Criterion: 2.6 Benthic Impacts

Key considerations

This criterion has been developed with the support of a Technical Working Group (TWG) formed by ASC. A proposal for revised requirements for cages and suspended molluscs in marine systems and a recommended approach for cages in freshwater systems (lakes and reservoirs) was subjected to a 60-day public consultation in March-April 2022. Revised requirements are now presented for another round of consultation for further feedback. The TWG will use this feedback to develop the final requirements of Criterion 2.6: Benthic Impacts.

Marine/brackish cage systems:

Based on the feedback received from the past consultation, the scope of the proposed requirements for marine systems has been expanded to incorporate brackish systems. The proposed revised indicator requirements for marine/brackish cage systems are based on a three-tiered sampling approach. The approach is designed to reduce the compliance burden on farms while enhancing a farm's understanding of its benthic impacts. Under the approach, a farm will conduct increasingly detailed benthic analysis if initial results in Tier 1 or Tier 2 do not meet the established limits. Conversely, a farm that meets the limits in Tier 1 does not need to conduct additional analysis and by doing so, the standard rewards good farm management. The sampling program requires monitoring stations to be established within three Ecological Quality Status (EQS) monitoring zones. A range of abiotic and biotic indicators have been selected which serve as proxies for numerically classifying the EQS of marine/brackish cage farm systems.

The proposed tiered approach uses total free sulphide (S^{2}-) measurement as one of the primary indicators for monitoring the effects of organic enrichment on benthic habitat, biodiversity and ecosystem function. Whilst the standard approach for measuring S^{2}- in surficial sediments has been the Ion-Selective Electrode (ISE) method, owing to the relative simplicity compared with other analytical options available, numerous users have stated that the ISE method exhibits low analytical robustness and is prone to contamination and other measurement biases. As such, the revised requirements recommend the use of UV spectroscopy technique (S^{2-}_{UV}).

Some international regulatory monitoring standards for benthic organic enrichment already meet or even exceed the goals of the revised ASC requirements. Flexibility is therefore provided to allow operators to submit user-defined specific benthic monitoring programs. The ASC will determine, through an internal and external expert review process, if the proposed user-defined specific monitoring programs meet stringent ASC requirements. However, operators are encouraged to adopt the multi-tiered monitoring system that addresses all mandatory requirements for benthic organic enrichment monitoring with approval of user-defined specific monitoring programs limited to exceptional and well-documented cases.

Suspended marine mollusc systems:

The proposed revised requirements for monitoring mollusc farms display many similarities to the marine/brackish cage systems requirements, with the exception that the sampling effort is focussed on detecting organic enrichment impacts inside the farm boundaries as opposed to sampling adjacent to the cages. The revised requirements utilise the same tiered sampling and analysis approach and a range of abiotic and biotic indicators. The sampling design uses a "gradient" approach in which seabed samples are collected at stations situated 10 m apart from each other along transects that extend across the farm boundary. Suspended marine mollusc farms that demonstrate three consecutive years of acceptable results may reduce sampling to once every five years as long as there are no significant changes to farming practices.

As with marine/brackish cage systems, flexibility is provided to allow marine mollusc farming operators to submit user-defined specific benthic monitoring programs, where these are determined to go beyond the revised requirements of the ASC.

Considering the feedback received during the last consultation, the revised requirements for these systems provide more detail on how to proceed in situations where farms are located over hard bottom. Likewise, more details are provided on the location and directions of the sampling transects required and on the location of reference sites.

Cages systems in lakes and reservoirs:

Similar to the proposal for marine/brackish systems, the proposed requirements for cages in lakes and reservoirs incorporate tiered sampling, an EQS classification and direct benthic monitoring. Compliance against the requirement of meeting an acceptable benthic status (Indicator 2.6.2) is not, however, required for the first three years of the aligned ASC Farm Standard being effective. Currently, none of the existing ASC freshwater-related standards includes benthic requirements. One explanation for this has been that the diversity of freshwater aquaculture systems makes it difficult to develop standardised benthic requirements. Also, the relative lack of scientific literature has hampered the development of such requirements as most freshwater aquaculture environmental impact studies have focused on water quality rather than benthic impacts. ASC believes the proposal is a step forward in assessing aquaculture impacts in lakes and reservoirs. In that context, and since farms will need to comply with the monitoring and reporting requirements of the standard (Indicators 2.6.1 and 2.6.3), it is expected that the information generated during this period will provide meaningful knowledge and data which will serve to better understand the impact of aquaculture in lakes and reservoirs. Likewise, the information will be used to support or revise the proposed requirements, with the long-term goal of helping the industry to mitigate impacts on those systems.

Freshwater systems that discharge into rivers:
The TWG is proposing the maintenance of current requirements for systems that discharge into rivers (i.e., macroinvertebrate surveys in the receiving water body downstream and upstream of the effluent discharge point, as per the ASC Freshwater Trout Standard and Section 8 of the ASC Salmon Standard).

For information on the rationale from the TWG for the proposed revised indicator requirements, see the "Whitepaper on Standards for Aquaculture Impacts on Benthic Habitat, Biodiversity and Ecosystem Function".

Scope Criterion 2.6 – Every UoC using cages in marine/brackish water or freshwater lakes/reservoirs or suspended marine mollusc systems

Rationale – The most common aquaculture production systems discharge effluents containing organic material (e.g., faeces, uneaten feed) and, on some occasions, heavy metals (i.e., copper from treated nets). Although the manner of discharge can vary (dispersed vs point-source), all have the potential to negatively impact the structure and function of the receiving ecosystem.

When the deposition of organic material occurs at a rate that exceeds the capacity of the receiving environment's ability to assimilate it, changes in the chemical and physical composition of the sediment can occur, which in turn can negatively affect the (in)faunal benthic community. The extent of these impacts depends on the flux of organic material released by the operation, the characteristics of the water body, and the natural decomposition capacity of the benthic microbial community. However, if managed well, the rate of deposition is kept within the rate of natural aerobic decomposition, thereby minimising benthic impacts.

Intent – To maintain the ecosystem structure and function of the area surrounding the farm.

Indicators:	
Indicator 2.6.1	The UoC shall monitor the benthos for organic enrichment following the monitoring programme outlined in Appendix I[1].
Indicator 2.6.2	*Indicator scope[2]: marine/brackish cages and suspended marine mollusc systems* The UoC shall meet the benthic status "acceptable" in the area surrounding the farm as outlined in Appendix I.

Indicators on reporting:	
Indicator 2.6.3 Reporting symbol	The UoC shall annually report to ASC on EQS categories in the surrounding area, according to Annex 2 and using the template provided on the ASC website.

[1] Farms situated in areas classified as having "hard bottom" are exempted from the revised requirements. Bottom video or other evidence is required to support the classification "hard bottom".

[2] For cage farms in lakes and reservoirs, compliance with the requirement of meeting an acceptable benthic status in the area surrounding the farm (Indicator 2.6.2) is not required for the first three years of the aligned ASC Farm Standard being effective. Compliance with the monitoring (2.6.1) and reporting (2.6.3) requirements is required from the effective date of the ASC Fam Standard.

Appendix I: Benthic Monitoring Programme

Introduction

This appendix describes the standardised requirements for an ASC benthic monitoring programme but also includes an option for a user-defined benthic monitoring programme.

Section 1.1 - The Ecological Quality Status (EQS) System and Categories

In order to make consistent decisions related to the impact of organic enrichment, Ecological Quality Status (EQS) categories are defined based on specific abiotic and biological quality elements that collectively describe the health/ecological status of the benthic macroinfauna community. The EQS categories system is widely reported in the scientific literature; it is currently in use for conducting regulatory sediment quality assessments in multiple countries and underpins some of the current ASC standards (e.g., the Salmon Standard). EQS categories are defined using standardised descriptions of the associated macrofaunal community (Table 1).

Table 1: Descriptions of benthic macrofauna assemblages for each of the five Ecological Quality Status (EQS) categories.

EQS categories	Definition
High Status	***No or very minor disturbance****:* Species abundance, richness and diversity is high and sensitive taxa dominate. Opportunistic taxa are absent or of negligible abundance. Geochemical quality elements indicate aerobic conditions with low free sulphide toxicity.
Good Status	***Slight disturbance****:* The level of diversity and abundance of invertebrate taxa is slightly reduced. Most of the sensitive taxa are present but slightly reduced. Opportunistic taxa are present but negligible in abundance. Geochemical quality elements indicate aerobic sediment conditions with a slight increase in free sulphide levels.
Moderate Status	***Moderate disturbance****:* The level of diversity and abundance of invertebrate taxa is moderately reduced. Sensitive taxa have negligible abundance or are absent. Tolerant and first-order opportunistic taxa co-dominate in abundance. Geochemical quality elements indicate a moderate increase in anaerobic conditions with free sulphide levels known to be lethal to sensitive and indifferent taxa.
Poor Status	***Major disturbance****:* Evidence of major alterations to the values of the biological quality elements.

	Diversity is greatly reduced with sensitive and indifferent taxa showing negligible abundance or are absent. Tolerant taxa are sub-dominant to first-order opportunistic taxa. Geochemical quality elements indicate a major increase in anaerobic conditions and sulphide concentrations lethal to most taxa.
Bad Status	***Severe disturbance****:* Evidence of severe alterations to the values of the biological quality elements and in which large portions of the relevant biological communities normally associated with undisturbed conditions are absent. First-order opportunistic taxa dominate but are greatly reduced in abundance. Geochemical quality elements indicate a severe increase in sulphide concentrations that are lethal to all taxa.

Section 1.2 - Thresholds and Numerical Boundaries for Indicators of Organic Enrichment and Corresponding EQS Categories

The interpretation of monitoring data on abiotic or biotic indicators of organic enrichment requires thresholds and numerical boundaries to distinguish the five EQS categories (High, Good, Moderate, Poor, and Bad) described in Table 1. Table 2 defines these thresholds and numerical boundaries for many of the commonly employed indicators of organic enrichment.

Table 2: Abiotic and biotic indicator thresholds and numerical boundaries for each of the five EQS categories (Table 1).

Indicators of organic enrichment	Indicator thresholds and numerical boundaries per EQS category				
	High Status	Good Status	Moderate Status	Poor Status	Bad Status
Total Free Sulphide (S^{2-}; µM)*	0 to 75	75 to 250	250 to 500	500 to 1100	>1100
Redox potential (Eh_{NHE})	>0		0 to -100	-100 to -150	<-150
pH**	>7.5		7.1 to 7.5	6.8 to 7.1	<6.8
Total Ammonia Nitrogen** (TAN; mg/L)	NA	NA	1.9***	NA	NA
Richness (*S*%; % of max *S*)	>80	50 to 80	35 to 50	15 to 35	<15
Opportunistic Taxa (*GrV; %*)	<20	20 to 40	40 to 60	60 to 80	>80
Polychaete/Amphipod Ratio (*BPOFA*)	<0.031	0.031 to 0.126	0.126 to 0.187	0.187 to 0.237	>0.237

AZTI's Marine Biotic Index (*AMBI*)	<1.2	1.2 to 3.0	3.0 to 3.9	3.9 to 4.8	>4.8
Multivariate *AMBI* (*M-AMBI*)	>0.83	0.83 to 0.59	0.59 to 0.47	0.47 to 0.35	<0.47
Benthic Habitat Quality (*BHQ*)	8 to 15	6 to 8	4 to 6	2 to 4	<2
Simplified Richness (S_{50})	>16	11.7 to 16	7.5 to 11.7	5.4 to 7.5	<5.4
Benthic Quality Index (*BQI*)	>16.0	12.0 to 16.0	8.0 to 12.0	4.0 to 8.0	<4.0
Benthic Quality Index (*BQI-family*)	>20.8	9.2 to 20.8	5.7 to 9.2	1.9 to 5.7	<1.9
BENTIX	>0.67	0.5 to 0.67	0.42 to 0.49	0.33 to 0.41	<0.33
Norwegian Quality Index (*NQI1*)	>0.86	0.68 to 0.86	0.43 to 0.68	0.20 to 0.43	<0.20
Norwegian Sensitivity Index (*NSI*)	>27.4	23.1 to 27.4	18.8 to 23.1	10.4 to 18.8	<10.4
Indicator Species Index (ISI_{2012})	>9.6	7.5 to 9.6	6.2 to 7.5	4.5 to 6.2	<4.5
Enrichment Stage (*ES*)	1	2	3 to 4	4 to 5	6 to 7

* Measured by UV spectrophotometry.
**Only to be used for freshwater lakes.
*** At pH 7 and 20ºC. For other pH and/or temperature see dependent value in Section 1.7, Table 10.

Section 1.3 - Spatial Scale of Benthic Monitoring and Compliance Decision Framework

A. Marine/brackish cage systems:

Sampling locations are to be established within each of three farm monitoring zones and within a reference zone (Figure 1).

Where the monitoring outcome does not determine a High Status EQS within each monitoring zone (i.e. acceptable benthic status), Table 3 must be followed to determine if the benthic status is acceptable or unacceptable.

Table 3: Three possible scenarios of benthic status which qualify as “acceptable” (2.6.2) for marine/brackish cages, as well as two examples with an “unacceptable” benthic status.

	Monitoring Zones (Fig.1)*	Required sampling & Distance to farm (cage edge)**	Sample analysis outcome - EQS category per monitoring zone	Benthic Status
Scenario 1	Farm zones 1, 2 and 3 and reference zone	Zone 1: 30 m	Moderate Status or better	Acceptable
		Zone 2: 100 m	Good Status or better	
		Zone 3: 150 m	High Status	
		Ref zone: 500 m	High status	
Scenario 2	Farm zones 1, 2 and 3 and reference zone	Zone 1: 30 m	Moderate Status or better	Acceptable
		Zone 2: 100 m Zone 3: 150 m	Good Status	
		Ref zone: 500 m	Good Status	
Scenario 3	Farm zones 1, 2 and 3 and reference zone	Zone 1: 30 m Zone 2: 100 m Zone 3: 150 m	Moderate Status	Acceptable
		Ref zone : 500 m	Moderate Status	
Scenario 4	Farm zones 1, 2 and 3	Zone 1: 30 m Zone 2: 100 m Zone 3: 150 m	Poor or Bad Status	Unacceptable
Scenario 5	Reference zone	Ref zone : 500 m	Poor or Bad Status	Unacceptable

*1 or 4 sampling locations within each zone, depending on whether Tier 1 or Tier 2/3 sampling is being carried out.
**The EQS category for zones 1, 2 and 3 must be achieved by the distance to the farm indicated in this column.

B. Cage Systems in Freshwater Lakes

Sampling locations are to be established within each of two farm monitoring zones and within a reference zone (Figure 2).

Table 4: Three possible scenarios of benthic status which qualify as “acceptable” for cage systems in freshwater lakes, as well as two examples with an “unacceptable” benthic status.

<table>
<tr><th></th><th>Monitoring Zones (Fig.2)*</th><th>Required sampling & Distance to farm (cage edge)**</th><th>Sample analysis outcome - EQS category per monitoring zone</th><th>Benthic Status</th></tr>
<tr><td rowspan="3">Scenario 1</td><td rowspan="3">Farm zone 1, 2 and reference zone</td><td>Zone 1: 30 m</td><td>Moderate Status or better</td><td rowspan="3">Acceptable</td></tr>
<tr><td>Zone 2: 100 m</td><td>High Status</td></tr>
<tr><td>Ref zone: 150 m</td><td>High Status</td></tr>
<tr><td>Scenario 2</td><td>Farm zone 1, 2 and reference zone</td><td>Zone 1: 30 m
Zone 2: 100 m
Ref zone: 150 m</td><td>Good Status</td><td>Acceptable</td></tr>
<tr><td>Scenario 3</td><td>Farm zones 1, 2 and reference zone</td><td>Zone 1: 30 m
Zone 2: 100 m
Ref zone: 150 m</td><td>Moderate Status</td><td>Acceptable</td></tr>
<tr><td>Scenario 4</td><td>Farm zones 1& 2</td><td>Zone 1: 30 m
Zone 2: 100 m</td><td>Poor or Bad Status</td><td>Unacceptable</td></tr>
<tr><td>Scenario 5</td><td>Reference zone</td><td>Ref zone: 150 m</td><td>Poor or Bad Status</td><td>Unacceptable</td></tr>
</table>

*1 or 4 sampling locations within each zone, depending on whether tier 1 or tier 2/3 sampling is being carried out.

**The EQS category for zones 1 and 2 must be achieved by the distance to the farm indicated in this column.

C. Suspended marine mollusc systems:

Sampling locations are to be established along transects that run from 30 m inside the farm boundary (farm monitoring zone) to 30 m outside the boundary (reference zone) (Figure 3).

Table 5: Three possible scenarios of benthic status which qualify as "acceptable" (2.6.2) for suspended marine mollusc, as well as two examples with an "unacceptable" benthic status.

	Monitoring Zones (Fig.3)	Required sampling & Distance to farm	Sample analysis outcome - EQS category per monitoring zone	Benthic Status
Scenario 1	Farm and reference zone	0, 10, 20, and 30 m inside farm boundary	Moderate Status or better	Acceptable
		Ref zone: 10, 20 and 30 m outside farm boundary	High Status	
Scenario 2	Farm and reference zone	0, 10, 20, and 30 m inside farm boundary	Moderate or Good Status	Acceptable
		Ref zone: 10, 20 and 30 m outside farm boundary	Good Status	
Scenario 3	Farm and reference zone	0, 10, 20, and 30m inside farm boundary	Moderate Status	Acceptable
		Ref zone: 10, 20 and 30 m outside farm boundary	Moderate Status	
Scenario 4	Farm zone	0, 10, 20, and 30m inside farm boundary	Poor or Bad Status	Unacceptable
Scenario 5	Reference zone	Ref zone: 10, 20 and 30 m outside farm boundary	Poor or Bad Status	Unacceptable

Section 1.4 - Timing of Sampling

A. & B. Timing of sampling – marine/brackish and freshwater cage systems

Sampling shall occur during the period when the benthic impact is expected to be highest (i.e., worst-case scenario). This period can occur around the time of peak feeding, at peak biomass or during the period of maximum water temperature when waste degradation processes are most rapid. Farms shall provide information on planned peak biomass and peak feeding, estimated time of maximum water temperature, and when the maximum impact on the benthos is predicted to occur. Based on this preliminary information, the following monitoring requirements will apply:

- Sampling shall be conducted during the final year of each production cycle at the facility and within 30 days after peak feeding, after peak biomass, or after maximum water temperature, based on the farm's prediction on highest benthic impact.
- In the case of multiple peaks in feeding/biomass occurring in any year, sampling shall take place within two weeks of the estimated maximum annual water temperature.
- In the case of sustained biomass in the months before harvest, sampling shall take place two weeks prior to the final harvest date.

C. Timing of sampling - suspended marine mollusc systems

- For mollusc farms containing a single cohort, sampling shall be conducted in the final year of production within 30 days after peak biomass.
- For mollusc farms containing more than one production cycle (several cohorts present with the potential for multiple peaks in biomass), sampling shall be conducted annually within 30 days from the time of estimated maximum water temperature.

After three years of demonstrating consistent results, farms with single or multiple cohorts may reduce sampling to once every five years as long as there have been no significant changes to farming practices.

Section 1.5 - Tiered Sampling Approach

The benthic monitoring programme employs a tiered assessment approach in which the number of sampling locations and the complexity of sample analysis increases in relation to risk or preliminary monitoring data. Farm operators may decide to begin monitoring at any of the following monitoring tiers based on the past performance of the farm.

The monitoring and sampling analysis is to be conducted by personnel that are either independent of the company owning the farm or approved by regional/national regulators. Personnel performing this work are required to undergo training and demonstrate competence and proficiency in the use of all required methodologies and technologies employed under the revised requirements.

A. Sampling protocol – marine/brackish cage systems

Tier 1

- Triplicate sediment samples shall be collected at three different sampling locations (i.e., at 30, 100, and 150 metres from the farm [edge of the cage array]), and at the reference zone, in the direction of the predominant current direction.
- Each sediment sample shall be analysed immediately onboard the survey vessel for total free sulphide (S^{2-}; in triplicate [9 analysis in total for each sampling location]) and redox potential (*Eh*: single measure [3 analysis in total for each sampling location]) in surface sediments (0 to 2 cm depth) using the rapid field analysis methods given in Section 1.7.
- The sediment samples are to be analysed and results interpreted immediately onboard the sampling vessel. In order to interpret the results, the mean values of the 9 S^{2-} and 3 *Eh* analysis are compared with Table 2 to identify the EQS category, and compared with Table 3 to determine if the EQS categories in all monitoring zones lead to an acceptable benthic status.

- If the results of the sediment sample analysis of both indicators and each monitoring zone indicate an acceptable benthic status, no additional monitoring is required.
- If any of the three zones leads to an unacceptable benthic status, Tier 2 monitoring shall immediately be applied.

Tier 2

- Sediment sample collection and analysis shall be conducted as for Tier 1 but in three additional directions according to Figure 1.
- If the results[3] of the sediment sample analysis of both indicators and each monitoring zone indicate an acceptable benthic status, no additional monitoring is required.
- If any of the three zones leads to an unacceptable benthic status, the risk for benthic community impacts is estimated to be high, and the UoC shall immediately apply Tier 3 monitoring to further characterise spatial impacts by employing biotic indicator monitoring.

Tier 3

- Triplicate grab samples shall be collected at the same sampling locations as for Tier 2.
- The grab samples shall be screened through a 1.0 mm mesh and all organisms preserved for taxonomic analysis.
- The grab samples shall be analysed for three biotic indicators from Table 2.
- The analysis results of the three biotic indicators shall be compared with Table 2 to determine the dominant EQS category per monitoring zone[4].
- If the dominant EQS category of each monitoring zone indicate an acceptable benthic status, no additional monitoring is required.
- If any of the three monitoring zones lead to an unacceptable benthic status, then the farm is non-compliant with indicator 2.6.2, unless results from grab samples in the reference zone at 500 metres distance from the farm (edge of the cage array) provide for a lower EQS. Indicator monitoring data from the reference sampling locations will be used to determine the Reference Zone EQS that applies to the farm. For example, if the Reference Zone is shown to be 'Moderate', then the same category in zone 1, 2 and 3 is acceptable. The proposed revised indicator requirements do not allow certification when the Reference Zone is shown to be 'Poor' or 'Bad'.
- In cases where the potential benthic impact of a farm may overlap with another farm (e.g. the reference site falls within 200 m of the adjacent farm) the overlapping transect location or direction may be adjusted to help avoid potential farm interactions. The same applies for any transect/sampling station that would intersect with dry land. Transect directions may also be altered to avoid sampling in areas where water depth changes rapidly along the transect. In all cases, four sampling transects are required, with each being as close to 90 degrees from each other as possible.

[3] Mean value per indicator per monitoring zone, derived from 36 data points: three analysis replicates for each of the triplicate samples, for each of the four sampling location per zone.

[4] Of the 12 EQS categories within a monitoring zone (3 biotic indicators times 4 sampling location), the dominant, i.e., 6 or more, determine the EQS category for the monitoring zone. For example, in the case of 6 Moderate Status EQS' and 6 Poor Status EQS', the dominant EQS can be regarded as Moderate Status (which leads to an acceptable benthic status in zone 1 according to Table 3). In the case of 5 Moderate Status EQS' and 7 Poor Status EQS', the dominant EQS is Poor Status (which leads to an unacceptable benthic status in zone 1 according to Table 3).

Each monitoring tier is summarised in Table 6.

Table 6: Benthic Monitoring Programme for Marine/Brackish Cage Systems - Tiered Assessment Approach

Tier	Description	Indicators	Sampling Locations
Tier 1	**Rapid screening:** Low-cost farm impact screening using practical, near-real-time abiotic measurements to determine the risk for organic enrichment impacts.	S^{2-} and *Eh*	At 30, 100, 150 and 500 m distances in the predominant current direction.
Tier 2	**Impact delineation:** Enhanced spatial analysis of abiotic impacts around the farm using practical monitoring tools.	S^{2-} and *Eh*	Same as Tier 1 but including sampling in three additional directions.
Tier 3	**Biotic impact:** Comprehensive characterisation of biotic impacts around the farm.	3 biotic indicators from Table 2	Same locations as Tier 1 and Tier 2.

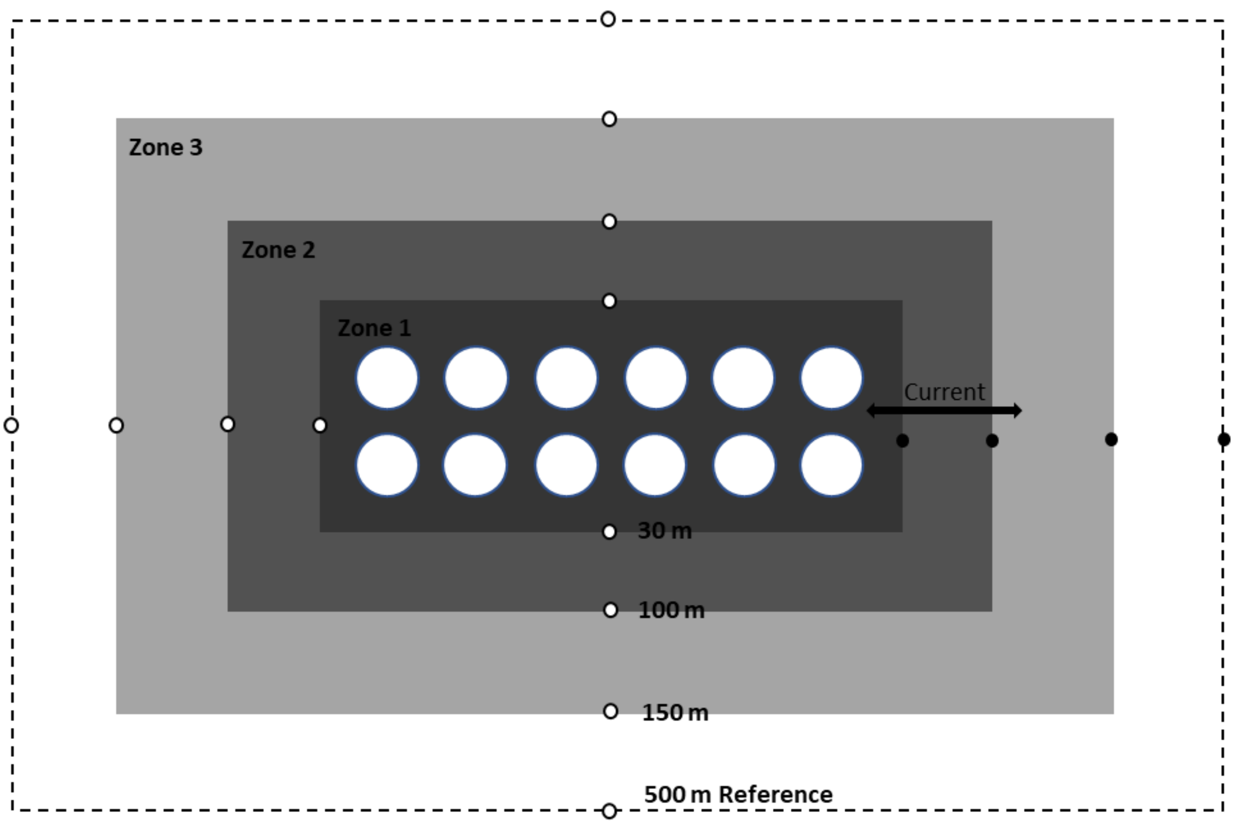

Figure 1. Schematic of sampling locations and EQS Zones under Tier 1 (●), 2 (● and ○) and 3 (● and ○) monitoring programmes for marine/brackish cages. The EQS monitoring zones are shown with sampling sites located at the outer boundary of each zone.

B. Sampling protocol – Cage Systems in Freshwater Lakes

Tier 1

- Triplicate sediment samples shall be collected at two different sampling locations, i.e., at 30 and 100 metres from the farm (edge of the cage array), and at a reference site.
- Each sediment sample shall be analysed immediately for redox potential, pH and Total Ammonia Nitrogen (TAN) (single measure for each of the three indicators [9 analysis in total for each sampling location]) in surface sediments (0 to 2 cm depth) using the rapid field analysis methods given in Section 1.7.
- The sediment samples shall be analysed and results interpreted immediately. To interpret the results, the mean values of the 3 *Eh,* 3 pH and 3 TAN analysis are compared with Table 2 to identify the EQS category and compared with Table 4 to determine if the results from all monitoring zones lead to an acceptable benthic status.
- If the results of the sediment sample analysis of all three indicators and each of the two monitoring zone indicate an acceptable benthic status, no additional monitoring is required.
- If any of the two zones leads to an unacceptable benthic status, Tier 2 monitoring shall immediately be applied.

Tier 2

- Sediment sample collection and analysis shall be conducted as for Tier 1 but in three additional directions according to Figure 2.
- If the results[5] of the sediment sample analysis of all three indicators and each monitoring zone indicate an acceptable benthic status, no additional monitoring is required.
- If any of the two zones leads to an unacceptable benthic status, the risk for benthic community impacts is estimated to be high, and the UoC shall apply Tier 3 monitoring to further characterise spatial impacts by employing biotic indicator monitoring.

Tier 3

- Triplicate grab samples shall be collected at the same sampling locations as for Tier 2.
- The grab samples shall be screened through a 1.0 mm mesh and all organisms preserved for taxonomic analysis.
- The grab samples shall be analysed for three biotic indicators from Table 2.
- The analysis results of the three biotic indicators shall be compared with Table 2 to determine the dominant EQS category per monitoring zone[6].
- If the dominant EQS category of each monitoring zone indicate an acceptable benthic status, no

---

[5] Mean value per indicator and monitoring zone, derived from 12 data points: a single analysis for each of the triplicate samples, for each of the four sampling transects

[6] Of the 12 EQS categories within a monitoring zone (3 biotic indicators times 4 sampling location), the dominant, i.e., 6 or more, determine the EQS category for the monitoring zone. For example, in the case of 6 Moderate Status EQS' and 6 Poor Status EQS', the dominant EQS can be regarded as Moderate Status. In the case of 5 Moderate Status EQS' and 7 Poor Status EQS', the dominant EQS is Poor Status.

additional monitoring is required.

- If any of the two zones leads to an unacceptable benthic status, then the farm shall use the results from grab samples in the reference zone at 150 metres distance from the farm (edge of the cage array) to confirm whether they provide for a lower EQS. Indicator monitoring data from the reference sampling locations will be used to determine the Reference Zone EQS that applies to the farm. For example, if the Reference Zone is shown to be 'Moderate', then the same category in zone 1 and 2 is acceptable. The proposed revised indicator requirements, when effective, will not allow certification when Reference Zone is shown to be 'Poor' or 'Bad'.
- In cases where the potential benthic impact of a farm may overlap with another farm (e.g. the reference site falls within 200 m of the adjacent farm) the overlapping transect location or direction may be adjusted to help avoid potential farm interactions. The same applies for any transect/sampling station that would intersect with dry land. Transect directions may also be altered to avoid sampling in areas where water depth changes rapidly along the transect. In all cases, four sampling transects are required, with each being as close to 90 degrees from each other as possible.

Each monitoring tier is summarised as shown in Table 7:

Table 7: Benthic Monitoring Programme for Cage Systems in Freshwater Lakes - Tiered Assessment Approach

Tier	Description	Indicators	Sampling Locations
Tier 1	**Rapid screening:** Low-cost farm impact screening using practical, near-real-time abiotic measurements to determine the risk for organic enrichment impacts.	*Eh*, pH, TAN	At 30, 100, and 150m distances in the predominant current direction.
Tier 2	**Impact delineation:** Enhanced spatial analysis of abiotic impacts around the farm using practical monitoring tools.	*Eh*, pH, TAN	Same as Tier 1 but including sampling in three additional directions.
Tier 3	**Biotic impact:** Comprehensive characterisation of biotic impacts around	3 biotic indicators from Table 2	Same locations as Tier 2.

	the farm.		

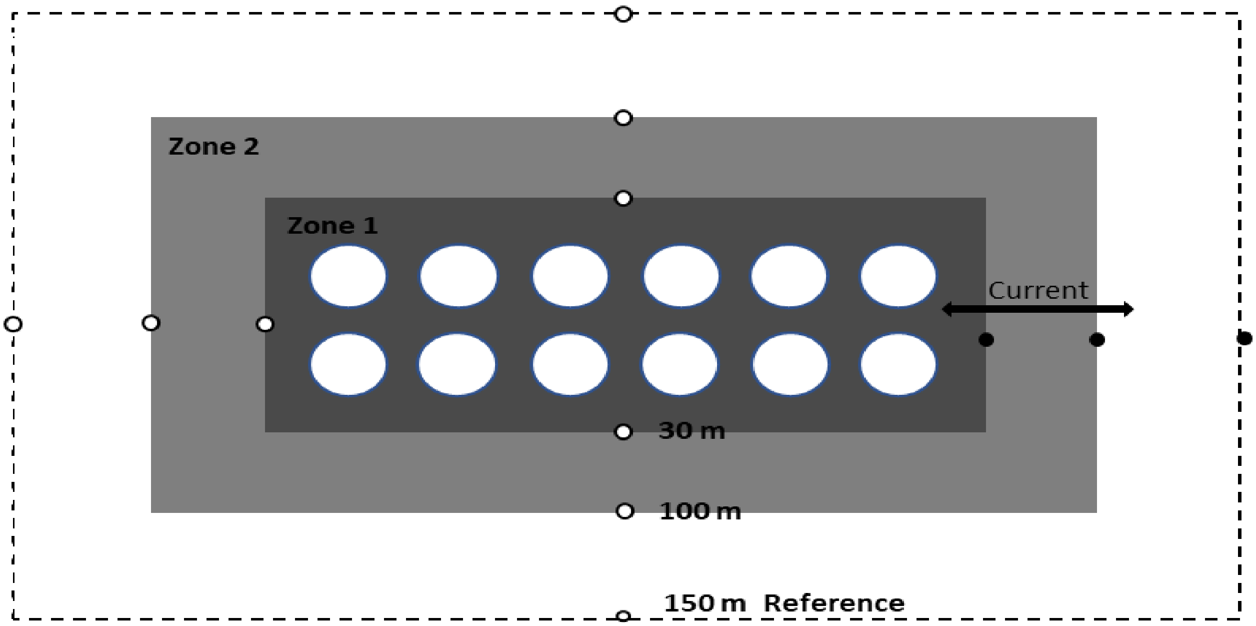

Figure 2 Schematic of sampling locations and EQS Zones under Tier 1 (●), 2 (● and ○) and 3 (● and ○) monitoring programmes for freshwater cages. The EQS monitoring zones are shown with sampling sites located at the outer boundary of each zone.

C. <u>Sampling Protocol - Suspended Marine Mollusc Systems</u>

Tier 1

- Triplicate sediment samples shall be collected at each of the seven sampling locations situated 10 m apart along a single transect that runs in the direction of the predominant current (Figure 2).
- Each sediment sample shall be analysed immediately onboard the survey vessel for total free sulphide (S^{2-}; in triplicate [9 analysis in total per each sampling location]) and redox potential (*Eh*: single measure [3 analysis in total for each sampling location]) in surface sediments (0 to 2 cm depth) using the rapid field analysis methods given in Section 1.7.
- The sediment samples shall be analysed and results interpreted immediately onboard the sampling vessel. In order to interpret the results, the mean values of all S^{2-} and *Eh* analysis within all four sampling locations located at and inside the farm boundary are compared with Table 2 to identify the EQS category, and compared with Table 5 to determine if the benthic status is acceptable i.e., Moderate Status or better.
- If the results of the sediment sample analysis indicate an acceptable benthic status – i.e., “Moderate” or better, no additional monitoring is required.
- If an unacceptable benthic status is determined, Tier 2 monitoring shall immediately be applied.

Tier 2

- Sediment sample collection and analysis shall be conducted as for Tier 1 but in three additional directions according to Figure 3.
- If the results[7] of the sediment sample analysis indicate an acceptable benthic status i.e., Moderate Status EQS or better, no additional monitoring is required.
- If an unacceptable benthic status is determined, the risk for benthic community impacts is estimated to be high, and the UoC shall immediately apply Tier 3 monitoring to further characterise spatial impacts by employing biotic indicator monitoring.

Tier 3

- Triplicate grab samples shall be collected at the same locations as described for Tier 2.
- The grab samples shall be screened through a 1.0 mm mesh and all organisms preserved for taxonomic analysis.
- The grab samples shall be analysed for three biotic indicators from Table 2. The three biotic metrics shall be averaged per indicator to determine the EQS for each sampling location within the farm and at the boundary.
- If the calculated results indicate an acceptable benthic status i.e., Moderate Status EQS or better for all three biotic indicators, no additional monitoring is required.
- If an unacceptable benthic status is determined, then the farm is non-compliant with indicator 2.6.2.
- Certification is not allowed when the Reference Zone is shown to be ‘Poor’ or ‘Bad’.

Each monitoring tier is summarised as shown in Table 8:

Table 8 Benthic Monitoring Programme for Suspended Marine Mollusc Systems - Tiered Assessment Approach

Tier	Description	Indicators	Sampling Locations
Tier 1	**Rapid screening:** Low-cost farm impact screening using practical, near-real-time abiotic measurements to determine the risk for organic enrichment impacts.	S^{2-} and *Eh*	Seven sampling locations are situated 10 m apart along a single transect that runs in the direction of the predominant current*
Tier 2	**Impact delineation:** Enhanced spatial analysis of abiotic impacts around the farm using practical monitoring tools.	S^{2-} and *Eh*	Same as Tier 1 but including sampling in three additional transects*.

[7] Mean value, derived from 144 data points: three analysis replicates for each of the triplicate samples, for each of the four sampling locations and each of the four transects within the farm and at the boundary.

Tier 3	**Biotic impact:** Comprehensive characterisation of biotic impacts around the farm.	3 biotic indicators from Table 2	Same locations as Tier 2.

* If a farm boundary is contiguous with another farm, the additional transects can be relocated to a location that crosses both farm and reference conditions.

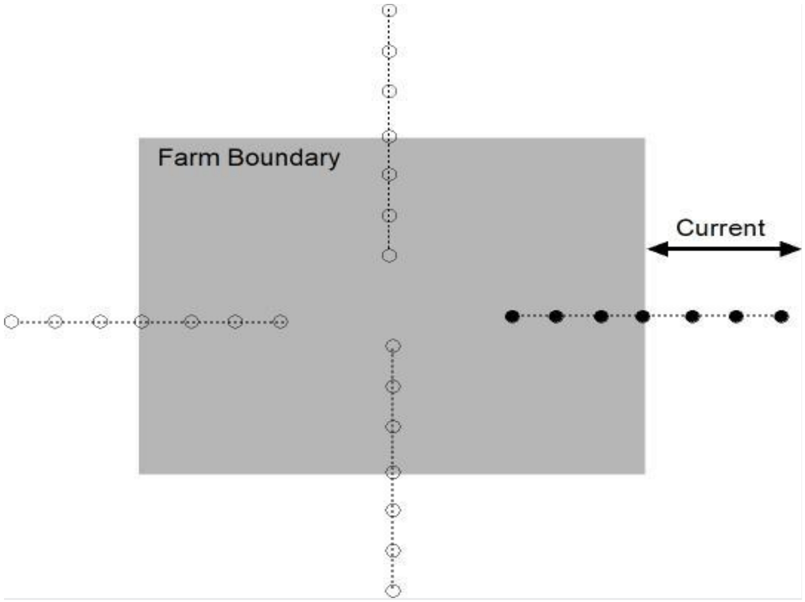

Figure 3: Schematic of sampling locations under Tier 1 (●), 2 (● and ○) and 3 (● and ○) monitoring programmes. Sampling locations on each transect are 10 m apart with the middle station located on the farm boundary.

Section 1.6 – User-Defined Monitoring Programme

The benthic organic enrichment monitoring requirements include some flexibility for operators to use an approach that aligns with regional regulatory requirements while demonstrating the capacity to detect the same thresholds for indicators of organic enrichment across all spatial monitoring zones provided (see Figures 1, 2 and 3 above). This non-prescriptive approach to monitoring is meant to recognise the in-depth monitoring and regulation of aquaculture in some jurisdictions/countries and to foster innovation. Although ASC does not mandate the use of the ASC benthic monitoring programme, the onus is on the operator to make a highly detailed and convincing case to the ASC that their proposed farm monitoring programme meets the following requirements:

a) The user-defined monitoring approach shall be aligned with the overall purpose of the revised benthic organic enrichment monitoring requirements.

- The operator shall write a statement clearly outlining their environmental policy and how their monitoring approach is capable of minimising, mitigating or eliminating negative benthic habitat, biodiversity and ecosystem effects from seabed organic enrichment.

b) The programme shall quantify both the magnitude and spatial scale of benthic impacts from organic enrichment adjacent to the farm using proven methodologies. The programme shall:

- Provide information on the sampling design including all sampling locations and range of distances to the farm (as per Table 3, 4 and 5), benthic sampling methodologies employed, and the number of replicates.
- Provide a rationale for reference station selection that aligns with ASC intent of quantifying spatial and annual temporal interactions between the farm and the surrounding natural benthic environment.
- Provide a rationale for the timing of monitoring that is in line with the maximum potential for benthic impacts. Although annual sampling is expected, any proposal to reduce the frequency of sampling would require a strong justification.
- Describe all impact indicators to be employed and the sample preparation and analysis procedures.

c) The user-defined monitoring programme needs to address benthic ecological quality objectives that are at least as stringent as those described in the ASC benthic requirements. The programme shall:

- Describe the farm-management decision framework to be employed, including quantitative benthic indicator thresholds that drive these decisions and the rationale for selecting these thresholds.
- Compare and demonstrate compatibility between the user-defined site impact classifications and the EQS category system as defined in Tables 1 and 2.

1. *The user-defined monitoring programme submitted by operators will be pre-screened within the ASC for compatibility with the purpose, rationale, intent and general requirements of the revised requirements. Those programmes that appear to meet general criteria will be reviewed externally by a panel consisting of international science experts in aquaculture-environment interactions to ensure that they fulfil the overall purpose and specific requirements. Given the comprehensive and stringent amendments to the monitoring requirements, approval of user-defined programmes is anticipated only in rare cases. The ASC encourages operators to implement the ASC Benthic Monitoring Programme.*

Section 1.7 - Standard Operating Procedures for the Field Analysis of Abiotic Indicators Employed in Tier 1 and Tier 2

A. Total Free Sulphide (S^{-2}) Analysis in the Field by Direct UV Spectrometry

The methodology includes both the field extraction and analysis of porewater in surficial sediments (grabs or cores) as described in Cranford et al. (2017) and as modified in Cranford et al. (2020).

Materials List

- UV Spectrophotometer suitable for field use (e.g. IMPLEN C40 mobile nanophotometer.[8]
- Quartz cuvette: 200-2500 nm spectral range, pathlength 10 mm, 1.4 ml capacity (e.g. Hellma Analytics No 104-B-10-40). Note that quartz is required.[9]
- 5 cm RizoCera porewater extractors.[10]
- 10 cc syringe.
- Stainless steel compression springs that fit inside the 10 cc syringe.
- 100 µL gas-tight syringe.[11]
- 1 mL pipettor or bottle dispenser for rinsing cuvette and for sample dilutions.
- Ammonia hydroxide, 0.44M or similar concentration.
- pH strips for adjusting the dilution water (potable water will suffice) to between 8 and 10.
- Sulphide WP - Certified Reference Material (available from Sigma: QC1034-20 mL) for instrument calibration at one-month intervals. [12]
- 1 and 5 L pipettors and 10 to 20 mL vials for preparing standards.
- Lint-free optical wipes (e.g. Kimwipes) for cuvette cleaning surfaces.

Porewater Extraction

1) Drain water in sediment sampler to sediment surface.
2) Using syringe containing a stainless spring, depress plunger, attach RhizoCera, and insert into sediment surface at a 45° angle. Release plunger to start automatic porewater extraction from 0 to 2 cm depth.
3) After approximately 2 min, the syringe should contain sufficient porewater (0.5 to 1 mL).
4) Remove the syringe from the sediment and remove the RhizoCera. Discard the water in the syringe as this is only used to flush out the RhizoCera.
5) Insert the 100 µL syringe needle directly into the interior of the RhizoCera and withdraw the 100 µL sample.
6) Rinse any sediment from the exterior of the RhizoCera before reusing.

Note: The interior of the RhizoCera is flushed automatically between samples during the extraction procedure.

UV Spectrophotometric Analysis

1) Turn on the spectrophotometer and, if available, select data output for the 230, 240 and 250 nm wavelengths. Otherwise save the full sample scan.
2) Add small amounts of ammonium hydroxide to 1 L of dilution water until the pH is between 8 to 10. This volume of buffered dilution water is sufficient for daily use.
3) Rinse the quartz cuvette and add 1 mL of the buffered water.
4) Clean the outside of the cuvette with a lint-free wipe and place in instrument. Zero the instrument using this blank solution. Instrument blanking should be performed regularly.

[8] https://www.implen.de/product-page/implen-nanophotometer-c40-cuvette-spectroscopy/
[9] https://www.hellma.com/en/home/
[10] https://www.rhizosphere.com/rhizocera
[11] https://www.hamiltoncompany.com/laboratory-products/syringes/80630
[12] https://www.sigmaaldrich.com

5) Add the 100 µL porewater sample to the cuvette containing 1 mL of buffered water, invert to mix, and record the absorbances at the three wavelengths. Most instruments have the capacity to save the full scan.
6) Remove the cuvette, rinse with buffered water and prepare for next sample.
7) Calculate the total free sulphide concentration using the absorbance values and the regression equations determined by the calibration procedure below. Although absorption data are provided for three wavelengths, S^{2-} is only calculated using the lowest wavelength that provides absorbances below 2. If the absorbance at 230 nm is >2, then use the 240 nm absorbance, etc.

Instrument Calibration

The calibration is highly stable and only needs to be conducted once a month to ensure the instrument has not been damaged. An ISO Certified Reference Material (CRM; Sulphide WP) of known concentration is used as the stock solution for preparing five working standards by serial dilution (1:2, 1:5, 1:10, 1:50 and 1:100).

1) Dilute the stock CRM solution to prepare the five known concentrations using pipettors and the buffered water.
2) Blank (zero) the instrument and then analyze the standards using the same procedure as the samples, including dilution with 1 mL of buffered water. Record the results for the three selected wavelengths (230, 240 and 250 nm), omitting any absorbances greater than 2.0.
3) Calculate the three calibration equations (one for each wavelength) using regression analysis (x = absorbance at selected wavelength and y = standard concentration in µM units) while excluding any absorbance values above 2.0.

Note: The following S^{2-} concentration ranges typically apply for the three wavelengths:

230 nm: 0 to 2,000 µM (suitable for quantifying all EQS conditions from High to Bad)
240 nm: 2,000 to 4,000 µM
250 nm: 4,000 to 10,000 µM
Note: 260 nm can be used for higher concentrations

B. Redox Potential (*Eh*) measurement

Eh can be measured directly in the grab/core using an Oxidation Reduction Potential (ORP) probe that uses a silver/silver chloride or platinum reference electrode. The ORP probe must be calibrated, operated and maintained according to strict manufacturer specifications. ORP measurements (referred to as ORP, $E_{Ag/AgCl}$ or E_{Pt}), are by themselves ambiguous and it is only through specifying the reference scale can the data be interpreted by the user. ORP measurements converted to a hydrogen scale are reported as "*Eh*" and some publications designate the same measurements as Eh_{NHE}. ORP data (mV) obtained in the field with Ag/AgCl or Pt electrodes are converted to the hydrogen scale as follows:

$$Eh = \text{ORP (mV)} + \text{half-cell potential of reference electrode}$$

where the half-cell potential of the Ag/AgCl or Pt reference electrode is related to the molarity of the filling solution and measurement temperature.

Table 9 Half-cell potential of Ag/AgCl reference electrode

T (°C)	Molarity of KCl filling solution				
	1.5M	3M	3.3M	3.5M	4M
5	254	224	220	219	219
10	251	220	217	215	214
15	249	216	214	212	209
20	244	213	210	208	204
25	241	209	207	205	199
30	238	205	203	201	194

1. The ORP probe can be inserted directly into the sediment surface inside the core/grab to ~1 cm depth after mixing the sediment around the probe location to 2 cm depth. Ensure full contact between the ORP electrode tip and wet sediment.
2. Record the sample temperature.
3. The ORP mV reading should stabilize within 1-2 min. If redox conditions are not controlled by single oxidation-reduction reactions, as in oxic sediments, there is often a slow, continuous drift of electrode potentials. An arbitrary time (3-4 min) can be chosen to record mV readings if they do not stabilize in less than this time. Potentials in reduced sediments usually stabilize more rapidly.
4. Correct the ORP potential (mV) relative to the normal hydrogen electrode as described above using manufacturer information on the electrode filling solution and data on sediment temperature.

C. Total Ammonia Nitrogen Measurement

Total ammonium nitrogen (TAN) consists of the ammonium ion (NH4+) and un-ionized ammonia (NH3). NH3 makes up a higher proportion of TAN at higher pH and is typically associated with most of the toxic effects of TAN. As with total free sulphide analysis, TAN is measured using porewater samples extracted from surficial sediments (0 to 2 cm depth). The extraction procedure is described in Section 1.7, part A, and utilizes RhizoCera samplers inserted to a depth of 2 cm in grab samples. Subsamples should be collected without unnecessary exposure to air. Avoid trapping bubbles of air when filling and capping plastic sample vials.

The Eh, pH and temperature of the sediment sample are measured directly in the grab sample (stirred upper 2 cm of sediment) using Oxidation Reduction Potential (ORP), pH and temperature probes while the porewater is being extracted in another section of the grab.

Acceptable methods for TAN analysis include spectrophotometry, fluorometry, and electrochemical detection. The gas sensing ISE method (Standard Method 4500-NH3 Nitrogen D and E) is an approved approach for TAN analysis, but it should be recognised that it can also be challenging to perform correctly. The major drawback with this method is that it requires at least 50 ml of sample and collection of that quantity of porewater for routine monitoring is not practical under field conditions. The ISE technology has additional disadvantages including high maintenance, frequent calibration, poor performance at low TAN concentrations, and frequent replacement of the sensor system.

Low sample volumes can be accurately analyzed using a variety of manual and automated colourimetric methods. The phenate method (Standard Method 4500-NH3 F and G) reacts alkaline phenol and hypochlorite with ammonia to form indophenol blue. The colour intensity is measured photometrically to determine the final concentration. The salicylate method (EPA 350.1) reacts at pH 12.6 with hypochlorite ions and salicylate ions in the presence of sodium nitroprusside as a catalyst to form indophenol. The amount of colour formed is directly proportional to the ammonia in the sample. Results are read at 690 nm. It is preferred that porewater samples should be analysed as soon as possible after sampling (i.e., within an hour). However, samples can be stored in plastic bottles for up to one month in a freezer at below -18°C. Before determination of ammonia, samples should be allowed to defrost slowly, preferably overnight, in darkness.

Hach® Company gained US EPA Equivalence on a simple salicylate method for use in wastewater based on the TNTplus™ Ammonia platform. This is a simple, cost-effective, 15-min test, requiring no calibration and just 0.5 mL of porewater. Independent analysis (Guadalupe-Blanco River Authority, Seguin, Tx) reported the limit of quantification of this Test-In-Tube 831 kit was 1 mg/L, which is sufficient for detecting TAN concentrations exceeding the EQS threshold (Table 10). During analysis, the pH of the water sample must be between pH 4–8 and the temperature of the water sample and reagents must be between 20–23°C. The equipment required consists of a Hach DR3900 spectrophotometer and Hach TNTplus 831 Low Range (1-12 mg/L NH3-N) reagent kits, which each contain 25 test vials.

The TAN concentration, pH, Eh and temperature reported for sediment collected at each sampling site will be used to assess caged fish farm compliance for lake systems (see Tables 4 and 10).

Table 10: Temperature and pH-dependent concentration values for total ammonia nitrogen (mg/L) describing the threshold between Moderate and Poor Ecological Quality Status[13]. The highlighted value is the threshold that applies to sediments with 7.0 pH and 20ºC. The applicable threshold for measurements taken at other ambient sediment conditions are shown.

[13] From "Aquatic Life Ambient Water Quality Criteria For Ammonia – Freshwater 2013. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology Washington, DC.

pH	Temperature (°C) 0-7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6.5	4.9	4.6	4.3	4.1	3.8	3.6	3.3	3.1	2.9	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.6	1.5	1.5	1.4	1.3	1.2	1.1
6.6	4.8	4.5	4.3	4.0	3.8	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1
6.7	4.8	4.5	4.2	3.9	3.7	3.5	3.2	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1
6.8	4.6	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1
6.9	4.5	4.2	4.0	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0
7.0	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	0.99
7.1	4.2	3.9	3.7	3.5	3.2	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95
7.2	4.0	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.96	0.90
7.3	3.8	3.5	3.3	3.1	2.9	2.7	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.97	0.91	0.85
7.4	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.96	0.90	0.85	0.79
7.5	3.2	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.83	0.78	0.73
7.6	2.9	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.6	1.5	1.4	1.4	1.3	1.2	1.1	1.1	0.98	0.92	0.86	0.81	0.76	0.71	0.67
7.7	2.6	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	0.94	0.88	0.83	0.78	0.73	0.68	0.64	0.60
7.8	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.84	0.79	0.74	0.69	0.65	0.61	0.57	0.53
7.9	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.84	0.79	0.74	0.69	0.65	0.61	0.57	0.53	0.50	0.47
8.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	0.94	0.88	0.83	0.78	0.73	0.68	0.64	0.60	0.56	0.53	0.50	0.44	0.44	0.41
8.1	1.5	1.5	1.4	1.3	1.2	1.1	1.1	0.99	0.92	0.87	0.81	0.76	0.71	0.67	0.63	0.59	0.55	0.52	0.49	0.46	0.43	0.40	0.38	0.35
8.2	1.3	1.2	1.2	1.1	1.0	0.96	0.90	0.84	0.79	0.74	0.70	0.65	0.61	0.57	0.54	0.50	0.47	0.44	0.42	0.39	0.37	0.34	0.32	0.30
8.3	1.1	1.1	0.99	0.93	0.87	0.82	0.76	0.72	0.67	0.63	0.59	0.55	0.52	0.49	0.46	0.43	0.40	0.38	0.35	0.33	0.31	0.29	0.27	0.26
8.4	0.95	0.89	0.84	0.79	0.74	0.69	0.65	0.61	0.57	0.53	0.50	0.47	0.44	0.41	0.39	0.36	0.34	0.32	0.30	0.28	0.26	0.25	0.23	0.22
8.5	0.80	0.75	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45	0.42	0.40	0.37	0.35	0.33	0.31	0.29	0.27	0.25	0.24	0.22	0.21	0.20	0.18
8.6	0.68	0.64	0.60	0.56	0.53	0.49	0.46	0.43	0.41	0.38	0.36	0.33	0.31	0.29	0.28	0.26	0.24	0.23	0.21	0.20	0.19	0.18	0.16	0.15
8.7	0.57	0.54	0.51	0.47	0.44	0.42	0.39	0.37	0.34	0.32	0.30	0.28	0.27	0.25	0.23	0.22	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.13
8.8	0.49	0.46	0.43	0.40	0.38	0.35	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.21	0.20	0.19	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11
8.9	0.42	0.39	0.37	0.34	0.32	0.30	0.28	0.27	0.25	0.23	0.22	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.09
9.0	0.36	0.34	0.32	0.30	0.28	0.26	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08