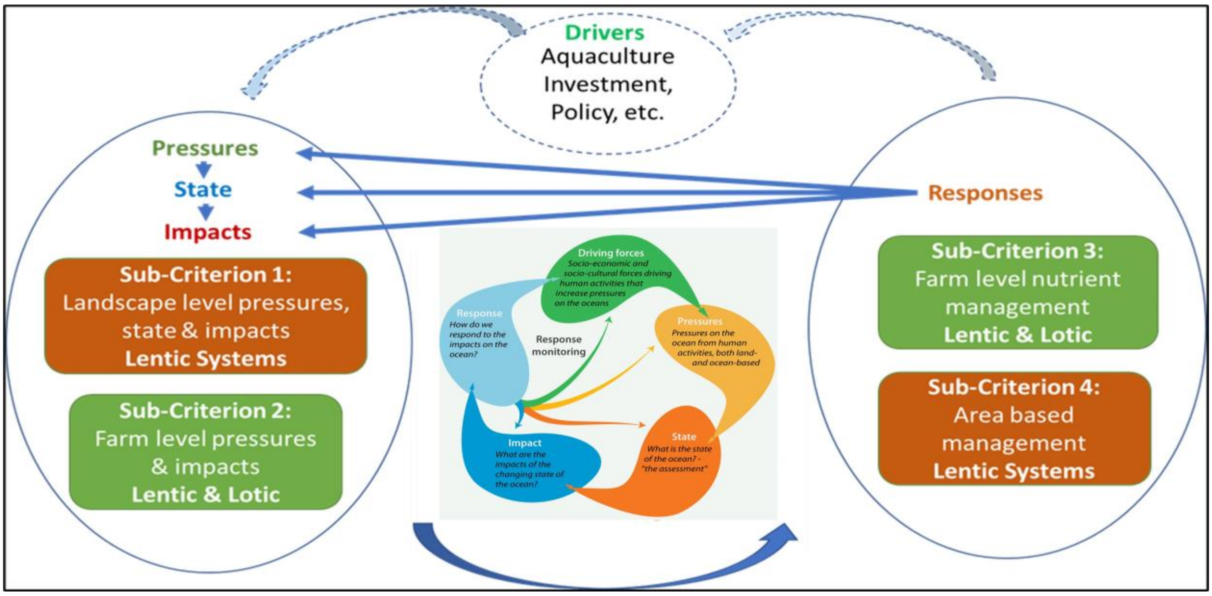

Figure 1. A framework for ASC WQ requirements (adapted from the OECD DPSIR Framework)

Working definitions: In this adapted framework we define the DPSIR indicator categories as follows:

Drivers: are the wider societal forces underpinning aquaculture development. Here we envision water quality PSIR requirements (below) contributing to the wider influence of certification as a market-based form governance. Thus, we propose no such indicators within the standard.

Pressures: are stresses that human activities place on the environment. Here we adapt the 'Pressure' and 'Impact' terms to differentiate water quality parameters as independent (causal) variables e.g., nitrogen concentration ([N]), phosphorus concentration ([P]) and dependent variables, e.g., dissolved oxygen concentration ([DO]), chlorophyll-a concentration ([chl-a]) and Secchi disk transparency (SD) with respect to eutrophication.

State: is the condition of the environment. Here we use the term more narrowly with respect to wider ecosystem condition conferred by trophic status classification. A combination of Pressure ([N] and [P]) and Impact indicators (SD and [Chl-a]) are used to calculate trophic status indices in lentic systems.

Impacts: are direct effects of environmental degradation. Here specifically referring to direct negative effects on aquatic ecosystems e.g., oxygen depletion, SD and total suspended solids (TSS) load, Chl-a etc. (see above).

Responses are responses by society to the environmental situation. Here we differentiate between farm-level responses and more coordinated area based collective action to address cumulative effects of eutrophication. We also frame Sub-criterion 3 IOE requirements as Response (rather than Pressure) indicators for corrective actions against Sub-criterion 1 (landscape level) and Sub-criterion 2 (farm-level) PSI non-compliances.

Risk Based Approach

To avoid unnecessary burden in lower risk situations, indicator requirements are differentiated according to risk-specific contexts, based on the criteria shown in Table 1 i.e., with lentic-lotic RW classification being most fundamental. This also addresses inconsistencies in blanket siting preclusions in current standards e.g., variously for oligotrophic, mesotrophic and meromictic lakes and hydrodynamically isolated embayments (HIE).

Table 1 Criteria for risk-based indicator development

Nutrient retention	Limiting nutrients	Effluent source	Production intensity	Other derogation parameters
Lentic	N &/or P limited	Diffuse	NA	
		Point	Semi-intensive	
			Intensive	
Lotic	NA	Diffuse	NA	Flow rate & [TSS] Effluent flow: RW flow ratio
		Point	Semi-intensive	
			Intensive	

1. Sub-criterion 1: Landscape requirements for lentic receiving waters

1.1 Lentic & lotic receiving waters boundary setting

Risks of eutrophication are relatively greater in 'lentic' compared to 'lotic' systems with higher nutrient export rates. Thus, farms discharging effluents to lotic systems with low HRT are exempted from Sub-criterion 1. Current requirements for lotic FW systems instead focus on localised receiving water impacts; mainly downstream dissolved oxygen (DO) (See Sub-criterion 2) and precautionary 'management' measures to limit nutrient outputs (Sub-criterion 3).

Classification of receiving water (RW) as lentic or lotic is therefore the starting point for implementation.

- For standard setting purposes we propose an HRT boundary of >5 days for what we hereafter refer to as 'lentic' (still and slower flowing) systems i.e., and ≤5 days for lotic (faster flowing systems)[7].
- Calculation of HRT should be based on system volume and average annual flow rate (using the flow assessment method proposed in separate annexes).

[7] There have been attempts to provide objective definitions for "lentic" and "lotic" summarized in Jones et al. 2017. Residence-time-based classification of surface water systems. Water Resources Research, 53(7), pp.5567-5584 but there are no universally agreed upon and readily implemented metrics.

- Greater diligence will be required for classification of transitional systems e.g., impounded artificial lakes or reservoirs, particularly those with relatively narrow, shallow profiles in mountainous terrain, where HRT may be as low as 2-3 days[8].

A full classification methodology is given in a separate annex within the Criterion proposal.

1.2 Characterisation of a lentic waterbody unit of management (WUM)

For lentic systems a WUM should next be delineated as a discrete unit with coherent characteristics in terms of natural processes and land use[9], considering the zone in which cumulative eutrophication impacts may occur, water movement and other relevant aspects of ecosystem structure and function. Existing regulatory boundaries used to assess water quality and set targets for environmental improvements should be used where available[10].

1.3 Stratification and hydrodynamically isolated embayments in lentic systems

Hydrodynamically isolated embayments (HIE) within larger lentic systems should be treated as a separate WUM. Methods for determination of HIE are included in separate annexes within the Criterion proposal.

Current requirements frame stratification effects at the whole lake/reservoir level. The TWG observed potential for more localised effects, particularly in waterbodies with highly variable depth profiles and isolated embayments, which should be considered when setting WUM boundaries.

- Siting should be precluded in shallower systems with a history of episodic adverse turnover events (> 1 per decade) resulting in fish-kills or where there is evidence of a progressive increase in hypolimnetic anoxia.
- DO and temperature depth profiles should be collected at monitoring sites around cages to characterize stratification patterns and to monitor mixing in the WUM. Results will be subject to metric requirements described below.

1.4 Far field (downstream) impacts

Benthic quality requirements permit more severe impacts within a near-field ‘allowable zone of effect’ (AZE) compared to an outer ‘far-field’ zone. Although the AZE concept is of more limited relevance to WQ standards, greater risk may arise when nutrients are exported from a waterbody unit of management (WUM, see below) e.g., due to flushing from embayments during turnover events or following lotic to lentic transitions. The proposed schema does not directly consider such cumulative downstream impacts, however farm-level ‘nutrient efficiency’ requirements (Sub-criterion 3) provide a degree of precautionary protection. The TWG also noted:

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[8] Examples of ‘lake’ residence times are given in the following link: https://en.wikipedia.org/wiki/Lake_retention_time

[9] Guidance for how this might be accomplished is provided in the Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No 2 Identification of Water Bodies. (https://circabc.europa.eu/sd/a/655e3e31-3b5d-4053-be19-15bd22b15ba9/Guidance%20No%202%20-%20Identification%20of%20water%20bodies.pdf)

[10] Note: Water Framework Directive (WFD) implementation has proved challenging where boundaries are operationally (e.g., jurisdictional boundaries) rather than biophysically defined.

- Farms should also review if there are any sensitive downstream ('far field') environments where farming could be contributing to wider unacceptable eutrophication effects. For example, if the farm is contributing to a tipping point in a progressively lentic downstream environment, or if it is causing problems at sensitive times of year.

1.5 Trophic status and assimilative capacity modelling (ACM) for lentic systems

Current status: Currently only FW salmonid (Salmon, Trout) and Tilapia Standards for cage-systems in freshwater lakes and reservoirs directly link Pressure (nutrient concentration) indicators to classification of trophic status[11] (with only P envisaged a limiting nutrient for eutrophication). These standards preclude any upward transition in trophic status as well as placing limits on rate of change in [P] and movement toward such transitions.

The Salmon Standard also requires nutrient assimilative capacity modelling (ACM) i.e., to the next trophic boundary transition or 'breakpoint'), but only for waterbodies <1,000km2, as '*meaningful interpretation of outputs becomes increasingly challenging in larger waterbodies'*. Operators in larger RW must avoid siting in more sensitive locations, including hydrodynamically isolated embayments. A more precautionary maximum limit of 20% [TP] change from baseline is required for larger waterbodies compared to 25% for smaller systems.

1.5.1 TWG recommendations and rationale for lentic farm level survey requirements

The TWG proposed that lentic requirements be further adapted as follows.

- Compliance assessment to be based on two overlapping sets of longitudinal survey instruments at WUM and farm-level (see below). Outcomes will also influence compliance requirements under **Sub-criterion 3** (Farm-level nutrient management and **Sub-criterion 4** (Area Based Management; ABM; lentic RW only).

- Whilst there is a broad consensus around P being limiting for eutrophication in temperate FW systems, greater uncertainty exists for tropical systems where, under certain conditions N may become the limiting macro-nutrient (and N&P may become co-limiting in mesotrophic systems).
- Steady-state equilibria should not be anticipated as eutrophication is a process subject to ongoing and naturally variable rates of change. Thus, in practice, the baseline state will be a parameter average or rate over a defined period for which historic water quality data is available/ selected.
- A simple steady state nutrient loading model is proposed, as a minimalist assimilative capacity study. N & P inputs to be estimated based on limited collection of epilimnetic WQ data in order to determine (i) which macronutrient, N or P, is likely to be limiting for eutrophication[12] (ii) the baseline concentration of the limiting nutrient(s) (iii) the assimilative capacity of the limiting nutrient to the next upward trophic status breakpoint. Requirements should also be extended to lentic saline environments, also highly susceptible to eutrophication.
- The proposed method is viewed as a basic minimum in terms of assimilative capacity assessment; farms can and should use more robust approaches where needed. Where well-

[11] Vollenwieder and Kerekes 1982

[12] Paerl et al (2015) propose a trophic status index (TSI) incorporating a ratio of N:P.
However, greater Challenges remain regarding ability to collect representative samples of [TN] compared to [TP]

developed ecosystem-based water quality targets factoring in eutrophication risks & impacts exist (e.g., the European Water Framework Directive), 'Landscape PSI' requirements should defer to these regulatory frameworks.

- Certification should only be permitted, in any lentic system (FW or saline, temperate or tropical) where the cumulative impact of all farms and other anthropogenic and natural inputs do not result in an upward transition of the WUM trophic status since completion of the first WUM survey - or where appropriate baseline data exists the date when the aligned standard become effective. Determination to be based on calculation of relevant **trophic status indices** using the geometric means of the limiting nutrient(s); [TN] or [TP], [Chl-a] or SD results as described below.

- A uniform limit of 30% maximum increase in the concentration of limiting nutrient(s), over any two consecutive rolling years of monitoring, compared to a baseline value (see below) should be applied to all lentic water bodies regardless of scale etc. This is approximately equivalent to the (most conservative) 20% annual limit for larger waterbodies in the Salmon Standard and is more conservative than some regulatory approaches.
- Limits should be based on the geometric mean of minimum quarterly WQ measurements over consecutive 2-year data collection periods for a delineated waterbody unit of management (WUM) with (i) trophic status limits based on comparison of the most recent 2 years of data with the two years of collection prior to certification of the first UoC in the waterbody, or where available the limiting nutrient concentration at the point of publication of the aligned standard (ii) rate of change requirements which should be based on comparison of successive 2-year rolling (geometric) averages.
- When necessary (only), compliance determinations can be based on single year averages (e.g., for initial audits) using the same 30% rate of change limit (consistent with higher sampling error over the shorter period).
- In the event of non-compliance with the above requirements – or as an alternative to these requirements - farms may elect to engage an appropriately qualified/ accredited third-party to conduct an assimilative capacity study of the WUM, validated by independent experts to a high scientific standard[13], that shows there will be no change in trophic status based on limiting nutrient(s).
    - The approach must consider seasonal variations based on baseline data on farm N&P effluent concentration and volumes relative to the total system flow and background concentrations. Contingent on this, receiving water quality limits may also be imposed beyond the immediate downstream vicinity of the farm i.e., far-field. It should also always be a mandatory requirement for farms discharging to ultra-oligotrophic WUM with biologically active lower layers or other sensitive environments and where it is a requirements of existing statutory water quality limits.
    - If third party surveys also indicate non-compliance, for certification of any sites in the WUM to continue, evidence must be provided of management actions coordinated at

[13] The AC model used should be appropriate for the type of lake under study, including the systems stratification characteristics. The qualification of the person/ agency conducting the study should reflect the degree of eutrophication risk considering the current status and scale of the system. This should incorporate a review of secondary data and catchment land and water use characteristics from satellite imagery. Results should be systematically validated against empirical evidence, including data collected by certified farmers. Further consideration should be given as to how this might be incorporated in area-based management requirements (see Section 4).

WUM level (Sub-criterion 4) that also correspond with evidence of an arrest or decrease in the rate deterioration.

A. Landscape lentic 'WUM level' survey: This is a multi-site survey of epilimnetic water quality designed to account for spatial variability in the WUM. Its primary purpose is to identify/ assess **(a) limiting nutrient(s) for eutrophication (b) trophic status (TS) (c) assimilative capacity for the limiting nutrient to the next upward TS breakpoint and (c) nutrient source apportionment for the entire WUM for BOD assessment.**

- A single WUM survey can be used to determine compliance requirements for all UoCs within a WUM.
- Sampling of all parameters to be repeated quarterly aiming to capture seasonal variations. Each sampling event must include a (i) minimum of 10 sites where the WUM surface area is less than 200km^2 or one (1) site for every 20km^2 of WUM area, (ii) all farm reference sites (see below, should be included in this total - but not farm impacted downstream sites.
- WUM compliance decisions will be based on comparison of geometric means over successive rolling two-year monitoring periods (rate of change parameters) or baseline data (trophic status).
- Farm level compliance will be based on comparison of farm impacted site with WUM averages.
- In the event of WUM-level non-compliances farms will be expected to cooperate on coordinated management actions (Sub-criterion 4: ABM) including adoption of more conservative 'nutrient-efficiency' metric limits under Sub-criterion 3.

The following sampling and analytical steps are proposed for the WUM level survey:

1. **WQ parameters:** Concurrent WUM level measurements to be made on the following parameters commencing at least 2 years prior certification of the first UoC in the WUM.

   (i) **Pressure indicators for trophic status assessment:** total nitrogen **[TN] and** total phosphorous **[TP]**, water transparency based on **Secchi-disc depth (SD)** and **chlorophyll-a [Chl-a].**

   (ii) **Other 'Impact' indicators:** DO & temperature depth profiles should also be collected concurrently at the same sample points.

- At each site, epilimnetic (0.5m) samples are to be collected for already certified UoCs. At each location, SD is to be measured and TN, TP and Chl-a are to be analysed. Profiles for temperature and DO are to be collected at 5m depth intervals to the shallowest of: (a) a depth of 1m off bottom, (b) a depth where the overlying 5m of DO measurements are 2mg/l or less or (c) 50m. Profiles can be made using an appropriate calibrated probe.

2. **Determination of limiting nutrient(s) and trophic status**

   (iii) Calculate normalised trophic status indices (TSI) of the WUM based on the geometric mean of the Pressure indicators over the entire 2-year reference period following the annexed method.

   (iv) Determine limiting macro-nutrient(s): Identify N & P macro-nutrient(s) that are limiting for eutrophication of the WUM or any relevant sub-system following the annexed method.

   (v) Determine the trophic status of the WUM following the annexed method. The choice of which of the four TSI results to use should reflect the following considerations.

   - Commence with the limiting macro-nutrient(s) identified in step (iv).

- SD will serve as a 'supporting' indicator for oligotrophic WUM only, i.e., where it correlates closely with primary productivity.
  - If the annual geometric mean of SD readings of successive farm-level surveys under Sub-criterion 2, is >10m farms will not be required to measure other TSI parameters.
  - However, where there is a marked inconsistency between the limiting nutrient concentration (see below) and SD trends farms **must use [Chl-a]** as the most robust indicator of trophic status, overriding all other TSI parameters.

3. **Conduct a nutrient source apportionment assessment**: calculated as the total load of limiting nutrient(s) originating from all aquaculture operations discharging directly to the WUM as a percentage of the total nutrient loading (from all sources) derived from the eplimnetic survey (see annexed methods).

   - Based on the outcomes of this modelling - the total direct sectoral contribution of aquaculture should not exceed **50% of the total limiting-nutrient input(s)** measured in the epilimnion[14]

4. **Biological oxygen demand (BOD) as a further WUM-level pressure indicator**

   Where N is determined to be limiting and the rate of increase in [N] over successive rolling 2-year monitoring periods exceeds 20% – a 5% reduction in modelled BOD based on WUM survey data including sectoral source, apportionment should be applied as an area-based requirement (Sub-criterion 4). However, the requirement should be limited to a monitoring requirement in v1.0 of the aligned standard subject to review of farm data submission to ASC.

Biological oxygen demand (BOD) rationale: BOD accounts for bacterial metabolism more sensitive to nitrogen limitation, thus it could serve as an 'Impact' indicator of eutrophication impacts in sub-photic zones, in more meso-eutrophic/ mixotrophic contexts with high Ps loadings[15], where there is greater probability of [N] being limiting or co-limiting for eutrophication (a more prevalent situation in tropical contexts). The TWG acknowledged practical limitations around laboratory-based analysis of BOD for settling of farm-level limits but recommended that BOD of the entire fed/ fertilised aquaculture sector discharging effluents to a WUM be modelled overt 2yr rolling monitoring periods– using the nutrient mass-balance approach [16] (including total organic carbon; **TOC**) detailed in the current ASC Salmon Standard.

5. **DO and temperature depth profiling in stratified lentic systems**

   Measurement of oxygen and temperature-depth profiles will be required in stratified (meromictic water) bodies or their stratified parts. Holomictic systems experiencing full-turnover events in most years are excluded from the requirement.

   - Using a temperature compensated DO probe, profiling should be extended below the photic zone (2X SD)[17] and to the start of the anoxic zones or depth at which [DO] variability

[14] Assumed to representative of the mixed biologically active upper layers.
[15] Nitrogen can also be limiting in oligotrophic waters, particularly in mountainous regions or high latitudes where both phosphorus and nitrogen are naturally in short supply.
[16] Based on estimation of the difference between N & C input/ output in feed and fish production over a production cycle
[17] If aquaculture is purely in photic zone, e.g., shallower areas, sampling should potentially be extended to deeper areas.

ceases to be significant. The candidate depth for profiling can be defined as the minimum of: (a) 1 m off bottom, (b) the depth at which there is 5 m of overlying water where [DO]<=2mg/l or (c) 50m. Data should be collected simultaneously with monthly water chemistry samples at the farm and reference sites. Proposed metrics are as follows:

(i) **Depth of DO depletion** this is the shallowest depth over the preceding 12 months where the dissolved oxygen concentration was less than 4mg/l. In the event that DO concentrations never drop below 4mg/l, this is the maximum depth of the DO profile.

(ii) **Depth of anoxia** this is the shallowest depth over the preceding 12 months where the dissolved oxygen concentration was less than 2mg/l. In the event that DO concentrations never drop below 2mg/l, this is the maximum depth of the DO profile.

A decrease in depth of > 25% in either the zone of depletion or anoxia, compared with the previous 24-month farm-level monitoring survey will result in a non-compliance.

DO & temperature profiling rationale: The TWG observed that monitoring of DO/ temperature profile trends can be an excellent indicator of longer-term eutrophication impacts in stratified systems – and that climate change is pushing all lakes into less mixed meromictic states. If a water body can be demonstrated to be meromictic over a sufficiently long period, nutrients falling through the active zone to bottom waters/ sediments are likely to be sequestered over the longer term.

B. Lentic farm level survey: The following sampling and analytical steps are proposed:

- Farms to be responsible for monitoring at an impacted (downstream) site and unimpacted (upstream) reference. The unimpacted site will contribute to the WUM sample frame (see above)
- Sampling to commence at least one year prior to initial certification of any site in the WUM, with quarterly measurements taken, coordinated to be concurrent with WUM survey monitoring dates.
- The same pressure and impact (i.e., [N], [P], [Chl-a], Secchi and DO/ temperature profiling) and state indicator requirements, metric limits and derogations will be imposed at farm as at WUM level e.g.
    - Inputs from new or expansion of existing certification cannot result in an upward transition of TSI breakpoints based on measurements at the downstream site.
    - The annual geometric mean of the limiting nutrient or [Chl-a] at the downstream RW site shall not be ≥30% higher than the previous 24-months farm-level average.

- To preclude localised WQ (and benthic) impacts, cages should only be sited at locations with a minimum of 2x cage depth or ≥ 10m depth; whichever is greatest.

Support tools: An Excel spreadsheet support tool for clients and auditors, is being prepared. This will include worksheets for calculation of geometric means, limiting nutrient(s), trophic status index and assimilative capacity modelling and for Sub-criterion 2, lotic RW flow estimation and nutrient concentration estimation.

1.6 Exemptions to landscape level requirements in current standards & variance requests

The Salmon, FW Trout and Tilapia Standards preclude certification of cage-farms sited in mesotrophic systems ([TP] >20 ug/l) to limit risks associated with turn-over in the meta and epilimnion - with derogations for closed land-based systems. The Tilapia Standard precludes cage-farm certification in ultra-oligotrophic systems as well as mesotrophic lakes.

The highest number of historic water quality variance requests (VRs: 13 to mid-2021) were on limits on the discharge of phosphorous by land-based producers of salmon and trout smolts. The VRs were approved based only on the Salmon standards failure to *address effluent discharge by smolt producers into a marine* [i.e., rather than FW) *environment 'in a binding manner*.

The salmon standard exempts closed production systems i.e., land based and floating closed containment systems (FCCS) from water quality requirements, when they can demonstrate **collection and responsible disposal of > 75% of solid nutrients and > 50% of dissolved nutrients** (through biofiltration, settling and/or other technologies).

- The TWG felt preclusions on certification in permanently stratified, ultra-oligotrophic and mesotrophic systems in current standards should be replaced with more context specific risk-based requirements.
- Farms discharging effluents to saline RW should also be subject to the same requirements as FW RW i.e., subject to lotic-lentic classification (above), limiting nutrient and assimilative capacity requirements (below). Residual current patterns should also be assessed in tidal settings.

Five VRs (approved) requested a reduction in N&P monitoring frequency from the weekly periodicity required to a quarterly basis - based on the homogeneity of long-term water quality data and (in one instance) DEPOMOD modelling that determined separate pen arrays to be in a single allowable zone of effect (AZE).

- Consistent with this determination, the TWG recommended WQ monitoring to be at a minimum quarterly basis subject to variability in local environmental conditions. Sites determined to have a single contiguous AZE should also be considered as a single entity for farm-level (upstream-downstream) WQ monitoring.

2. Sub-criterion 2: Farm Level Pressure and Impact indicators - lotic systems

2.1 Background

Requirements under Sub-criterion 2 address ‘Pressures’ and ‘Impacts’ at the individual farm level in both lentic and lotic systems. Examples of such indicators in current ASC standards are as follows:

(i) **‘Pressure’ Indicators**: include causal nutrient concentrations e.g., total (organic and inorganic) [N], [TP], [Chl-a], SD.

(ii) **'Impact' indicators**: correlated with the causal factors above: dissolved oxygen (DO), DO%, Daily Diurnal DO (DDDO) fluctuation, total suspended solids/ turbidity levels (TSS)[18].

Whereas cage systems predominate in 'lentic' FW and marine waters, land-based systems are most prevalent systems discharging to flowing 'lotic' systems (e.g., rivers, streams, canals, creeks etc.). More intensive land-based systems are likely to source water from, and discharge effluents to flowing waters from a riparian location. Less intensive, pond systems including shrimp and tilapia farms may also apply organic and inorganic fertilisers to promote primary production. However, such systems are likely to have relatively high HRT corresponding with minimal discharge requirements, principally around harvests.

No trophic status or assimilative capacity assessments (State indicators) of the type described for lentic RW are feasible/ required for lotic systems. Instead, a more precautionary approach is proposed with limits on the rate of discharge of nutrients in farm effluents relative to receiving water flow and concentration[19]. Metric limits are set on just one Impact indicator; DO. These attributes address auditing challenges associated with periodic/ irregular effluent releases (from culture units or treatment systems) and also limit need for baseline data collection compared to lentic systems.

The approach aims to limit acute local impacts of high inputs on sensitive systems and potential cumulative 'far-field' downstream impacts e.g., following transitions to reservoir impoundments with oligotrophic background conditions. Greater risk of adverse water quality impacts exists in more sensitive 'oligotrophic' headwaters compared to lower alluvial deltaic river zones with naturally high suspended/dissolved solids loads and flowrates for which derogations are recommended.

2.2 Recommendations and rationale for lotic farm level survey requirements

Lotic farm-level indicators will require monitoring at one of more of the following samples sites adjacent to the farm:

- RWRP - Receiving water reference point (unimpacted upstream sample station[20])
- RWFE – Receiving water (farm) effluent outfall point – effluents to sampled before mixing with RW
- RWFA – Receiving water farm afar (sample station just out with a downstream mixing zone) (Residual current direction should also be assessed in tidal settings).

Monitoring should be initiated at least 12 months prior to initial audit at a minimum quarterly frequency to account for seasonal variation.

2.2.1 Pressure metrics

Measurement of RWRP and RWFE [N] and [P] concentrations, along with stream and effluent flow rates are used to model RWFA concentrations i.e., no downstream monitoring will be required for [N] and [P] pressure indicators (only impact indicators including DO). This addresses the challenge of detecting episodic effluent releases.

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[18] Closed production systems (exchanging ≤10% of total water volume per day) in the Salmon Standard are further exempted from certain discharge requirements.

[19] Siting limitations may also be imposed by other aligned standard criteria e.g., addressing water abstraction (relative to vital flow), navigation impedance, protected/ sensitive habitats etc.

[20] Unimpacted by the farm and as far as possible, other point-sources of nutrient enriched effluents

The following requirements are proposed for fed and/ or fertilised land-based farms with point source of effluents discharging to lotic systems with HRT <5 days based on system volume and average annual flow i.e., including most rivers, streams and man-made canals outside the farm boundary.

(i) **Determine RW flow rates** (or residual tidal flows) based on secondary data (e.g., local authority or scientific study) where available, or on quarterly measurements over at least 12 months[21].

(ii) **Determine farm water use rates** This must be recorded at least quarterly covering periods of lowest flow, over at least 12 months prior to initial certification. Rates to be based on effluent volume (RWFE) - rather than abstraction volumes at RWRP.

- Ongoing [N] & [P] monitoring will only be required if the above data (the maximum of the two estimates when both are available) indicates that farm water use rates, exceed 10% of the receiving water flow rate at any time including periods of minimum flow rate[22].

(iii) **Measure [N] and [P]** in water samples from farm RWRP and RWFE at least quarterly over the 12 months prior to initial certification. Sample timing should account for anticipated peaks in upstream nutrient concentrations and farm effluent loads.

These results should then be used to determine compliance against the following requirement:

- [N] and [P] macronutrient concentrations in farm effluents must be managed to ensure the modelled geometric mean of the downstream concentration is not more than 25% greater than the concentration measured in the farm inflow, based on the annexed calculation method.

2.2.2 Impact metrics

For fed/ fertilised land-based systems, existing limits on DDDO fluctuations with a maximum of ≤ 65% at RWFA should be retained.

3. Sub-criterion 3: Farm-level nutrient efficiency management

3.1 Background

Species and system-specific ‘nutrient efficiency’ requirements are designed to promote interceptions at the following production stages where feasible.

A. **Feed quality assurance** – during manufacture and on-farm

B. **Assimilation in cultured species** – estimated in harvested fish, standing stock and mortalities.

[21] Baseline (reference) data collection should account for seasonal variability in stream-flows and ambient (i.e., non-anthropogenic) N&P levels (which may be highest during rains due to leaching). should be collected over a year or more. Limits and sampling requirements should then be adjusted to account for worst-case impact scenarios based on concurrence of farm nutrient discharge rates and environmental conditions.

[22] This requirement effectively precludes land-based farms with point-source effluents

C. **Other interception during and post-culture -** effluent treatment; solids settlement and storage systems, biofiltration and adsorption of dissolved P[23]. Results are expressed as TN & TP input and/ or release (discharge) per metric tonne of harvest over 12 months prior to audit. Associated requirements set metric limits for input (N & P) and/ or output to RW (TP only).

3.1.1 Feed quality assurance

Feed quality metrics correlated with eutrophication risk include (i) protein digestibility as the main source of N & P in fish feeds, (ii) presence of anti-nutritional factors (especially in plant-based ingredients such as phytate), (iii) pellet buoyancy/ sink rate (iv) water stability (v) fines content (vi) format (non-extruded/ extruded) (vii) pellet size (viii) protein content (ix) binder (e.g., starch) content.

On-farm risks of quality deterioration are associated storage and handling conditions and delivery systems etc. Upstream (manufacturing) assurance risks are also likely to be greater in sectors with more fragmented feed manufacture and supply chains.

- The TWG recommends retaining a limit on fines content[24] as a simple low-cost on-farm method. Derogations on this requirement based on effective standard operating procedures (SOPs) are also proposed consistent with VRs submitted by Salmon farming companies.

Compliance against proposed requirements under sub-criteria 1 and 2 will help leverage feed manufacturer performance improvements on other upstream quality attributes (and may also be addressed as part of sourcing requirements in a future ASC feed standard revision).

3.1.2 Interception of Settleable Solids (SS)

Intensive culture ponds and settling ponds and canals accumulate sludge and sediments that need to be removed periodically. Sediment from lined and permanently aerated intensive ponds is of lower density (more fluid) and more enriched in organic matter than sediment in semi-intensive and extensive ponds.

Well dimensioned settling basins (with a hydraulic retention time (HRT) of 6 hours and at least 1.5 times this minimum HRT volume) or more are effective in removing larger particles; including about 100% of settleable solids (SS), 90% of total suspended solids (TSS), 60% of biological oxygen demand (BOD), 50% of phosphorus and 30% of nitrogen[25].

- Point-source effluents from intensive closed production systems (permanently aerated or with high (weekly or more) water exchange rates at peak biomass) should require treatment to lower suspended concentrations. Requirements should also be extended to floating closed-cage containment systems with ability to interception solids unlike open cage systems.

- Performance limits should be set on effluent Settleable Solids (SS) rather TSS concentrations. SS can be measured easily, accounts for the fraction of the TSS that will settle out fairly rapidly and is most environmentally harmful with respect to BOD, {TP] and turbidity. An SS limit of 3.3 millilitres per litre was defined for discharge permits in a USEPA study of aquaculture facilities (EPA, 1974).

[23] Assumptions are also made for adsorption of dissolved P in earthen ponds.

- [24] A simple low cost method requiring only an over can also be used for on-farm assessment of pellet water stability

[25] Boyd & Queiroz, 2001; Ozbay & Boyd, 2004, Teichert- Coddington et al., 1999

- Auditors should be required to observe operation of treatment systems & SS measurement.

3.1.3 Nutrient input output efficiency indicators (IOE)

Current nutrient 'IOE' indicators set N and P limits per kg of harvest based on the following mass-balance accounting approaches:

(i) **Method A – for cage and less-intensive land-based systems:** inputs in feeds and/ or fertilisers net of removals in harvested fish[26] and unassimilated P intercepted within earthen pond systems.

(ii) **Method B – for more intensive land-based systems:** release of P (only) based on differences in measured influent and effluent concentrations.

Further allowances are made for documented nutrient removal using post-culture treatment systems for any land-based system.

- **Responsive feedback loops:** The TWG recommends retention of these IOE measures (i) as precautionary requirements for lotic systems (ii) but with addition of responsive feedback loops for lentic systems. This will transition them from 'Pressure' to 'Response' indicators. Limits on proposed IOE indicators could then be made more stringent subject to area-based management agreements (Sub-criterion 4) following non-compliance against WUM level TSI proximity or rate of change 'alert' indicators (Sub-criterion 1)[27]
- **Mass balance method B** (above); requiring measurement of effluent and influent N and P concentrations (already collected where sites are eligible for Criterion 2 requirements) should be applicable to all intensive point-source effluent farm systems in lotic waterbodies. This will include all farms that abstract more than 10% of upstream flow in more sensitive environments (Sub-criterion 2).
- **Mass balance method A** (above); which only requires data on feed/ fertiliser inputs and harvested output/ standing stock will be applicable for all diffuse-source systems – this should also be a mandatory requirement for all lower risk extensive or semi-intensive point source systems.

- **Setting nutrient load Limits:** Aligned standards should only place limits on effluent nutrient loads, as N and P inputs are already limited by feed metrics: FFDRm (incorporating eFCR) and PER, noting that most N&P in formulated diets will be in the protein component.
    - In lentic systems limits should be placed on limiting nutrient(s) only, and in lotic systems, on both N & P. Within these parameters, species specific limits in current farm standards should be used to set initial limits in the aligned standard (Table 2).

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[26] Framed as 'nutrient-use efficiency'.

[27] This will merit further consideration when the TWG considers impacts in flowing water or high energy systems. A case could also be made for maintenance of efficiency requirements as precautionary measure linking more generally improvement of husbandry measures with positive impacts on other criteria e.g., marine ingredient use, health management etc).

- Nutrient load limits should also be adjusted to account for life stage as well as culture species, noting higher dietary P requirements for juveniles; the basis for Several VRs approved based on animal welfare justifications.

Table 2. Nutrient load limits in current species-based ASC farm standards (tbc)

	kg N/T	kg P/T
Salmonids (land-based)	-	≤ 4
Salmonids (cages)	-	tbc
Pangasius	≤ 27.5	≤ 7.2
Tilapia	≤ 27.5	≤ 20
P. monodon	<32.4	<5.4
P. vannamei	<25.2	<3.9
Cherax spp., Procambarus spp., Astacus spp	<26.1	<4.0
Macrobrachium spp	<39.2	<6.1kg

4. Sub-criterion 4: Area based management – Lentic Systems

4.1 Background

Sub-criterion 4 requirements are intended to promote coordinated IOE actions for (i) WUM level WQ monitoring (ii) collection actions to address non-compliances against Sub-criterion 1 WUM level requirements and (iii) wider participation in assimilative capacity-based planning.

ABM requirements will only apply to lentic systems under this alignment, though the TWG recommended re-visiting options for lotic systems in future standard revisions.

WUM boundary setting should also reflect ability to realistically manage eutrophication risk within it; the AMA should also ideally have a catchment perspective.

Derogations could be justified where there are effective statutory water quality targets addressing eutrophication risks, that also incorporate area-based carrying capacity-based planning within appropriately defined boundaries.

4.2 TWG recommendations for aligned indicators

An Area Management Agreement (AMA) is a formal binding agreement between producers within the WUM, including measures to monitor, prevent and mitigate eutrophication impacts. Specifically, the AMA should support coordination of the following WUM level actions:

a) **Environmental monitoring:** implementation of a WUM level survey, with a baseline to be initiated 2 years prior to the first audit in the WUM (Sub-criterion 1).
b) **Data sharing:** between members of an AMA (see below), other non-ASC certified aquaculture entities and other stakeholders (sectoral contributors to/ impacted by eutrophication, civil society bodies etc.).

c) **Carrying capacity-based planning:** to reduce rates of transition towards TSI breakpoints. A source apportionment model to identify all significant upstream nutrient sources should be the collective responsibility of AMA (see Criterion 1 and Annex 1) with obligations codified in a WUMP (see below).
d) **Coordination of corrective (Response) actions** to prevent and mitigate non-compliances at WUM level, Including sectoral application of nutrient-efficiency Response measures under Criterion 3.
e) **Outreach to other aquaculture entities and other stakeholders in the WUM**

Requirements should be enforced through an agreement with the regulator or a formal MoU outlining the agreement between producers in the WUM, with an option to elevate this to a more legally binding contract should the membership wish.

- Evidence is required that UoC is actively participating and can demonstrate compliance with the plan's commitments.
- Verification is expected to include review evidence of the presence of the AMA and the coordinated practices applied (e.g., written records, meeting notes, contractual agreements, interviews).
- If area-based management is already a regulatory requirement of the farm's jurisdiction, then farms will use this definition of "area" for the purposes of these requirements. Where there is a pre-existing AMA i.e., designed to meet other certification or legal WQ requirements, mapping of and potential for integration of ASC requirements within a single or confederated entity, should be attempted with evidence of proactive steps available for audit.
- There should be clear documentation of the farms/companies included in the ABM, contact people (including contact information) and mechanisms for communication.

4.3 AMA participation

Actions a) to b) above including the initial WUM survey will be the collective responsibility of any UoCs already certified or entering certification at that point, with new applicants required to participate in successive monitoring phases.

Where the following conditions exist, then certified producers **must formalise an AMA** and demonstrate concrete actions to reduce total sectoral nutrient inputs through actions d) and e) above i.e., including setting of more stringent farm-level nutrient efficiency limits (Criterion 3).

(i) there are multiple ASC certified UoCs operated by different companies within a WUM
(ii) total aquaculture sector inputs contribute >50% of the modelled limiting nutrient(s) load to the WUM?
(iii) assimilative capacity modelling indicates the WUM is approaching a TSI breakpoint?
(iv) A non-conformance is detected in WUM level monitoring against a limiting [N], [P] or Chl-a rate of change indicators.

Outreach to other water users

- AMA participation should, at a minimum include all farms owned by any company with or seeking certification in the WUM, though not all must be applying for certification.
- Evidence of outreach to encourage voluntary membership other aquaculture farms releasing nutrients to the WUM should also be available for audit.

- Special focus should be given to inclusion of farms certified under other third-party audited standards sharing aligned WQ objectives.
- At a minimum such additional members should participate in reciprocal sharing of water quality monitoring data (i.e., creating an option to expand the WUM sample-frame) and any other information needed to ensure coordination.

Where conditions (i) to (iv) above are true outreach should extend to support measures for smaller non-certified farms to improve their nutrient use efficiency (recognising that reducing production will be more challenging). This may extend to broader advice on e.g., feed and seed input quality assurance, health management etc.

Coordination of WQ and area-based requirements under other WQ indicators

- As far as possible, water quality actions should be coordinated with other area-based requirements in the aligned standard, particularly those designed to prevent disease outbreaks and parasite transmission (e.g., synchronised year-classes and fallowing) - ideally under the same AMA.

  The AMA would also be well placed to coordinate any far-field benthic management actions – noting farms sharing a conjoined benthic AZE could be considered as a single site for water quality sampling.

5. WQ supplementary data requirements

Requirements can be broadly divided into data required to (i) demonstrate compliance with ASC indicator metric requirements and (ii) underpin future standards development.

TWG Recommendations

1. Farms to submit to ASC and make publicly available primary baseline and monitoring data.
2. Farms to submit data to allow mass-balance modelling of limiting nutrients and trophic status, assimilative capacity, and BOD (see Criteria 1 and 4). This may also require farms to request data from non-certified farms or to collaborate on modelling using proxy estimates e.g., based on cage numbers/ area.

- Noting that limited resources had been available to curate or analyse historic data submissions, the TWG recommended that future supplementary data requirements should be based on (i) a priori analytical model clearly linked to evaluation of existing requirements or creation of new metrics (ii) more systematic protocols and templates to support more standardised data collection.