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# Fundamentals of Water Management

An update on the natural  
scientific perspective for concrete  
environmental management



# Water Quality


Why do we assess WQ?

What is WQ?

How should WQ be measured?

Where and when to measure?

How to draw conclusions on the state of the environment and on pressures and changes influencing it?



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# Coastal Ecosystem Services

# Benefits Provided by Coastal and Estuarine Waters



## **Provisioning Services**

Coastal waters provide fisheries, aquaculture, raw materials, and genetic resources essential for food security and economy.

## **Regulating Services**

These ecosystems purify water, sequester carbon, and control floods and erosion, protecting coastal communities.

## **Supporting Services**

Nutrient cycling, primary production, and habitat provision sustain ecosystem health and resilience.

## **Cultural Services**

Coastal areas offer recreation, spiritual value, education, and research opportunities enhancing human wellbeing.

# Key Ecosystem Services of Coastal and Estuarine Waters



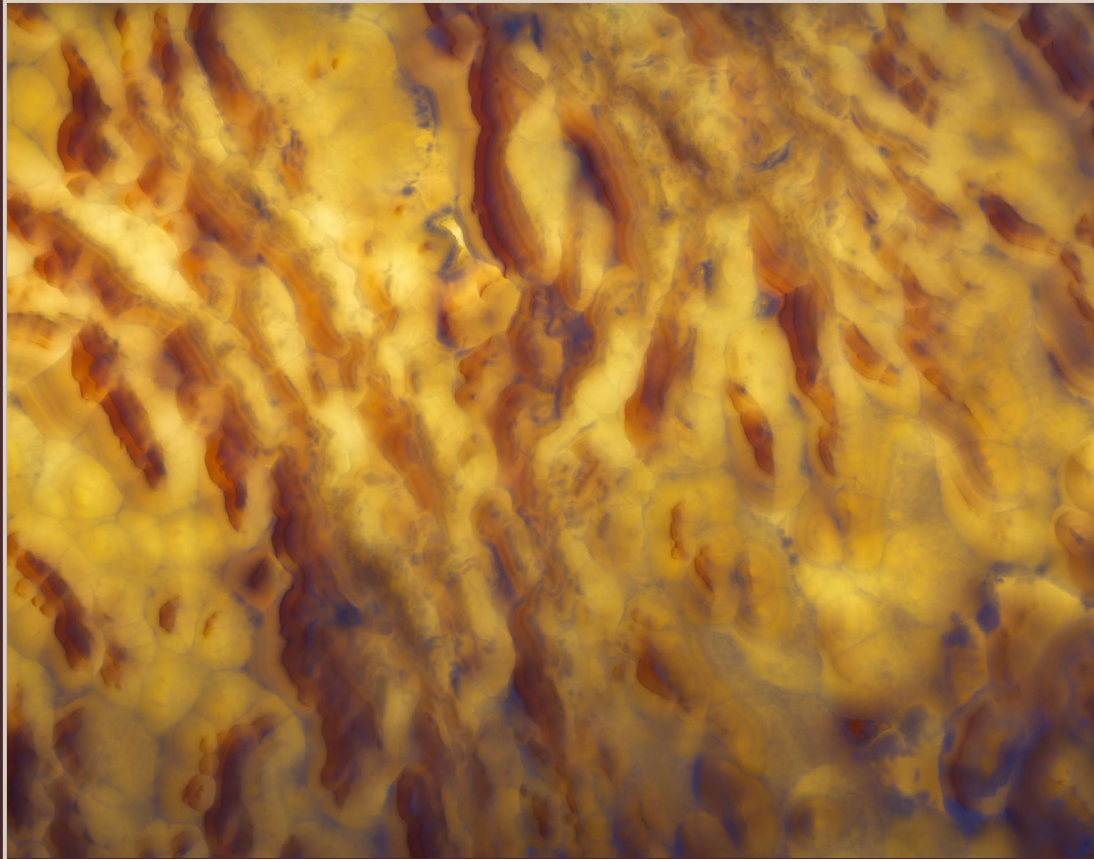
Category	Ecosystem Service	Description
Provisioning	Fisheries	Source of food through wild fish and shellfish harvest.
Provisioning	Aquaculture	Support for farming of marine species like mussels and seaweed.
Provisioning	Raw materials	Extraction of sand, salt, and other marine resources.
Provisioning	Genetic resources	Biodiversity for pharmaceuticals and biotechnology.
Regulating	Water purification	Removal of pollutants and excess nutrients by wetlands and vegetation.
Regulating	Carbon sequestration	Storage of carbon in sediments and coastal vegetation.
Regulating	Flood regulation	Buffering of storm surges and coastal flooding.
Regulating	Erosion control	Stabilization of shorelines by vegetation and sediment processes.
Regulating	Climate regulation	Influence on local and global climate via carbon and heat exchange.
Supporting	Nutrient cycling	Transformation and movement of nitrogen, phosphorus, and carbon.
Supporting	Primary production	Photosynthesis by phytoplankton and coastal plants.
Supporting	Habitat provision	Breeding and nursery grounds for fish, birds, and invertebrates.
Cultural	Recreation and tourism	Activities like boating, birdwatching, and beach use.
Cultural	Spiritual and aesthetic values	Cultural heritage, scenic beauty, and identity.
Cultural	Education and research	Natural laboratories for ecological and climate studies.



# Coastal eutrophication

Organic enrichment associated with multiple environmental problems in coastal waters

# Origins of organic matter in coastal waters



**Eutrophication – “an increase in the rate of supply of organic matter to an ecosystem”**


Nixon, S. W. (1995). Coastal marine eutrophication: A definition, social causes, and future concerns. *Ophelia*, 41(1), 199–219. <https://doi.org/10.1080/00785236.1995.10422044>.

## **Autochthonous Organic Matter**

Organic matter produced within coastal waters driven by nutrient input from agriculture, wastewater, and stormwater.

## **Allochthonous Organic Matter**

External organic material like leaves and soil as well as dissolved organic matter washed into coastal waters through rivers and runoff.



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# Problems associated with coastal eutrophication

# Environmental Problems of Coastal Eutrophication



## **Oxygen Depletion and Hypoxia**

Excess organic matter decomposition causes oxygen loss, leading to fish kills and benthic organism decline.

## **Light Reduction and Habitat Damage**

Increased turbidity from algal growth reduces light penetration, hampering photosynthesis and harming marine habitats.

## **Acidification and Brownification**

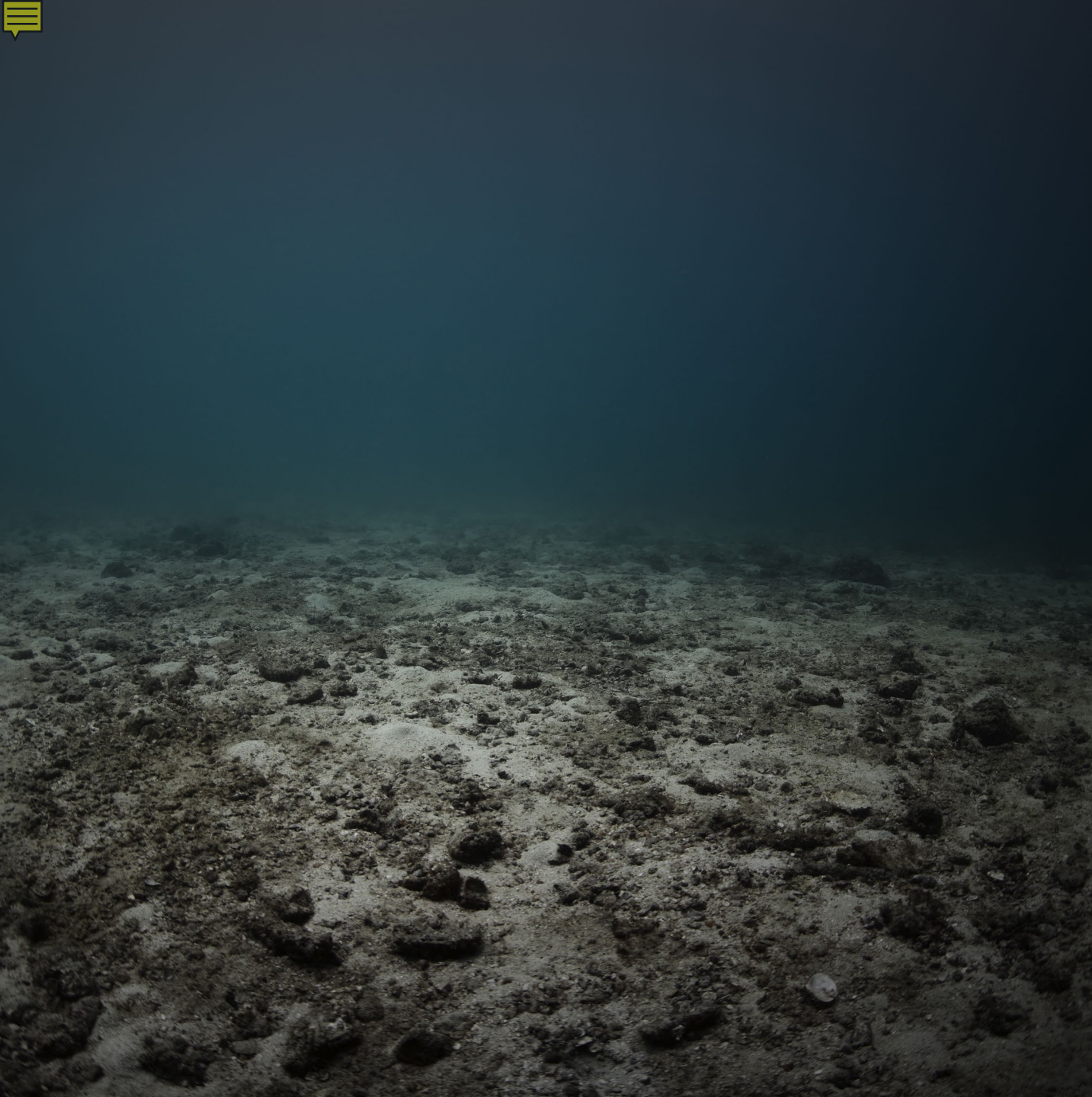
Microbial  $\text{CO}_2$  releases lower pH while organic matter causes brownification, altering microbial communities.

## **Harmful Algal Blooms and Biodiversity Loss**

Toxic algal blooms threaten marine life and human health, leading to ecosystem degradation and economic losses.

## **NET EFFECTS**

Most environmental phenomena associated with eutrophication incorporate opposite outcomes depending on the time frame observed. Examples on the following slides.



# OXYGEN DEPLETION (HYPOXIA/ANOXIA)

## Causes of Oxygen Depletion

Excess nutrients cause phytoplankton blooms that consume oxygen during decomposition, leading to hypoxia or anoxia.

## Effects on Marine Life

Low oxygen levels cause fish kills and loss of benthic organisms like worms and shellfish, disrupting ecosystems.

## Impact on Nutrient Cycling

Hypoxia promotes anaerobic microbes, which worsen eutrophication by releasing more soluble nutrients internally.

# DIMINISHED LIGHT PENETRATION



## Causes of Light Reduction

Algal blooms and suspended particles increase water turbidity, blocking sunlight from penetrating aquatic environments.

## Impact on Aquatic Vegetation

Reduced light limits photosynthesis, causing decline in seagrass beds and other submerged plants.

## Ecosystem Consequences

Loss of habitats decreases biodiversity and weakens sediment stability and carbon sequestration.

## Shift in Primary Producers

Low-light conditions favor adapted species, altering aquatic ecosystem structure and balance.



# INCREASED SEDIMENTATION

## **Organic Matter Accumulation**

Algal bloom organic matter settles, accumulating on the seabed and smothering benthic habitats.

## **Impact on Oxygen Levels**

Decomposition increases biological oxygen demand, leading to hypoxic conditions in sediments.

## **Nutrient Flux Alterations**

Sedimentation changes seabed chemistry, releasing nutrients back into water and sustaining eutrophication.



# ACIDIFICATION

## **Microbial Decomposition and Acid Formation**

Microbial breakdown of organic matter releases  $\text{CO}_2$  which dissolves in water to form carbonic acid, lowering pH levels.

## **Impact on Marine Organisms**

Lower pH harms organisms that rely on calcium carbonate like mussels and snails by weakening their shells.

## **Nutrient and Metal Availability**

Acidification changes the solubility and availability of nutrients and metals, disrupting biological processes and ecosystem health.

# BROWNIFICATION



## Causes of Brownification

Brownification is caused by increased dissolved organic matter from runoff and decaying algae in aquatic systems.

## Impact on Light Penetration

Brownification reduces light penetration in eutrophic coastal waters, worsening effects of algal blooms.

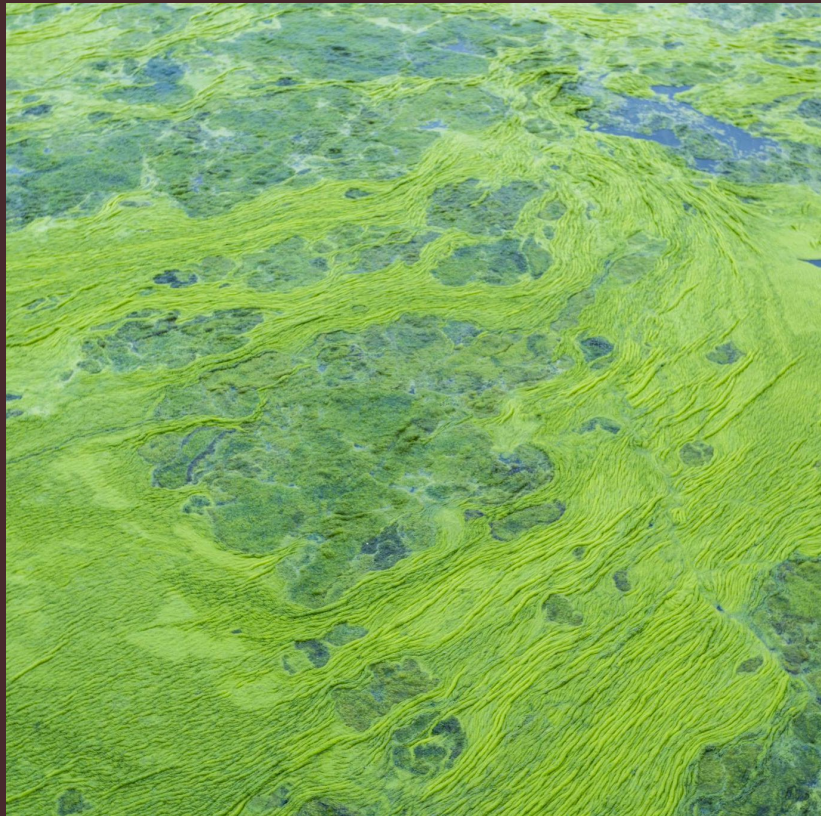
## Effects on Microbial Communities

It alters microbial community composition, shifting primary production from autotrophic to heterotrophic processes.

## Water Quality and Ecosystem Impact

Brownification affects water quality, aesthetic value, and chemical nutrient speciation, impacting recreation and ecology.

# HARMFUL ALGAL BLOOMS (HABS)



## Causes of HABs

HABs result from nutrient enrichment and climate changes, promoting algae growth in coastal waters.

## Toxic Effects

Certain algae produce toxins harmful to marine life, humans, and pets, causing health risks.

## Ecological Impact

HABs degrade water quality, reduce oxygen, and cause mass mortality of aquatic organisms.

## Economic Consequences

HABs lead to fishery closures and tourism declines, impacting public health and local economies.

# MACROPHYTE INFESTATION



## **Excessive Aquatic Macrophyte Growth**

Macrophyte infestation involves rapid growth of aquatic macrophytes like *Cladophora* and *Myriophyllum* in nutrient-rich waters.

## **Impact on Water Flow**

Dense plant and/or algal mats clog waterways, disrupting water flow and aquatic ecosystems.

## **Ecological and Economic Effects**

Overabundance reduces recreational value and increases management costs, altering oxygen and nutrient cycles.

## **Role in Habitat and Sediment Stabilization**

Some macrophytes provide habitat and stabilize sediments despite negative effects when overgrown.

# BIODIVERSITY LOSS



## Impact of Hypoxia

Low oxygen levels cause habitat degradation and reduce marine species diversity significantly.

## Shift in Species Composition

Sensitive species decline and opportunistic species increase due to altered environmental conditions.

## Ecosystem Function Disruption

Altered food webs affect nutrient cycling, energy flow, and ecosystem resilience to stressors.

## Effects on Ecosystem Services

Biodiversity loss impacts fisheries, water purification, and recreational opportunities.

# ALTERED BIOGEOCHEMICAL CYCLING



## Impact of Oxygen Depletion

Oxygen depletion alters microbial processes affecting nutrient transformation in coastal environments.

## Microbial Nutrient Cycling

Anoxic conditions promote denitrification and sulfate reduction, releasing nutrients and toxic compounds.

## Sustained Eutrophic Conditions

Internal nutrient loading sustains eutrophication even without external nutrient inputs.

## Ecosystem Stability Challenges

Disrupted biogeochemical cycles undermine ecosystem stability and complicate water quality management.

# CHANGES IN ECOSYSTEM STRUCTURE AND FUNCTION



## **Eutrophication Effects**

Persistent eutrophication causes algal blooms and macrophyte dominance, reducing biodiversity and trophic complexity.

## **Functional Changes**


Structural shifts impact ecosystem productivity, nutrient cycling, and resilience to environmental disturbances.

## **Ecosystem Service Decline**

Eutrophication compromises fisheries, water purification, and habitat provision, affecting human benefits.

## **Importance of Mitigation**

Understanding and addressing these changes is essential to preserve ecological integrity and societal benefits.



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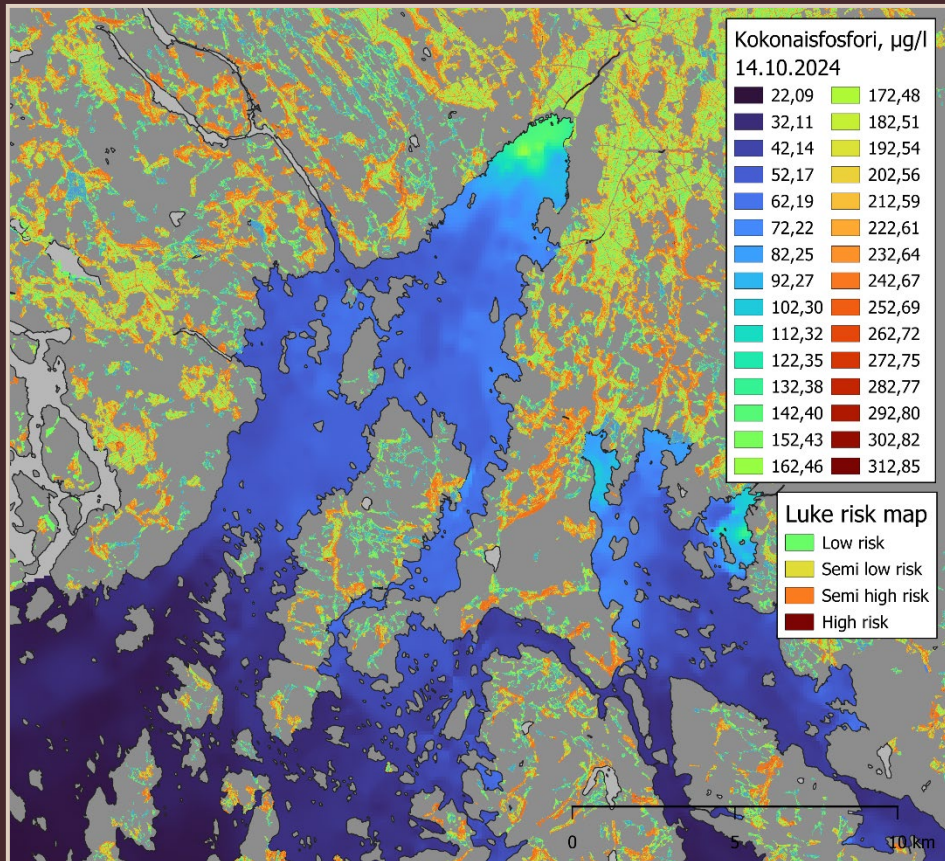


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# On the causes and consequences of organic and nutrient loading

# Defining environmental status and recognizing pressures



## 1. Assess environmental status

Various water quality indicators are used for determining the status of the aquatic environment. This is akin to evaluating the “health” of the environment from perspectives relevant to problems/services.

## 2. Define the environment

The measured and expected values of the indicator variables are conditional to environmental type and the prevailing conditions such as weather, currents and time of the season.

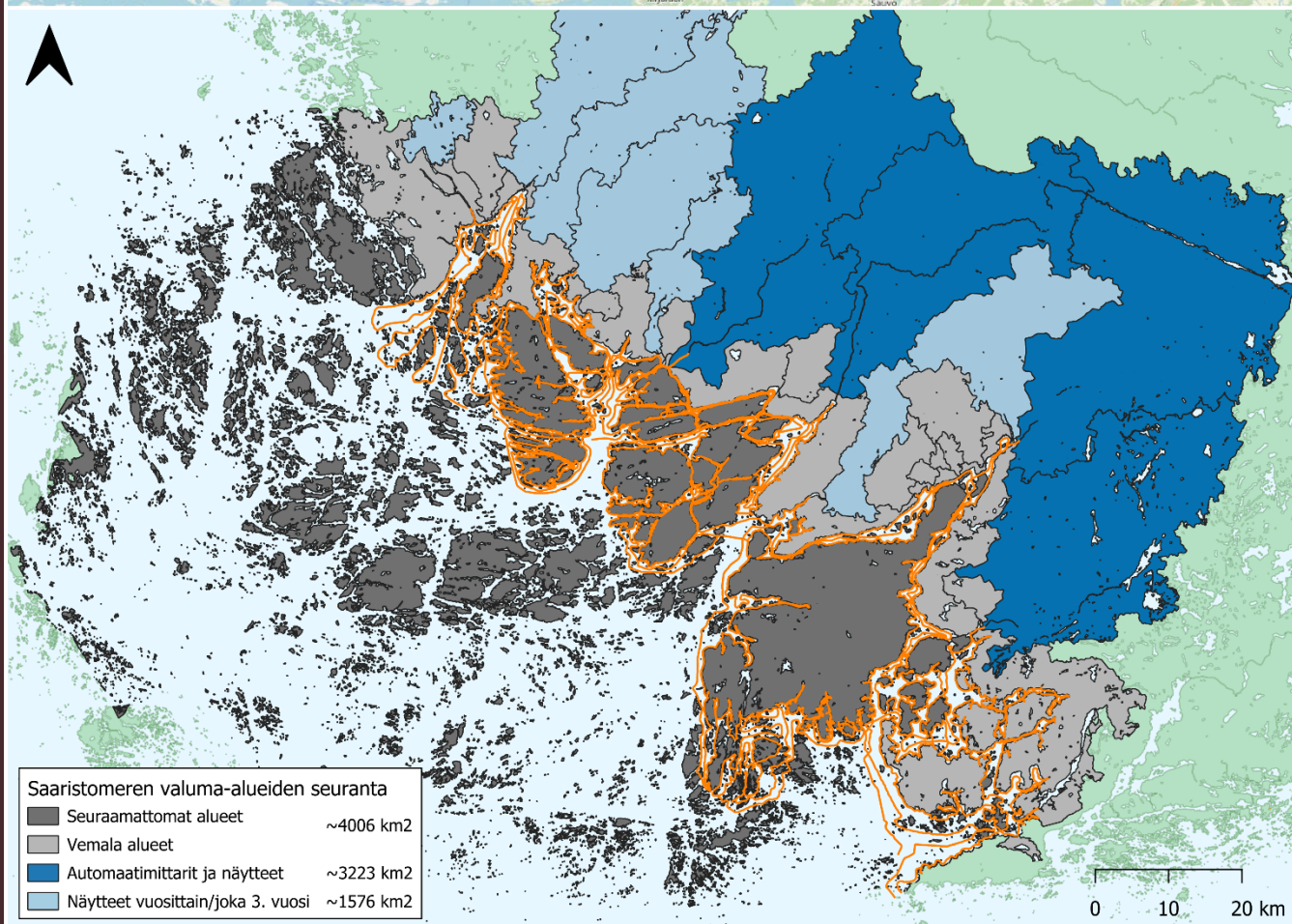
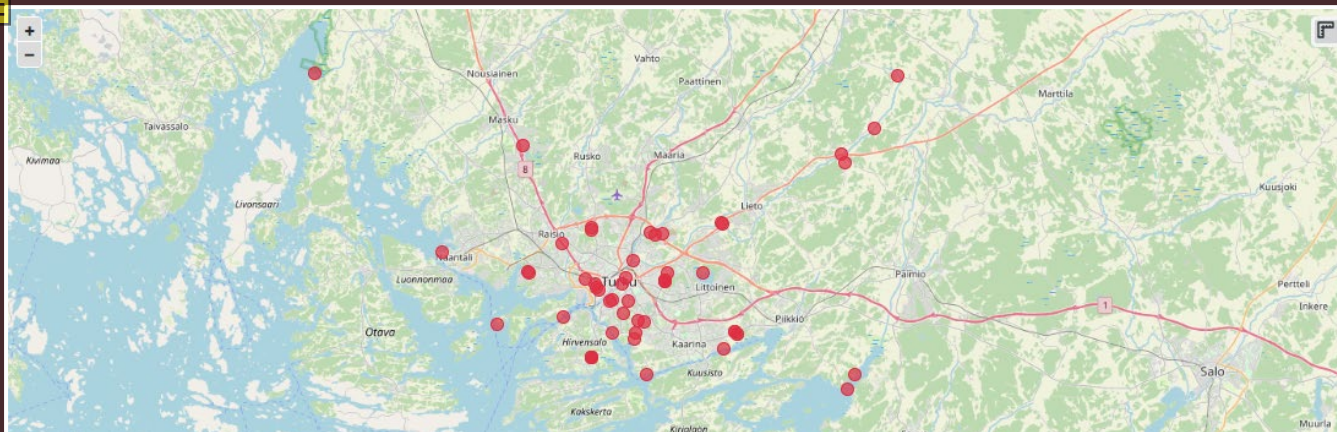
## 3. Recognize pressures/changes in the environment

Linking the causes and consequences of eutrophication (nutrient and organic loading) is a complex endeavor.

## 4. Target concrete actions and follow up their effects

Reliable and representative evidence-based monitoring is *fundamentally* necessary for targeting concrete management actions and for following up their impacts on the recipient environment.

→ INPUT-BASED vs. INDICATOR-BASED MONITORING



# Input-Based vs. Indicator-Based Monitoring

## Input-Based Monitoring

Measures ecosystem inputs like nutrient loads and emissions using models or estimates for regulatory compliance.

## Indicator-Based Monitoring

Focuses on direct measurements of ecosystem responses, including water quality and biodiversity from field data.

## Complementary Monitoring Methods

Combines predictive input-based models with real-time indicator observations for adaptive ecosystem management.

# CARBON AND NUTRIENT CYCLING IN COASTAL WATERS: KEY WATER QUALITY VARIABLES

Understanding vital processes  
affecting marine ecosystems



# INTRODUCTION AND FRAMEWORK

# CARBON AND NUTRIENT CYCLING IN COASTAL WATERS



## Water Quality Variables

Key water quality variables include physical, chemical, and biological factors that influence coastal ecosystem health.

## Carbon Cycling in Coastal Waters

Carbon cycling in coastal waters involves processes that regulate carbon flow and storage, affecting ecosystem balance.

## Nutrient Cycling Roles

Nutrient cycling drives productivity and supports aquatic life by recycling essential elements in coastal ecosystems.

## Ecosystem Management Importance

Understanding water quality assists policymakers and researchers in effective environmental management and conservation.



# FRAMEWORK AND CATEGORIZATION

## Hydrography and Hydrodynamics

Includes physical water parameters such as temperature, salinity, currents and mixing affecting the environment.

## Status Indicators

Chemical and biological metrics like dissolved oxygen, nutrients, pH, and greenhouse gases indicate water quality status.

## Framework Purpose

This framework helps understand interactions among variables and their role in carbon and nutrient cycling.

# INTERACTIONS AMONG VARIABLES

## Temperature Effects

Temperature influences water stratification and gas solubility, affecting chemical and physical water properties.

## Dissolved Organic Matter Role

Dissolved organic matter contributes to greenhouse gas production such as methane and nitrous oxide in water bodies.

## Currents and Nutrient Distribution

Water currents control residence time and distribute nutrients and organic matter throughout coastal ecosystems through lateral and vertical mixing.

## Stratification and Microbial Activity

Stratification governs vertical mixing and oxygen levels, which regulate microbial activity and gas emissions.



# HYDROGRAPHY AND HYDRODYNAMICS



# TEMPERATURE

## **Temperature and Biological Activity**

Temperature influences metabolic rates of marine organisms, affecting biological activity in coastal waters.

## **Impact on Gas Solubility**

Temperature affects solubility of gases like oxygen and carbon dioxide, critical for aquatic ecosystems.

## **Water Stratification Effects**

Warmer temperatures increase stratification, reducing oxygen exchange and causing hypoxic conditions.

## **Importance of Temperature Monitoring**

Monitoring temperature helps understand seasonal and climate-driven changes in carbon and nutrient cycling.

# SALINITY



## **Salinity Effects on Water Properties**

Salinity controls water density and mixing, influencing coastal ecosystem dynamics and nutrient distribution.

## **Sources of Salinity Variation**

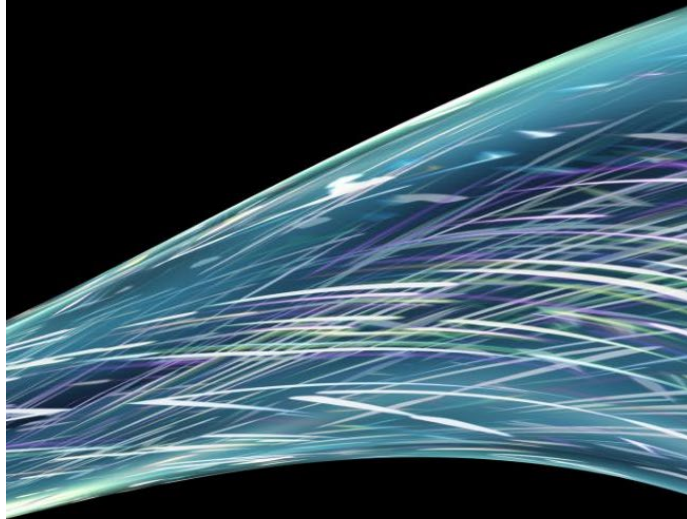
Freshwater inputs, evaporation, and tidal exchange cause salinity changes affecting water stratification.

## **Impact on Nutrient and Gas Cycling**

Salinity influences solubility and speciation of nutrients and gases, affecting biogeochemical cycles.

## **Role in Organic Matter Behavior**

Understanding salinity dynamics aids interpretation of organic matter behavior crucial for carbon cycling.



# CURRENTS AND MIXING

## **Nutrient and Gas Distribution**

Currents and mixing distribute nutrients and gases essential for aquatic ecosystems throughout the water column.

## **Oxygenation and Primary Production**

Mixing enhances oxygen levels and supports primary production by delivering nutrients to surface waters.

## **Pollutant Transport and Stratification**

Currents influence transport of pollutants and affect water stratification impacting ecosystem health.

## **Measurement and Modeling Importance**

Accurate measurement and modeling of currents are vital for predicting ecological changes and managing water quality.



# STRATIFICATION

## **Definition of Stratification**

Stratification is the layering of water caused by differences in temperature and salinity, influencing water column structure.

## **Impact on Oxygen and Nutrients**

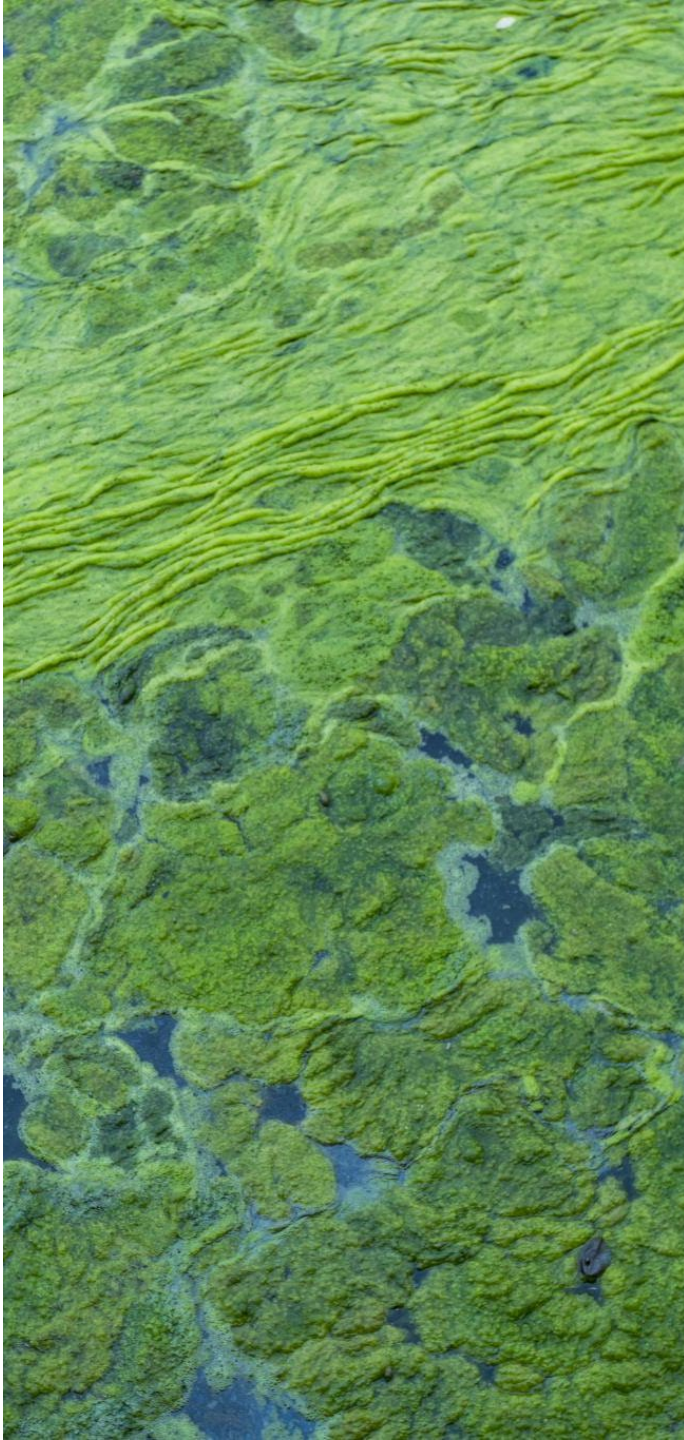
Stratification controls vertical mixing, affecting oxygen levels and nutrient distribution in different water layers.

## **Effects on Microbial Activity**

Strong stratification can cause oxygen depletion in bottom waters, influencing microbial processes and greenhouse gas production.

## **Monitoring and Environmental Impact**

Monitoring stratification aids in assessing hypoxia risk and understanding carbon and nutrient cycling seasonally.



# RESIDENCE TIME

## **Definition and Importance**

Residence time refers to how long water stays in an area before replacement, impacting ecosystem processes.

## **Effects on Nutrients and Pollutants**

Longer residence times increase retention of nutrients and pollutants, influencing biological transformations in water.

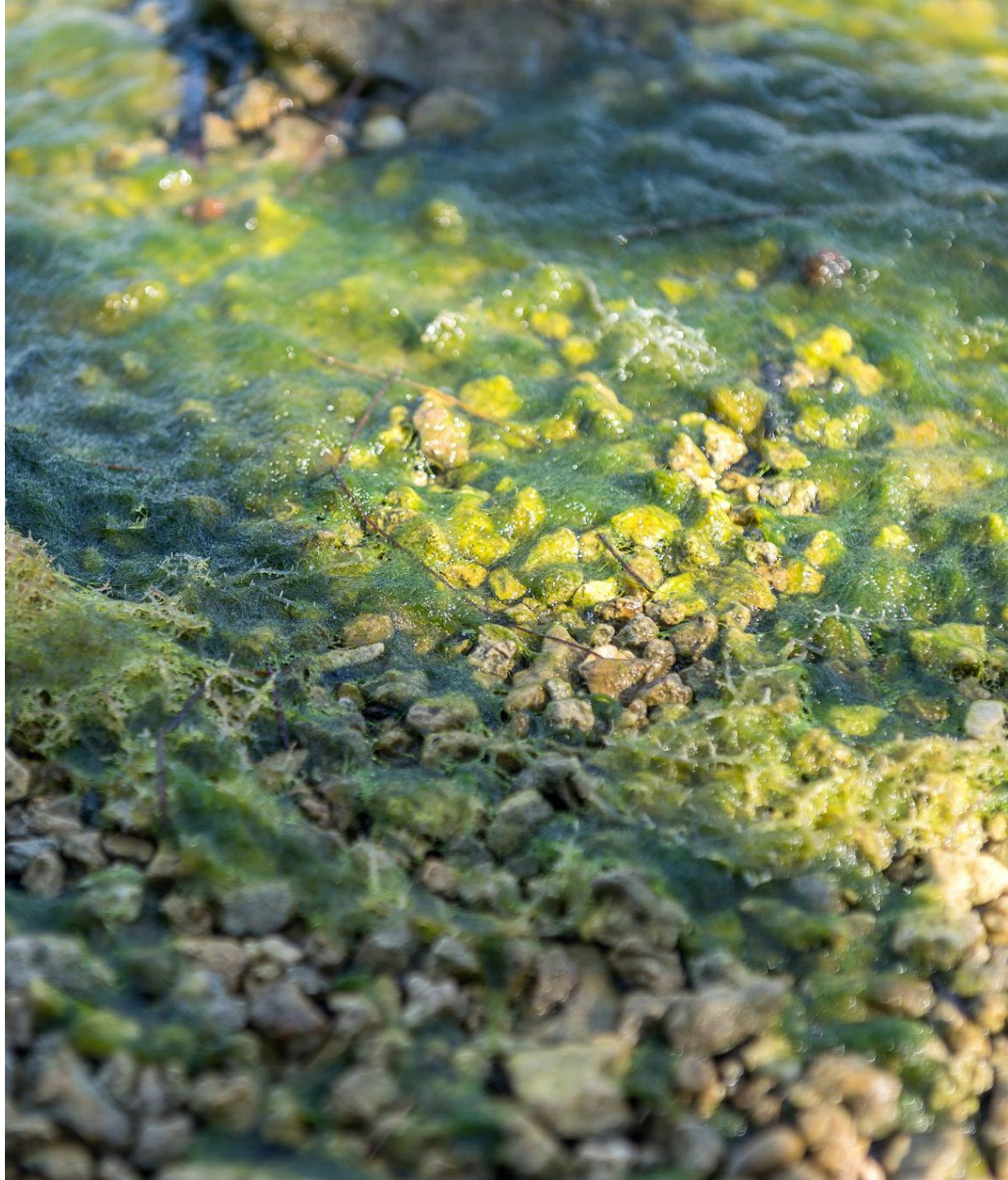
## **Biological Processing and Gas Production**

Extended residence times enhance biological activity, leading to gases like methane and nitrous oxide production.

## **Environmental Implications**

Residence time influences organic carbon accumulation and eutrophication potential, essential for ecosystem management.

# STATUS INDICATORS



# DISSOLVED OXYGEN

## Oxygen Balance in Water

Dissolved oxygen reflects the balance between oxygen produced by photosynthesis and consumed by respiration and decomposition.

## Effects of Low Oxygen

Low dissolved oxygen can cause hypoxia, harming aquatic life and promoting methane and nitrous oxide production by anaerobic processes.

## Ecosystem Health Monitoring

Monitoring dissolved oxygen is critical for assessing coastal ecosystem health and understanding carbon and nutrient cycling dynamics.



# NUTRIENTS (N, P, SI)

## **Role in Primary Production**

Nitrogen, phosphorus, and silicon are essential nutrients supporting phytoplankton growth and overall primary production in aquatic ecosystems.

## **Eutrophication Effects**

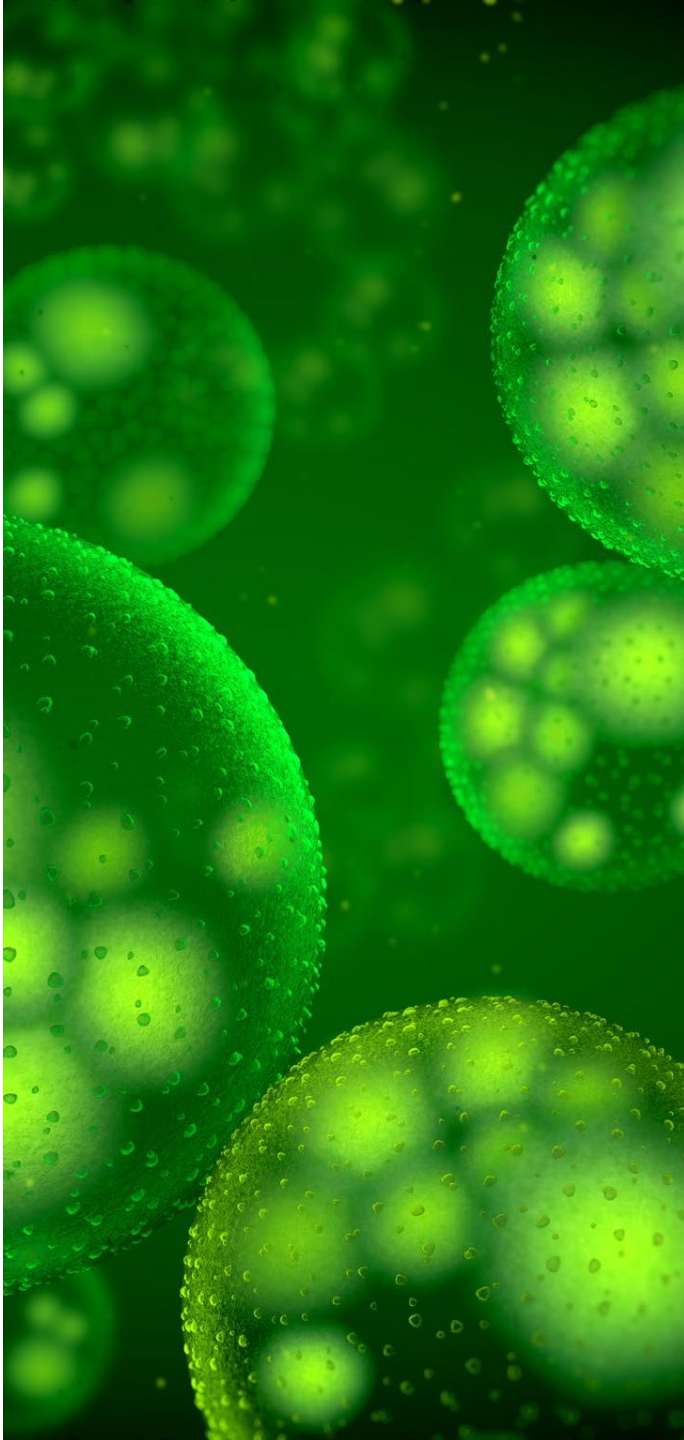
Excessive nutrient inputs cause eutrophication, leading to harmful algal blooms and depletion of oxygen in water bodies.

## **Microbial and Carbon Processes**

Nutrient availability influences microbial activity and transformation of carbon compounds in aquatic ecosystems.

## **Water Quality Monitoring**

Monitoring nutrient levels is crucial for managing water quality and understanding biogeochemical cycles in ecosystems.



# CHLOROPHYLL-A

## **Indicator of Phytoplankton Biomass**

Chlorophyll-a serves as a proxy to estimate phytoplankton biomass and overall productivity in aquatic environments.

## **Sign of Eutrophic Conditions**

High concentrations of chlorophyll-a can indicate eutrophic waters with nutrient enrichment and increased photosynthesis.

## **Impact on Oxygen and Food Web**

Chlorophyll-a influences oxygen levels and supports food availability for higher trophic levels in aquatic ecosystems.

## **Ecosystem Monitoring Tool**

Monitoring chlorophyll-a helps assess ecosystem health and the effects of nutrient enrichment on productivity.



# ORGANIC CARBON (DOC/POC)

## **Role in Microbial Activity**

DOC and POC serve as substrates that drive microbial respiration and activity in coastal ecosystems.

## **Carbon Cycling and Transport**

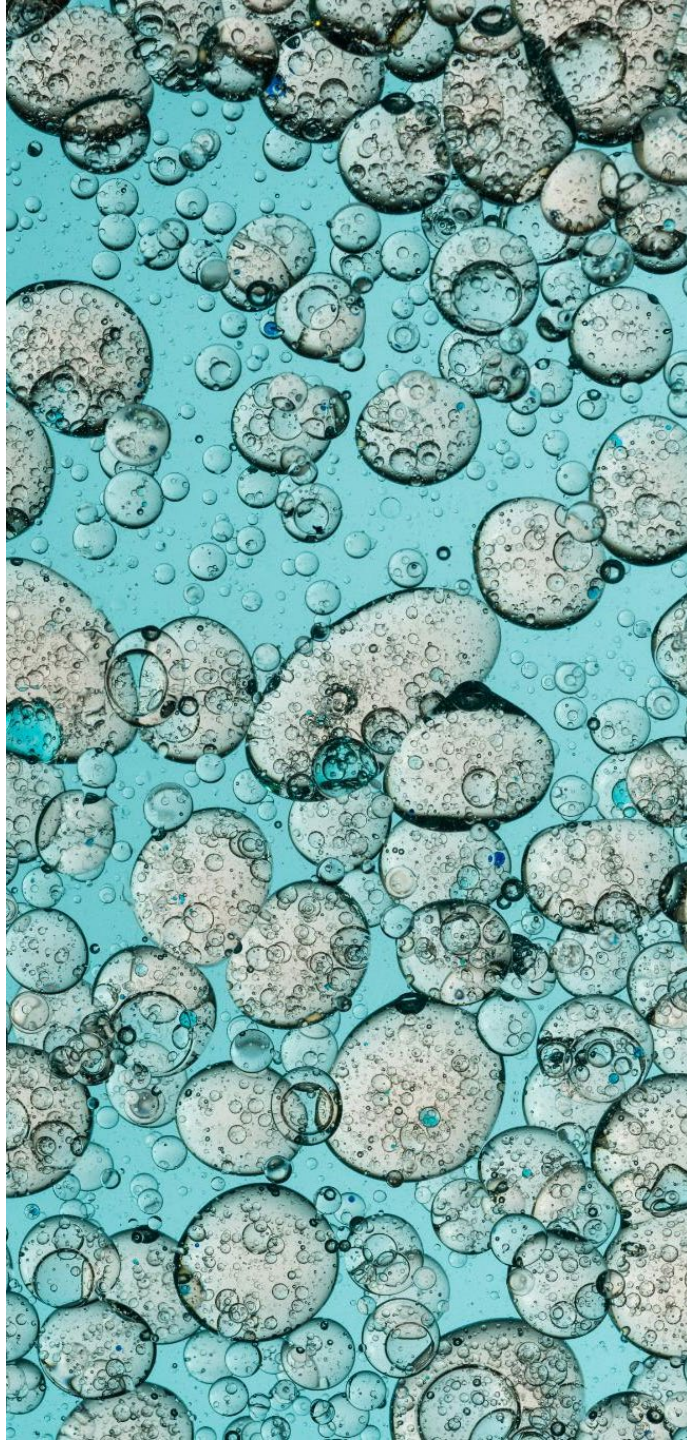
DOC is transported long distances in water, whereas POC settles and undergoes decomposition locally.

## **Impact on Greenhouse Gas Production**

Microbial processing of organic carbon contributes to greenhouse gas emissions in coastal environments.

## **Significance for Carbon Budgets**

Studying DOC and POC dynamics is crucial to understanding coastal waters' role in global carbon fluxes.



# DISSOLVED ORGANIC MATTER (DOM)

## Composition and Origins

DOM is a complex mix of organic compounds from biological activity and terrestrial sources.

## Role in Gas Production

DOM influences production of greenhouse gases like methane and carbon dioxide by microbes.

## Impact on Light and Chemistry

DOM affects light attenuation in water and alters chemical speciation in aquatic environments.

## Monitoring and Environmental Impact

Monitoring DOM is essential to understand carbon cycling and its impact on water quality and ecosystems.

# PH



## Role of pH in Chemistry

pH controls chemical speciation and the solubility of gases and nutrients in aquatic environments.

## Biological Process Influence

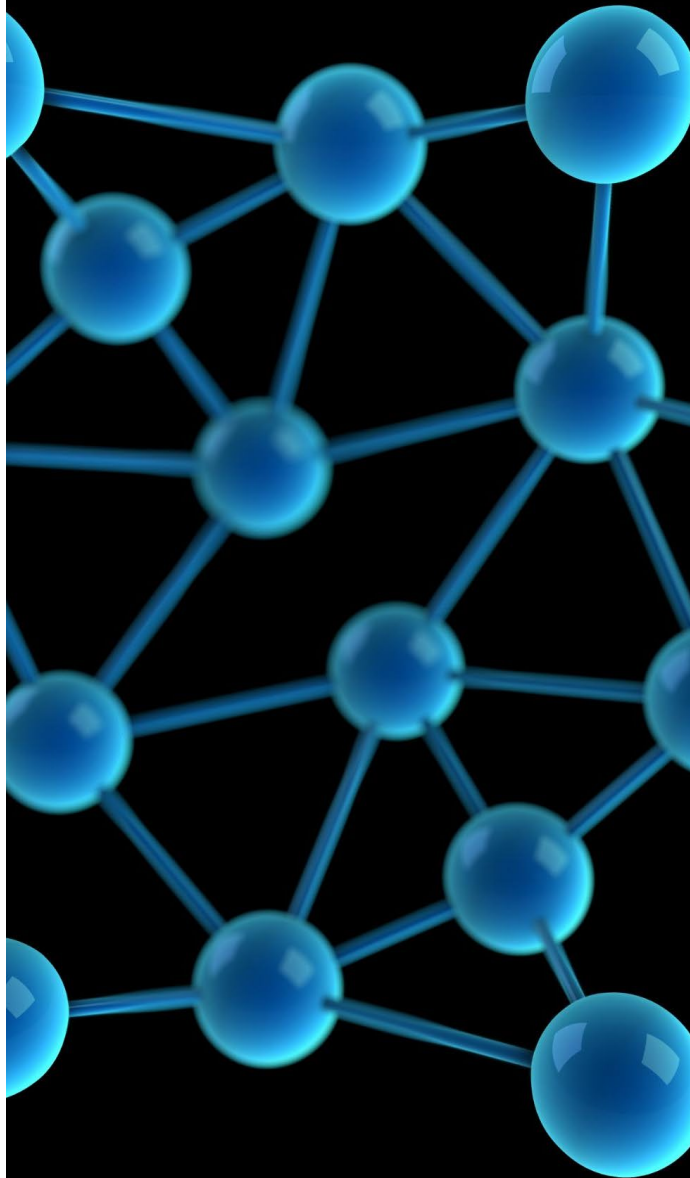
Respiration, photosynthesis, and carbon dioxide levels influence pH, impacting biological processes.

## Impact on Nutrients and Metals

Shifts in pH alter nutrient availability and the behavior of metals and organic compounds.

## Monitoring Ecosystem Health

Tracking pH is essential to assess acidification impacts on coastal ecosystems and carbon cycling.



# METHANE (CH<sub>4</sub>)

## **Methane Production Process**

Methane is generated anaerobically by microbes breaking down organic matter in oxygen-free environments.

## **Methane as Greenhouse Gas**

Methane is a potent greenhouse gas that significantly contributes to global climate change.

## **Methane in Coastal Waters**

In coastal waters, methane production depends on organic matter, oxygen levels, and water residence time.

## **Importance of Monitoring**

Monitoring methane helps understand its sources, sinks, and role in carbon cycling and emissions.



# CARBON DIOXIDE (CO<sub>2</sub>)

## **Role in Biological Processes**

CO<sub>2</sub> plays a critical role in respiration and photosynthesis, essential biological energy processes.

## **Chemical Buffering in Coastal Waters**

Carbon dioxide helps regulate pH levels, buffering chemical changes in coastal water environments.

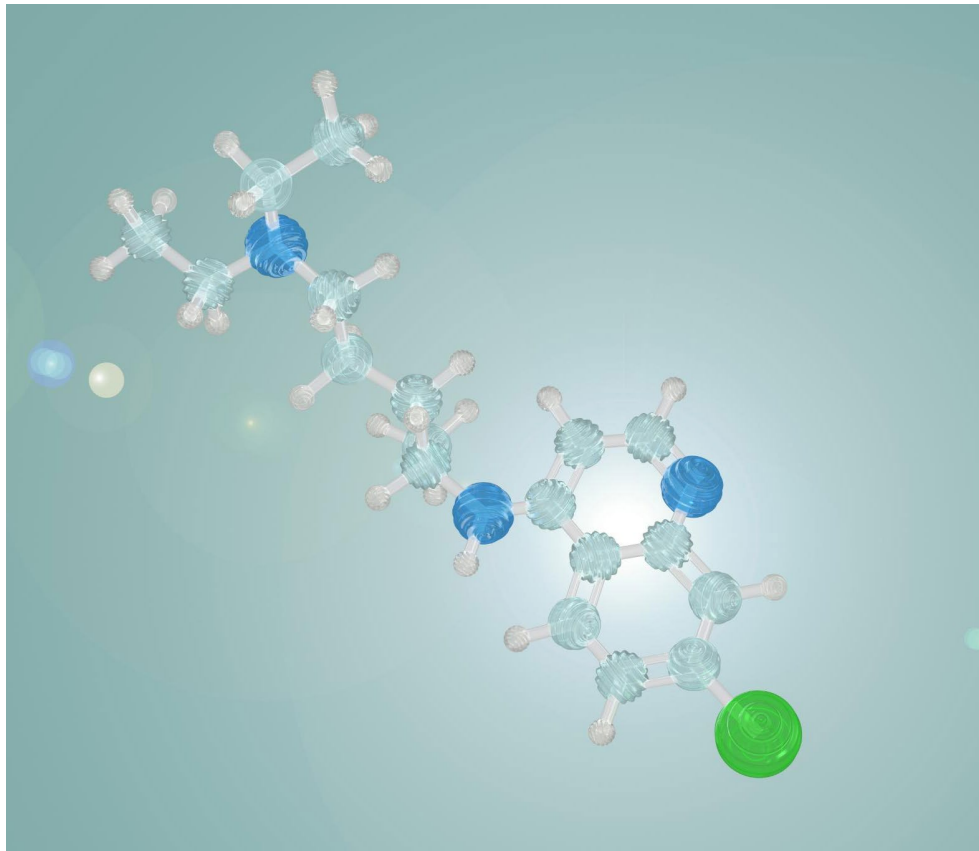
## **Indicator of Carbon Cycle Balance**

CO<sub>2</sub> levels indicate the balance between autotrophic and heterotrophic biological activity in ecosystems.

## **Monitoring and Environmental Impact**

Tracking CO<sub>2</sub> assists in assessing carbon fluxes, ocean acidification, and coastal waters' global carbon role.

# NITROUS OXIDE (N<sub>2</sub>O)



## Formation Processes

Nitrous oxide forms as a byproduct during nitrification and denitrification in soils and waters.

## Environmental Impact

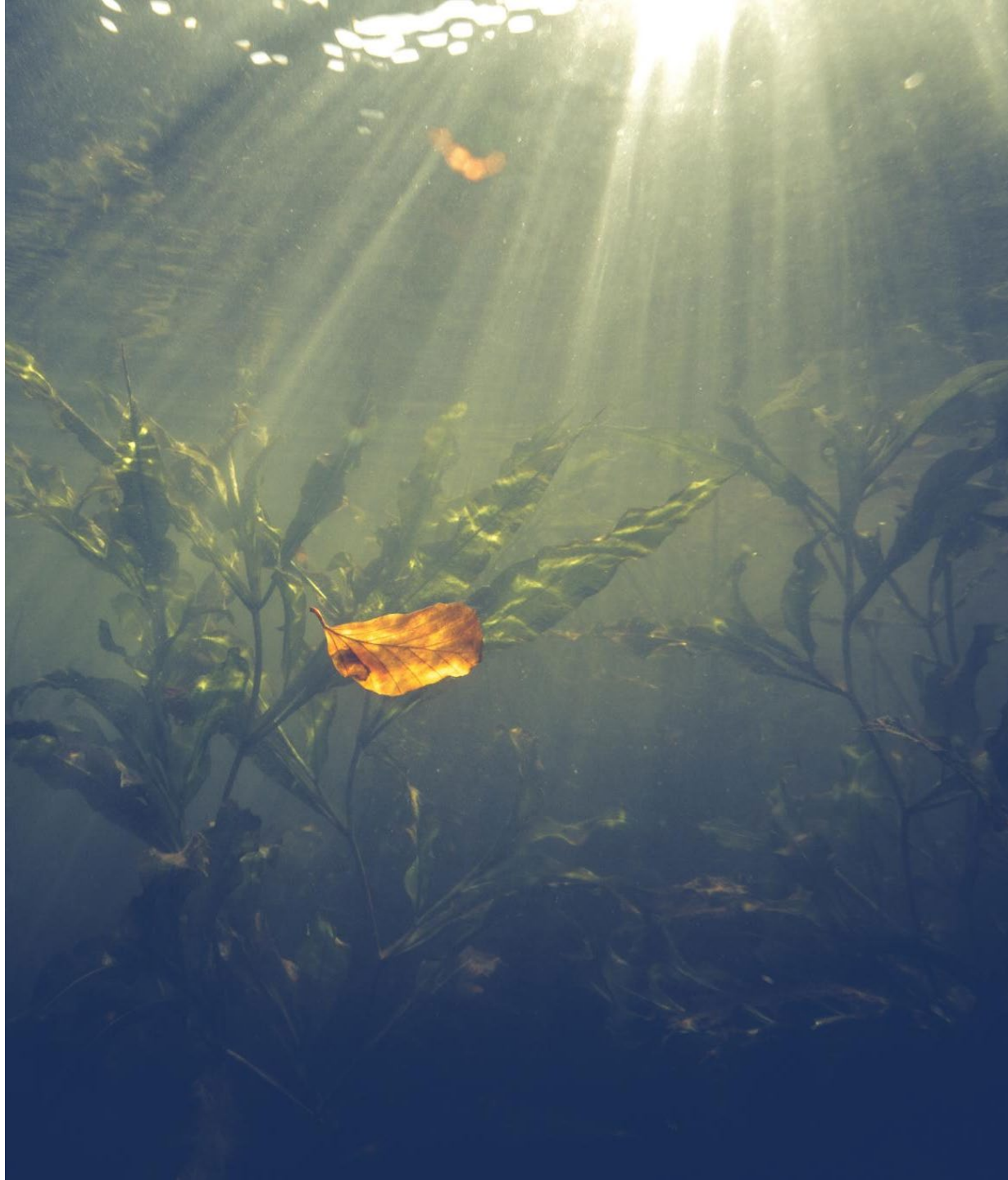
Nitrous oxide is a potent greenhouse gas that significantly contributes to climate change.

## Production Influences

Oxygen levels, organic matter, and nutrient availability control nitrous oxide production.

## Monitoring Importance

Monitoring N<sub>2</sub>O helps understand nitrogen cycling and impacts of nutrient enrichment in ecosystems.



# LIGHT ATTENUATION

## **Factors Influencing Attenuation**

Light attenuation is affected by suspended particles, dissolved organic matter, and the clarity of water in coastal areas.

## **Impact on Photosynthesis Depth**

Higher light attenuation reduces the depth where photosynthesis can occur, limiting primary production in aquatic ecosystems.

## **Ecosystem Monitoring Importance**

Monitoring light attenuation assists in assessing ecosystem productivity and the effects of turbidity and organic matter on water quality.

# SUMMARY AND OUTLOOK



# INTEGRATED MONITORING AND FUTURE DIRECTIONS

## **Importance of Integrated Monitoring**

Integrated monitoring captures complex interactions among physical, chemical, and biological water quality parameters.

## **Focus on Future Research**


Advancing measurement techniques and modeling will improve understanding of coastal ecosystem dynamics.

## **Climate Change and Human Impact**

Assessing effects of climate change and human activities is vital for sustainable coastal management.

## **Management and Policy Decisions**

Accurate monitoring data supports effective policy and ecosystem management decisions.



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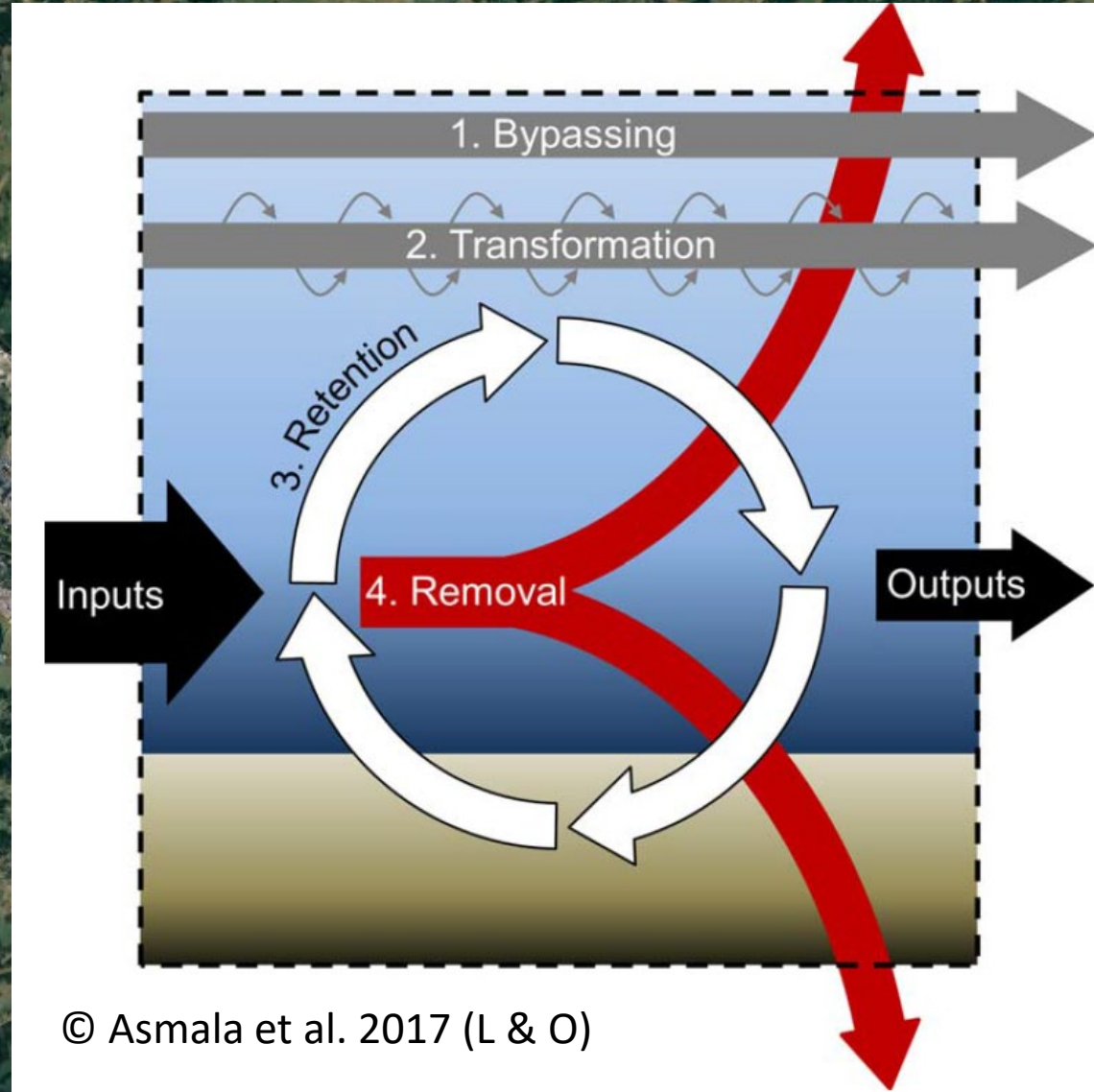
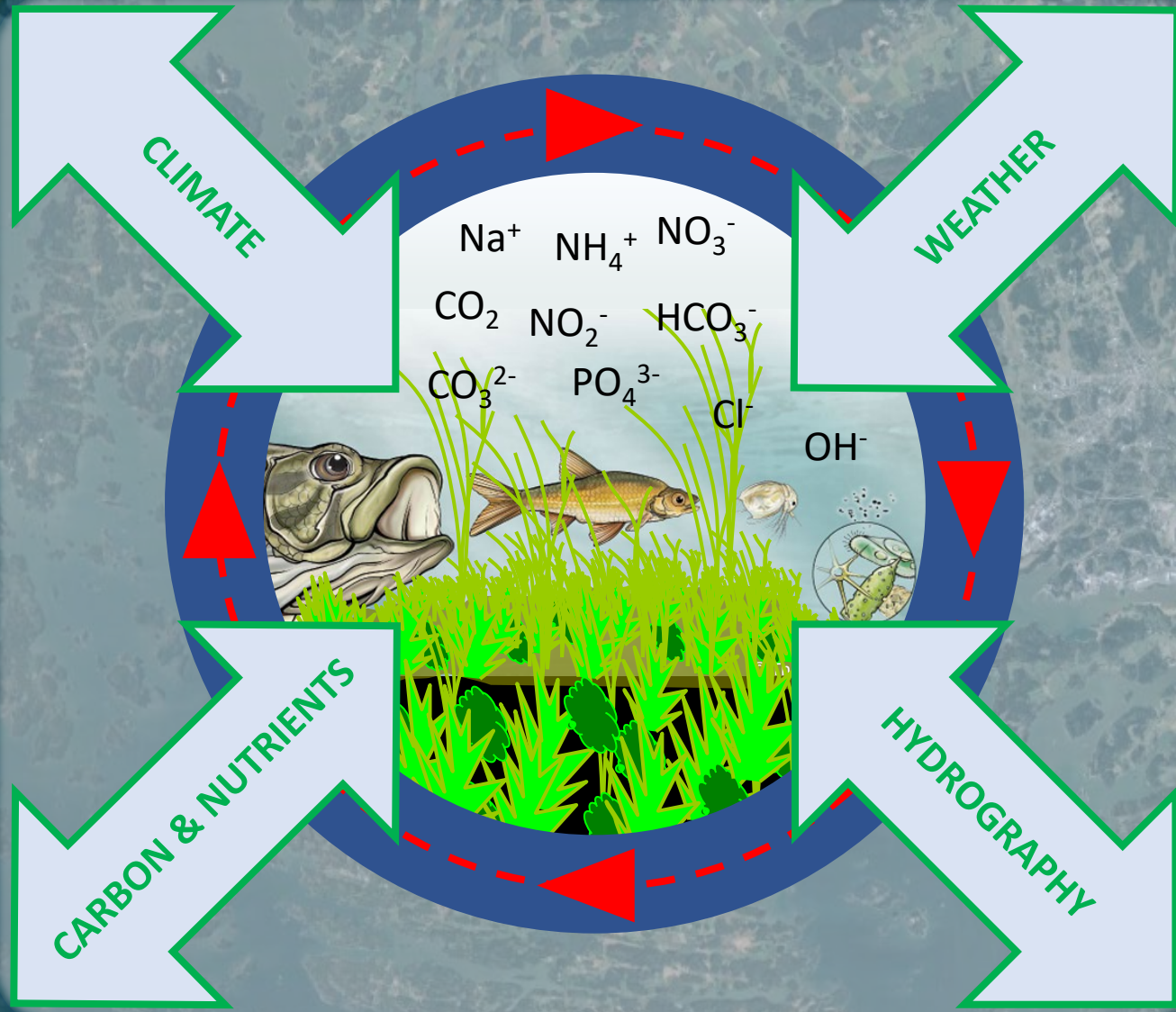
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# The Coastal Filter concept



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# Transformation Processes in the Coastal Filter



## Microbial Degradation Effects

Microbial degradation breaks down organic carbon, releasing  $\text{CO}_2$  and nutrients, causing acidification and oxygen depletion in coastal waters.

## Nutrient Uptake and Algal Blooms

Nutrient uptake by algae starts cycling but can lead to algal blooms and changes in habitat structure.

## Sedimentation and Nutrient Release

Sedimentation from dead biomass increases oxygen demand and releases nutrients, sustaining eutrophication.

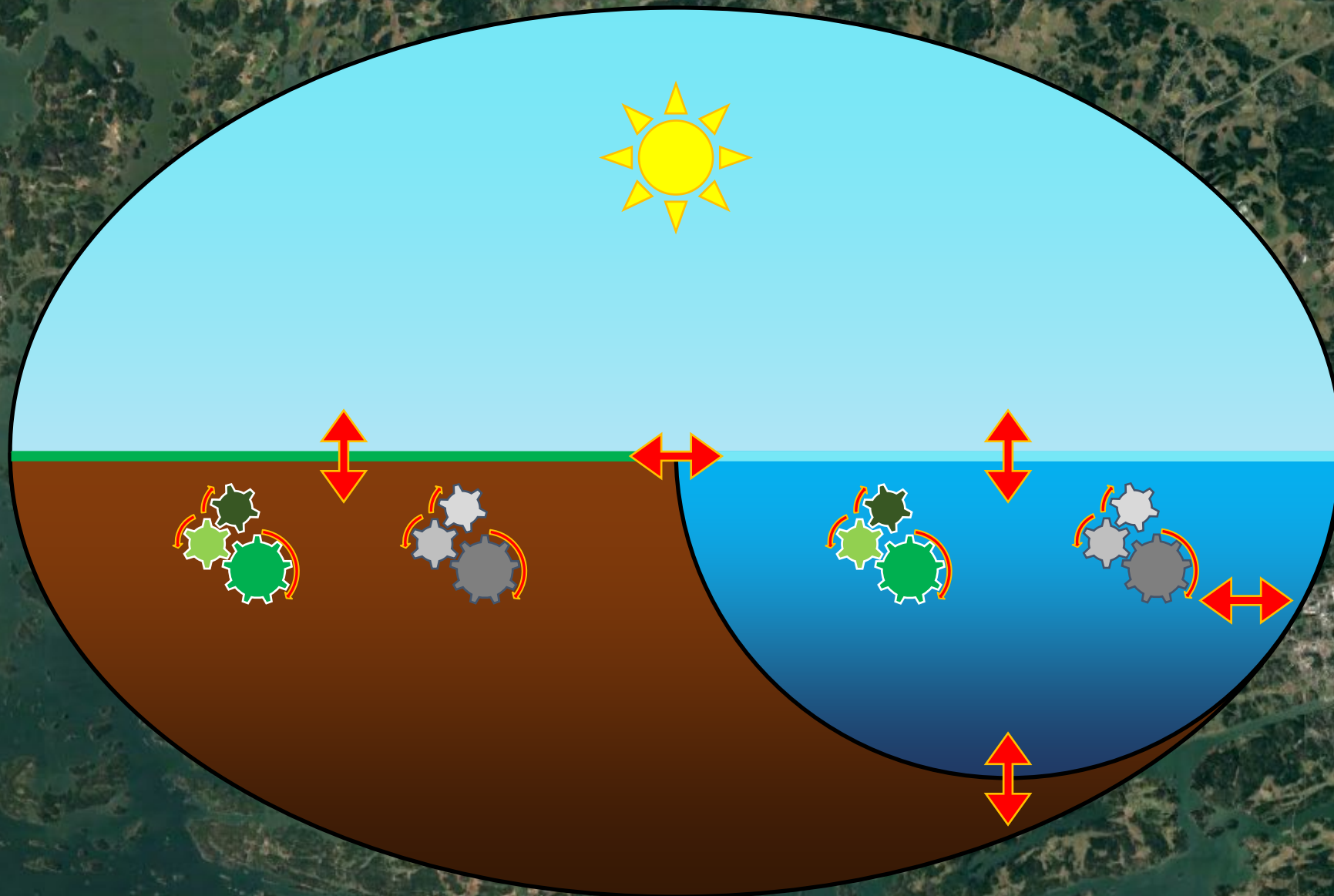
## Denitrification and Phosphorus Dynamics

Denitrification removes nitrogen in anoxic conditions; phosphorus sorption and release depend on redox state, influencing nutrient availability.

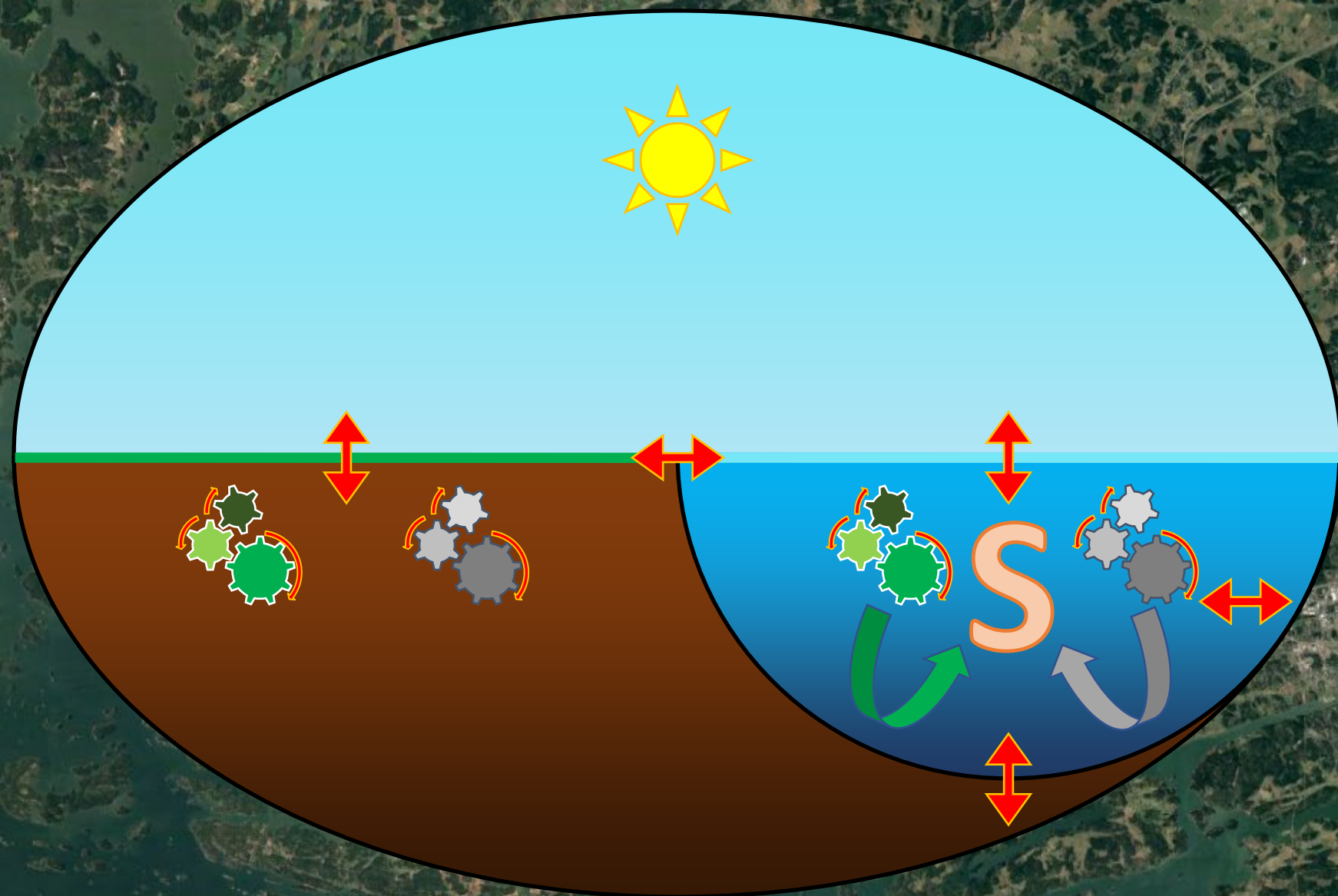
## PERSPECTIVE

- Carbon and nutrients
  - dissolved
  - particulate

- Coastal waters (coastal filter)
  - transportation
  - transformation
- important environments
- influential environments for the open sea and climate



# PERSPECTIVE



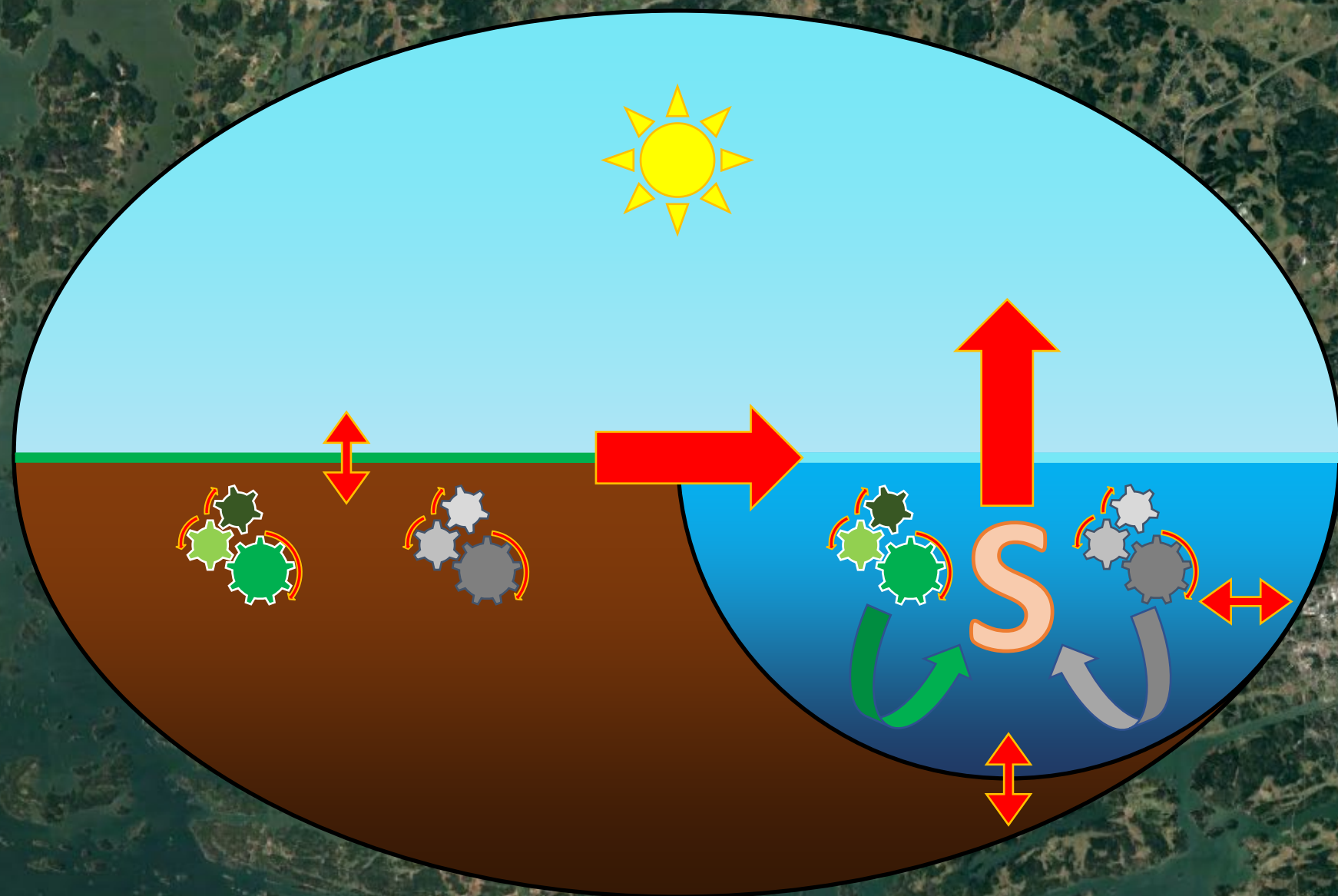
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→ important environments  
→ influential environments for the open sea and climate

Loading status depends on  
- fluxes [double arrows]  
- biochemical conditions [green wheels]  
- physical conditions [gray wheels]

Status indicators (e.g.)  
- dissolved organic matter  
- turbidity  
- chlorophyll *a*

# PERSPECTIVE



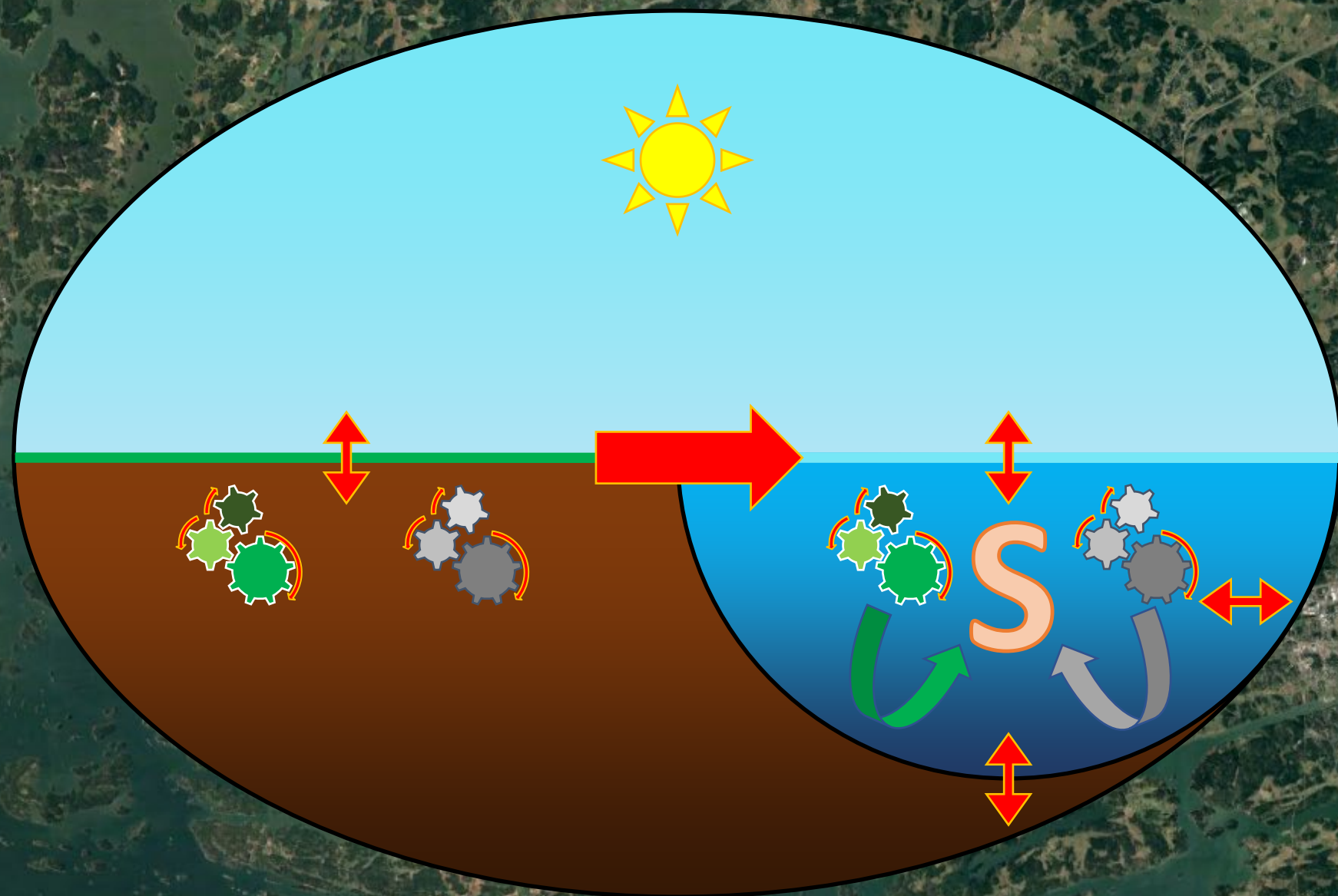
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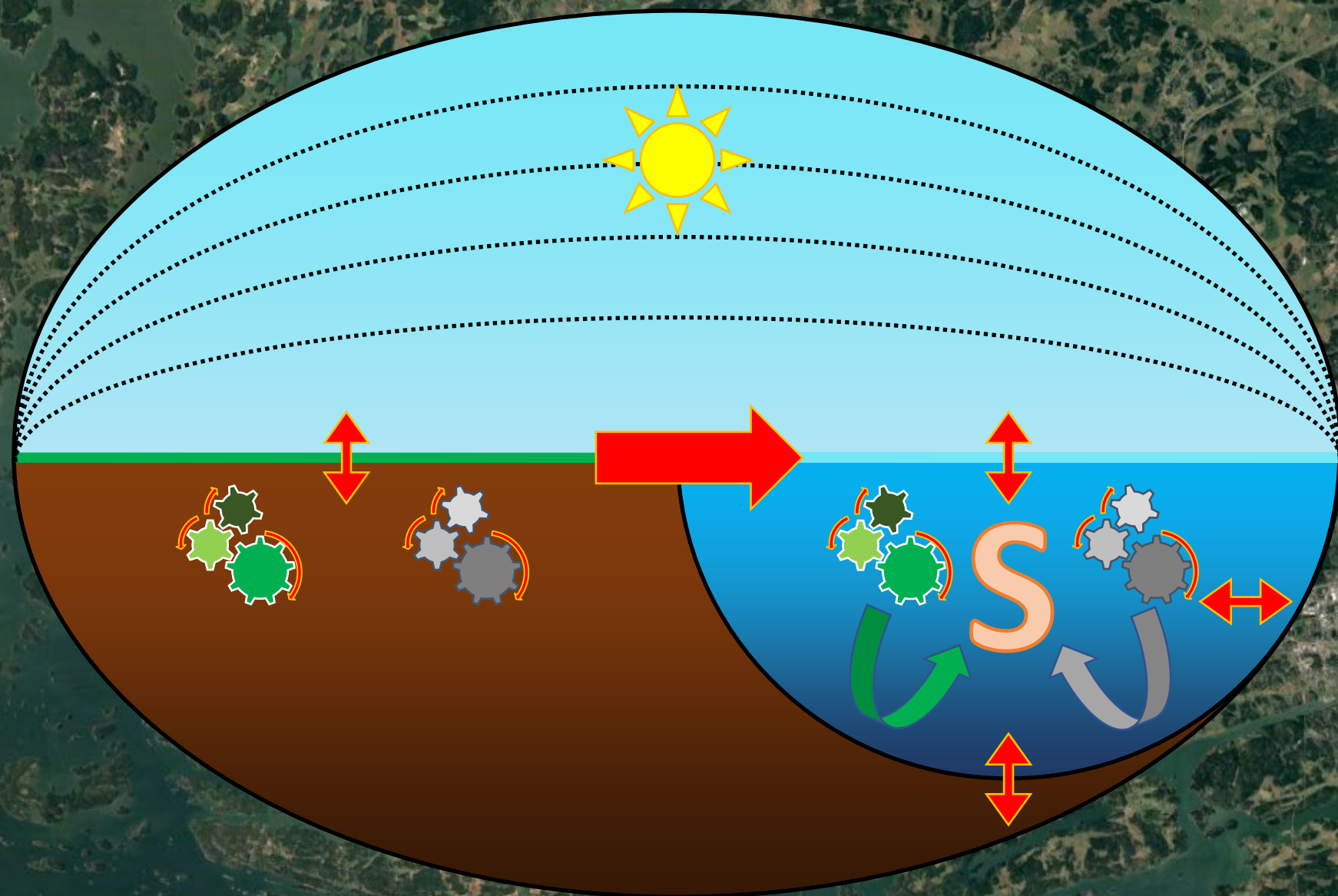
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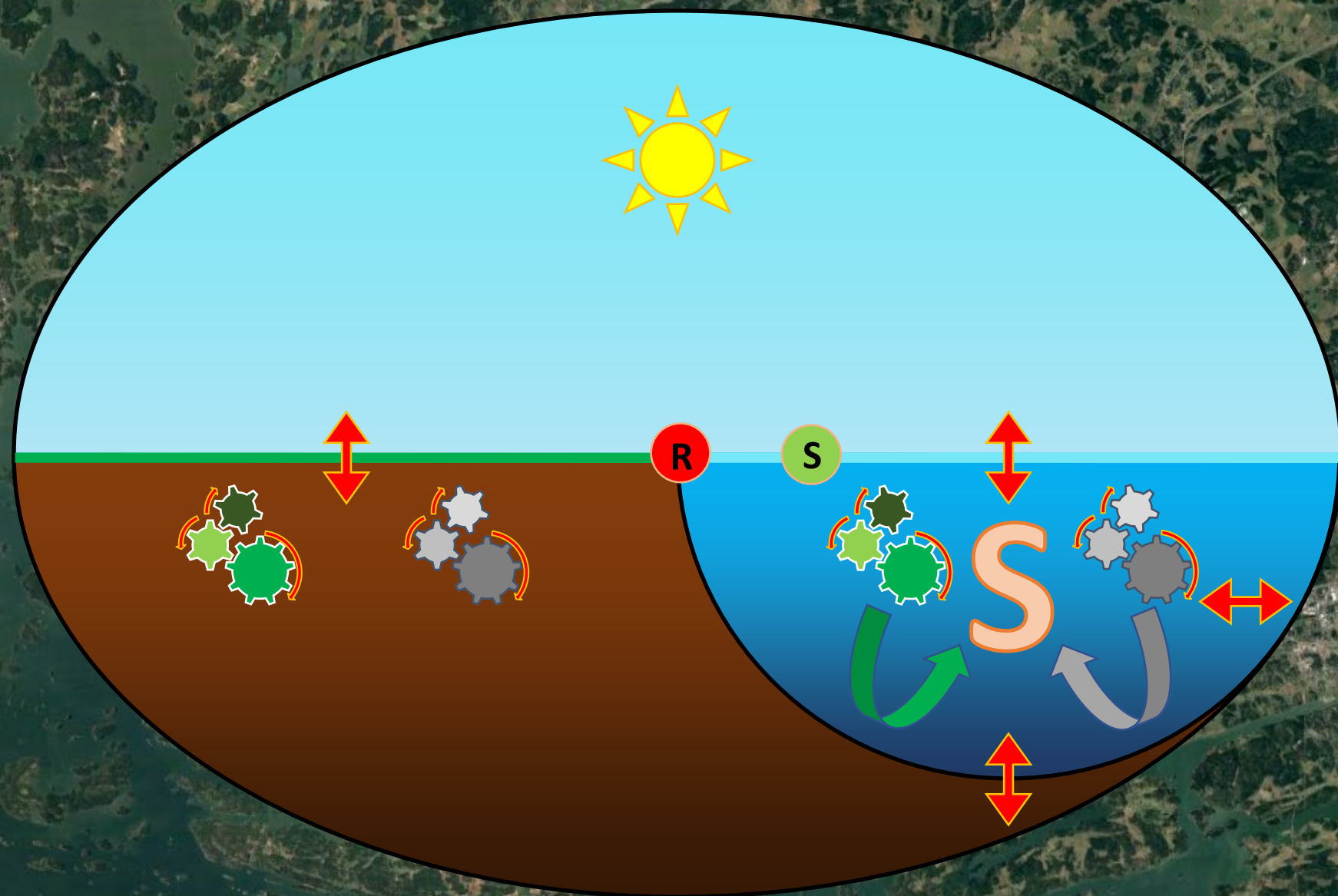
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# PERSPECTIVE



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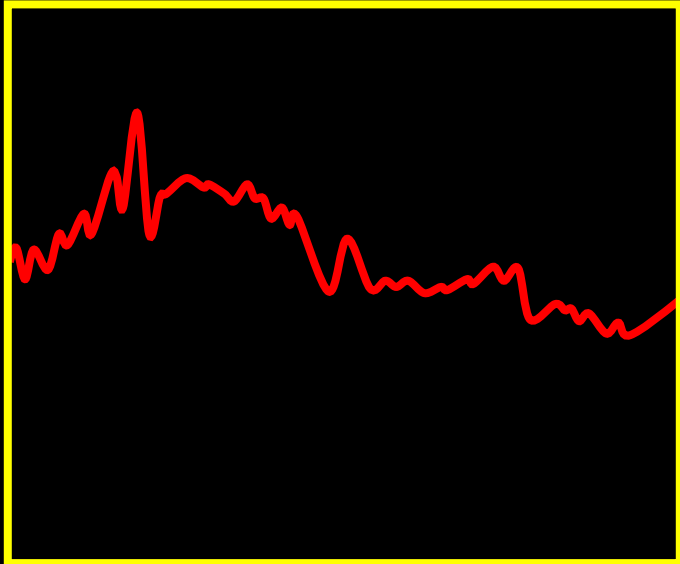
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- biochemical conditions  
- physical conditions

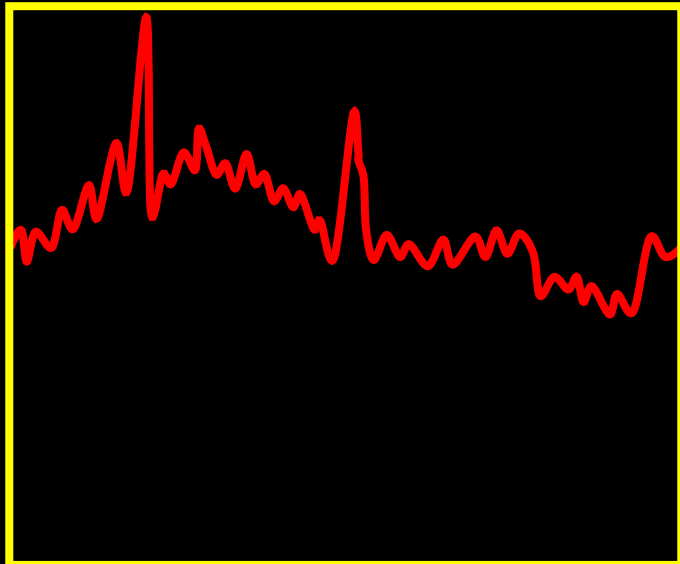
Status indicators (e.g.)  
- dissolved organic matter  
- turbidity  
- chlorophyll *a*

## RIVERWATER

STATUS INDICATOR



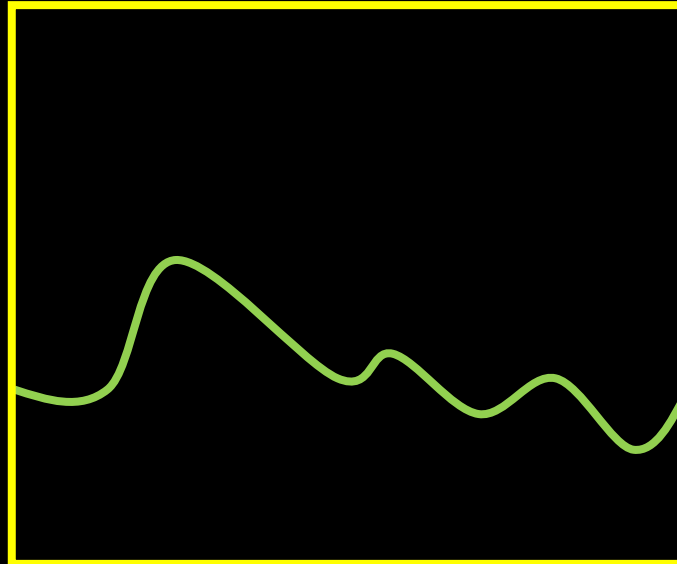
NUTRIENT COMPOUND



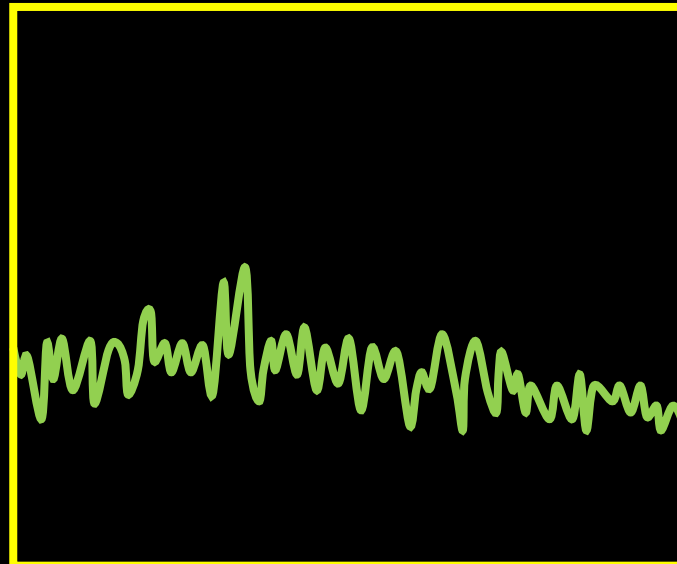
COURSE OF THE SEASON

## SEAWATER

STATUS INDICATOR



NUTRIENT COMPOUND



COURSE OF THE SEASON

## PERSPECTIVE

Carbon and nutrients

- dissolved
- particulate

Coastal waters (coastal filter)

- **transportation**
- **transformation**

→ important environments  
→ influential environments for the open sea and climate

Loading status depends on

- fluxes
- biochemical conditions
- physical conditions

Status indicators (e.g.)

- dissolved organic matter
- turbidity
- chlorophyll *a*

**Seasonal variation**

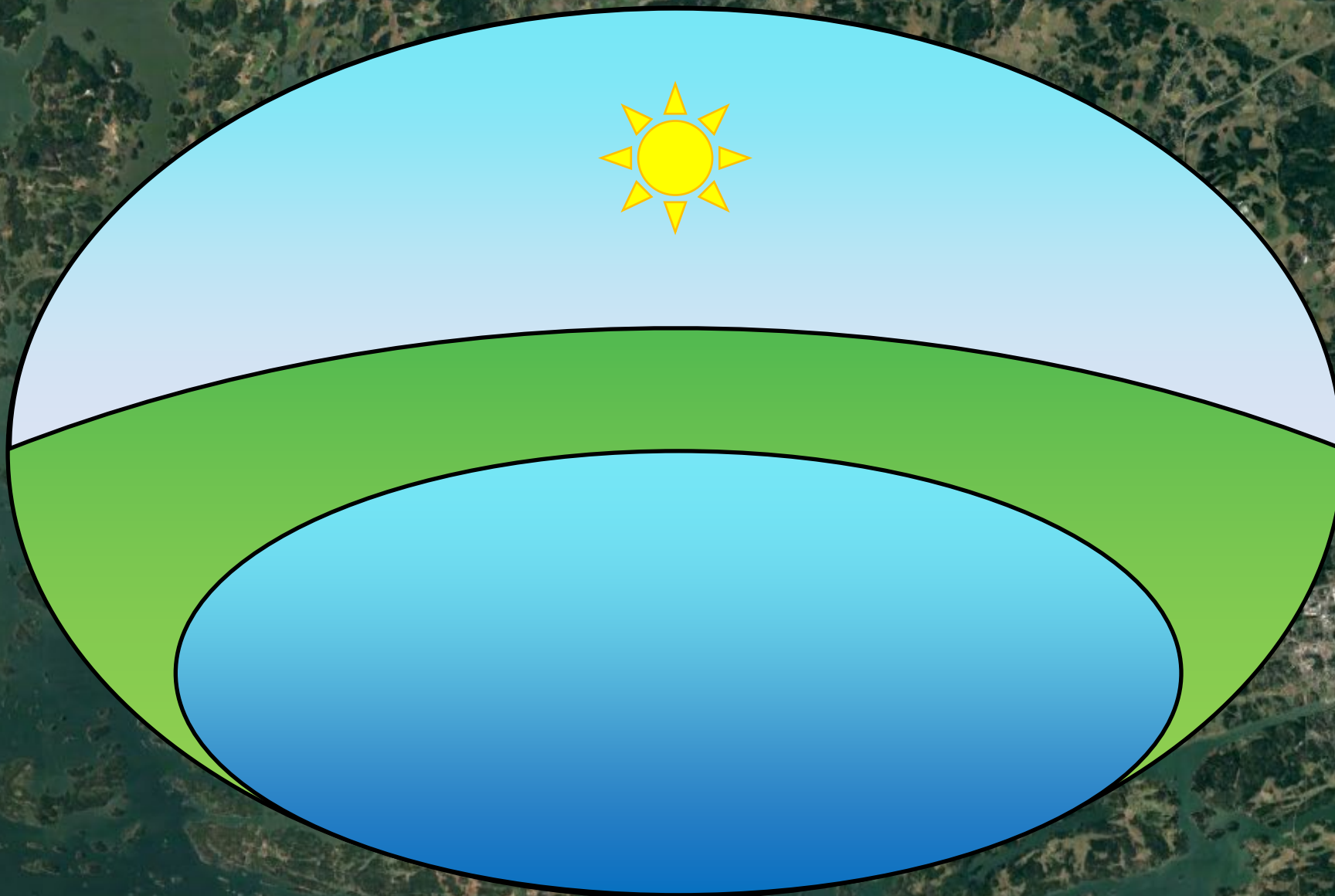
- measuring effects
- not the causes

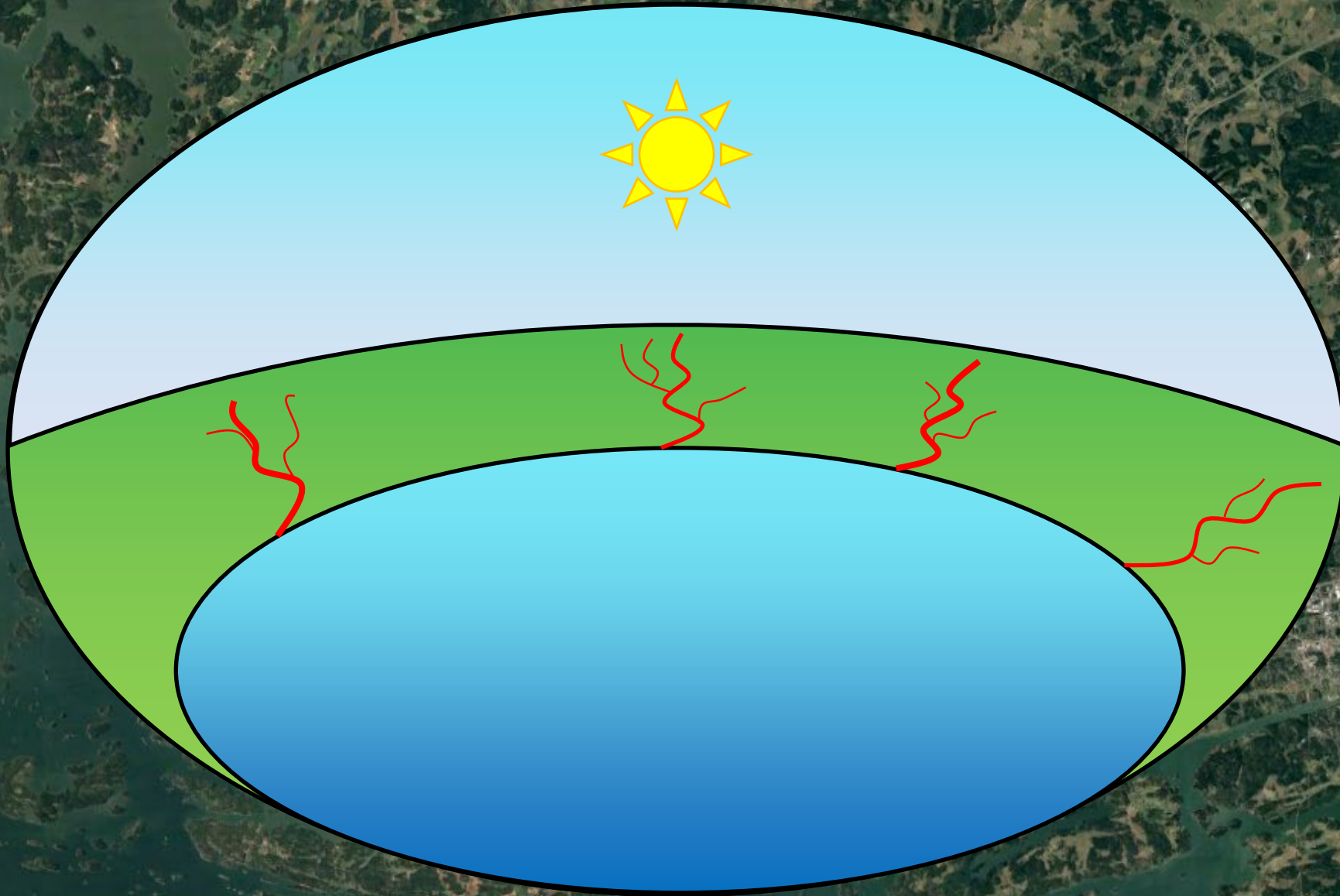
**Indicators**

Measuring effects instead of causes

**Seasonal variation**

The kind and amount of loading change along the year





**Indicators**

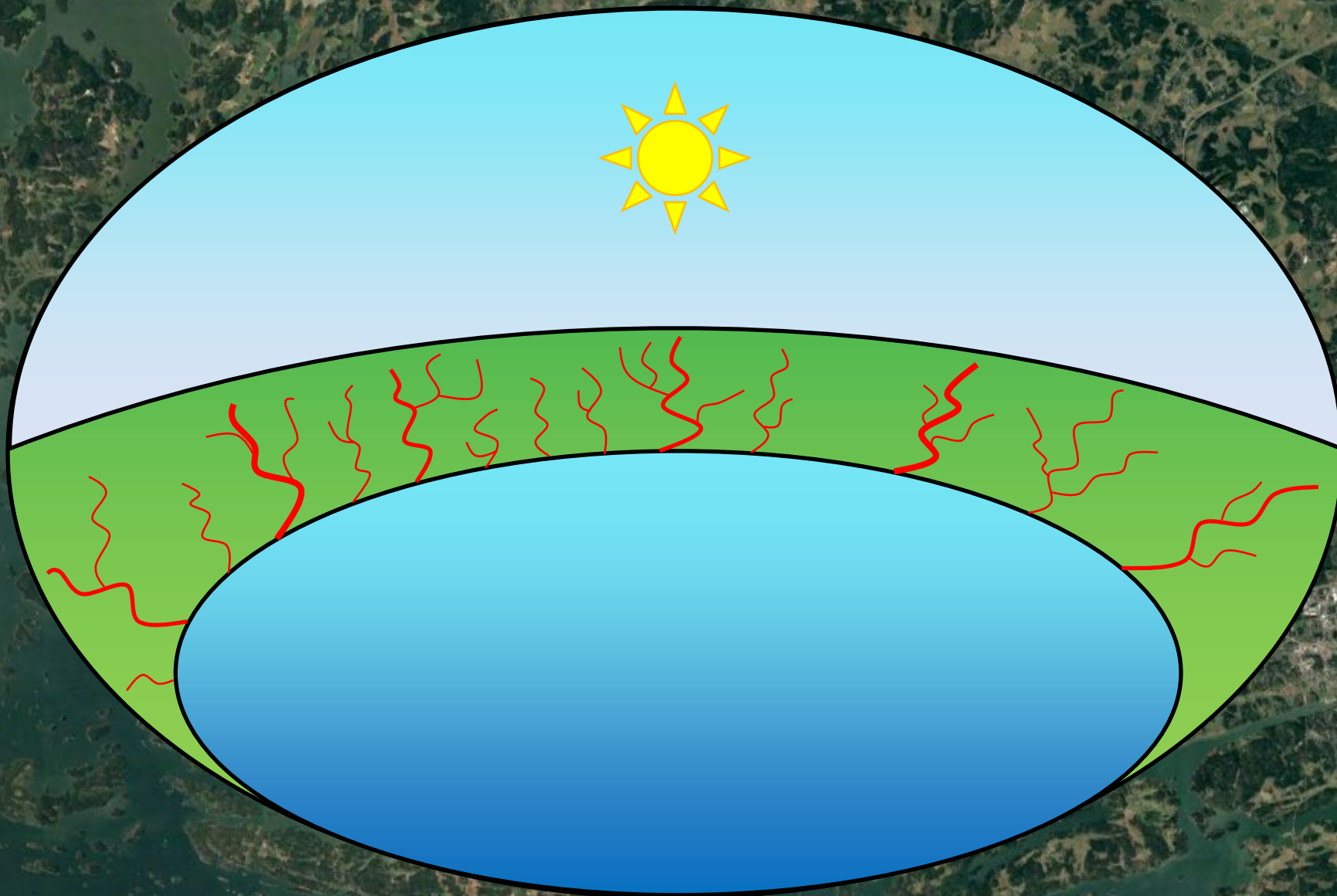
Measuring effects instead of causes

**Seasonal variation**

The kind and amount of loading change along the year

**Spatial variation**

Terrestrial loading comes from several rivers



**Indicators**

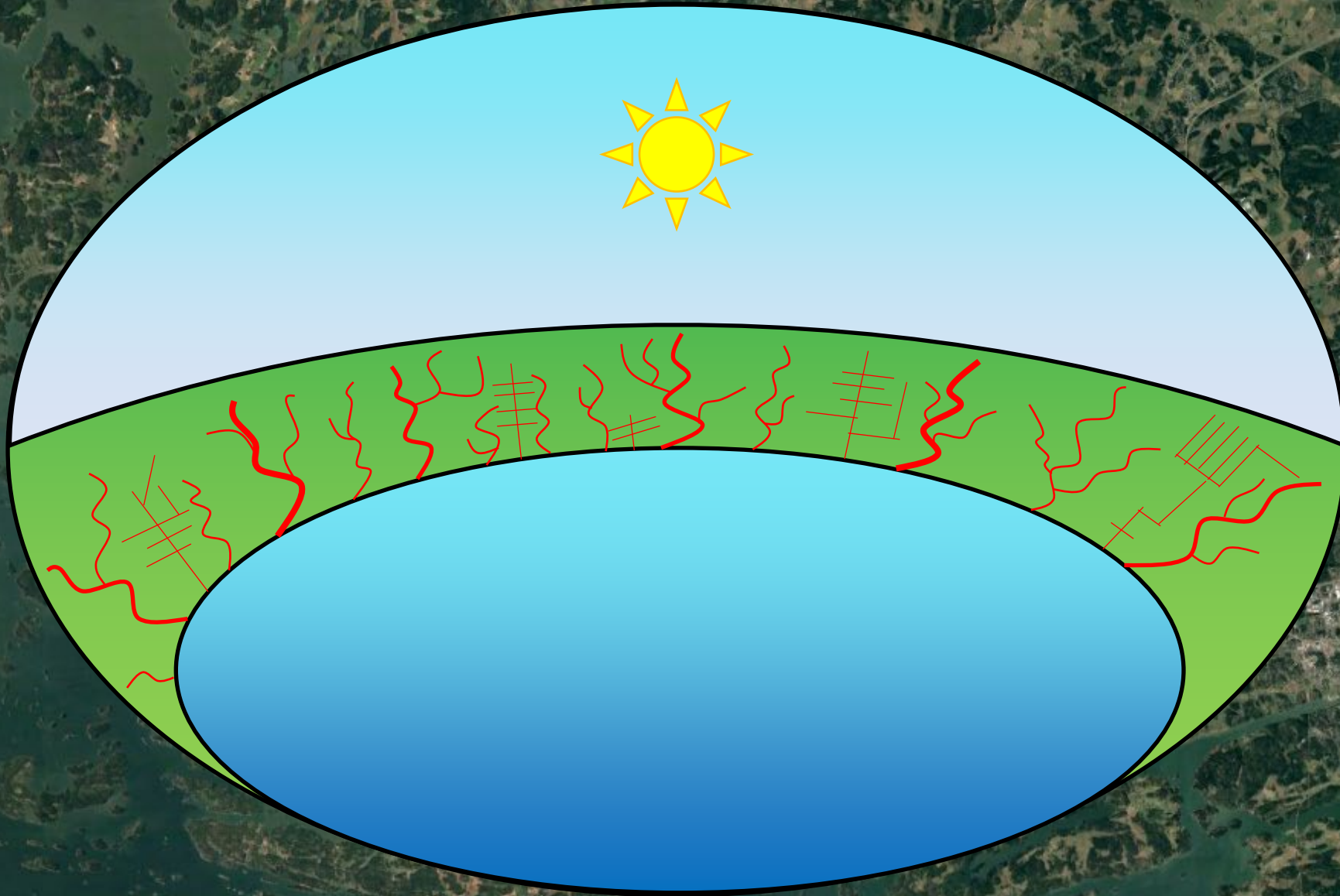
Measuring effects instead of causes

**Seasonal variation**

The kind and amount of loading change along the year

**Spatial variation**

Terrestrial loading comes from several rivers and creeks



**Indicators**

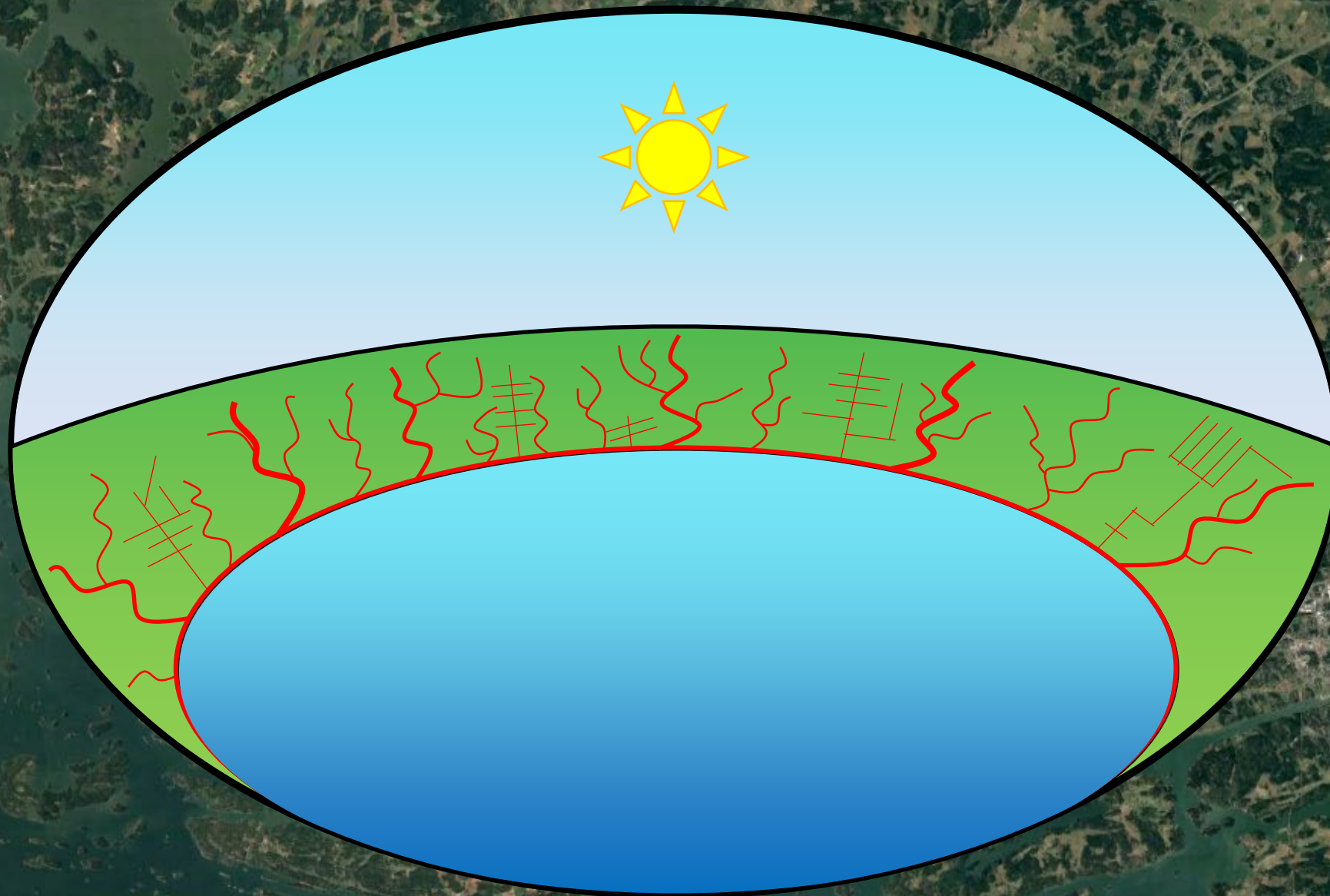
Measuring effects instead of causes

**Seasonal variation**

The kind and amount of loading change along the year

**Spatial variation**

Terrestrial loading comes from several rivers, creeks and ditches



**Indicators**

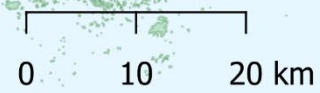
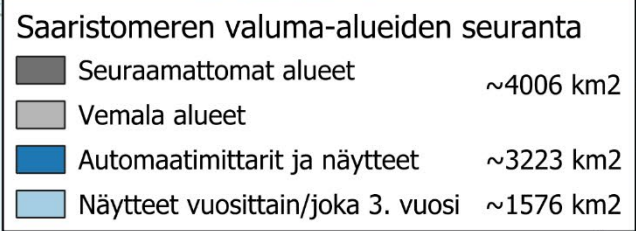
Measuring effects instead of causes

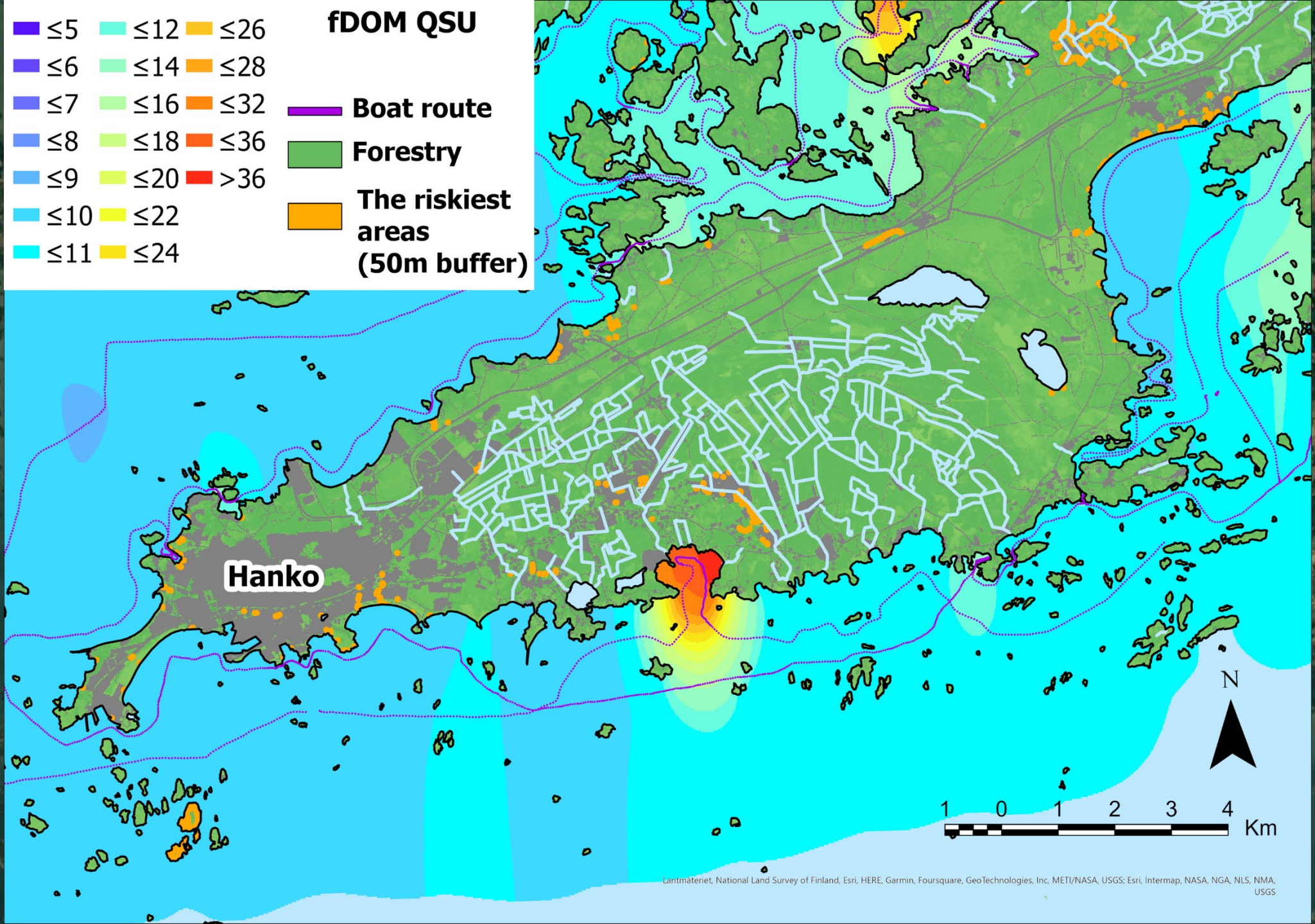
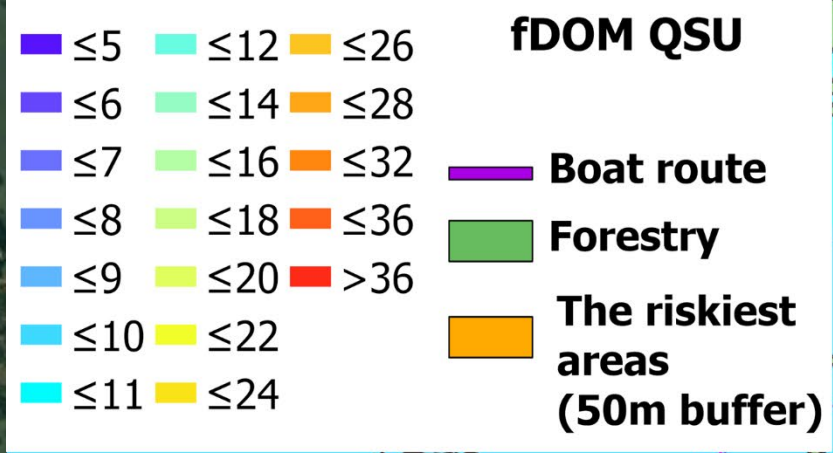
**Seasonal variation**

The kind and amount of loading change along the year

**Spatial variation**

Terrestrial loading comes from several rivers, creeks and ditches, or anywhere along the shoreline.





# Effect of measurement interval on detecting water level peaks (timing, duration and magnitude) in various urban catchments

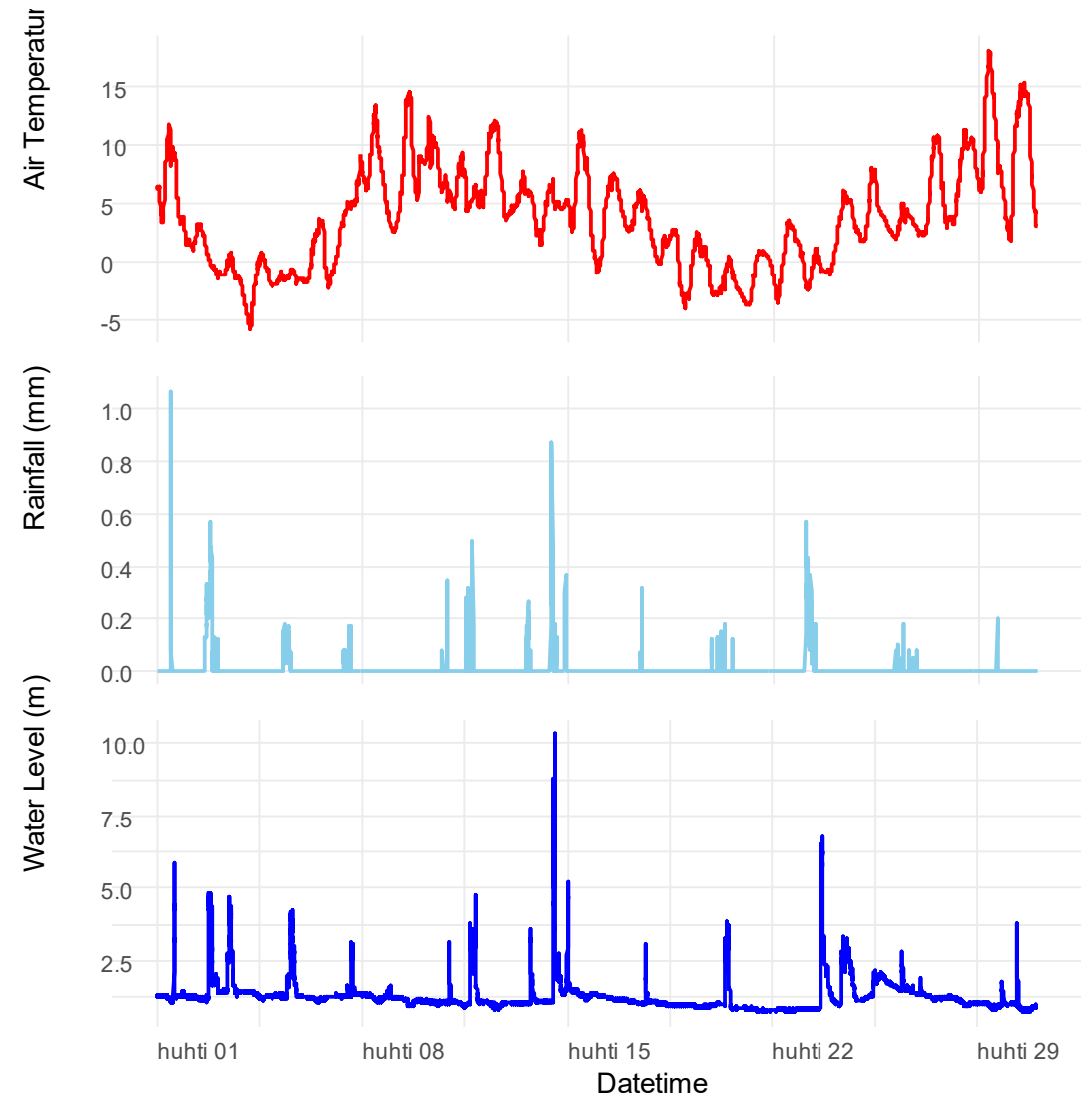
- The simplest metric to study hydrologic dynamics of urban stormwater conveyance systems is to measure variation in water level at drainage area outfalls
- We want to determine the effect of measurement interval on the ability of water level measurements to reliably detect, time and quantify water level peaks for a small impervious (road) drainage area
- **Need for study** – when utilizing affordable monitoring solutions, such as IoT solutions, measurement interval is restricted to suboptimal intervals (10 minutes or more) due to access point data traffic restrictions and potential packet loss – Can we reliably monitor flashy systems with measurement frequencies of  $\geq 10$  minutes?
- How much information is lost with decreasing measurement interval (unidentified peaks, underestimating peak magnitude, shifts in peak timing onset, maximum WL timing and peak duration)
- What are the practical implications of the occurring information loss?



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## Data

- Turku Artukainen air temperature, precipitation (mm/10 min) and Länsikeskus inlet well water level
- Flow dynamics driven by both snow-melt (to lesser extent) and direct precipitation during period under study
- System has fast response to rain events (rain data not optimally representative of measurement site rain, due to a distance of ~3 km from the northeast of the rain gauge)



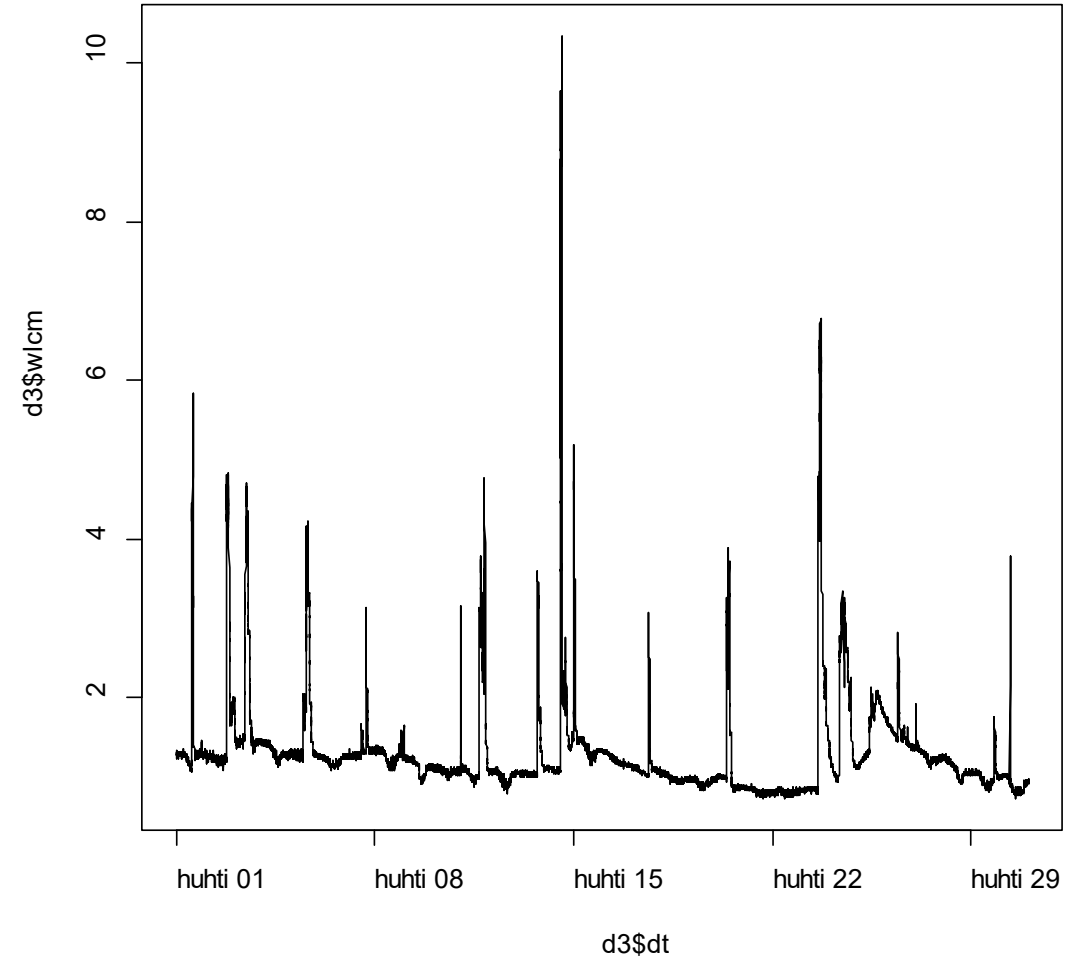


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## Data summary

Water level variation (cm), with original measurement interval (2 min)

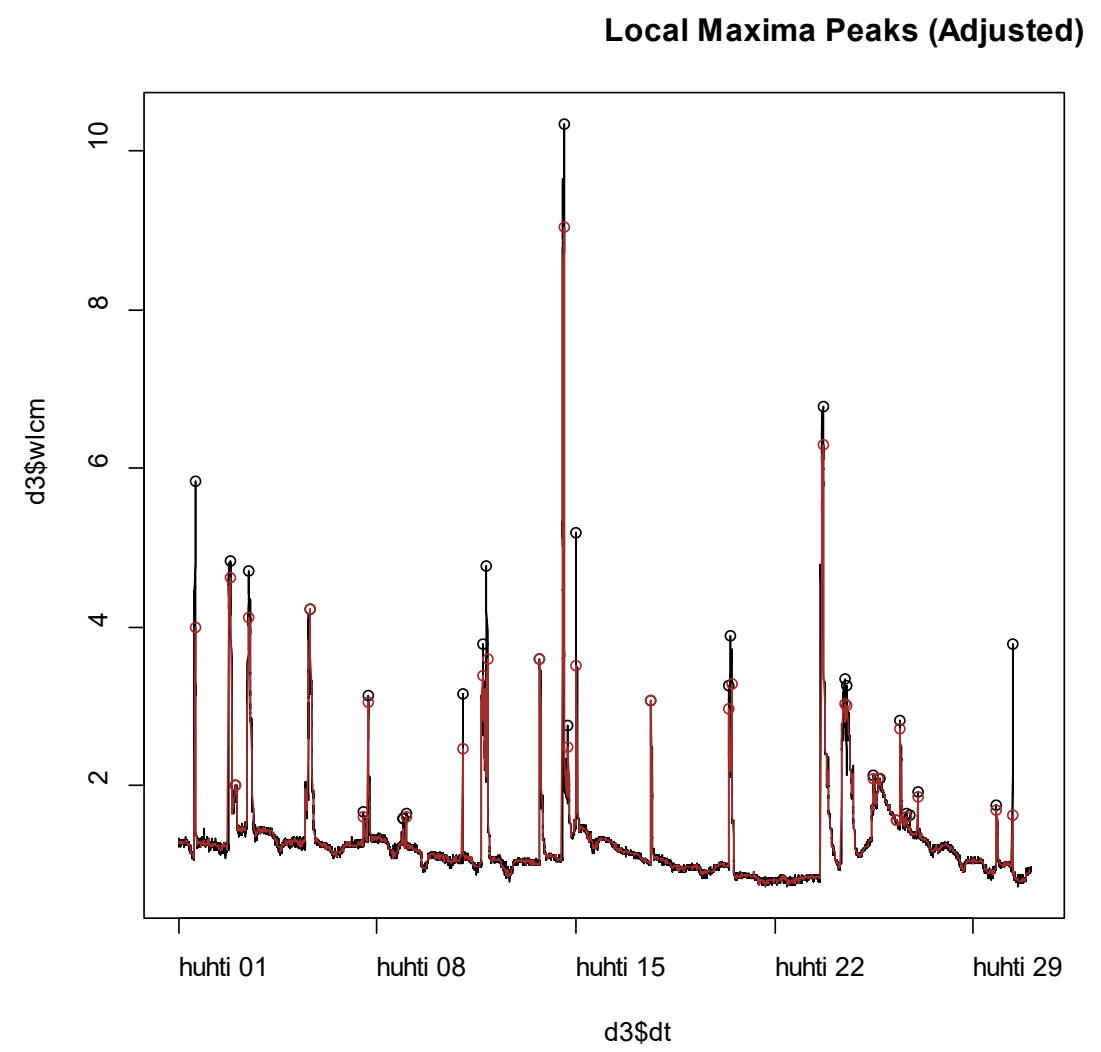
- Min.: 0.72 cm
  - 1st Qu.: 0.99 cm
  - Median: 1.16 cm
  - Mean: 1.29 cm
  - 3rd Qu.: 1.31 cm
  - Max.: 10.39 cm
- Pressure sensor reports WL in relation to V-notch weir notch bottom -> WL has been positive the whole period -> constant flow. Mean/median/3<sup>rd</sup> Qu. flow small, compared to max, other peaks quite sharp and large compared to mean/median/3<sup>rd</sup> Qu. too.
  - System very responsive to snow melt and precipitation, very little lag and rapid decline in hydrograph after peak





Dataset_ID	meas. Int. (min)	WL (cm)					RMSE	NSE
		min	max	range	mean	sd		
Original	2	0.716	10.349	9.633	1.290	0.616		
2	4	0.719	9.645	8.926	1.289	0.614	0.030	0.998
4	8	0.719	9.044	8.325	1.289	0.608	0.054	0.992
8	16	0.719	9.044	8.325	1.291	0.614	0.086	0.980
16	32	0.719	9.044	8.325	1.295	0.626	0.136	0.952
32	64	0.741	9.044	8.303	1.298	0.610	0.176	0.918
64	128	0.743	6.131	5.388	1.287	0.534	0.285	0.786
128	256	0.743	4.519	3.776	1.299	0.511	0.400	0.580

Compare whole data set information loss by re-interpolating down sampled data to original frequency and doing comparison with performance metrics (RMSE, NSE)



# RMSE and NSE results

Dataset ID	Measurement Interval	RMSE	NSE	Interpretation
2	4 minutes	0.0303	0.998	Excellent performance. Very little information is lost; the interpolated data closely matches the original.
4	8 minutes	0.0544	0.992	Still excellent, though slight smoothing is evident.
8	16 minutes	0.0861	0.980	Moderate smoothing; variability is still well preserved.
16	32 minutes	0.1356	0.952	More noticeable smoothing and loss of extreme values.
32	64 minutes	0.1761	0.918	Variability is moderately preserved, but interpolation errors are increasing.
64	128 minutes	0.2851	0.786	Information loss is significant; variability and extremes are not well preserved.
128	256 minutes	0.4001	0.580	Poor performance; interpolation struggles to reconstruct the variability in the original dataset.



# Summary on overall differences

Peaks detected with small loss (0-6% loss, 0-2 peaks lost out of 32 identified in original data)

Changes in minimum and median peak magnitude small (0-5% difference)

Changes in mean peak magnitude moderate (3-9% difference)

Changes in maximum peak magnitude moderate to large (7-10% difference)

- Less frequent sampling has immediate impact on maximum peak magnitude

- Can have practical implications on data usability when short term dynamics are of interest, e.g. model calibration and validation

- Longer measurement intervals are feasible for long term monitoring of long-term dynamics

Peak timing and duration analyses still to be done



# Summary on overall differences

## **Shorter Intervals ( $\leq 16$ minutes):**

Excellent performance (low RMSE, high NSE). The interpolated datasets effectively replicate the original dataset's variability and magnitude, with minimal information loss.

## **Intermediate Intervals (32–64 minutes):**

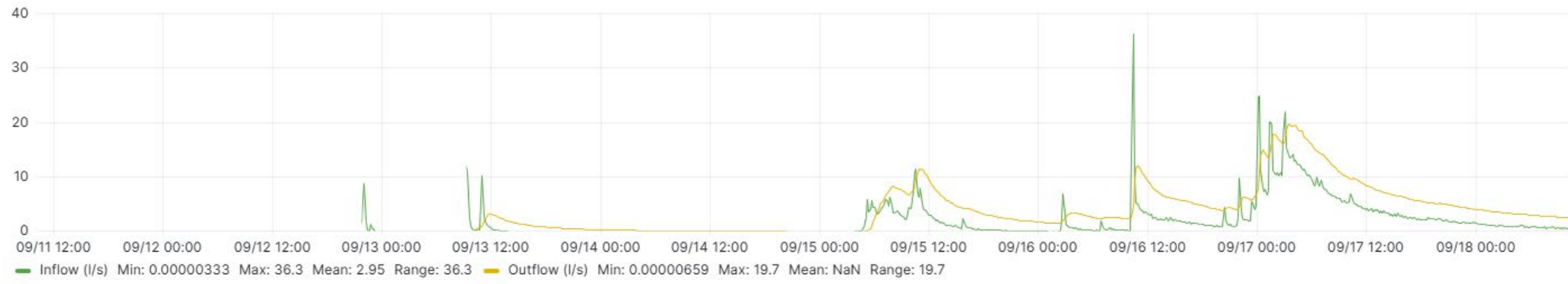
Moderate performance. RMSE starts to approach the variability of the original data, and NSE begins to drop below 0.95. Smoothing effects and loss of extremes become apparent.

## **Longer Intervals ( $\geq 128$ minutes):**

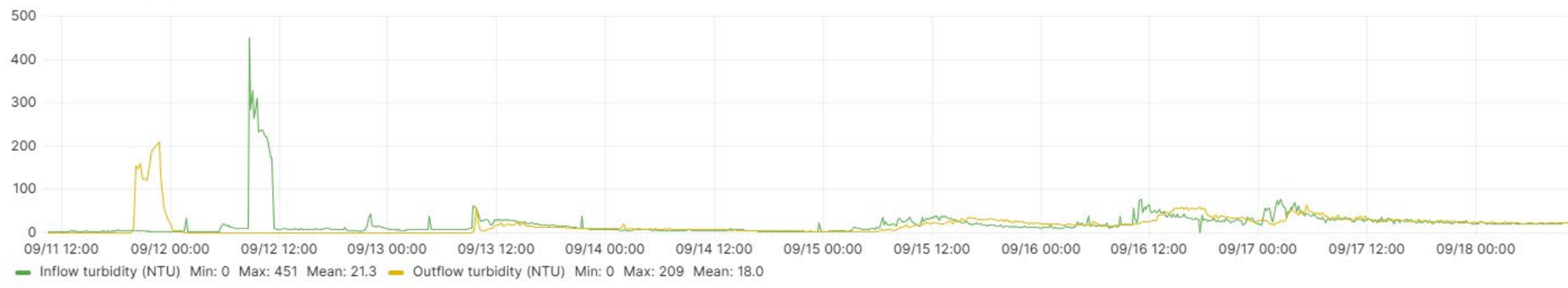
Poor performance. RMSE becomes significant relative to the variability, and NSE drops below 0.75. These intervals lose much of the original data's variability and key features.



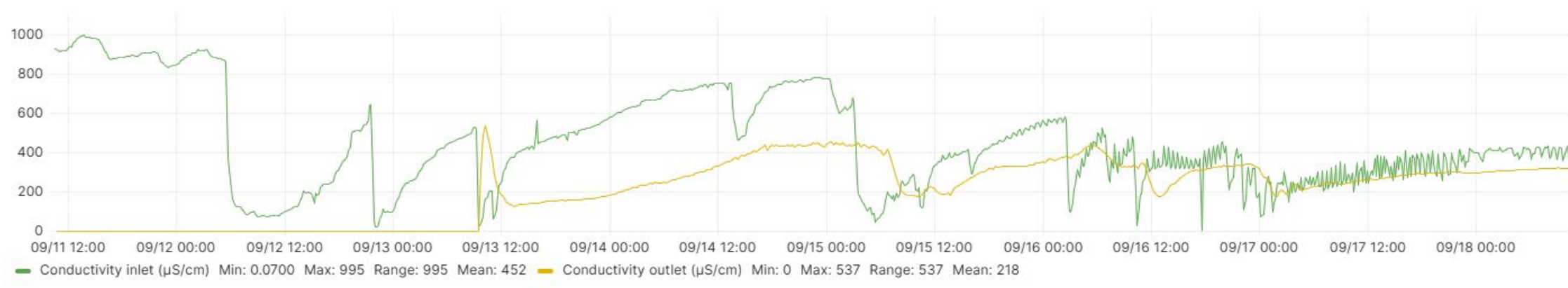
### Inflow/Outflow comparison

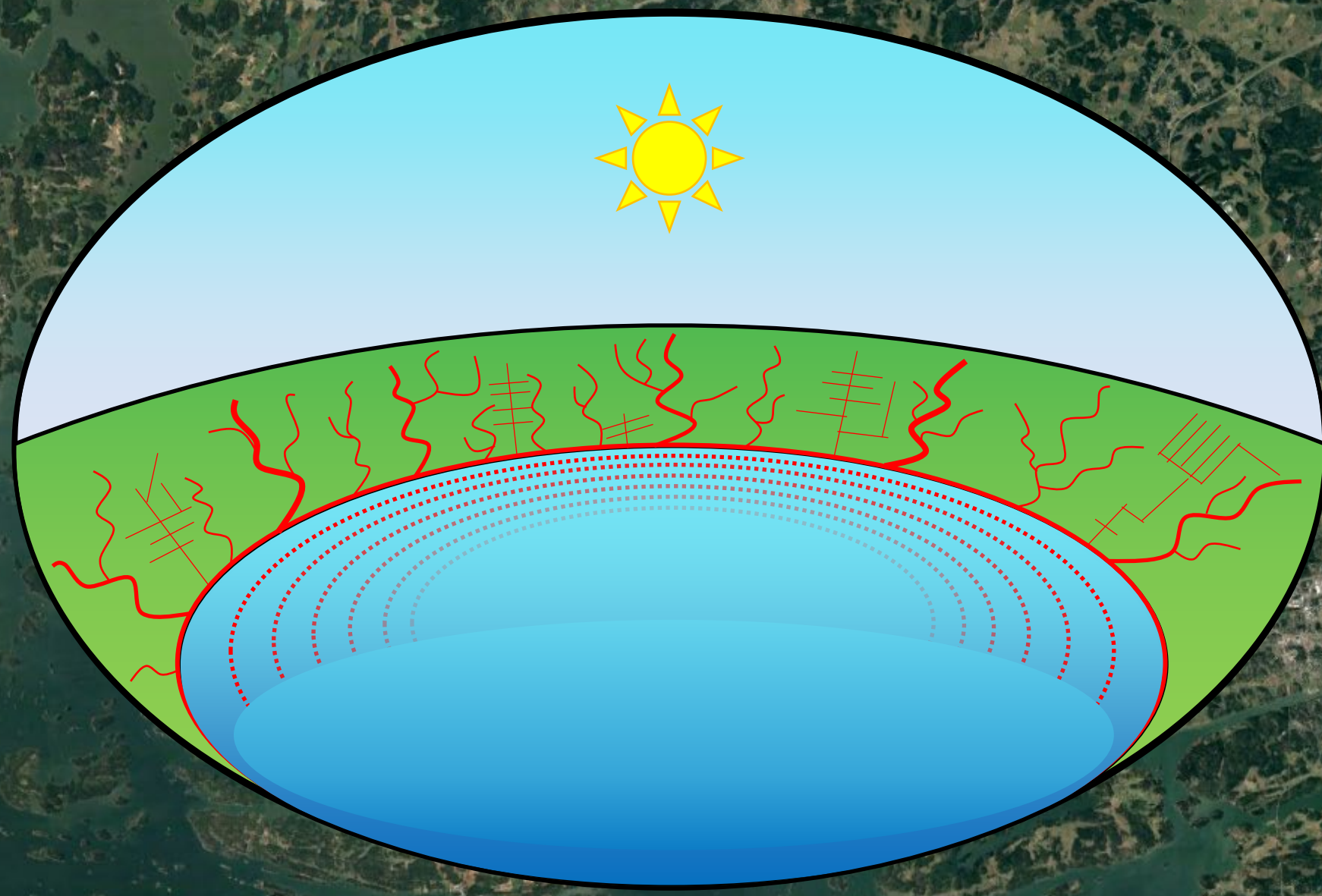


### In/out turbidity comparison



### In/out conductivity comparison





**Indicators**

Measuring effects instead of causes

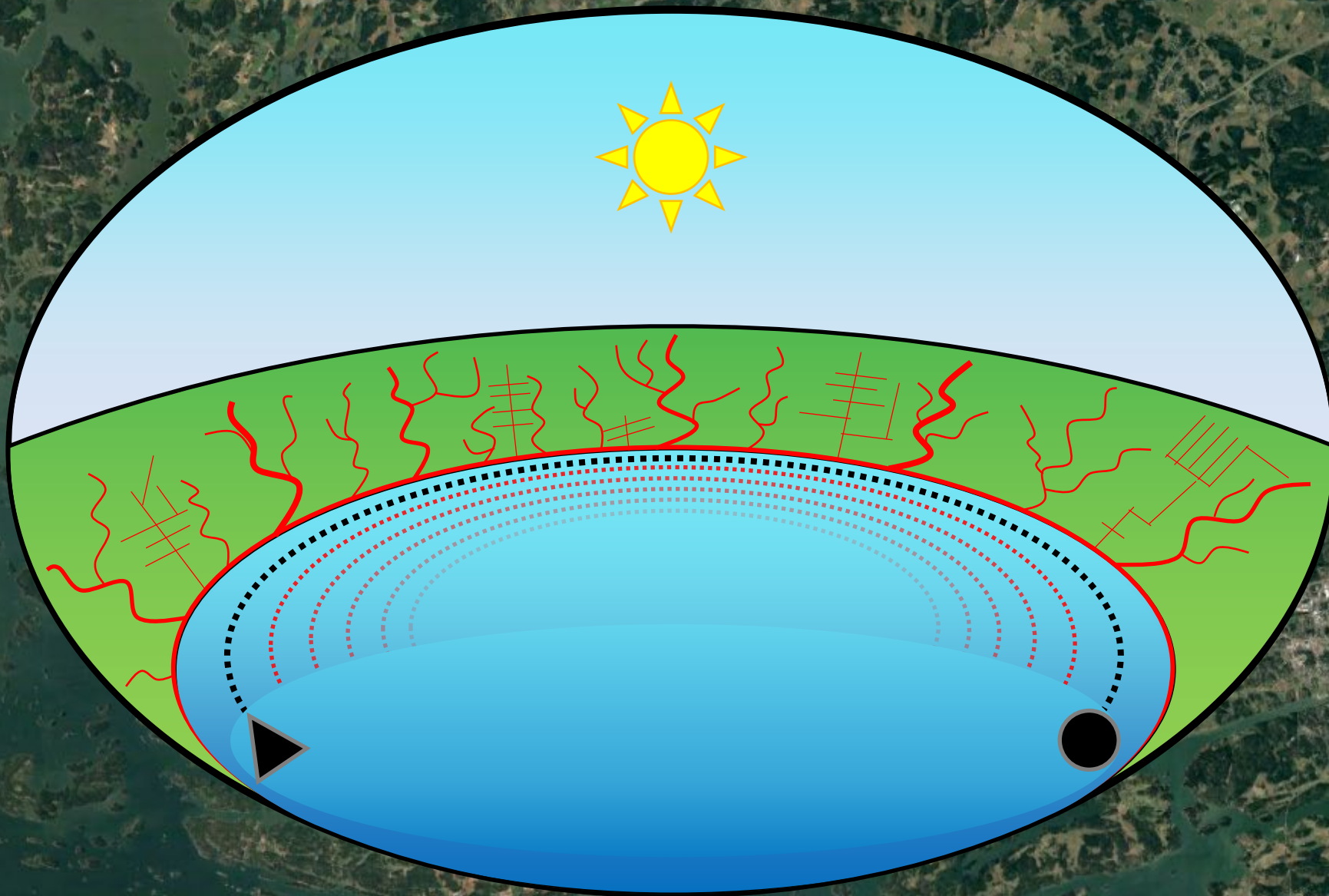
**Seasonal variation**

The kind and amount of loading change along the year

**Spatial variation**

Terrestrial loading comes from several rivers, creeks and ditches, or anywhere along the shoreline.

→ Horizontal dimensions



**Indicators**

Measuring effects instead of causes

**Seasonal variation**

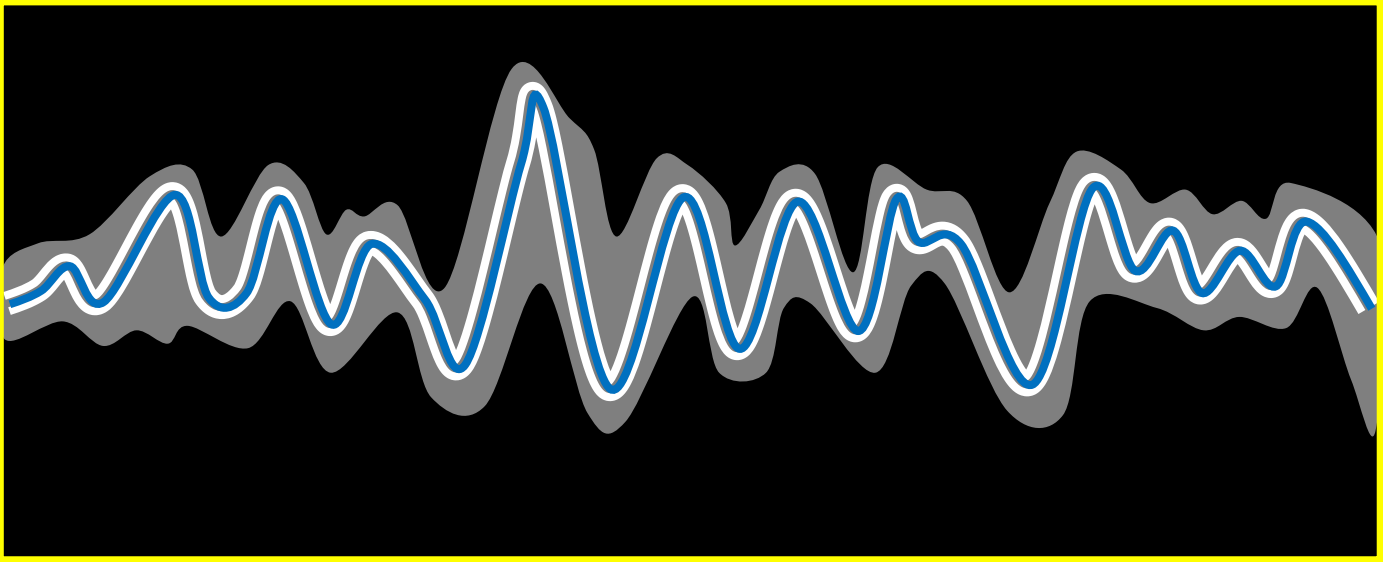
The kind and amount of loading change along the year

**Spatial variation**

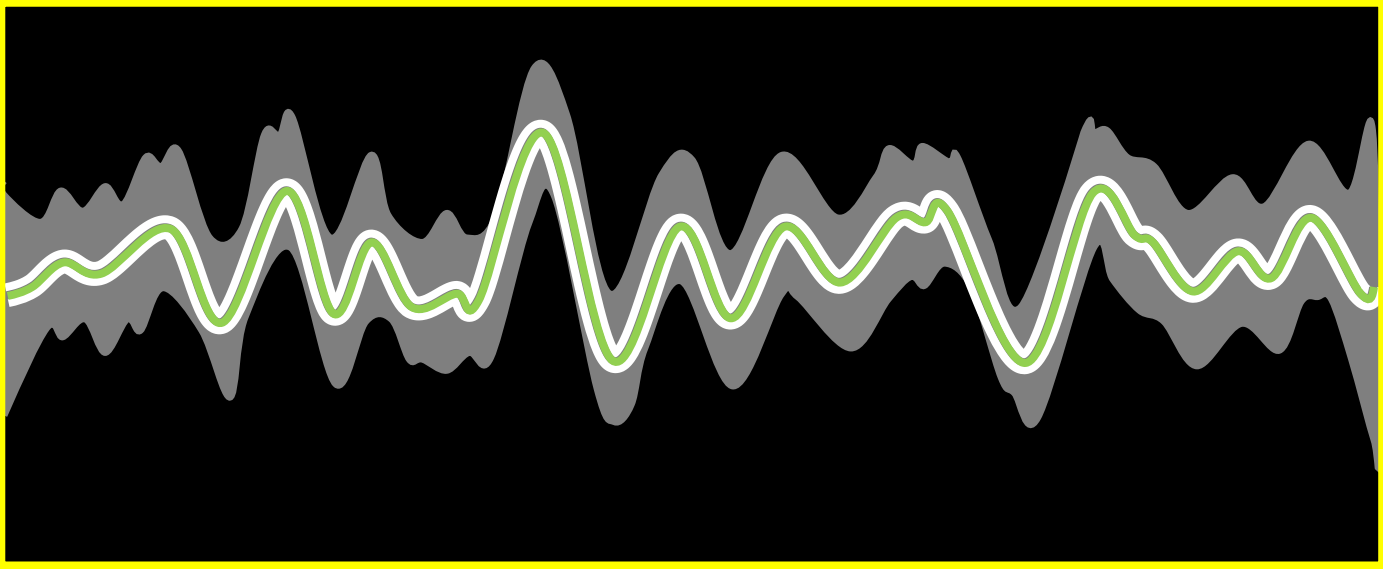
Terrestrial loading comes from several rivers, creeks and ditches, or anywhere along the shoreline.

→ Horizontal dimensions

PHYSICAL CONDITIONS



STATUS INDICATOR



DISTANCE ALONG THE COASTLINE



**Indicators**

Measuring effects instead of causes

**Seasonal variation**

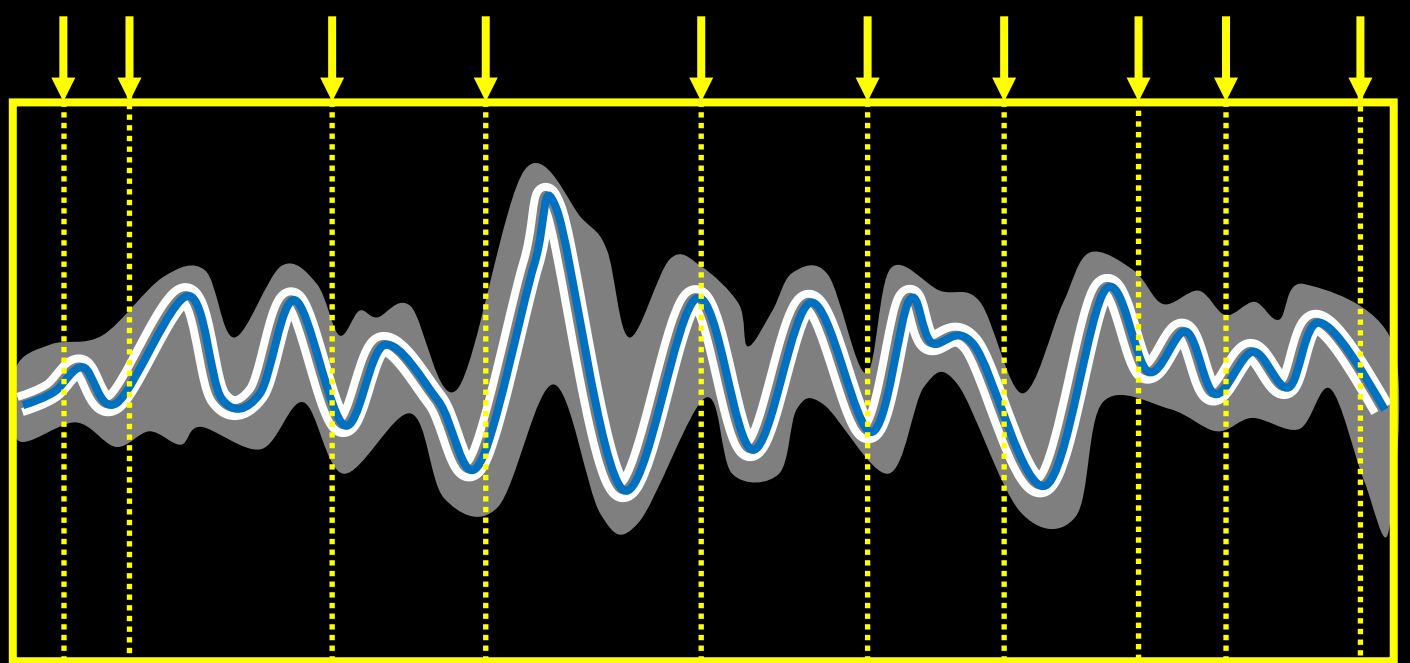
The kind and amount of loading change along the year

**Spatial variation**

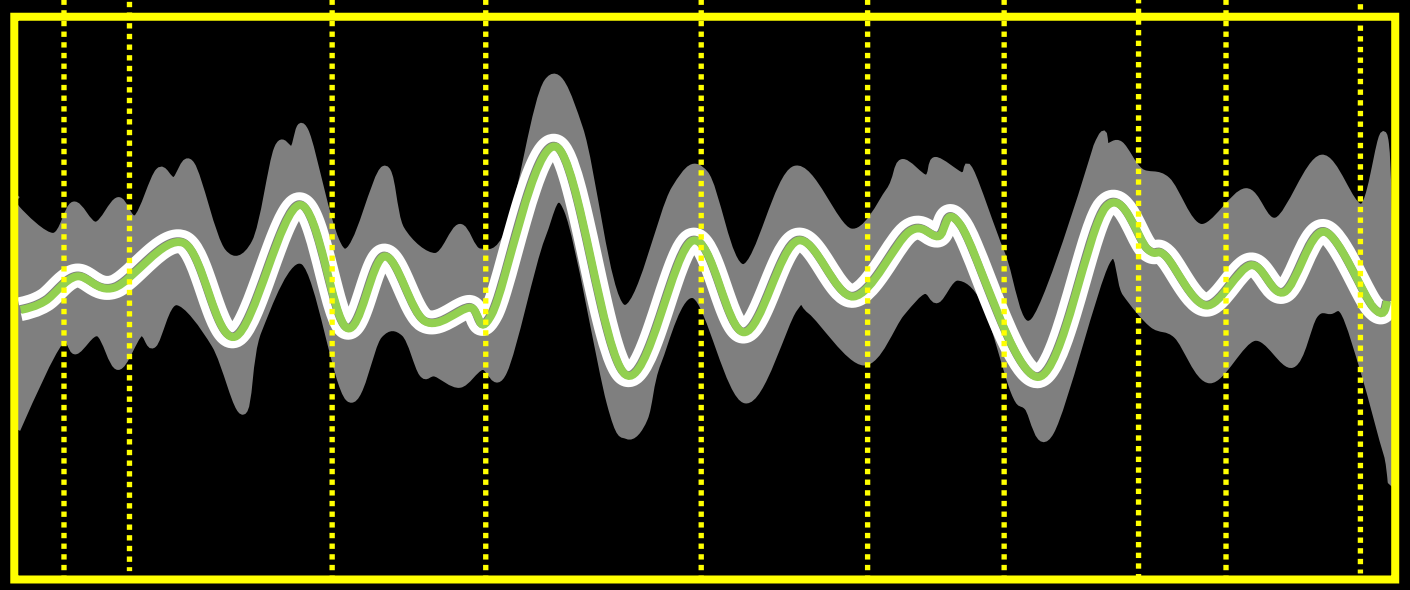
Terrestrial loading comes from several rivers, creeks and ditches, or anywhere along the shoreline.

→ Horizontal dimensions

PHYSICAL CONDITIONS



STATUS INDICATOR



DISTANCE ALONG THE COASTLINE

**Indicators**

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**Seasonal variation**

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Terrestrial loading comes from several rivers, creeks and ditches, or anywhere along the shoreline.

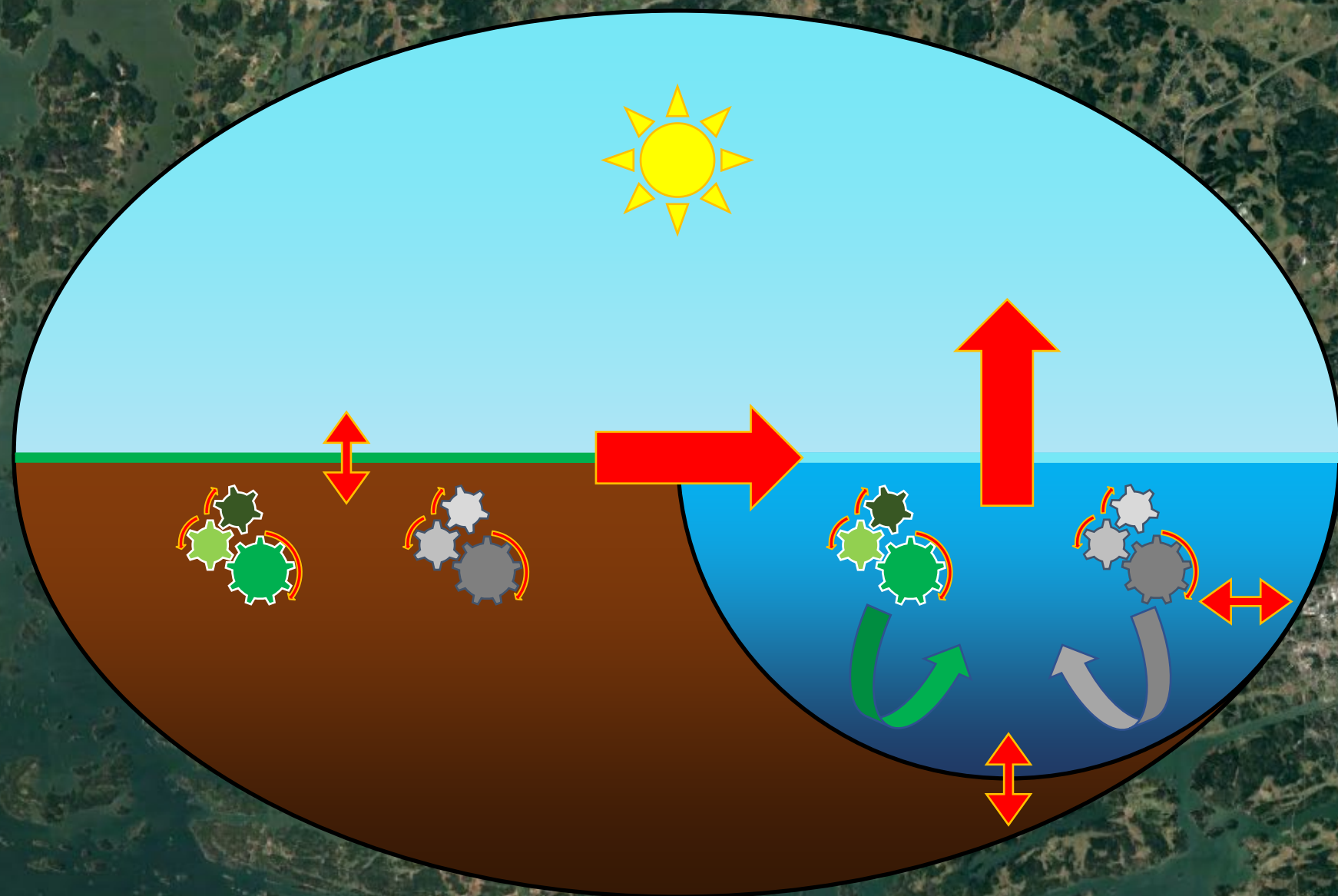
→ Horizontal dimensions

**Predicting status**

Specific reference values

→ Anomalies

→ Spatial loading gradients

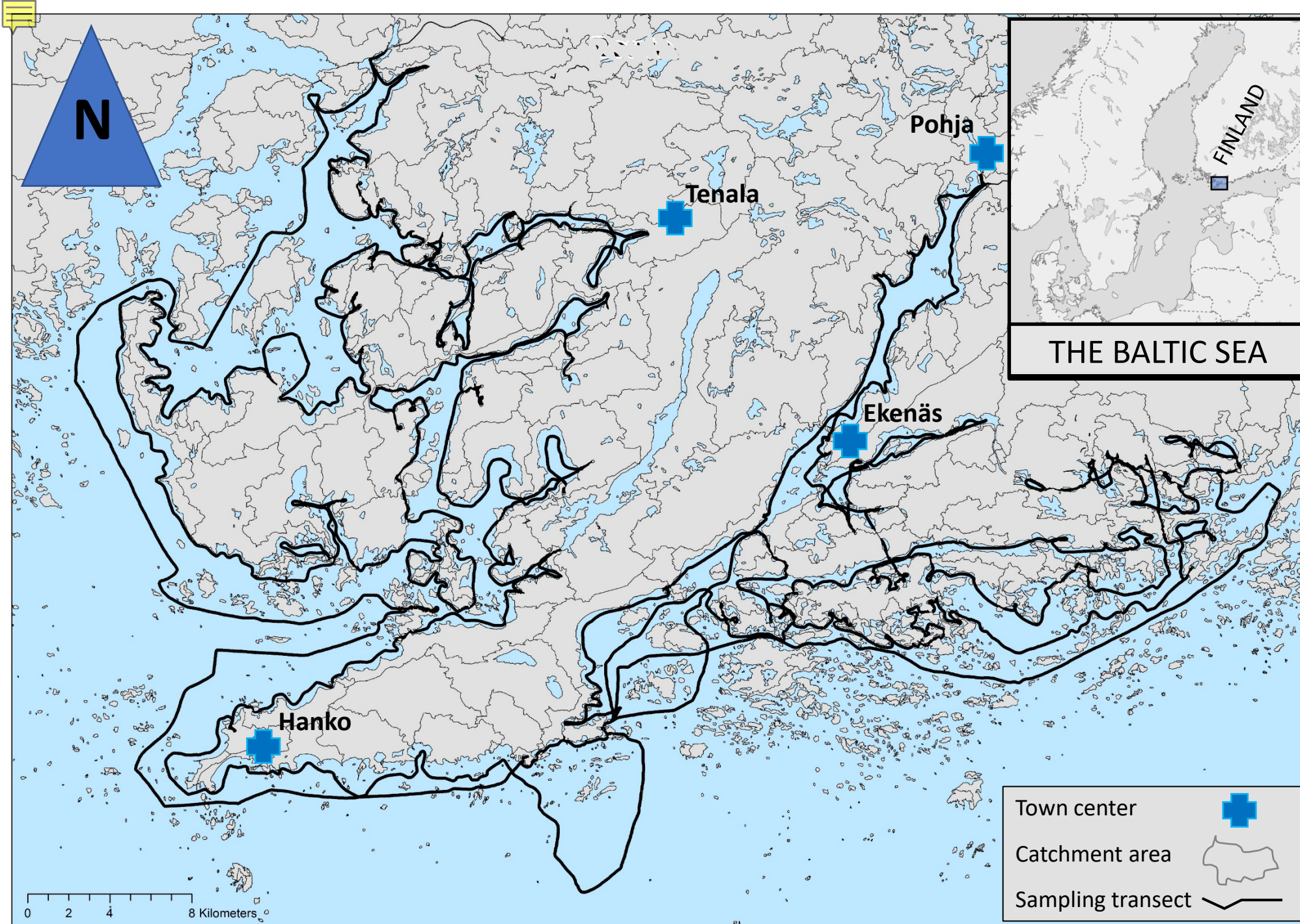


**Indicators**  
Measuring effects instead of causes

**Seasonal variation**  
The kind and amount of loading change along the year

**Spatial variation**  
Terrestrial loading comes from several rivers, creeks and ditches, or anywhere along the shoreline.  
→ Horizontal dimensions

**Predicting status**  
Specific reference values  
→ Anomalies  
→ Spatial loading gradients  
→ Hotspots of GHGs



**METHODOLOGY**

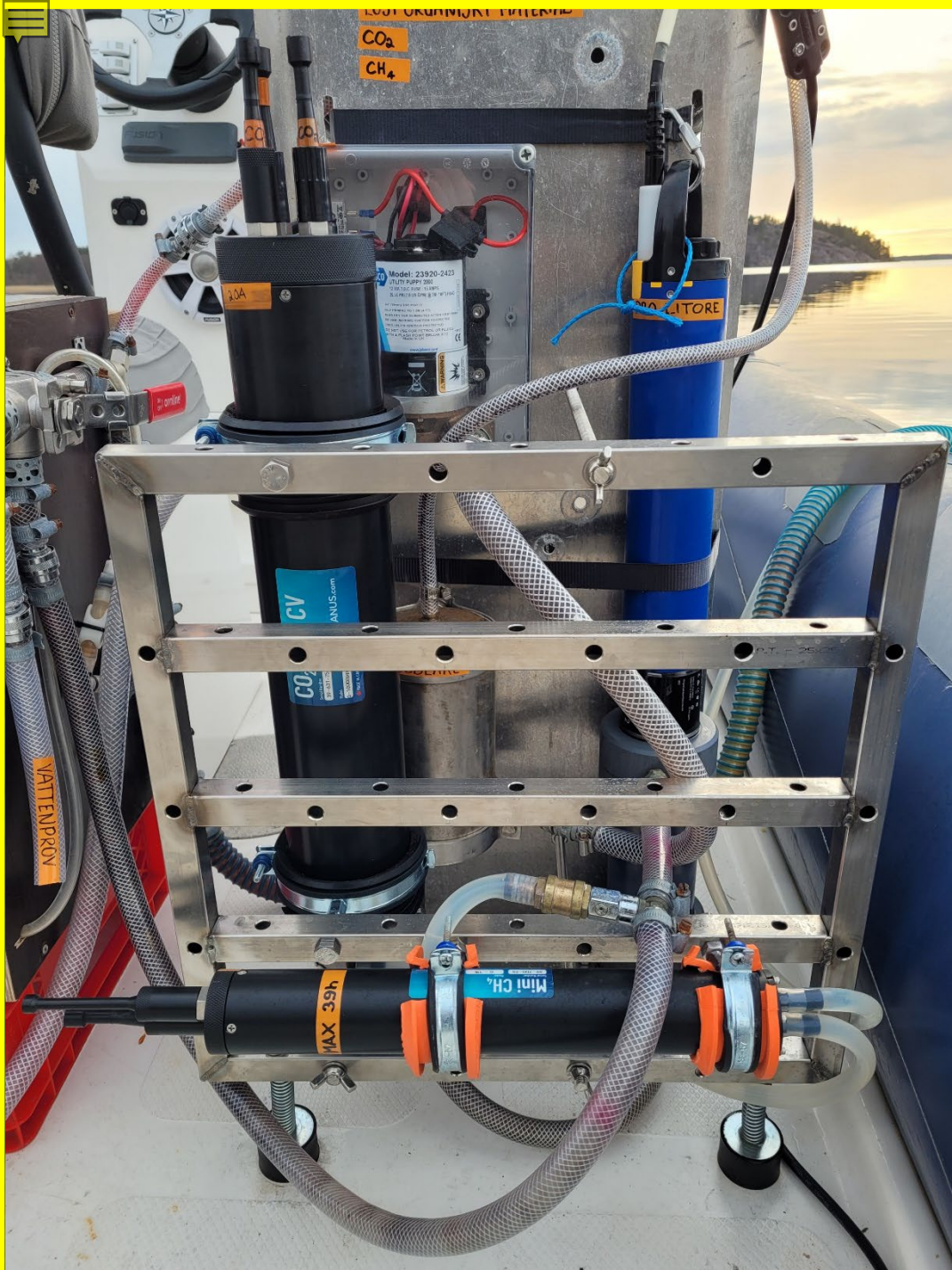
- Physical conditions**
- Horizontal and vertical mixing of water masses
  - Climate, weather, season

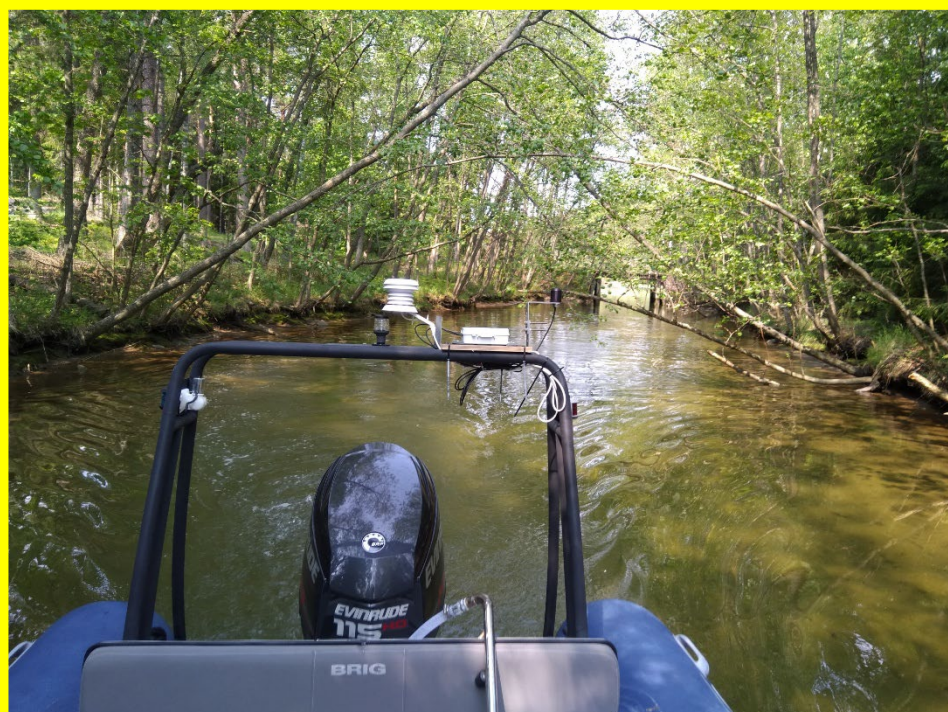
- C, N, P and particle loading are manifested as**
- chlorophyll *a*
  - dissolved organic matter
  - turbidity
  - greenhouse gases
- depending on**
- each other
  - the physical environment
  - the relative loading level

- Measuring variation**
- Defining reference values
  - Analysis of anomalies
  - Environmental status decreases towards the source of loading

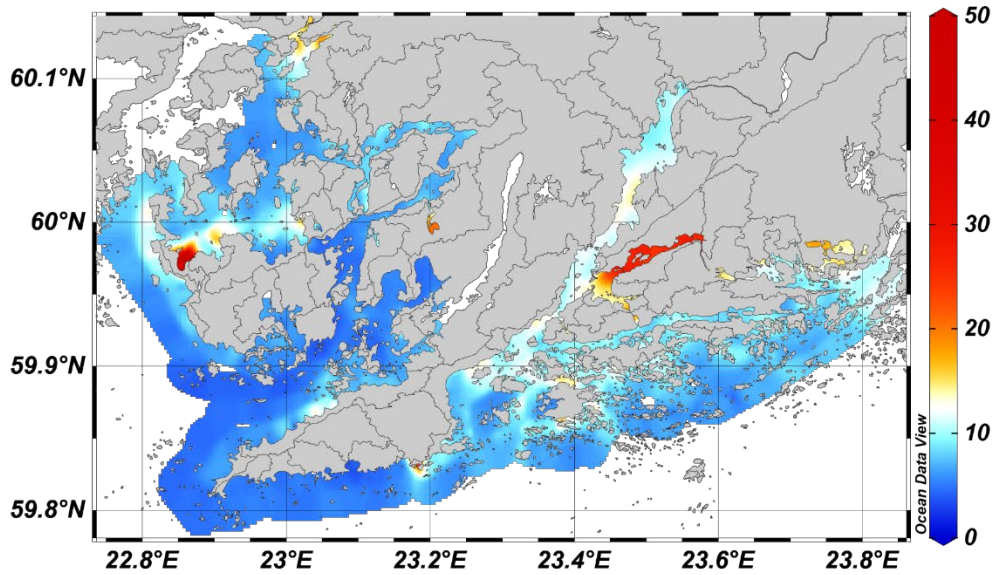
- Mappings**
- 500 NM transect
  - 17 rounds 2018-2020
  - 20,000 obs. per round
  - Ancillary data

Method	Type	Variable	Unit	2018(A)	2019(A)	2019(B)	2019(C)	2019(D)	2019(E)	2019(E)	2019(F)	2019(G)	2019(H)	2019(I)	2019(J)	2020(A)	2020(B)	2020(C)	2020(D)	2020(E)	2021(A)		
CONTINUOUSLY LOGGED	TAG	Date	YYMMDD	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
		Time	hhmmss	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Latitude	WGS84	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Longitude	WGS84	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	AIR	Air pressure	mbar	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		PAR	$\mu\text{mol m}^{-2} \text{s}^{-1}$				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Air temperature	$^{\circ}\text{C}$				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Air humidity	%				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	WATER	Water temperature	$^{\circ}\text{C}$	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Conductivity	$\mu\text{S cm}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Turbidity	NTU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Chlorophyll <i>a</i>	$\mu\text{g L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Phycocyanin	$\mu\text{g L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		fDOM	QSU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		O <sub>2</sub>	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		pH		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		pCO <sub>2</sub>	$\mu\text{atm}$							X	X	X	X	X	X	X	X	X	X	X	X	X	
		CH <sub>4</sub>	$\text{nmol L}^{-1}$													X	X	X	X	X	X	X	
		CALCULATED (E.G.)	Oxygen saturation	%	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
			Total dissolved solids	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
			Salinity		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
			CDOM	QSU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Total alkalinity		$\text{meq L}^{-1}$							X	X	X	X	X	X	X	X	X	X	X	X	X	
	HCO <sub>3</sub>		$\mu\text{mol kg}^{-1}$							X	X	X	X	X	X	X	X	X	X	X	X	X	
	CO <sub>3</sub>		$\mu\text{mol kg}^{-1}$							X	X	X	X	X	X	X	X	X	X	X	X	X	
	OH		$\mu\text{mol kg}^{-1}$							X	X	X	X	X	X	X	X	X	X	X	X	X	
	Revelle									X	X	X	X	X	X	X	X	X	X	X	X	X	
	ΩCa									X	X	X	X	X	X	X	X	X	X	X	X	X	
ΩAr									X	X	X	X	X	X	X	X	X	X	X	X	X		
PAR attenuation CFC	$\text{m}^{-1}$					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
DISCRETE WATER SAMPLES	EMPIRICALLY MODELLED (E.G.)		Dissolved inorganic nitrogen	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X							
			Total dissolved nitrogen	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X						
		Total nitrogen	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							
		Dissolved inorganic phosphorus	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							
		Total dissolved phosphorus	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							
		Total phosphorus	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							
		Dissolved inorganic carbon	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							
		Dissolved organic carbon	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							
		Total organic carbon	$\text{mg L}^{-1}$	X	X	X	X	X	X	X	X	X	X	X	X	X							

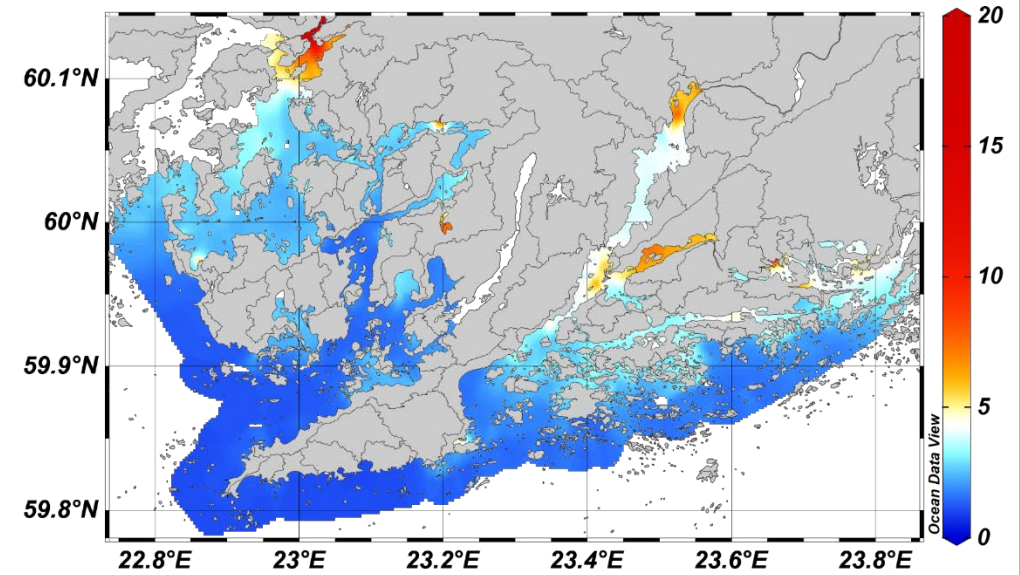




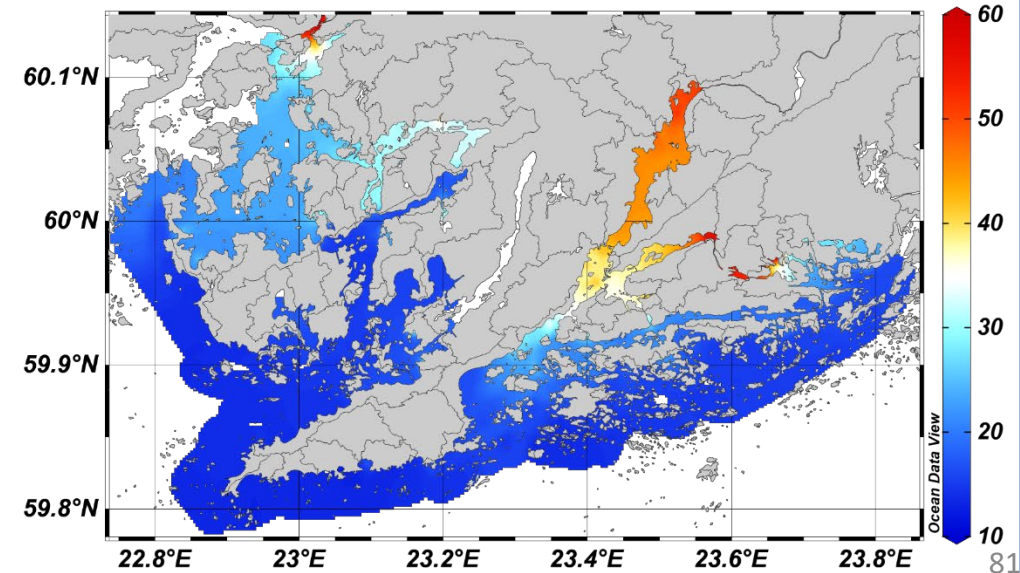
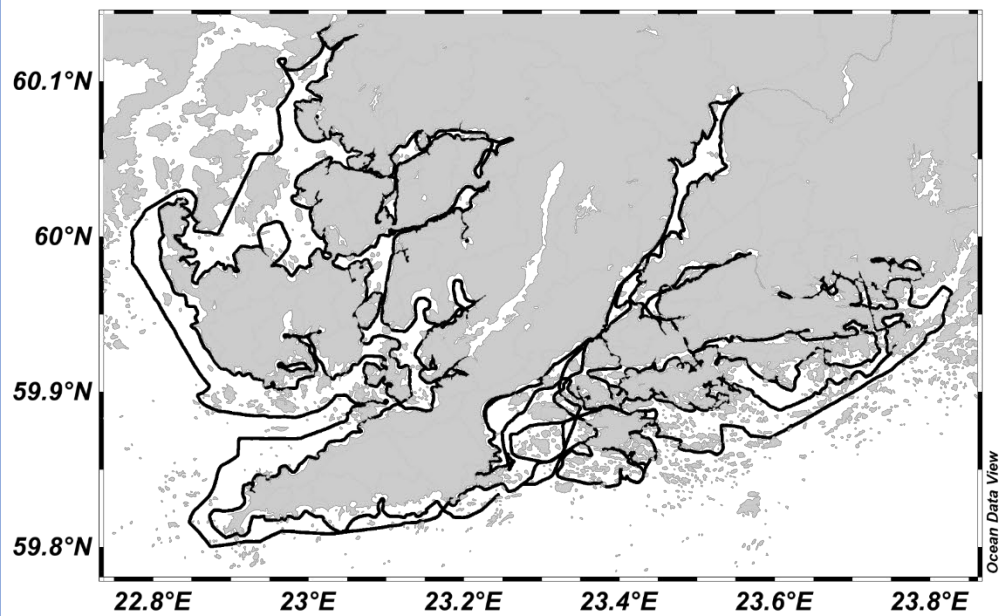
**ChlaDaLe [ $\mu\text{g/L}$ ] @ ChlaDaLe [ $\mu\text{g/L}$ ]=first**



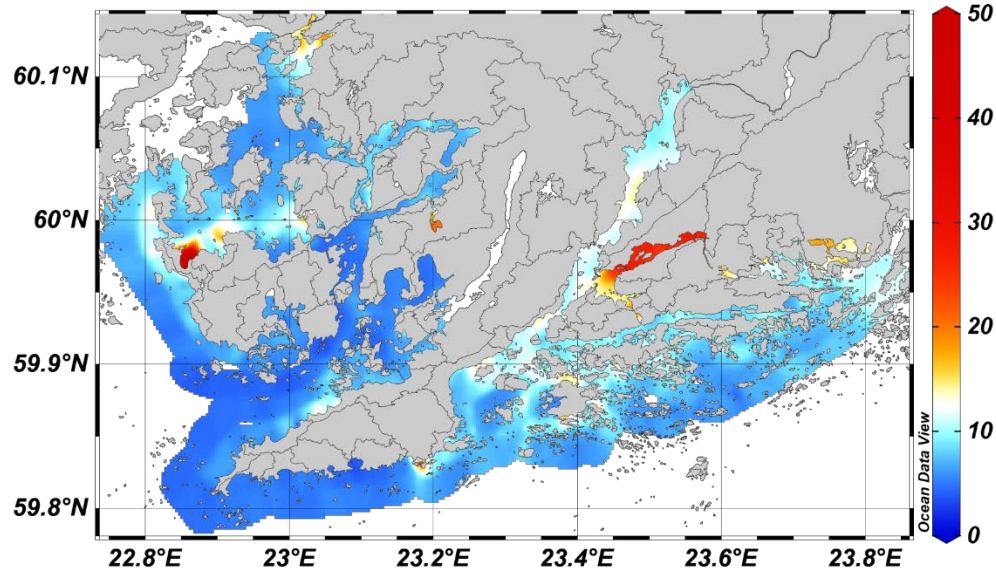
**Turb\_FNU [FNU] @ Turb\_FNU [FNU]=first**



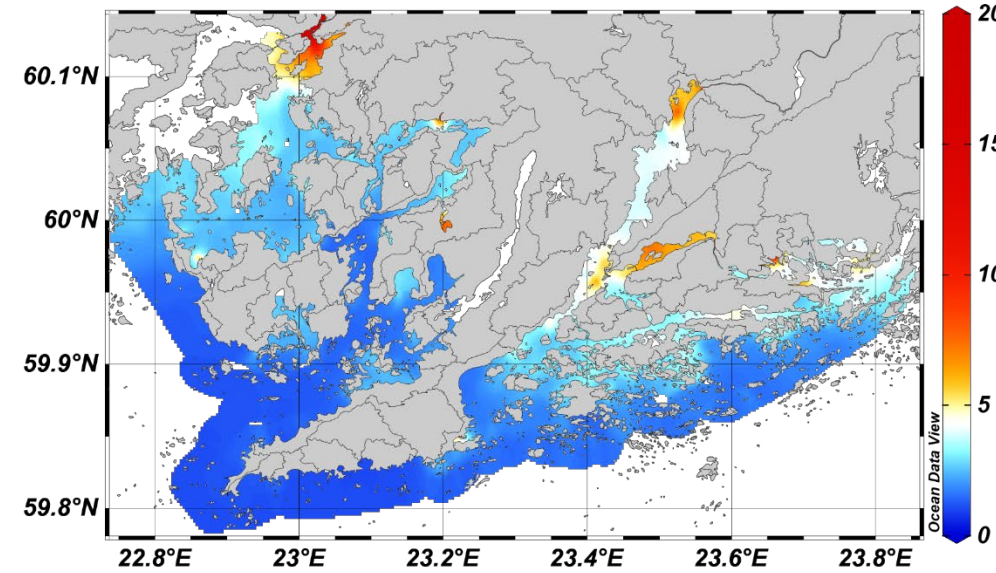
**fDOM\_QSU [QSU] @ fDOM\_QSU [QSU]=first**



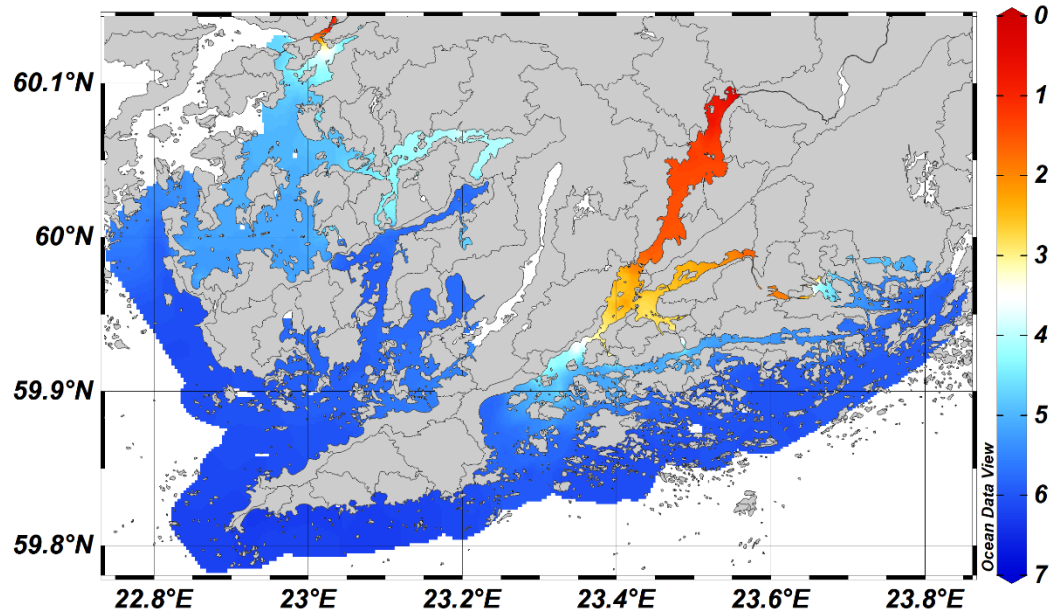
**ChlaDaLe [ $\mu\text{g/L}$ ] @ ChlaDaLe [ $\mu\text{g/L}$ ]=first**



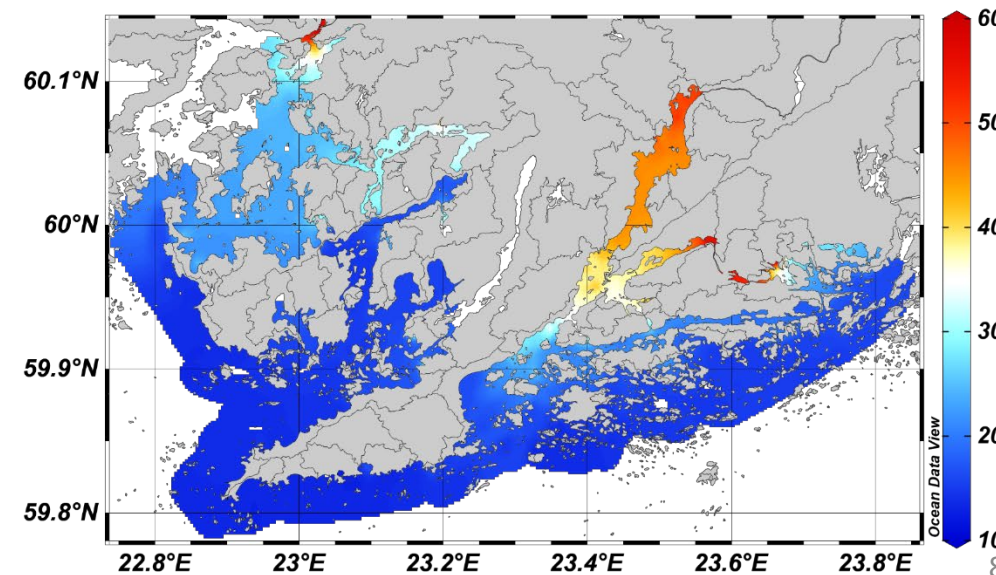
**Turb\_FNU [FNU] @ Turb\_FNU [FNU]=first**



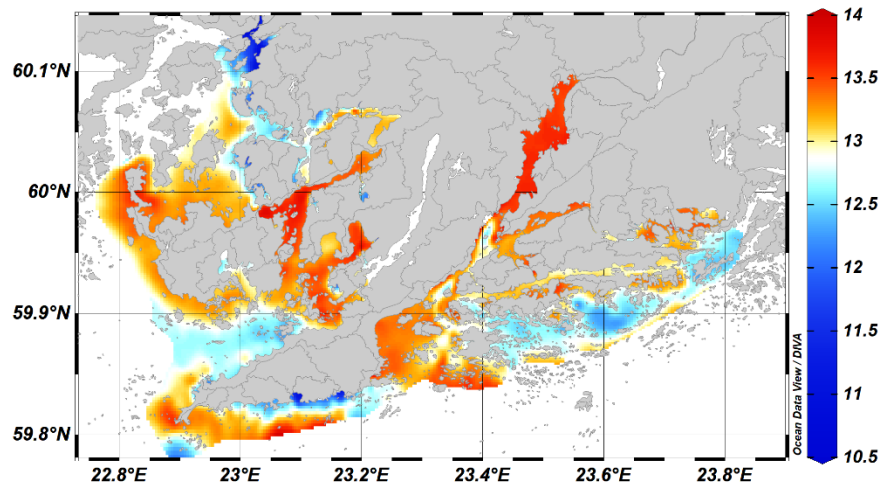
**Sali\_psu [psu] @ Sali\_psu [psu]=first**



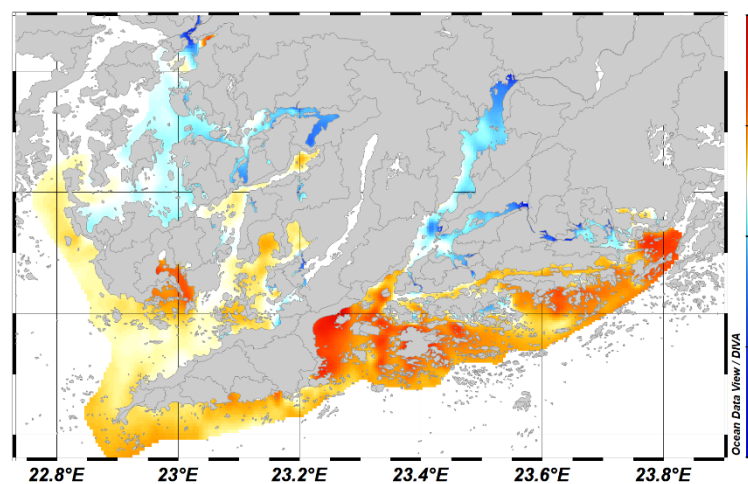
**fDOM\_QSU [QSU] @ fDOM\_QSU [QSU]=first**



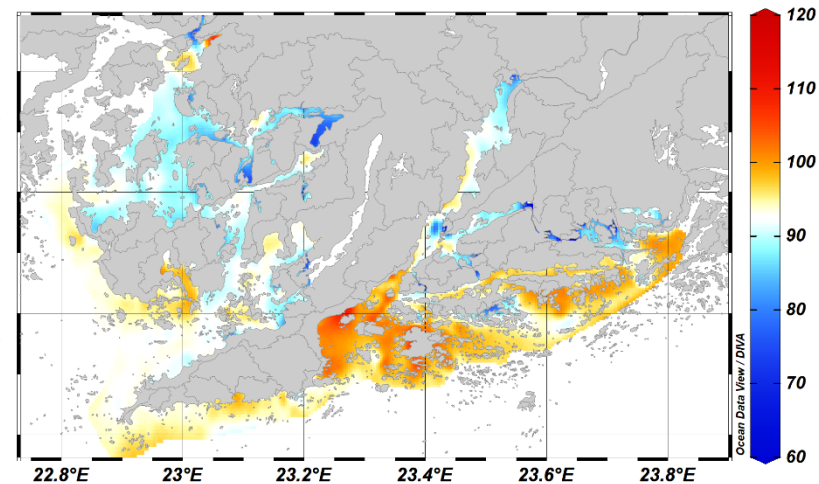
TempCels [°C] @ TempCels [°C]=first



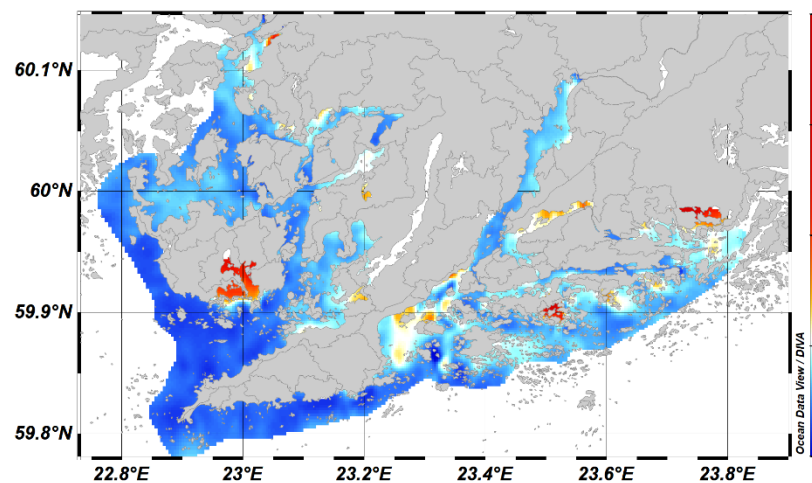
pHloguni [NA] @ pHloguni [NA]=first



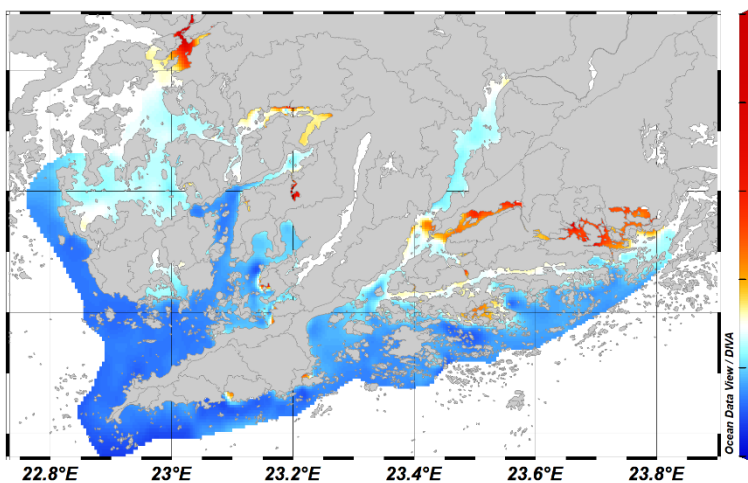
ODOpsat [%] @ ODOpsat [%]=first



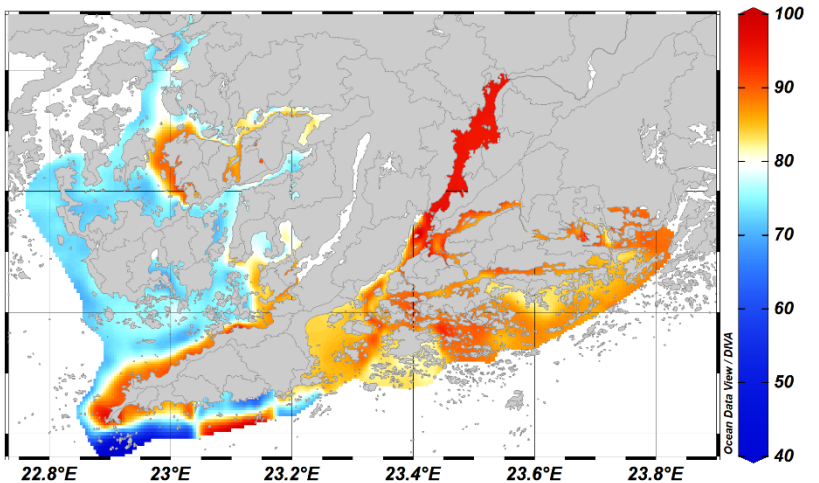
BGAPCUGL [µg/L] @ BGAPCUGL [µg/L]=first



TPPred [µg/L] @ TPPred [µg/L]=first

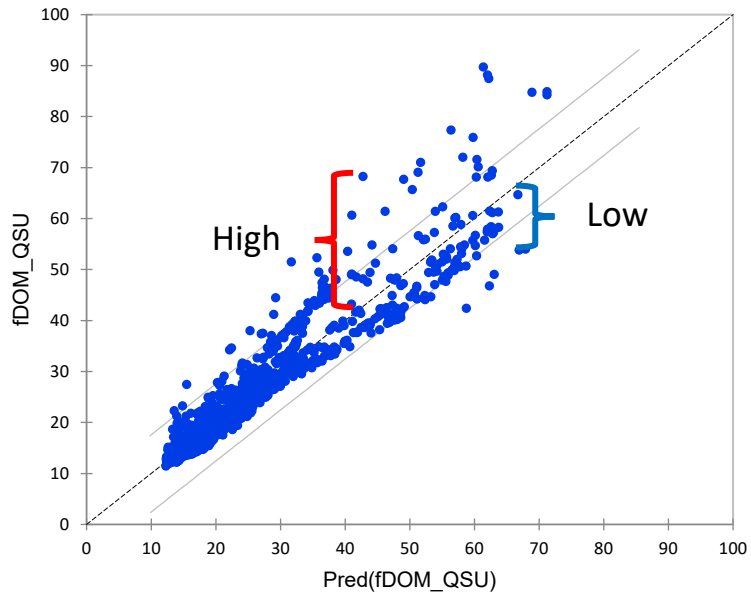


Rel\_Hum [%] @ Rel\_Hum [%]=first

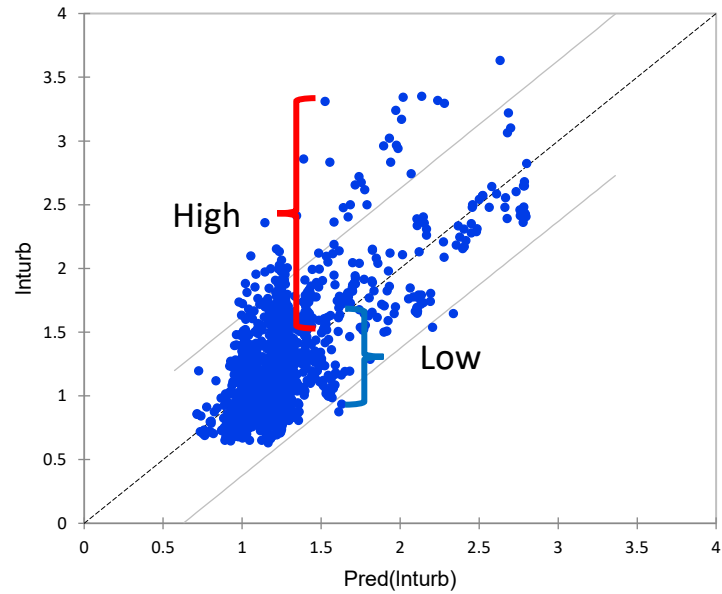




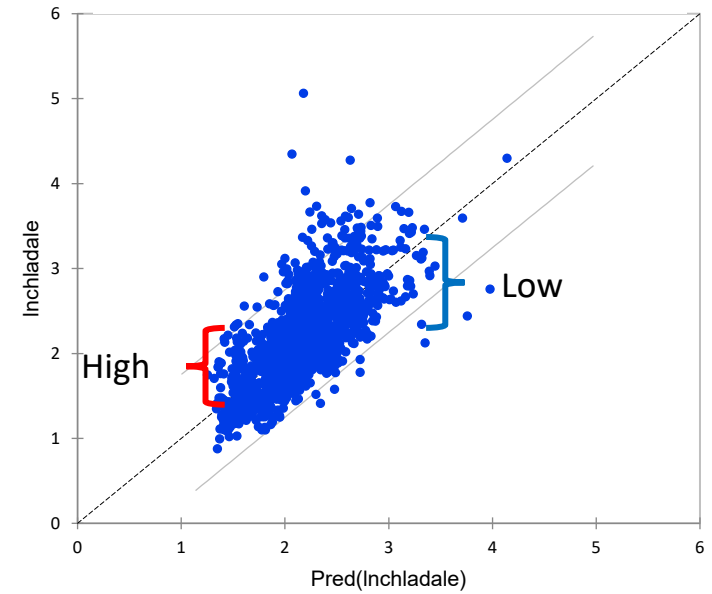
# Flourescent DOM (95 %)



# Turbidity (75 %)



# Chlorophyll a (72 %)



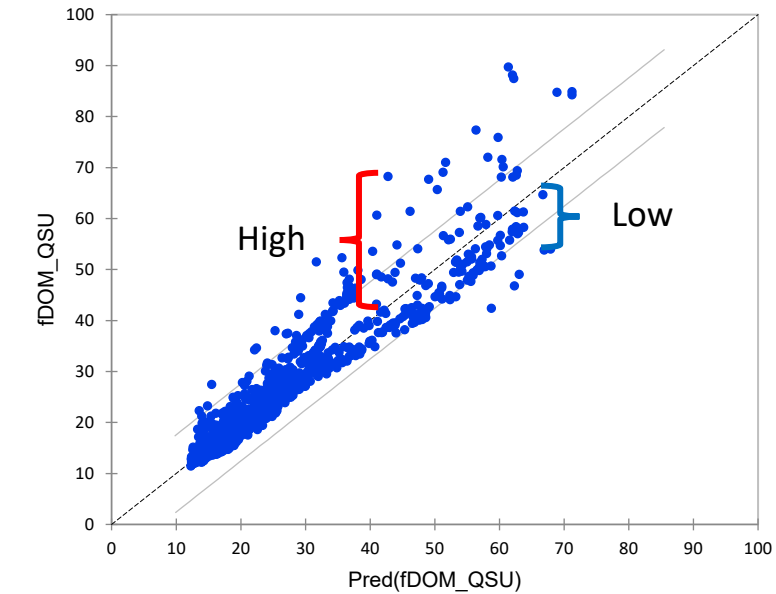
Source	Value	Standard error	t	Pr >  t	Lower bound (95%)	Upper bound (95%)
Week	0.856	0.184	4.660	<0.0001	0.496	1.216
Sali_psu	-0.398	0.124	-3.219	0.001	-0.640	-0.155
TempCels	0.295	0.175	1.686	0.092	-0.048	0.637
Week*Sali_psu	-1.241	0.253	-4.912	<0.0001	-1.737	-0.746
Week*TempCels	-1.160	0.294	-3.943	<0.0001	-1.737	-0.583
Sali_psu*TempCels	-0.653	0.226	-2.890	0.004	-1.096	-0.210
Week*Sali_psu*TempCels	1.426	0.334	4.269	<0.0001	0.771	2.081

Source	Value	Standard error	t	Pr >  t	Lower bound (95%)	Upper bound (95%)
Week	0.673	0.327	2.056	0.040	0.031	1.314
Sali_psu	-0.689	0.218	-3.166	0.002	-1.116	-0.262
TempCels	0.211	0.280	0.754	0.451	-0.338	0.759
Week*Sali_psu	-1.413	0.457	-3.092	0.002	-2.310	-0.517
Week*TempCels	-1.907	0.507	-3.762	0.000	-2.901	-0.912
Sali_psu*TempCels	-0.459	0.379	-1.211	0.226	-1.203	0.285
Week*Sali_psu*TempCels	2.711	0.596	4.549	<0.0001	1.542	3.880

Source	Value	Standard error	t	Pr >  t	Lower bound (95%)	Upper bound (95%)
Week	4.021	0.947	4.248	<0.0001	2.164	5.878
fDOM_QSU	2.923	0.747	3.914	<0.0001	1.458	4.388
Sali_psu	2.881	0.538	5.356	<0.0001	1.826	3.937
Turb_FNU	2.362	2.026	1.166	0.244	-1.613	6.336
TempCels	-1.074	1.009	-1.065	0.287	-3.053	0.904
Week*fDOM_QSU	-2.899	0.807	-3.591	0.000	-4.482	-1.315
Week*Sali_psu	-5.731	0.734	-7.811	<0.0001	-7.170	-4.292
Week*Turb_FNU	-4.096	2.400	-1.707	0.088	-8.805	0.612
Week*TempCels	1.083	1.207	0.897	0.370	-1.285	3.450
fDOM_QSU*Sali_psu	-0.476	0.480	-0.992	0.322	-1.418	0.466
fDOM_QSU*Turb_FNU	-2.064	2.019	-1.022	0.307	-6.025	1.897
fDOM_QSU*TempCels	2.914	0.722	4.037	<0.0001	1.498	4.331
Sali_psu*Turb_FNU	-1.129	0.408	-2.766	0.006	-1.930	-0.328
Sali_psu*TempCels	1.792	0.635	2.824	0.005	0.547	3.037
Turb_FNU*TempCels	5.721	1.999	2.861	0.004	1.799	9.643
Week*fDOM_QSU*Sali_psu	2.208	0.700	3.155	0.002	0.835	3.581
Week*fDOM_QSU*Turb_FNU	4.124	2.443	1.688	0.092	-0.668	8.916
Week*fDOM_QSU*TempCels	-2.675	0.771	-3.470	0.001	-4.188	-1.163
Week*Sali_psu*Turb_FNU	3.909	0.587	6.659	<0.0001	2.757	5.060
Week*Sali_psu*TempCels	0.000	0.000				
Week*Turb_FNU*TempCels	-3.511	2.306	-1.523	0.128	-8.034	1.012
fDOM_QSU*Sali_psu*Turb_FNU	1.019	1.090	0.935	0.350	-1.118	3.157
fDOM_QSU*Sali_psu*TempCels	-1.745	0.779	-2.240	0.025	-3.274	-0.217
fDOM_QSU*Turb_FNU*TempCels	-6.666	2.043	-3.263	0.001	-10.674	-2.658
Sali_psu*Turb_FNU*TempCels	-2.569	0.601	-4.272	<0.0001	-3.748	-1.389
Week*fDOM_QSU*Sali_psu*Turb_FNU	-3.526	1.181	-2.986	0.003	-5.842	-1.209

Where, when and how much does carbon, nutrient and particle loading deviate from their normal level as predicted by the environmental conditions and manifested as status indicators?

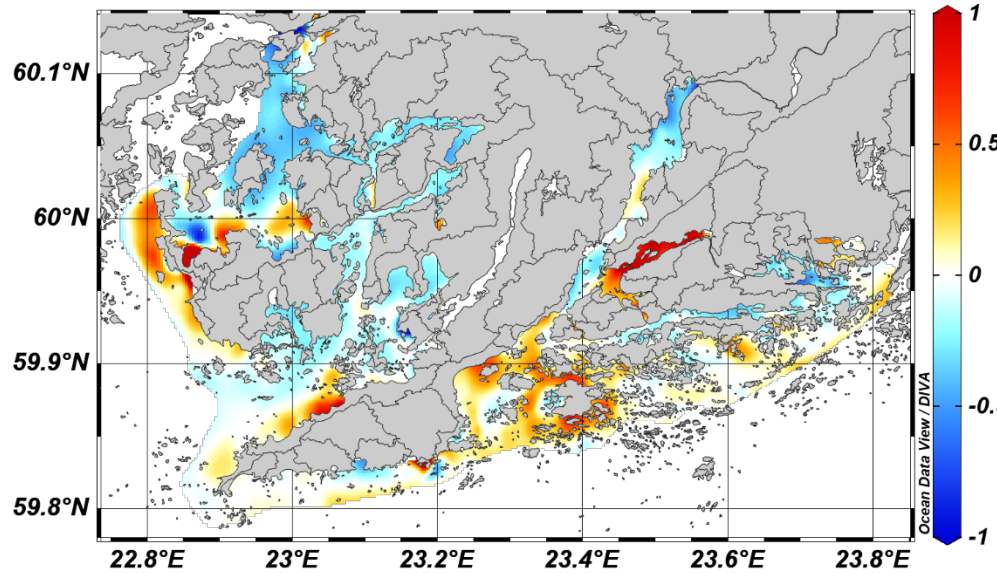
## Fluorescent DOM (95 %)



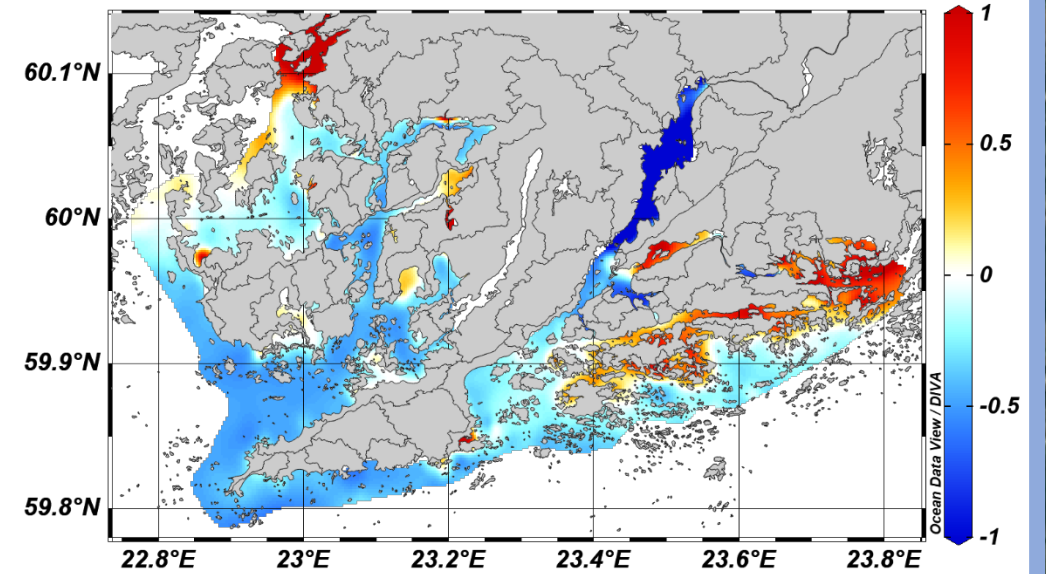
Source	Value	Standard error	t	Pr >  t	Lower bound (95%)	Upper bound (95%)
Week	0.856	0.184	4.660	<0.0001	0.496	1.216
Sali_psu	-0.398	0.124	-3.219	0.001	-0.640	-0.155
TempCels	0.295	0.175	1.686	0.092	-0.048	0.637
Week*Sali_psu	-1.241	0.253	-4.912	<0.0001	-1.737	-0.746
Week*TempCels	-1.160	0.294	-3.943	<0.0001	-1.737	-0.583
Sali_psu*TempCels	-0.653	0.226	-2.890	0.004	-1.096	-0.210
Week*Sali_psu*TempCels	1.426	0.334	4.269	<0.0001	0.771	2.081

Where, when and how much does carbon, nutrient and particle loading deviate from their normal level as predicted by the environmental conditions and manifested as status indicators?

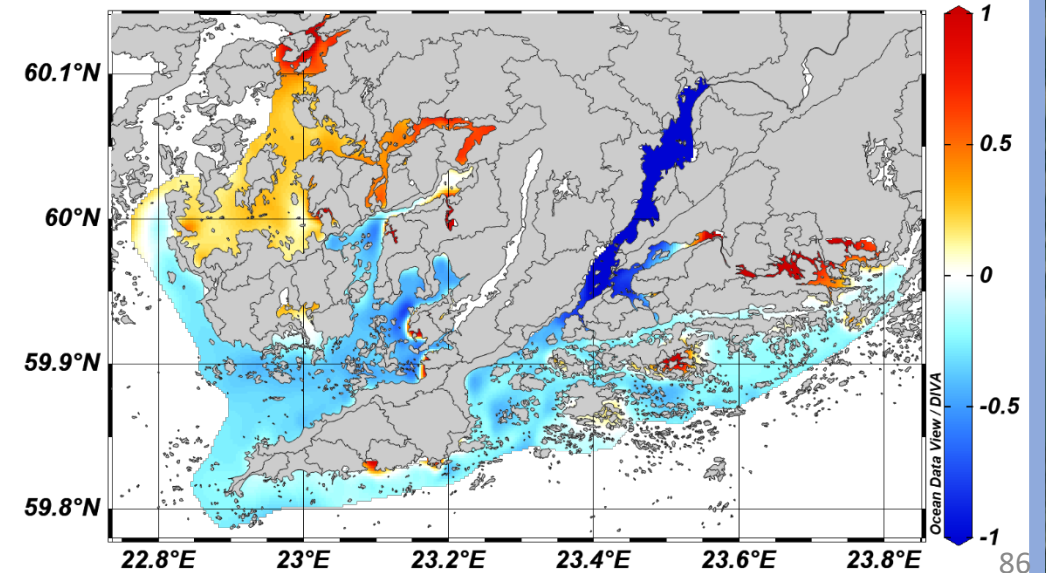
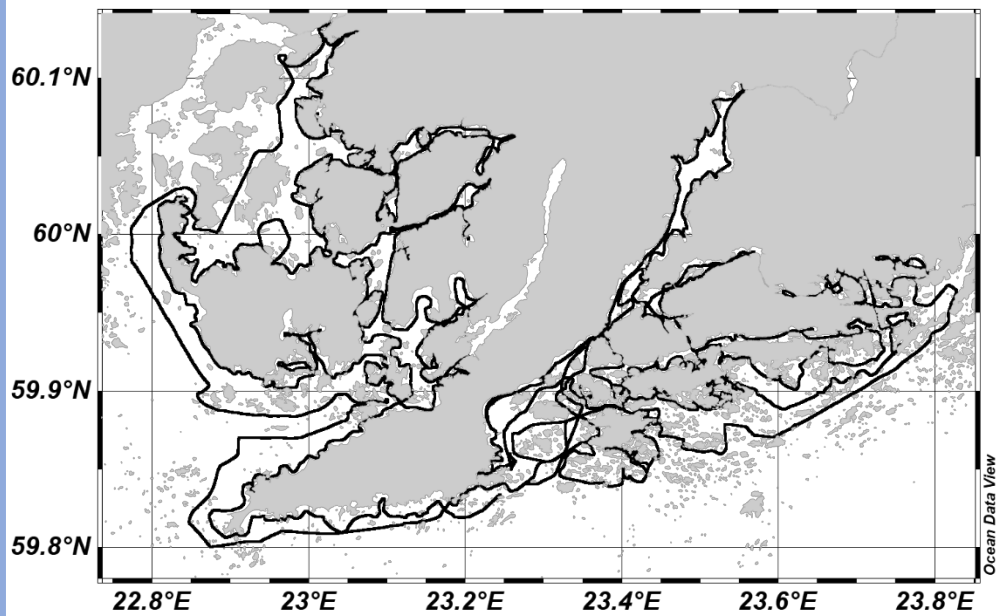
Z-Chla @ Z-Chla=first



Z-Turb @ Z-Turb=first



Z-fDOM @ Z-fDOM=first



## BACKGROUND

Coastal filter determines the fate of carbon and nutrients  
Coastal ecosystems alter carbon and nutrient pools on their way from land to sea via multiple biogeochemical processes. The main pathways through this coastal filter are *bypassing, transformation, retention and removal*<sup>1</sup>.

### The ecological status of coastal waters

Carbon, nutrient and particle loading drive the *status* of coastal waters by altering e.g. *trophic state, acidity, carbon balance* and *light climate*. Elevated freshwater input due to climate change can intensify this loading<sup>2</sup>.

### Central indicators for local anthropogenic impacts

In inshore waters, ecosystem state, functioning and services are mainly disrupted by *local human influence*<sup>3</sup>. This calls for spatiotemporally detailed data on associated indicators, with attention to parallel, *non-local influences*.

## AIMS AND MEANS

### Environmental contextualization in high resolution

Indicators for carbon, nutrient and particle loading to be surveyed in high spatiotemporal resolution and extent in parallel with capturing prevailing physical settings, thus siting the indicator values in their *environmental context*.

### Archipelago Sea/Western Gulf of Finland as model areas

Indicator values unmasked from external influences such as freshwater input, background loading or weather give a detailed view of local anthropogenic impacts on the coastal waters of SW Finland.

### Deliverables for sustainable management

Spatial patterns for the context-sensitive indicator values are used for *locating* hotspots of human influence, subsequent *targeting* and *implementation* of sustainable management actions, and *monitoring* their outcomes.

# Havainnollistava esimerkki

Perinteinen näytteenotto

Automatisoitu havainnointi

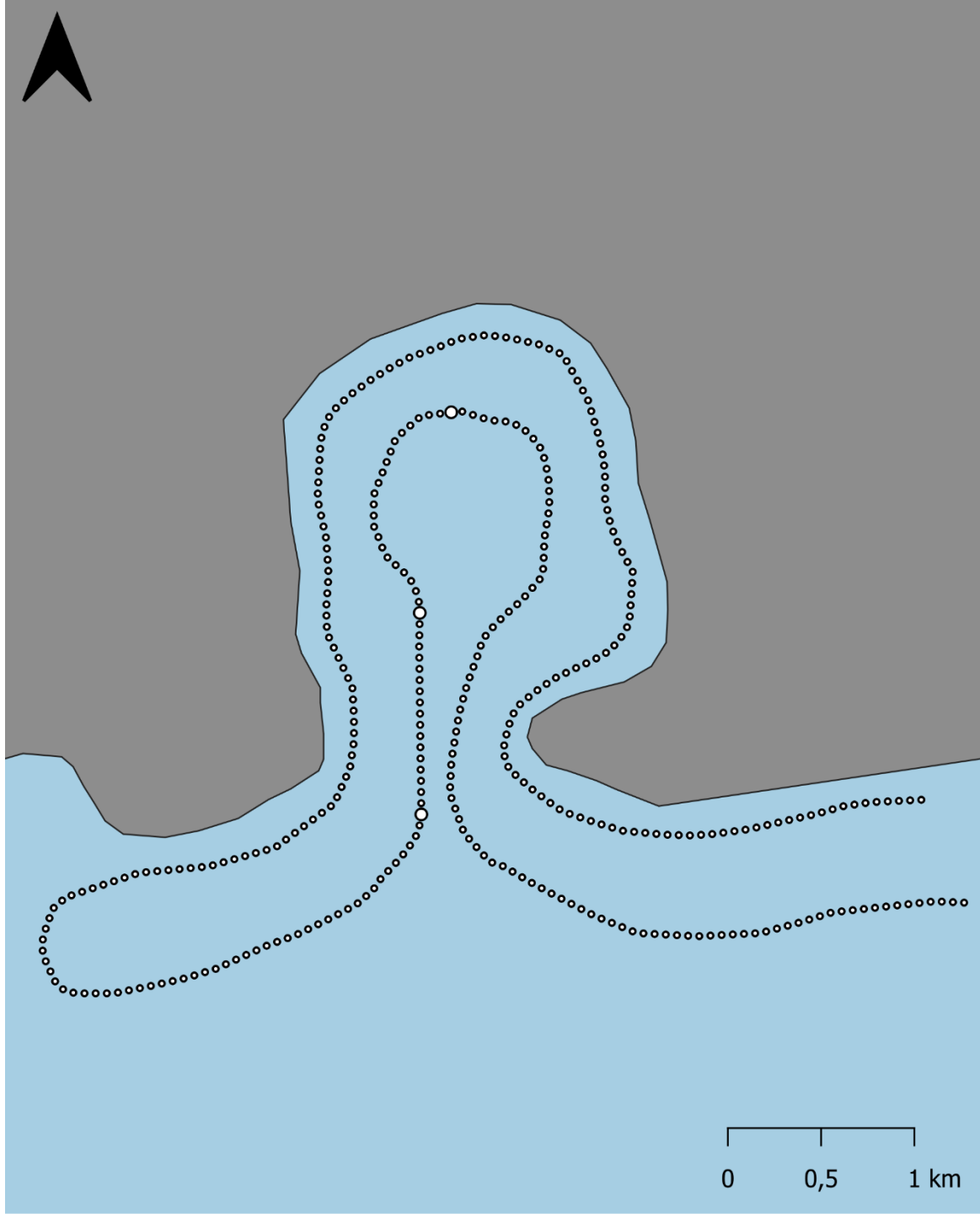


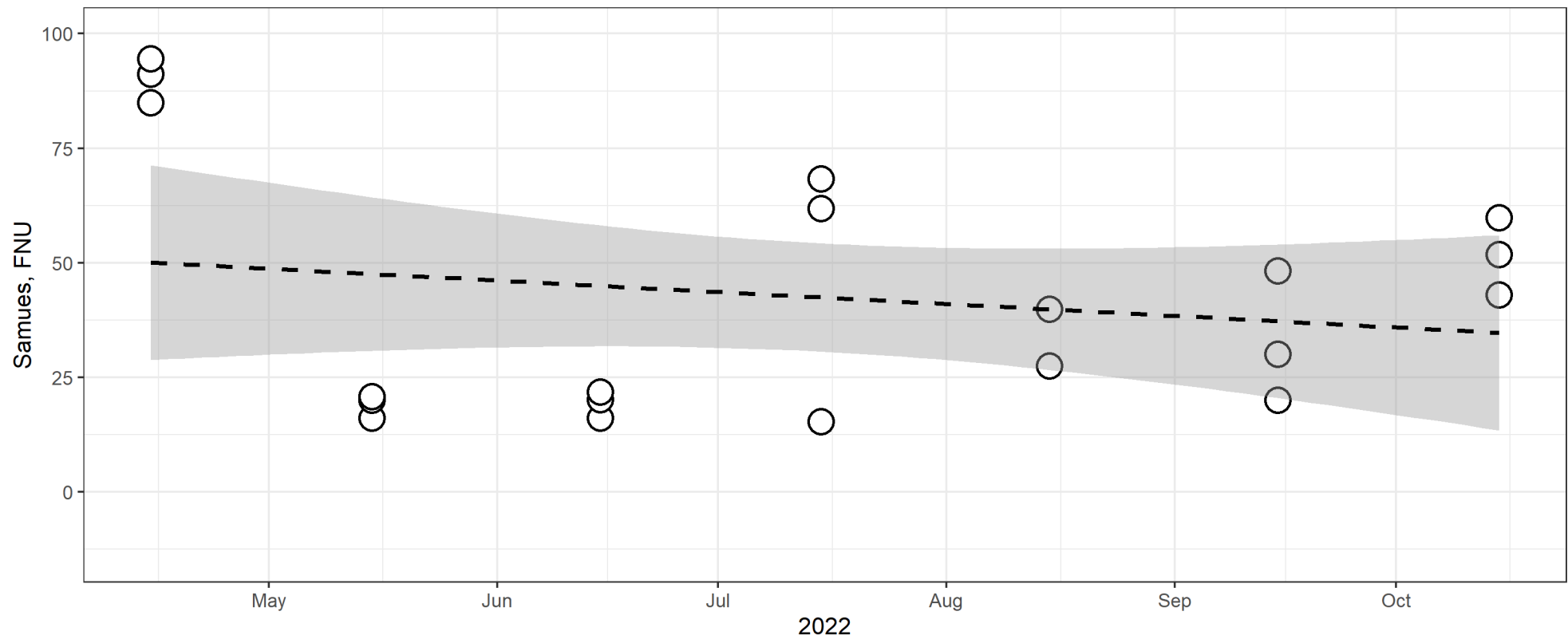
# Tehtävänanto 1: Seurannan suunnittelu

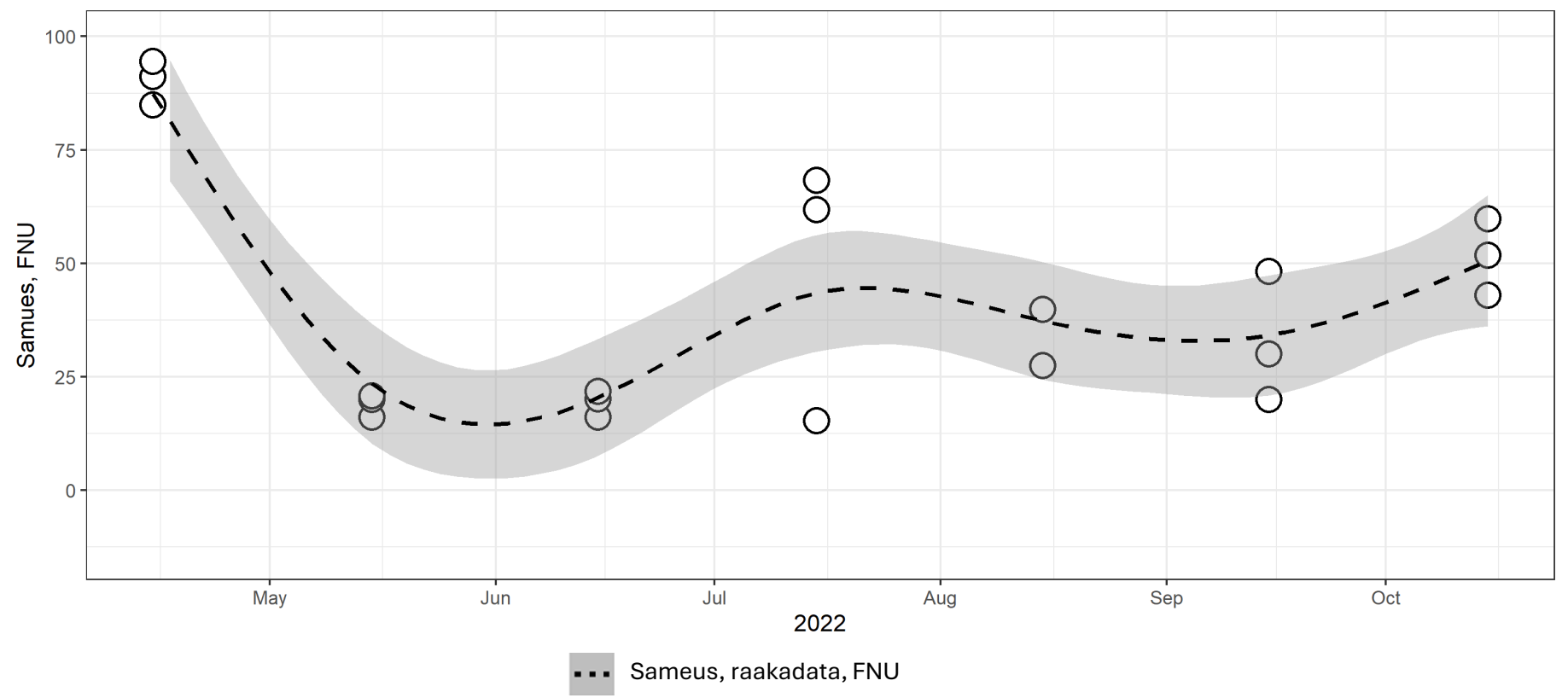
Tämän tehtävänannon aiheena on hahmotella mahdollisimman edullinen mutta luotettava seurantaohjelma. Kuvitteellisen, pienen merenlahden valuma-alueelle on läjitetty ruoppausmassoja. Alueen topografiasta johtuen mahdollisten valumien tiedetään päätyvän mereen vain yhdestä purkupisteestä. Kuvaa pääpiirteissään, miten seuranta kannattaisi mielestäsi toteuttaa purku-uomassa sekä vastaanottavassa vesistössä.

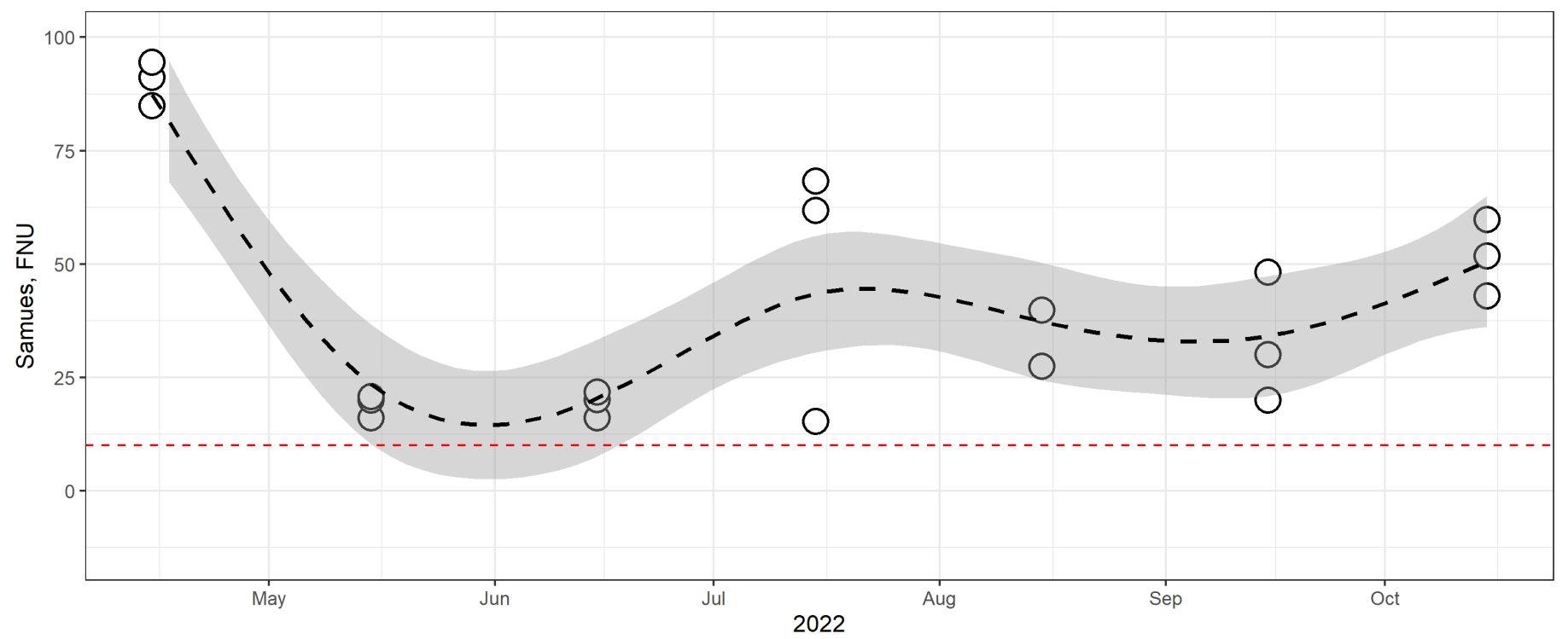
Tavoitteena on selvittää, lisääkö läjitys merenlahteen päätyvää kuormitusta ja vaikuttaako mahdollinen kuormitus vastaanottavan vesistön tilaan. Mitä muuttujia kannattaisi mielestäsi mitata tai muuten arvioida? Missä, milloin ja miten nämä mittaukset tai muut arviot olisi syytä toteuttaa? Millaisia taustatietoja suunnittelemasi arviot edellyttävät, ja mistä näitä tietoja on saatavilla? Millaisia kuluja suunnittelemasi seurannasta voisi muodostua?

Tehtävään pyydetään esseemuotoista vastausta, johon voi mieluusti liittää kuvia ja taulukoita. Kysymykseen ei ole olemassa ehdottoman oikeita tai väriä vastauksia. Tehtävän ensisijaisena tarkoituksena on heijastella, pohtia ja hyödyntää kurssilla läpikäytyjä asioita ennemmin kuin tehdä kirjallisuuskatsausta. Muun tiedon hankinta ja soveltaminen katsotaan toki tarkoituksenmukaiseksi ja kannustettavaksi. Vastaukseen ei ole ohjeellista pituutta. Pää tavoitteena on tarkastella vaikutusten seurantaa mahdollisimman monipuolisesti varsinkin luonnontieteellisestä näkökulmasta.

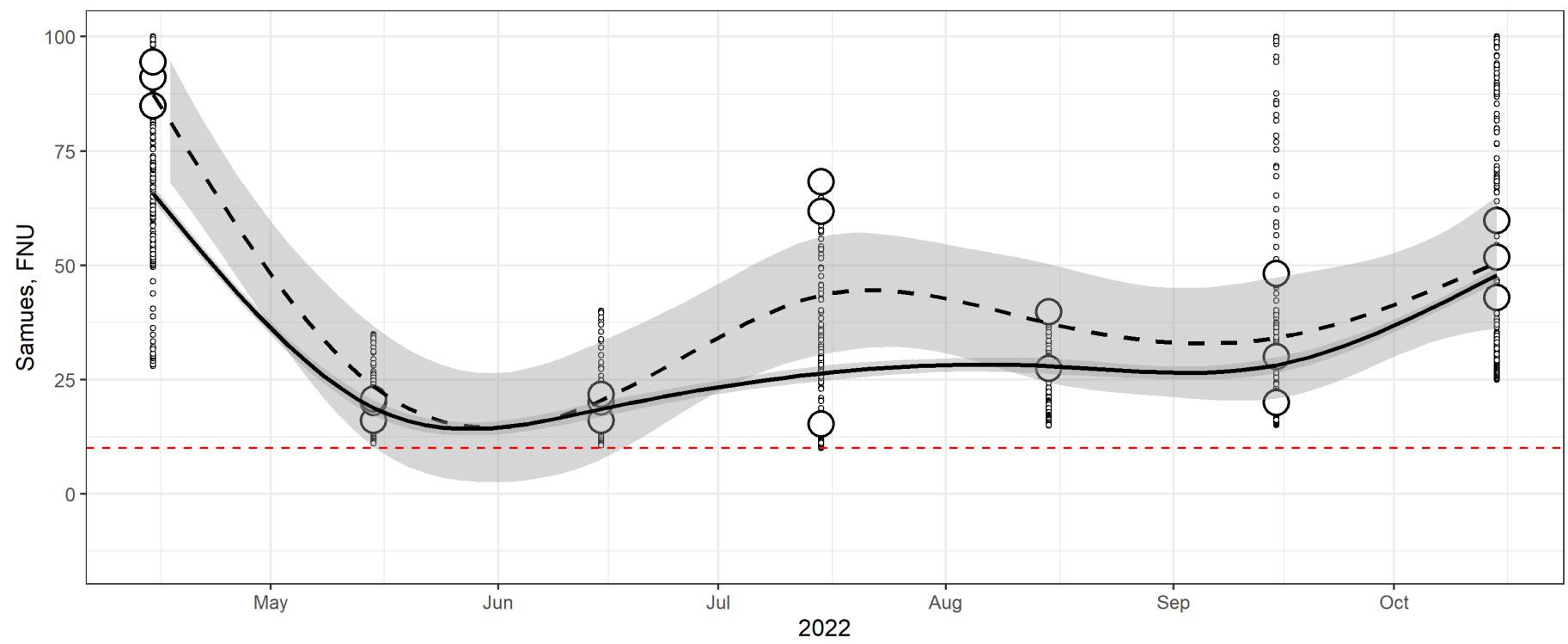






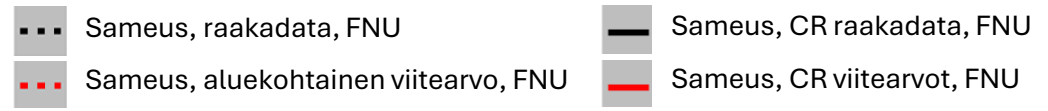
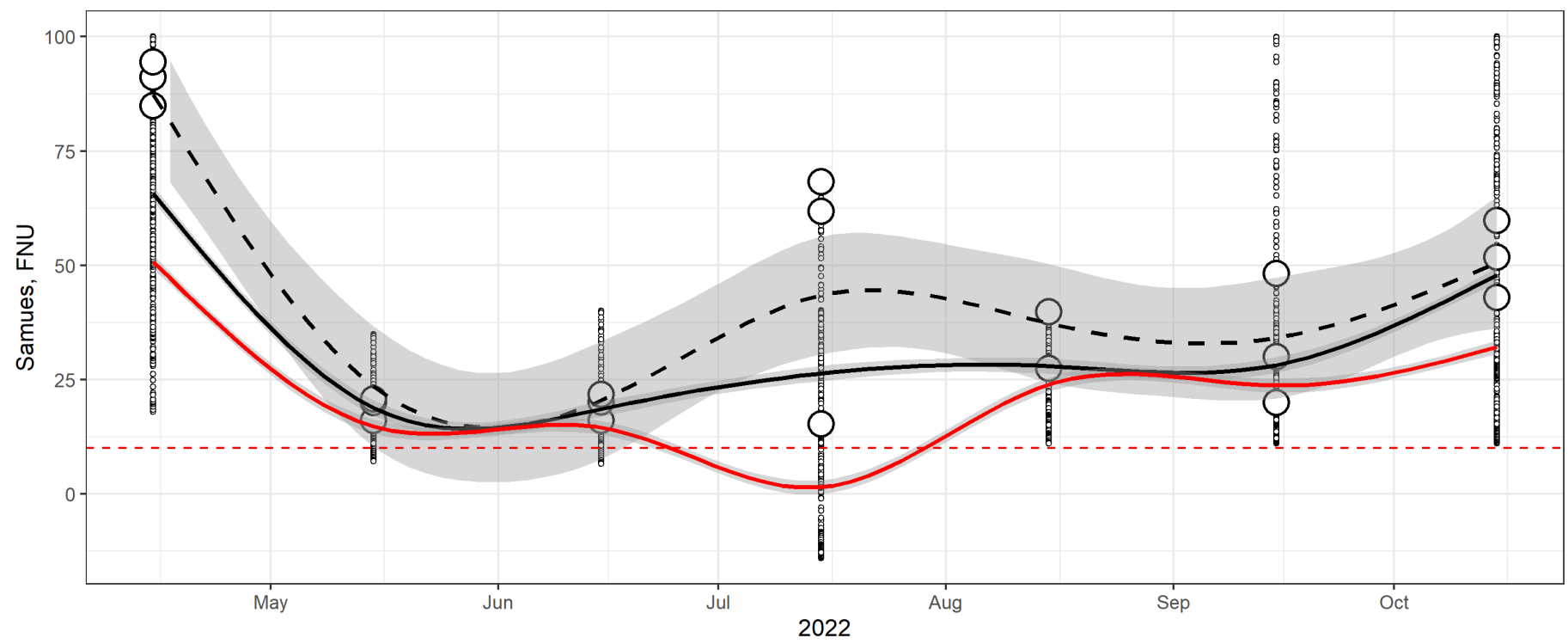


- Sameus, raakadata, FNU
- Sameus, aluekohtainen viitearvo, FNU

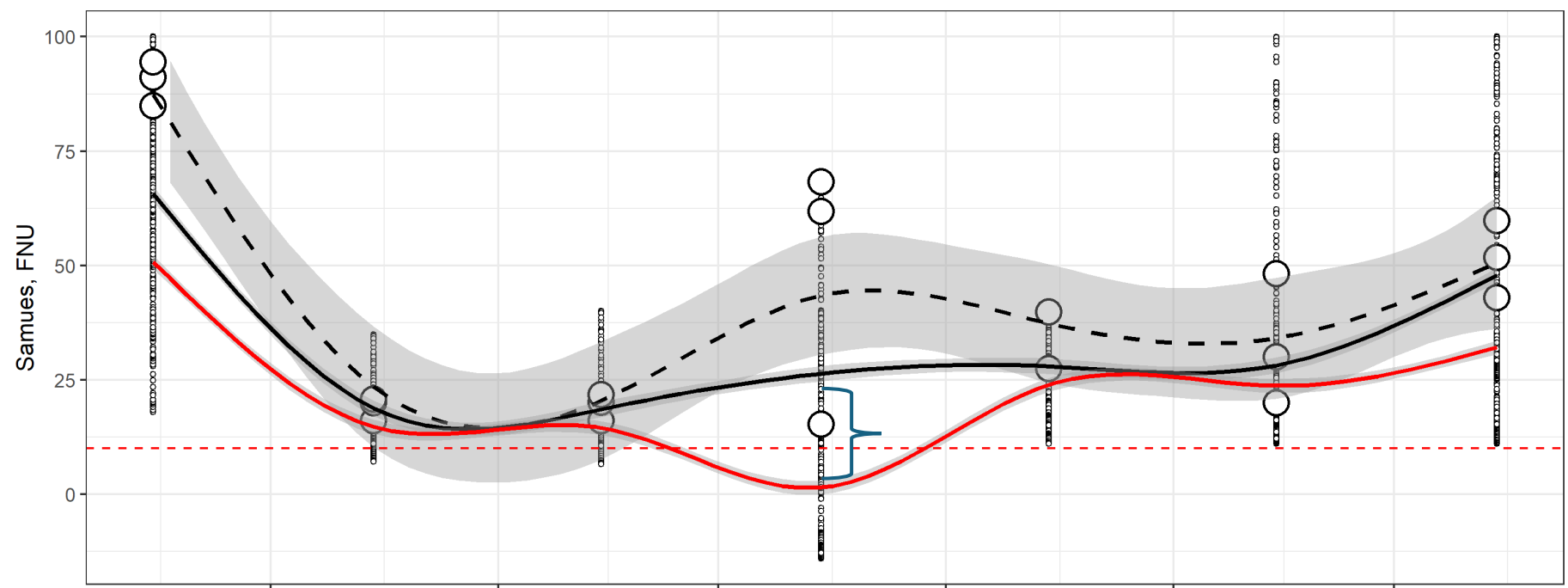
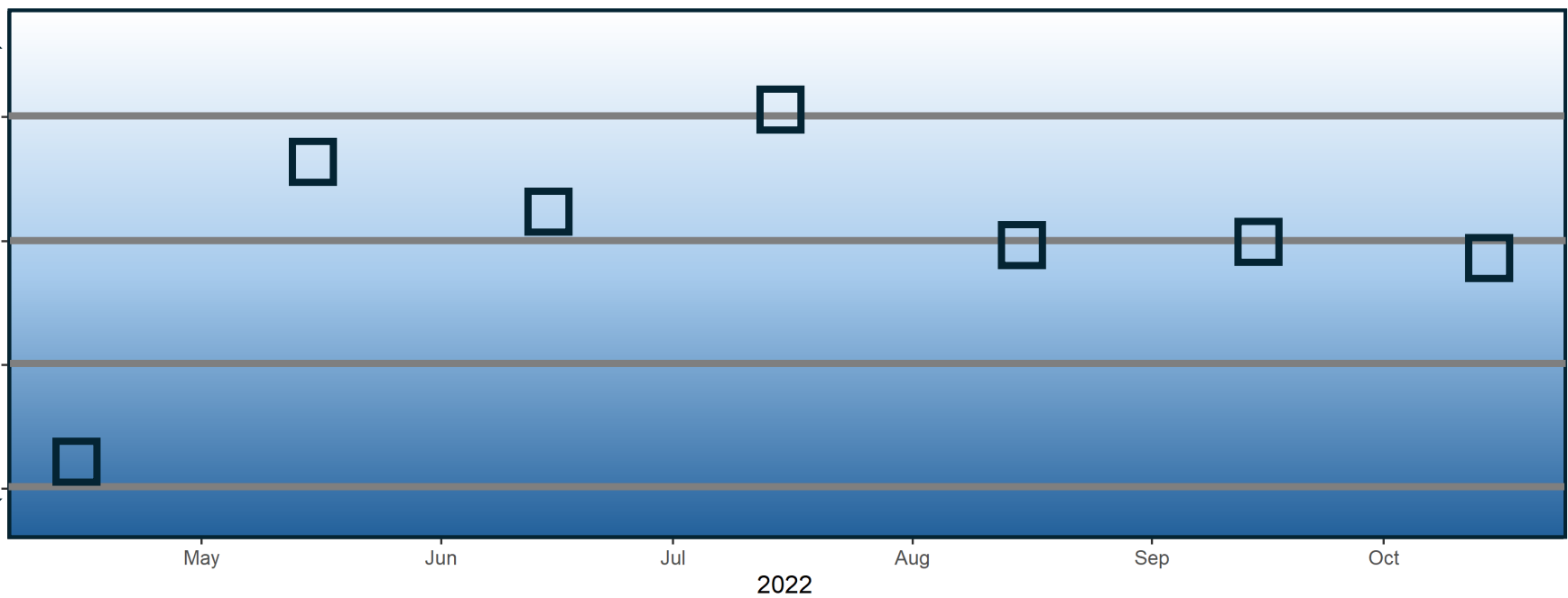


Sameus, raakaddata, FNU
  Sameus, CR raakaddata, FNU

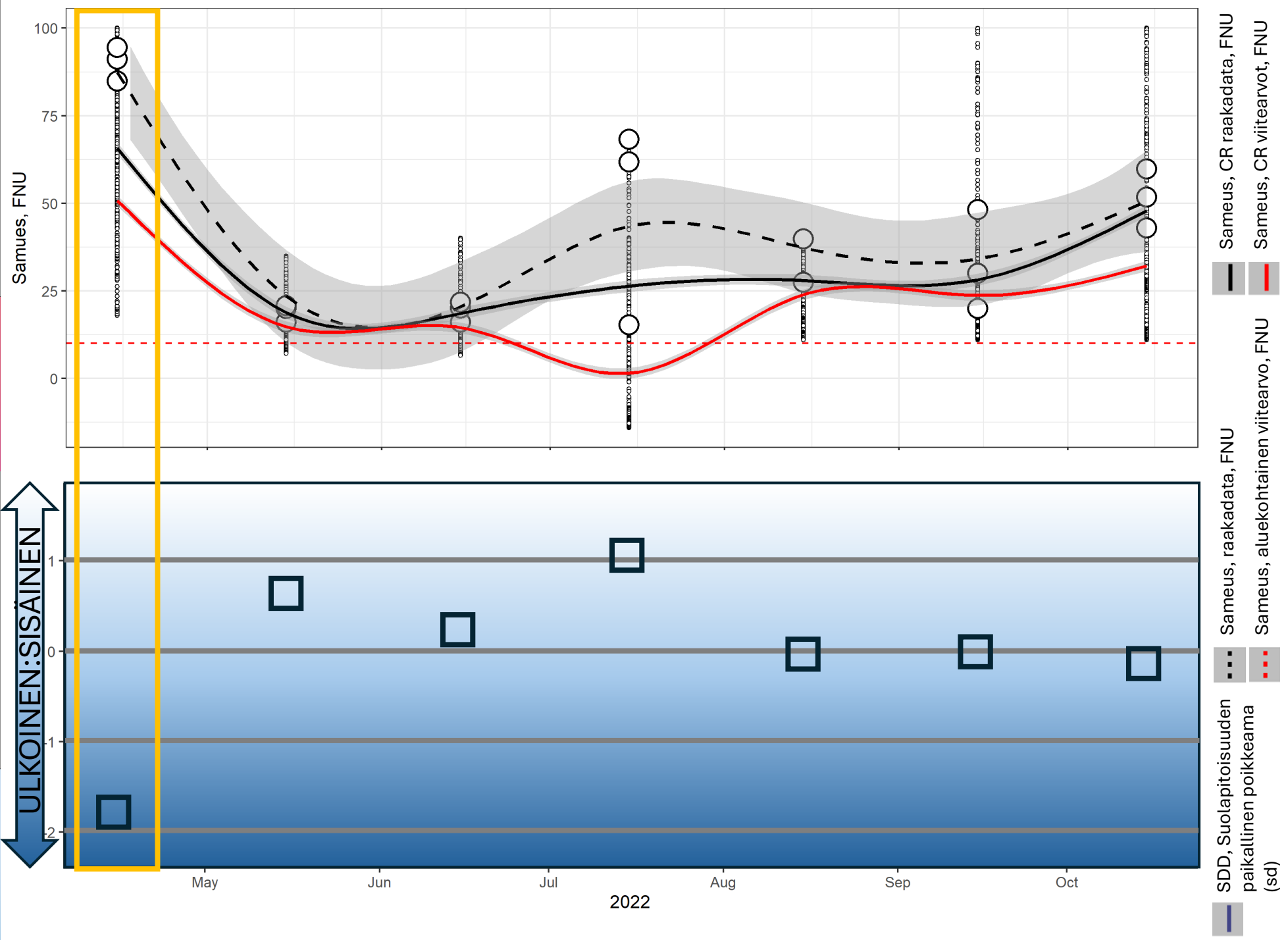
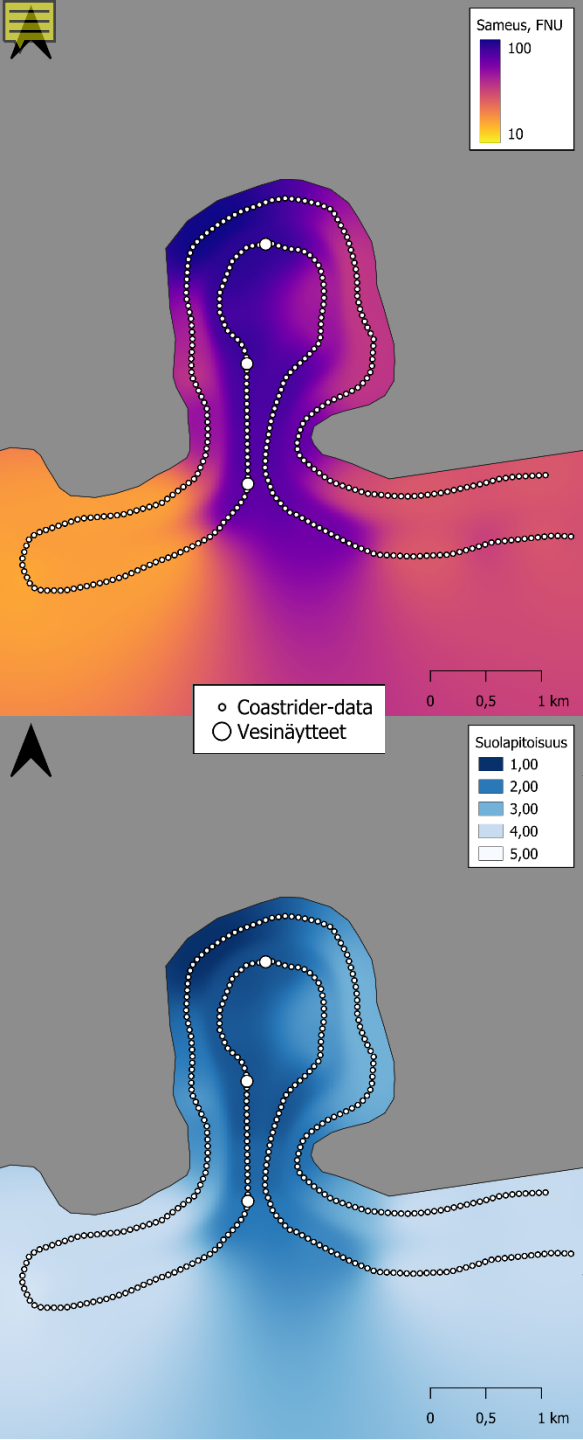
Sameus, aluekohtainen viitearvo, FNU

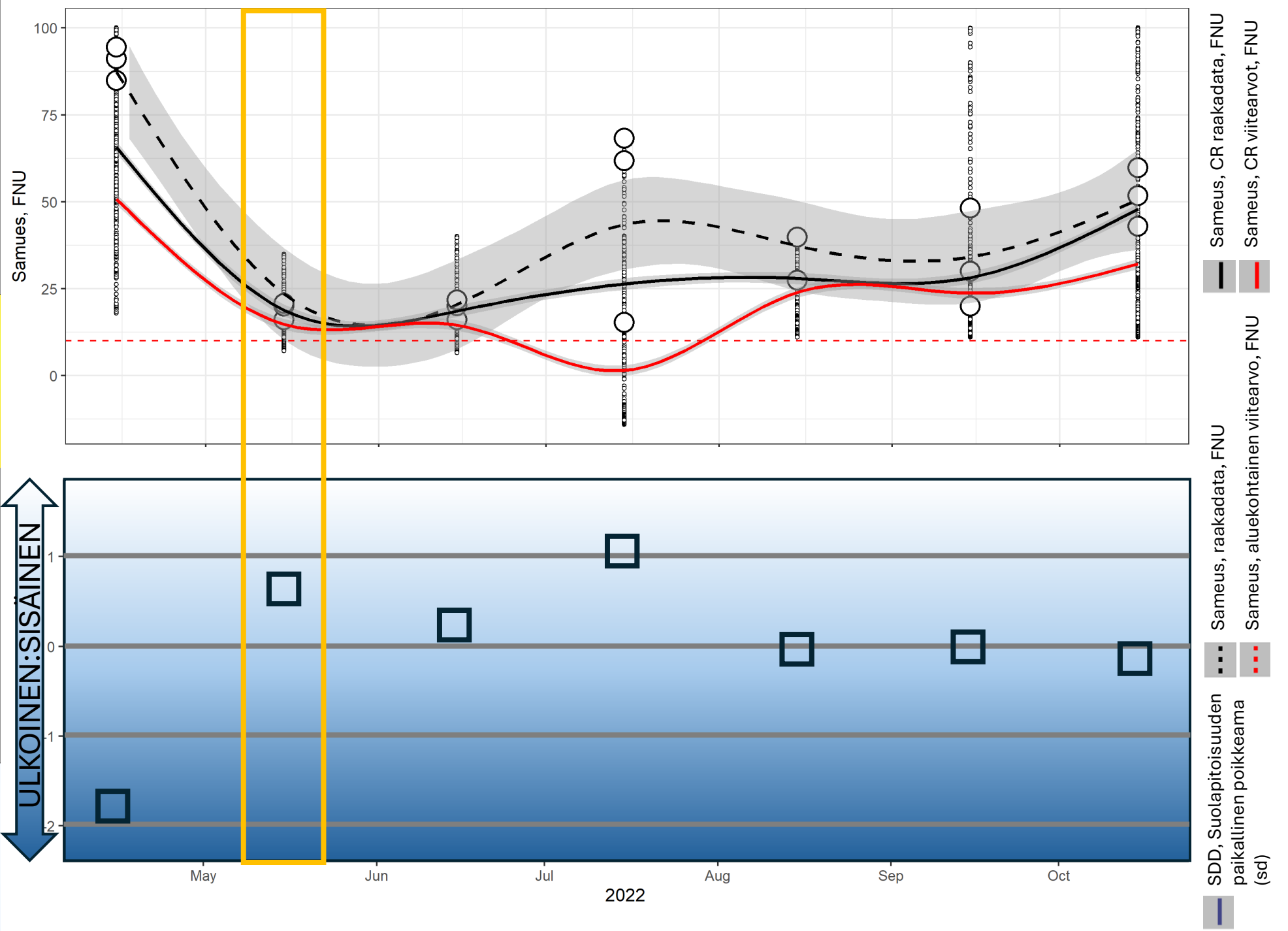
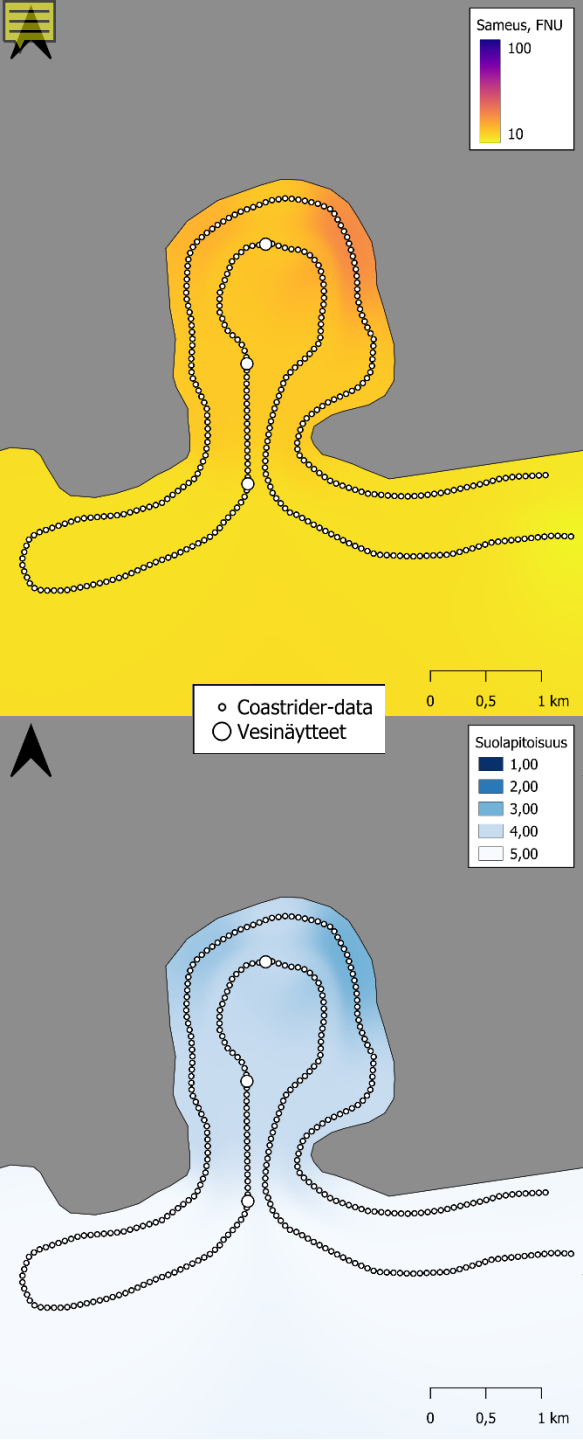


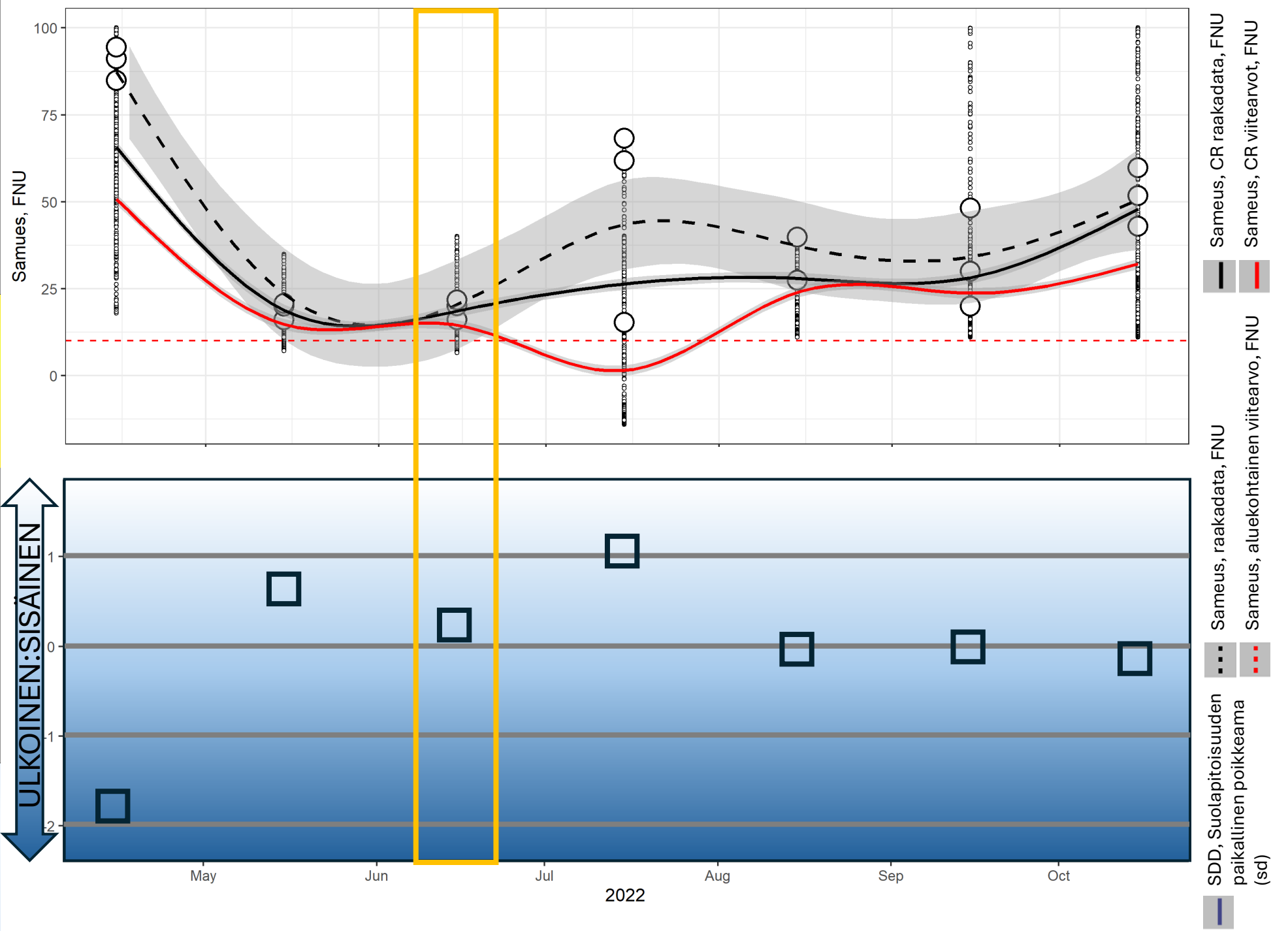
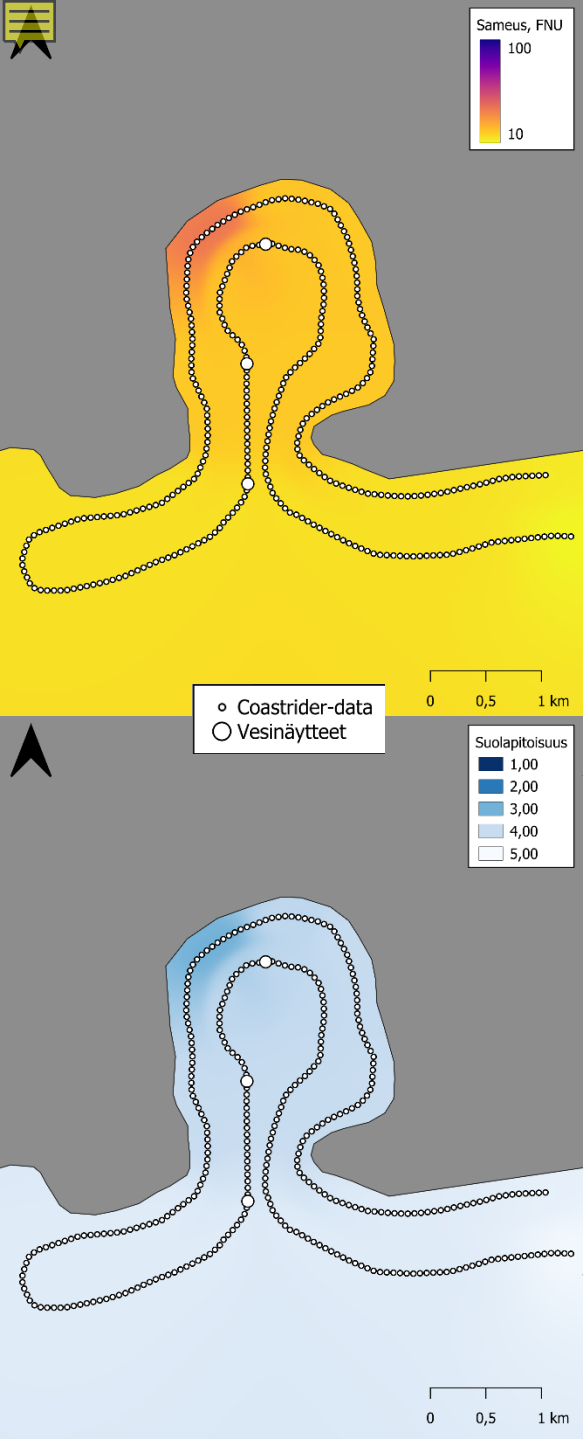
ULKOINEN: SISÄINEN

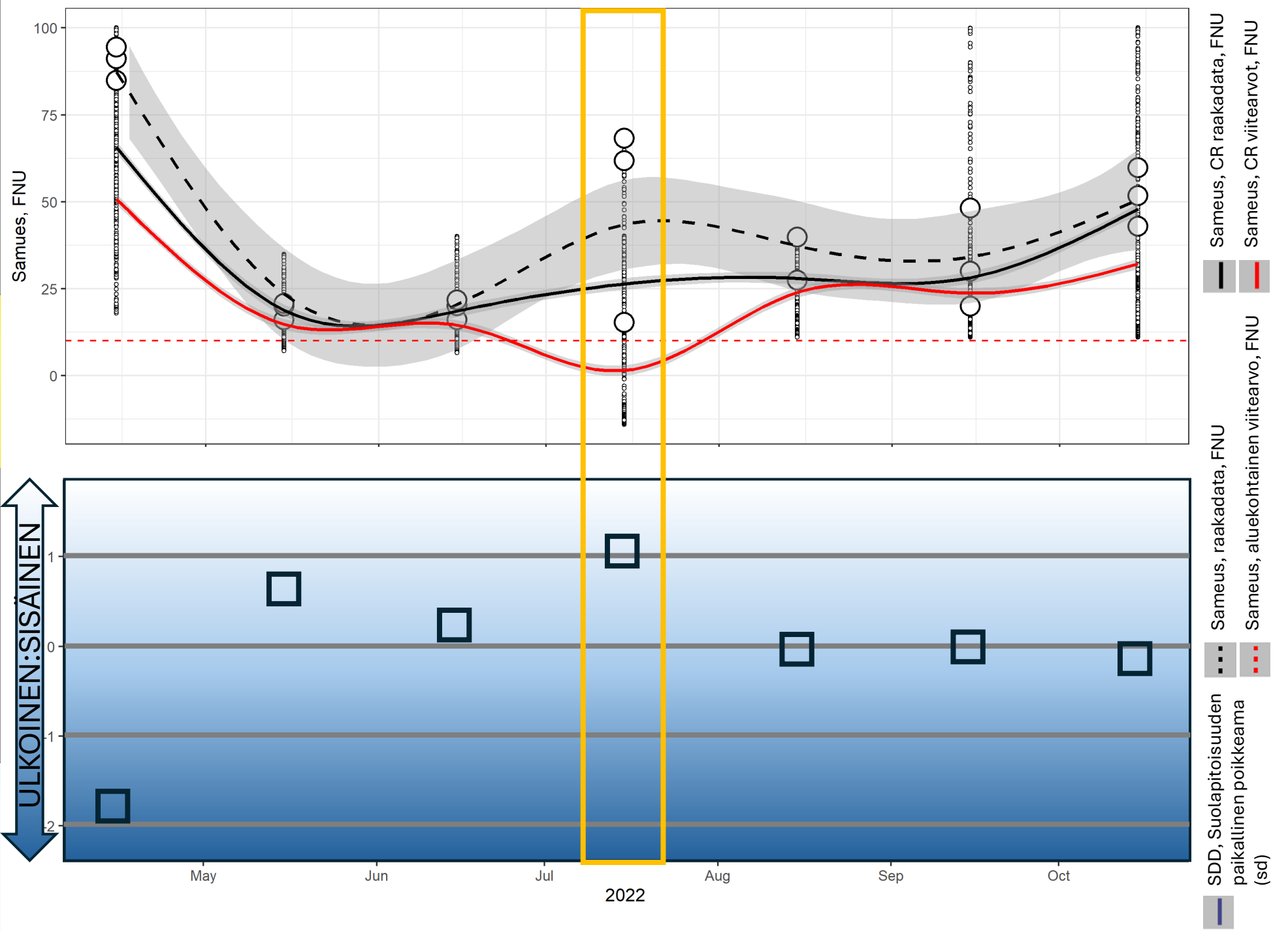
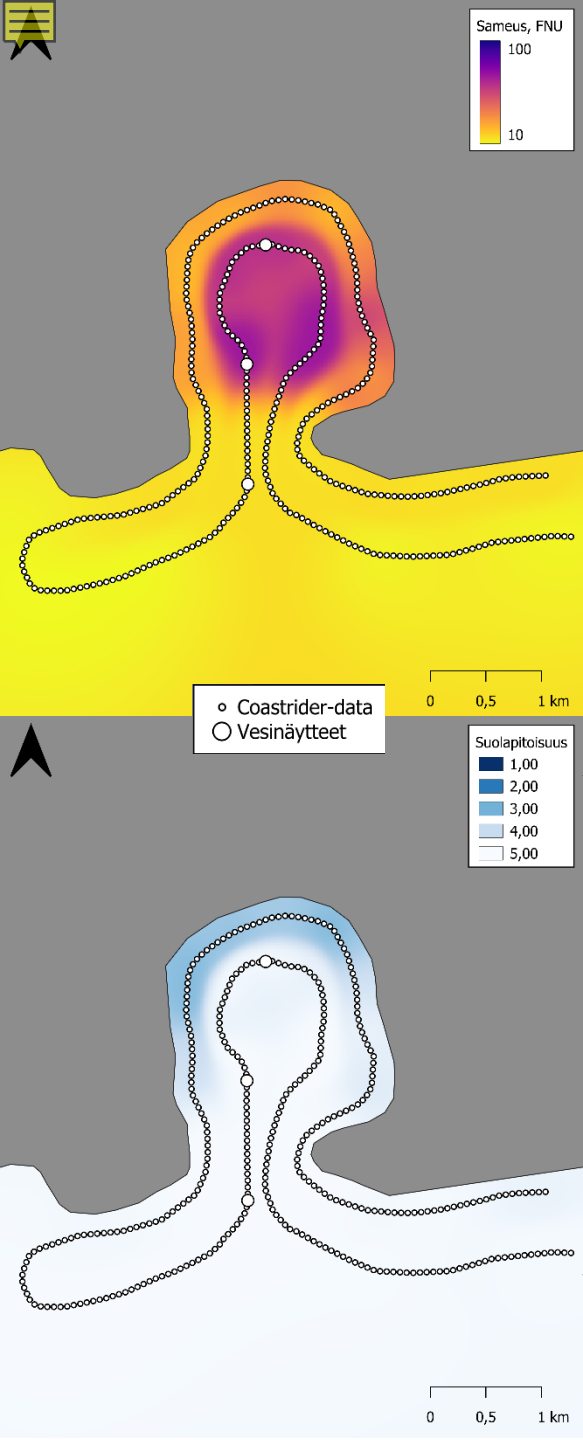


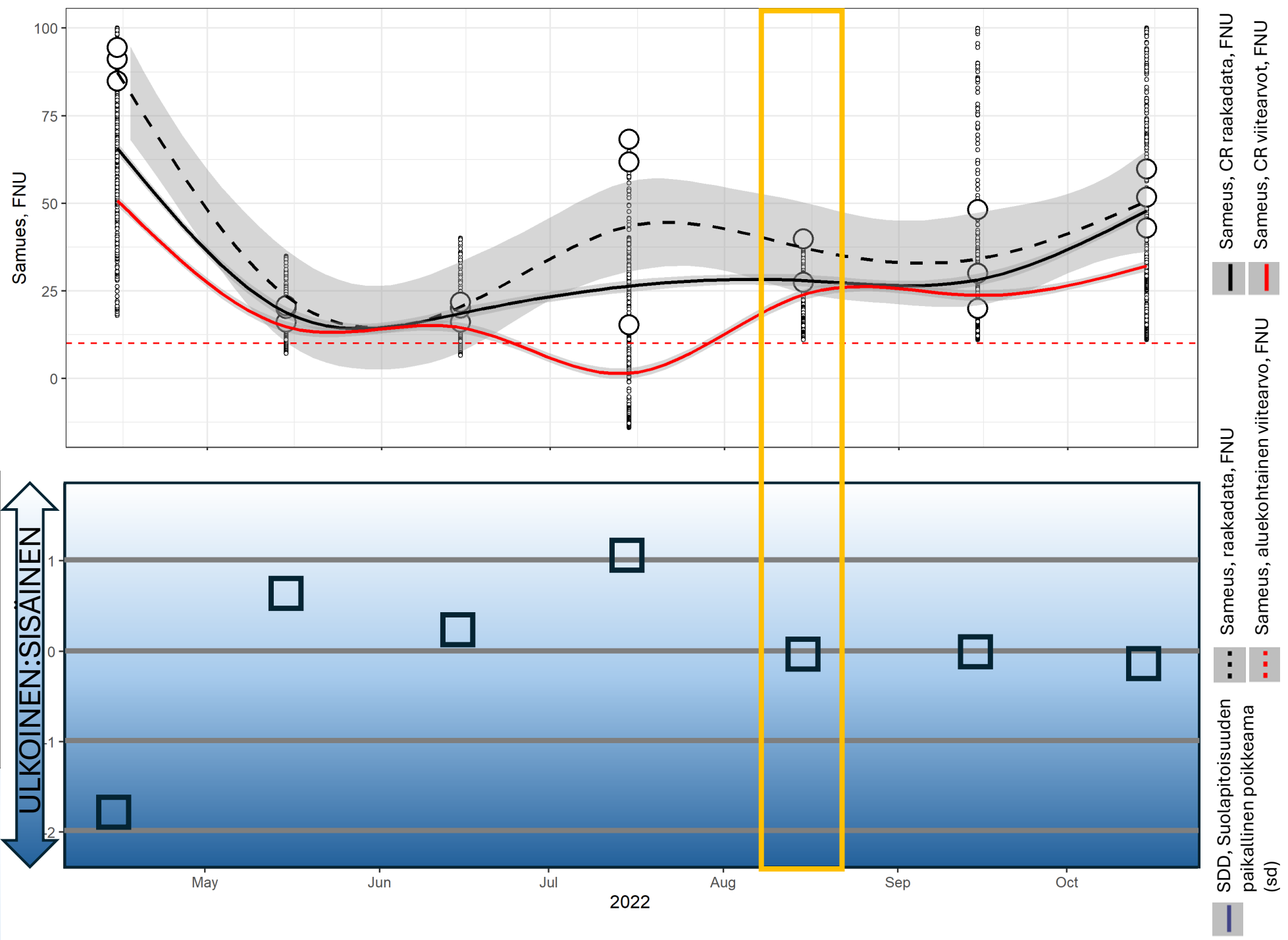
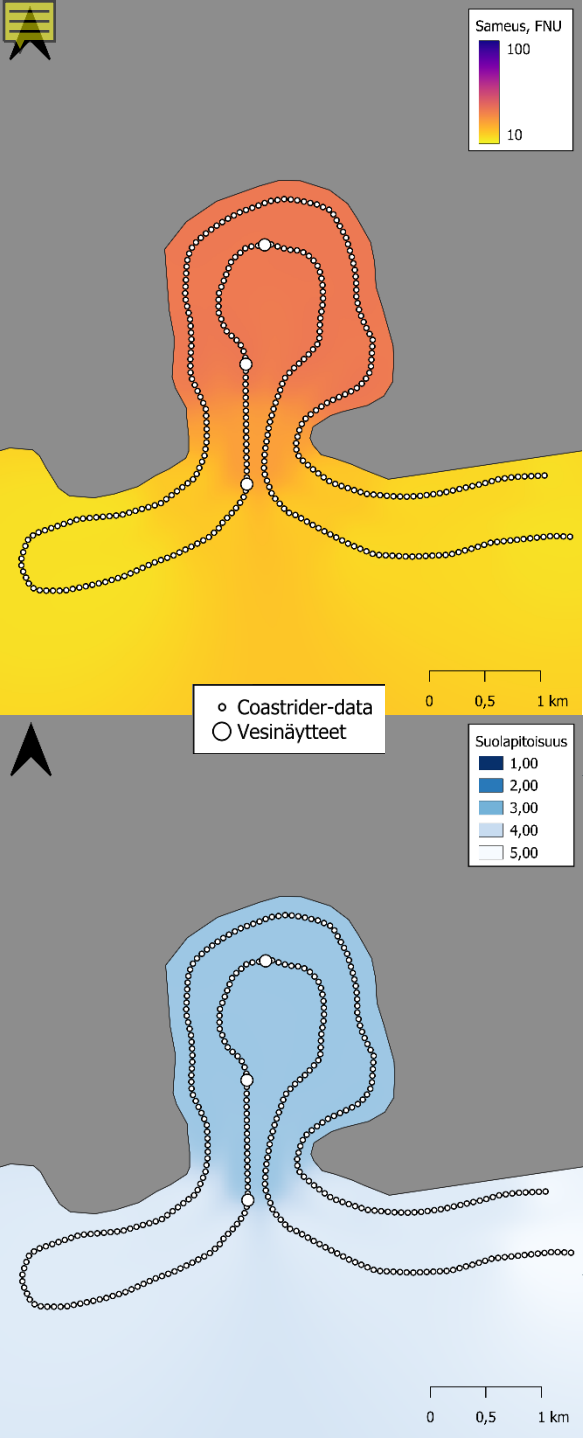
- Sameus, raakadata, FNU
- Sameus, CR raakadata, FNU
- Sameus, aluekohtainen viitearvo, FNU
- Sameus, CR viitearvo, FNU
- SDD, Suolapitoisuuden paikallinen poikkeama (sd)

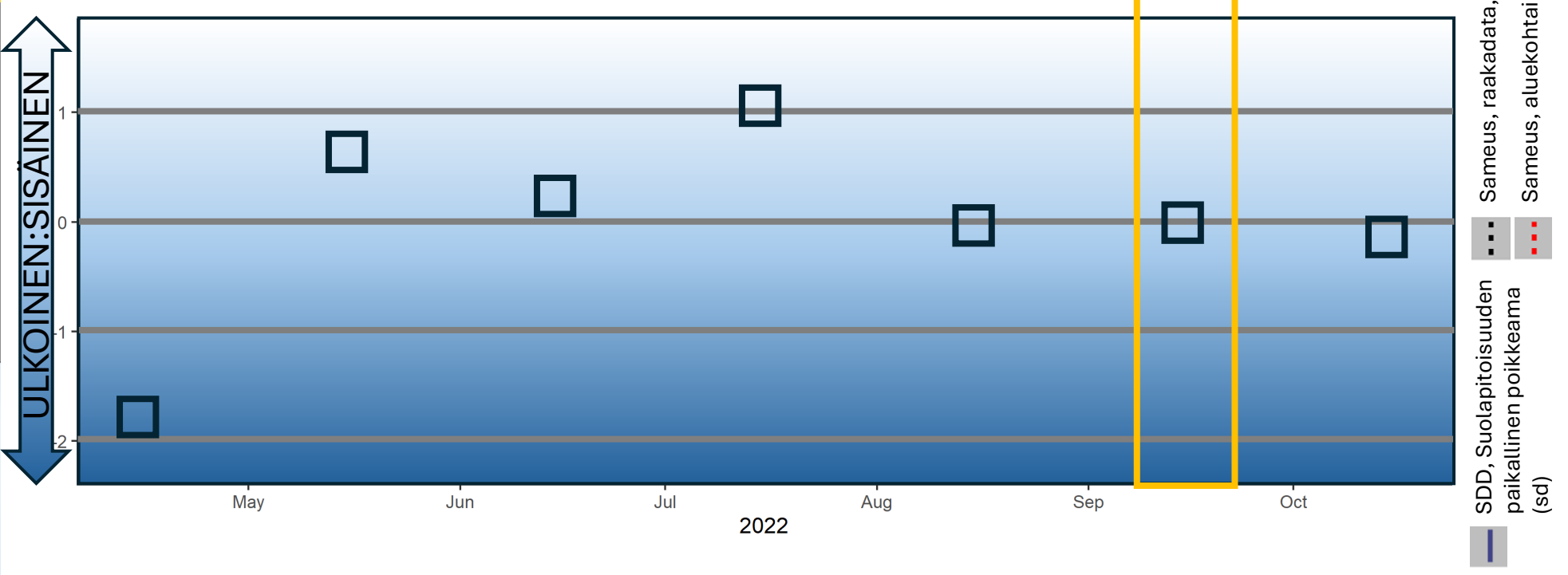
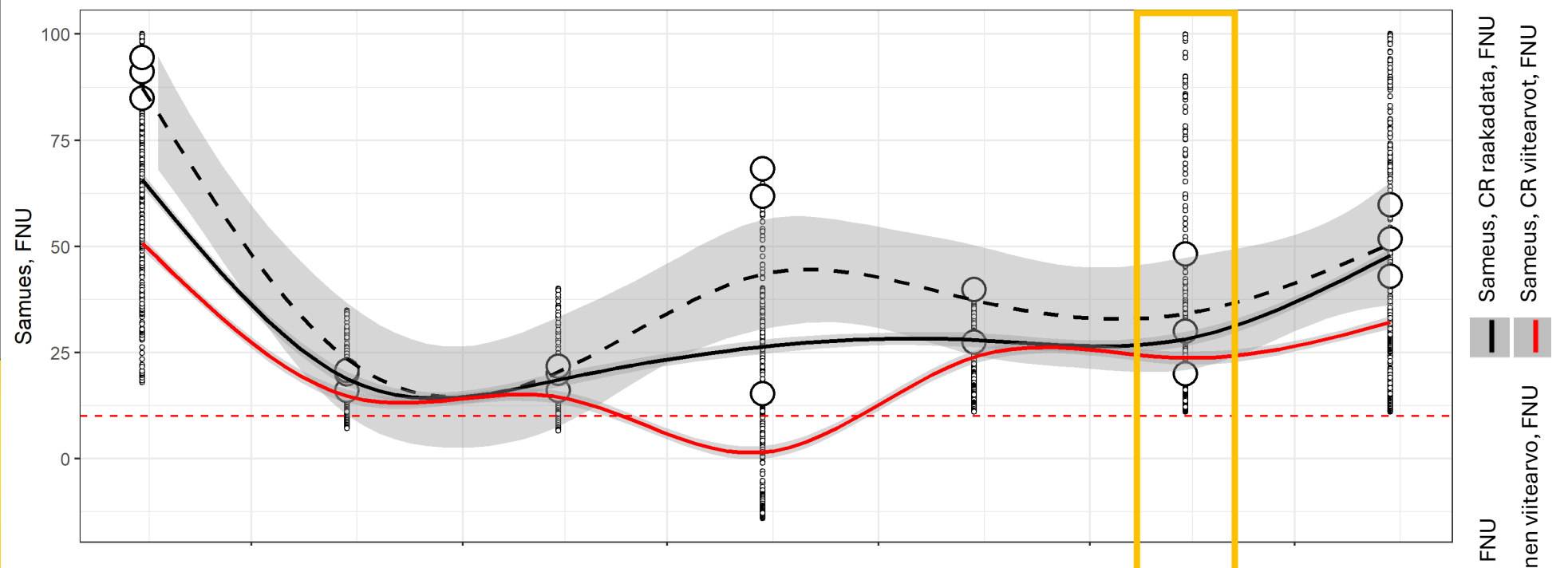
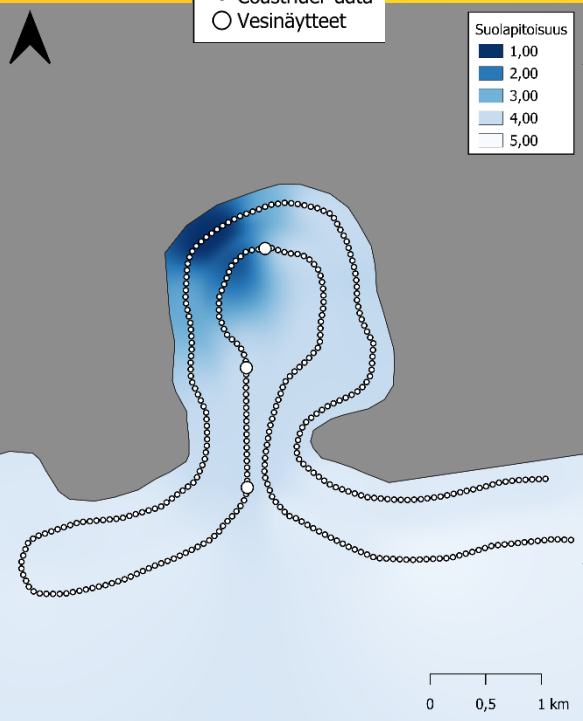
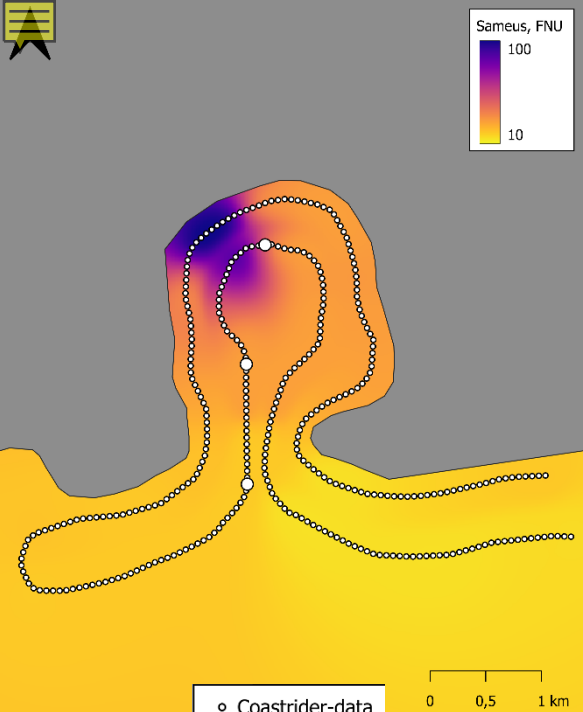




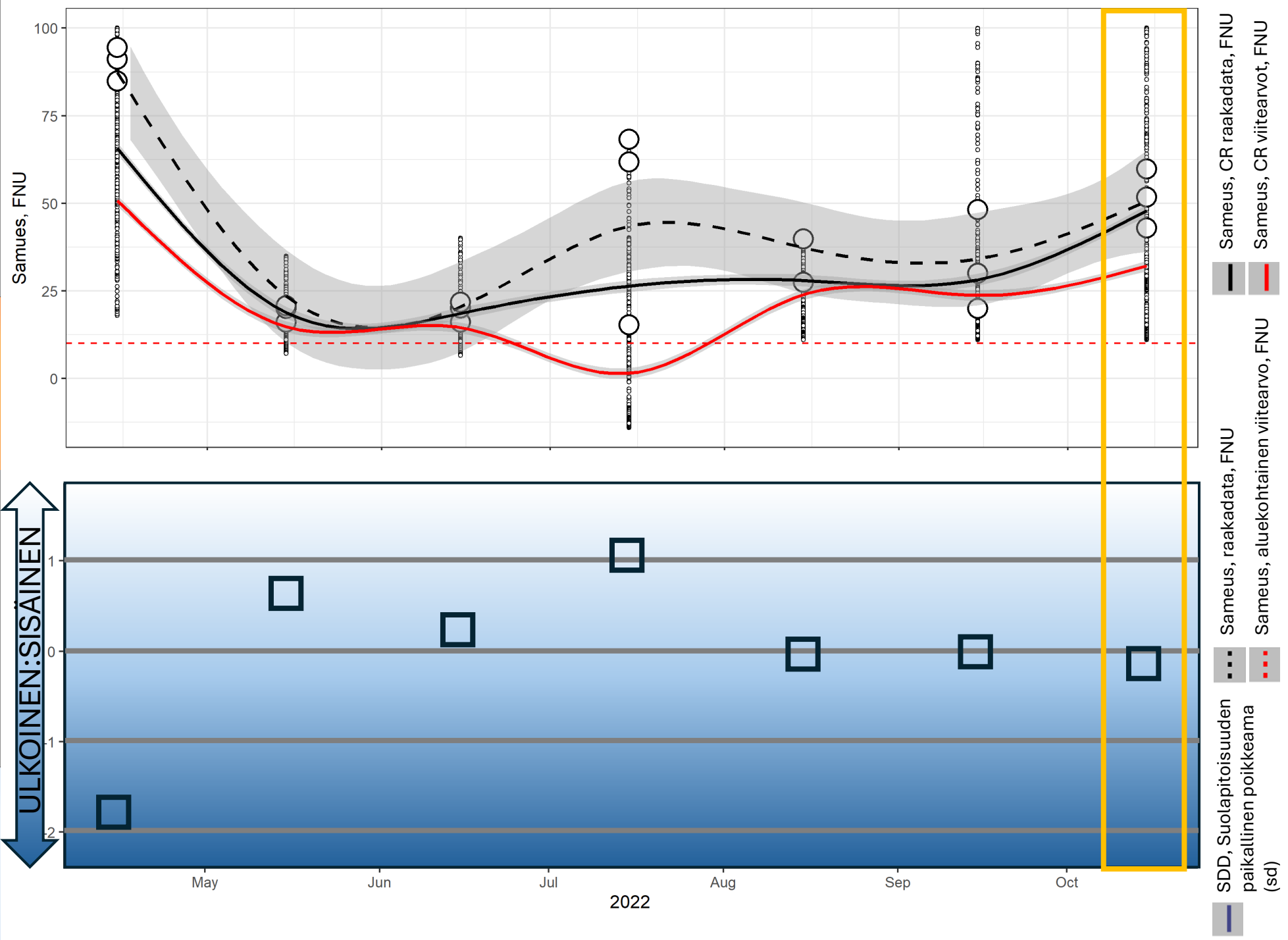
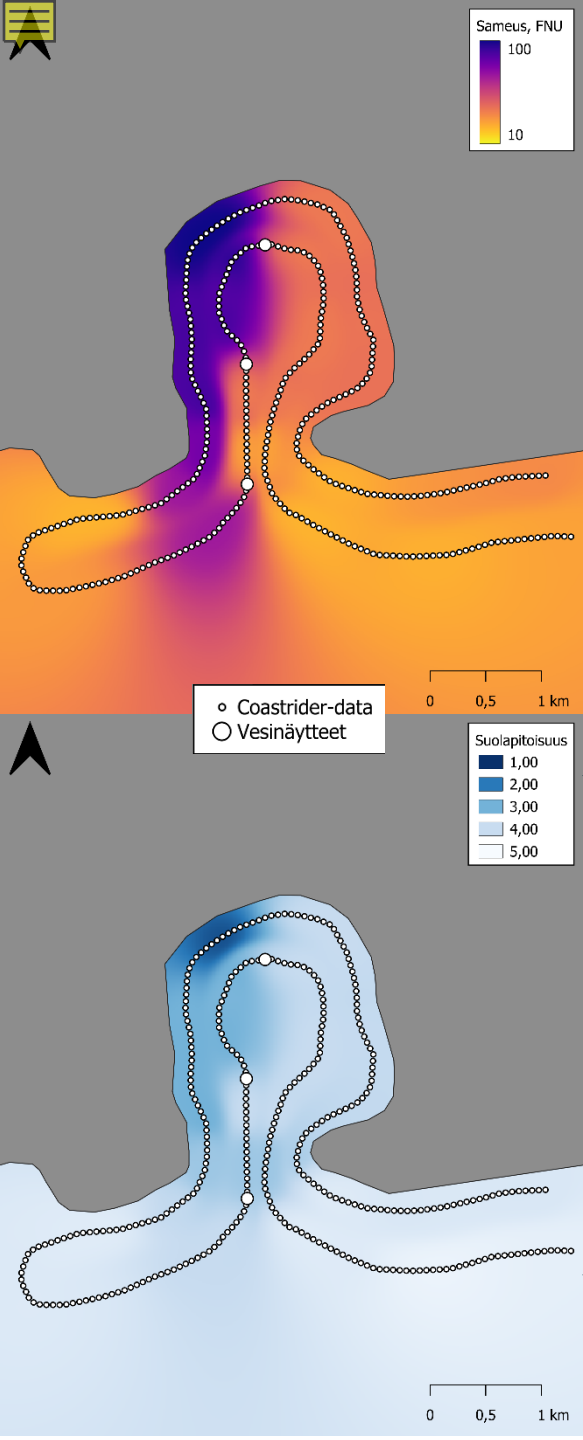








○ Coastrider-data  
○ Vesinäytteet



## Tehtävänanto 2: Vesienhallinnan tietotarpeet ja -lähteet

Tässä tehtävänannossa kurssille osallistujia pyydetään kirjoittamaan ja palauttamaan esseemuotoinen vastaus seuraaviin vesienhallintaan, -hoitoon ja -suojaan liittyviin kysymyksiin.

- 1) Mitä ja millaista luonnontieteellistä tietoa vesistöistä ja niiden valuma-alueista arjessasi erityisesti kaivataan?
- 2) Missä roolissa tai asemassa ja minkälaisissa asiayhteyksissä sinä ja/tai kollegasi tarvitsevat näitä tietoja?
- 3) Mitä tietolähteitä sinä ja/tai kollegasi hyödyntävät näissä asiayhteyksissä?
- 4) Miten kuvaisit keskeisimpiä tiedon olemassaoloon, laatuun/luotettavuuteen tai saatavuuteen liittyviä puutteita?

Esseen ohjeellinen kokonaispituus on yhdestä kahteen sivua.