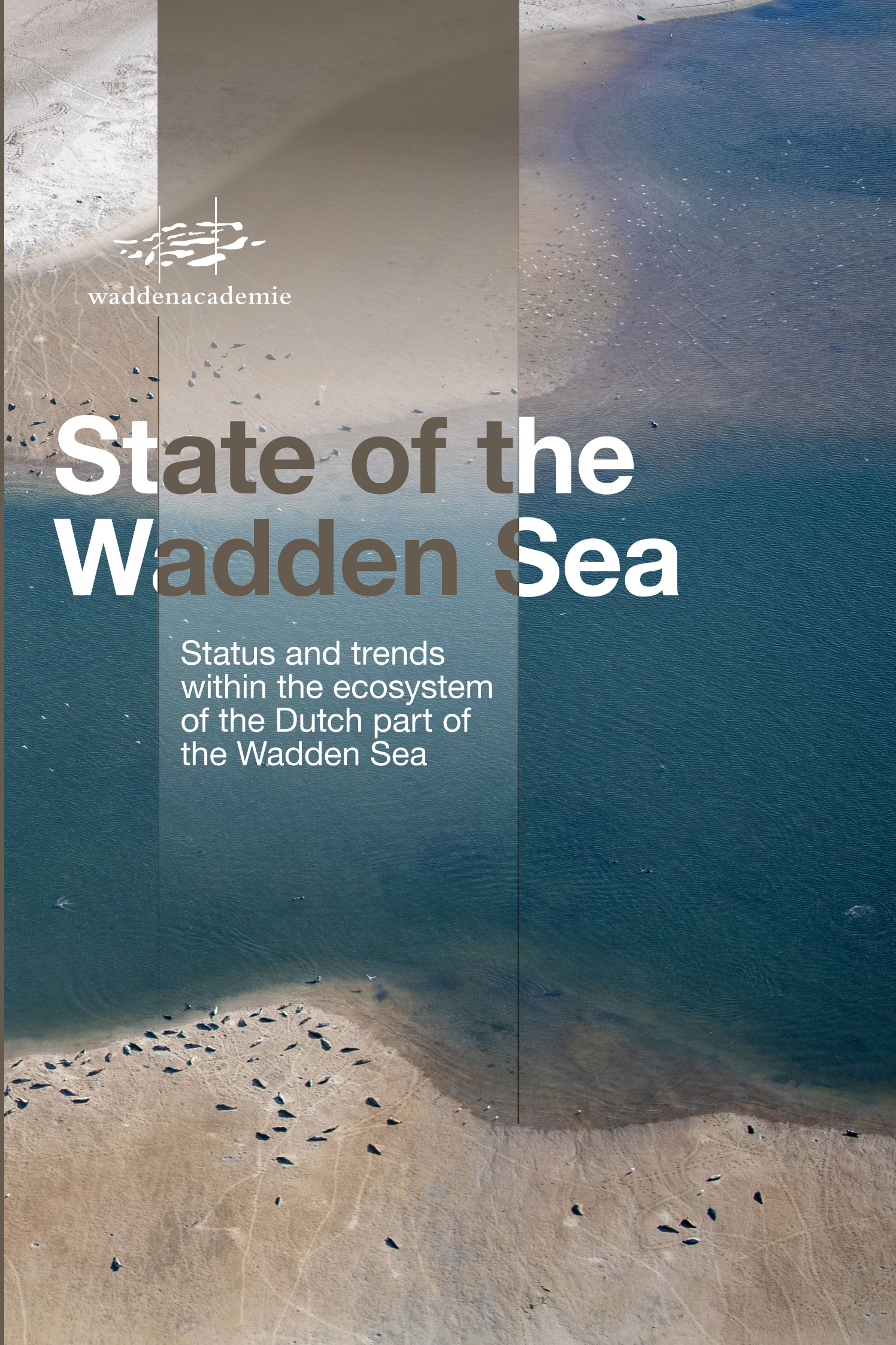

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State of the Wadden Sea

Status and trends within the ecosystem of the Dutch part of the Wadden Sea

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Colophon

Waddenacademie and Statistics Netherlands (CBS) jointly conducted this research on behalf of the Dutch Ministry of Agriculture, Fisheries, Food Security and Nature (LVVN) and the Dutch Ministry of Infrastructure and Water Management (IenW)

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1 INTRODUCTION

The Wadden Sea is the largest unbroken tidal flats system in the world, where natural processes proceed largely undisturbed. It extends along the coasts of Denmark, Germany and the Netherlands. The Wadden Sea is listed by UNESCO as a natural World Heritage site for its globally unique geological and ecological values. It plays, for example, a crucial role as a nursery ground for fish and as a feeding and resting site for migratory birds. In the framework of the Trilateral Wadden Sea Cooperation, the three countries take on the responsibility of preserving this irreplaceable ecosystem for the benefit of present and future generations.

In 2022, the Dutch ministries of Agriculture, Fisheries, Food Security and Nature (LVVN) and Infrastructure and Water Management (IenW) started the development of a **Policy Framework for Nature in the Dutch part of the Wadden Sea** for sustainable nature management of this part of the Wadden Sea. The intended outcomes of this Policy Framework are to reduce (possible) negative impacts of human activities on the Wadden Sea ecosystem, to provide perspectives for future developments, and to offer guidelines on how cumulative effects of various activities can be taken into account in decision-making.

Effective protection and development of a protected area begins with the **identification of the natural values** of the area that one wants or needs to preserve and enhance. These natural values are partly recorded in national, trilateral and European guidelines, and in international treaties (Table 1). Some treaties primarily focus on ensuring (preserving and restoring, if necessary) **healthy ecosystems** and characteristic **natural processes** (e.g., UNESCO World Heritage Convention). Others emphasize maintaining and restoring **habitat types and species** to a 'good environmental status' (e.g., EU Birds Directive and EU Habitats Directive). There are also treaties that focus on **ecosystem-based protection** and species protection (e.g., OSPAR Convention), on **the protection of the quality** and **quantity of water** (EU Water Framework Directive), or on the **preservation of landscapes** (e.g., the European Landscape Convention).

The process towards this Policy Framework started with the identification of the Wadden Sea's natural values under pressure. The ministries asked the Waddenacademie to develop and apply a transparent assessment system to gain an overview of the ecosystem components of which the current status is inadequate or unknown and those which show negative ecological trends. The Waddenacademie closely collaborated with Statistics Netherlands (CBS), and jointly published three reports (in Dutch), being a description of the methodology (in December 2024), a summary on the outcomes (in June 2025) and a more extensive technical report on these results (in December 2025).

This publication is an English version of the key findings of the Dutch summary report, which was published by the Waddenacademie and Statistics Netherlands CBS in June 2025. It has been edited to put findings more into a trilateral perspective and appendices were added containing tables of common and scientific names of the species that were studied.

To preserve and enhance natural values, data is needed to understand **how these values are related to (better/ worse) and develop (improving/ deteriorating) in relation to indicator-specific reference values.** In line with international standards, reference values were ecologically based, reflecting undisturbed, natural reference conditions. If available, the references values were taken from existing legal frameworks, such as the Water Framework Directive with reference values for water quality parameters. Given that such values are legally enforceable (e.g., N2000), they have consistently been prioritized by the State. Only where no externally established or ecological reference values were available, historically sound reference values were sought, which were aligned as closely as possible with a (historically) undisturbed or least disturbed condition.

The Wadden Sea is one of the most intensely monitored natural areas in the world, with long-term field observations being carried out as part of national monitoring networks, due to legal obligations (see Table 1), trilateral agreements

(Trilateral Monitoring and Assessment Program; TMAP), and based on scientific interests. The monitoring provides valuable time series with respect to climate, habitats, species and other ecosystem elements. The long-term status and trends of natural values are reported in national policy reports (e.g., for the evaluation of N2000 management plans), in the trilateral **Wadden Sea Quality Status Report (QSR)**, and in scientific publications.

However, due to fragmented data and information availability (accessibility of data, different methods of data analysis), it is often difficult to analyse and understand the status of the Wadden Sea and potential changes therein. The QSR, for example, consists of 12 thematic reports on ecosystem components and 15 on human activities, written by independent experts on specific themes, but the reports do not build on each other and are therefore not always directly comparable. An alternative way to present the information could be an index like the **'Living Planet Index,'** where trends for thousands of species are aggregated into one single global unit. However, it is important to keep in mind that in this index no comparison is made between the current and desired (such as legally established) status.

The **'State of the Wadden Sea'** is a **comprehensive assessment** of the status and trends of the Dutch part of the Wadden Sea. This is done through standardized aggregation of data regarding the current status of ecosystem indicators in relation to reference values and recent trends (over the past 12 years). A total of **238 indicators** have been used for this, divided over three themes: climate & weather, environment, and species.

The methodology builds on existing methods that are used for legal reporting purposes, including the EU Water Framework Directive and the Birds and Habitats Directive. Note, however, that the findings in this publication do not replace the evaluations that have been performed for those legal frameworks. Due to the broader scope of the present report and the need for a generic approach for all indicators, it was inevitable that the outcomes for these indicators may deviate from the outcomes of EU frameworks.

Year	Scale	Treaty
1971	International	Agreement on wetlands of international significance, particularly as habitats for waterfowl (Ramsar Convention; also known as the Wetlands Convention)
1972	International	Agreement on the Protection of the Cultural and Natural Heritage of the World (World Heritage Convention; applicable to the Wadden Sea since 2009)
1979	International	Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
1979	European	Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)
1979	European	Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (EU Birds Directive; part of Natura 2000; revised in 2010)
1982	Trilateral	Joint Declaration on the Protection of the Wadden Sea (Trilateral Cooperation Agreement Wadden Sea; not legally binding; updated in 2010)
1990	International	Agreement on the protection of seals in the Wadden Sea (Seal Treaty)
1992	International	Convention on the Protection of the Marine Environment of the North-East Atlantic (OSPAR Agreement)
1992	International	Convention on Biological Diversity (Biodiversity Convention)
1992	International	Agreement on the Conservation of Small Cetaceans of the Baltic Sea, [...] Northeast Atlantic Ocean, the Irish Sea and the North Sea (ASCOBANS Agreement on Small Cetaceans)
1992	European	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (EU Habitats Directive - Natura 2000)
1996	International	Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA Agreement)
1996	Bilateral	Supplementary Protocol to the Ems-Dollard Treaty for the regulation of cooperation regarding water management and nature management in the Ems estuary (Ems-Dollard Environmental Protocol)
2000	European	European Landscape Convention
2000	European	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community measures concerning water policy (EU Water Framework Directive)
2014	European	EU Regulation on the prevention and management of the introduction and spread of invasive alien species (EU Regulation on Invasive Species)
2024	National	Environmental Law (effective from 1-1-2024 but established earlier)
2024	European	EU Regulation on Nature Restoration

Table 1. *Overview of national, trilateral, European, and international treaties applicable to the Dutch part of the Wadden Sea with the year of establishment.*

2 METHOD

2.1 Indicators

The initial list of indicators was based on the time series as addressed in the most recent trilateral **Wadden Sea Quality Status Report**, assuming that the indicators were considered relevant to the functioning of the Wadden Sea and that data were publicly available. This list was supplemented with variables deemed relevant by the Waddenacademie (such as the naturalness of the Wadden Sea ecosystem and the connectivity between the Wadden Sea and the North Sea), but for which no indicators had yet been identified. This list was reduced to the current list based on the **actual availability of reliable data and reference values**, and then reviewed by domain experts.

For the indicators, time series from as many different measuring stations and as much distributed as possible over **the Dutch part of the Wadden Sea (including the Ems-Dollard area)** have been used. The analyses are based on **long, consistent, and complete time series**. For a very limited number of time series, such as those of macrozoobenthos and juvenile flatfish, there is a comprehensive data set (with the measuring stations more or less regularly distributed throughout the area). For most time series, the number of measuring locations is limited (1 to 6 sampling stations).

The 'State of the Wadden Sea' is based on a **total of 238** indicators for which current values compared to reference values and recent trends over the past 12 years can be displayed. These indicators are divided into three themes: **weather & climate (34 indicators), environment (85 indicators)**, and **species (119 indicators)** of the Dutch part of the Wadden Sea (Table 2). For the overviews presented in this publication, each of these 238 indicators was equally weighted, implying that salinity in the Marsdiep is as important as the total biomass of molluscs (group of macrozoobenthos).

Theme	Group	Variable	Number of indicators		
			Per variable	Per group	Per theme
Weather & Climate	Atmosphere	Air temperature	4	11	34
		Precipitation	3		
		Wind	3		
		Solar radiation	1		
	Water	Water temperature	3	23	
		Sea level	9		
		Freshwater discharge	10		
		Salinity	1		
Environment	Pollutants	Pesticides	3	30	85
		Non-ubiquitous substances	4		
		Specific polluting substances	11		
		Ubiquitous substances	3		
		Heavy metals	9		
	Turbidity	Transparency of the water	6	6	
	Nutrients	Phosphorus (P)	6	18	
		Nitrogen (N)	6		
		Ratio N:P	6		
	Habitats: surface area	Dunes	6	14	
		Wadden Sea	3		
		Salt-tolerant vegetation	5		
	Habitats: characteristics	Biogenic structures	5	17	
		Median grain size sediment	4		
		Silt content sediment	4		
		Zonation of salt marshes	4		
Species	Phytoplankton	Blooms *Phaeocystis*	1	15	19
		Total biomass	14		
	Macrozoobenthos	Biomass species groups	3	29	
		Densities of species	6		
	Fish	Marine juveniles	7	16	
		Resident species	9		
	Birds	Breeding species	13	55	
		Foraging species	66		
		Roosting species	6		
	Seals	Common seal	2	4	
		Grey seal	2		

Table 2. *Distribution of the number of indicators (n=238) for the state of the Dutch part of the Wadden Sea over themes, groups, and variables.*

2.2 Reference values

For all indicators, the current value is compared with a reference value. The indicator is classified as **'better'** or **'worse'** in terms of its current value if this value deviates significantly from the reference value. 'Better' can be either higher or lower than the reference value, depending on the indicator and desired situation. With respect to pollutants, for example, the lower the concentrations, the better. For bird numbers, on the other hand, lower numbers are considered worse than higher numbers.

Firstly, for all indicators, it was examined whether (legal) reference values had been established on the basis of international, EU and national directives and treaties. Natura 2000 and the Water Framework Directive, for example, provide explicit values as targets to be achieved for bird numbers and pollutant concentrations respectively, **as part of** the legally prescribed assessment. Where such values were not available, other indications from these directives (rather than numbers) were then considered, such as a **'conservation objective'** (e.g. densities of a species must not decline) or an **'improvement objective'** (e.g. densities of a species must increase over time). These reference values for the present state report should not be confused with the formal legal reference values for determining the 'good conservation status' of species under the Birds Directive and Habitats Directive or for determining the 'good environmental status' of water bodies under the Water Framework Directive.

For the indicators for which reference values were not available or could not be derived from treaties, **information from the time series itself** was, in collaboration with domain experts, extracted as a reference value. Examples of this are the **average value during the early years** of the time series (such as for weather and climate), the **average value of the entire time series** (such as for macrozoobenthos), and the **maximum value of the entire time series** (such as for fish) as a reference value. Only in one case (turbidity of the water), a **historical value** from literature was chosen indicating in least disturbed situation.

Theme	Group	Variable	Reference value	
			Unit	Definition/ Source
Weather & Climate	Atmosphere	Air temperature	° C & number of days	Start period of time series (1979-2008; average) & (1901-1974; extremes)
		Precipitation	mm/year & number of days	Start period of time series (1957–1986; average & extremes)
		Wind	m/s & number of days	Start period of time series (1957–1986; average & extremes)
		Solar radiation	W/m^2	Start period of time series (1964–1994)
	Water	Water temperature	° C & number of days	Start period of time series (1979-2008; average) & (1901-1974; extremes)
		Sea level height	cm	Beginning period of time series (1877–1906)
		Freshwater discharge	m^3/sec	Start period of time series (1976–2005)
		Salinity	psu	Starting period of the time series (1968-2008; MWTL) & (1861-1931; Marsdiep)
Environment	Pollutants	Pesticides	µg/l	RIVM guidelines for risks of substances
		Non-ubiquitous substances	µg/l	RIVM guidelines for risks of substances
		Specific polluting substances	µg/l	RIVM guidelines for risks of substances
		Ubiquitous substances	µg/l	RIVM guidelines for risks of substances
		Heavy metals	µg/l	RIVM guidelines for risks of substances
	Turbidity	Transparency of water	/m	Historical value (1932)
	Nutrients	Phosphorus (P)	mmol/m^3	OSPAR directive (coastal zone North Sea)
		Nitrogen (N)	mmol/m^3	OSPAR directive (coastal zone North Sea)
		Ratio N:P	mol/mol	Redfield ratio (N:P=16)
	Habitat area	Dunes	hectare	Water Framework Directive (WFD)
		Wadden Sea	hectare	Water Framework Directive (WFD)
		Salt-tolerant vegetation	hectare	Water Framework Directive (WFD)
	Characteristics of habitats	Biogenic structures	hectare	WFD (sea grass), Habitats Directive (mussel beds) & averages (2011-2024)
		Coarseness sediment	median grain size (µm)	Average values (2009-2019)
		Silt content sediment	% (< 62 µm)	Average values (2009-2019)
		Zonation of salt marshes	% per tidal marsh zone	Water Framework Directive
Species	Phytoplankton	Blooms Phaeocystis	% (months per year with blooms)	Water Framework Directive (coastal waters & transitional waters)
		Total biomass	mg/m^3	Framework Directive Water (Wadden Sea,Ems-Dollard)
	Benthic animals	Biomass species groups	gADW/m^2	Average values (2008-2022)
		Densities of species	number/m^2	Average values (2008-2022)
	Fish	Marine juveniles	CPUE (e.g. number/m^2/hour)	Maximum values (1985-2024)
		Resident species	CPUE	Maximum values (1985-2024)
	Birds	Breeding species	Number of breeding pairs	N2000 maintain conservation objectives
		Foraging species	Number of individuals	N2000 maintain conservation objectives
		Roosting species	Number of individuals	N2000 maintain conservation objectives
	Seals	Common seal	Number of individuals	N2000 improvement targets (since 2009)
		Grey seal	Number of individuals	N2000 improvement targets (since 2009)

Table 3. *Definition and/or sources of reference values for the indicators as used for determining the state of the Dutch part of the Wadden Sea.*

2.3 Calculations

First, **a long-term trend** with a 95% confidence interval is fitted to the data of the **complete time series** (see left panel of Figure 1). This means that for each year of the time series, in addition to a measured value (which can vary greatly from one year to the next), an estimated trend value is also available (a value in the context of a longer-term development). It is these **trend values** that are used for further calculations, not the actual values of the measurements themselves. The term '**current value'** used in this report is therefore in fact the **current trend value** of the last year of the analysed time series.

Then the **current trend value** (the value of the most recent year as estimated by the trend line) is compared to the **trend value from 12 years ago** (middle panel of Figure 1). If the current trend value is significantly **higher** than that from 12 years ago, there is an **increasing trend**. If it is lower, it is referred to as a decreasing trend. Furthermore, the recent trend can be stable (virtually the same values over time) or uncertain (for example, with a large variation in annual values, resulting in a wide confidence interval for the estimates).

Whether a significant trend is an indication of an **improvement or deterioration** of the situation depends on the aim for the value in value of the indicator in time, for example, a decrease (e.g., for pollutants) or an increase (e.g., for birds).

The **current value** of an indicator is determined by **comparing the current trend value with the reference value**. If the current trend value of an indicator significantly differs from that reference value, then the situation is **'better' or 'worse'** than the reference situation (depending on whether the desire is for the value of the indicator to be higher or lower than that of the reference). If the bandwidth of the confidence interval (the red area in Figure 1) of the estimate of the current trend value overlaps with the reference value (the blue line in the right panel of Figure 1), then the current value in relation to the reference value is **'uncertain'**.

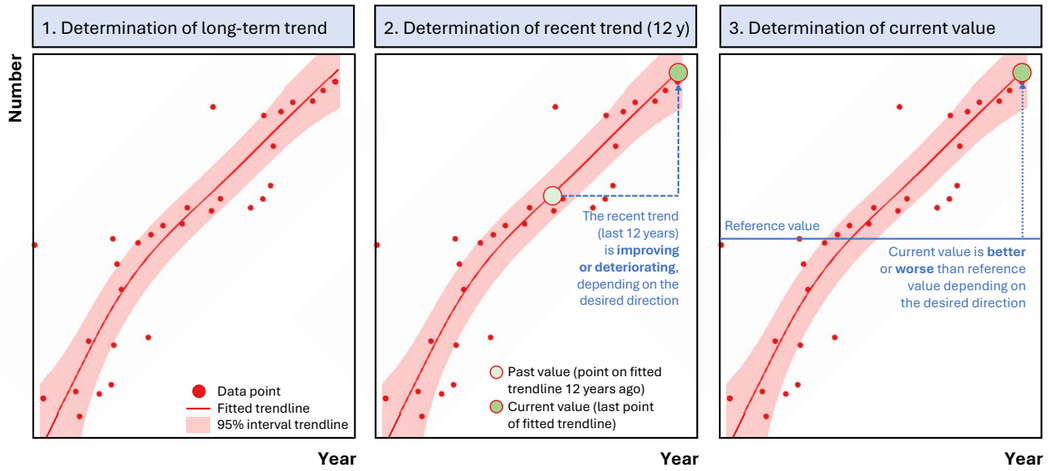


Figure 1. *Method used in the present state report for determining the recent trend (over the past 12 years) and the current value (compared to a reference value) of an indicator (e.g., the total number of individuals of a species) from a data set on long-term field observations.*

2.4 Visualization

Wadden Quadrant
For each of the indicators, the current trend (improving, stable, worsening, or uncertain over the past 12 years) and the current value relative to the reference value (better, worse, or uncertain) have been calculated in a mutually comparable manner. The information on the current value and recent trend is combined in a so-called **Wadden Quadrant**, with the results of the trend analysis along the horizontal axis and those of the current value relative to the reference value along the vertical axis (left panel of Figure 2). If the results for stable and uncertain trends are taken together (as no demonstrable change) and those of the uncertain values (regardless of the trend) are merged, then all indicators can be divided into seven categories (left panel of Figure 2).

The Wadden Quadrant places each indicator in one of five situations, each with a corresponding **ecological assignment** for policy and management:

1 **Current value is worse than the reference value and the recent trend is deteriorating, stable, or uncertain:** these indicators require the most attention in terms of policy and management, as the values are too low and there is strong evidence (or cannot be ruled out) that the indicator needs measures (e.g., pressure reduction) to reverse this undesirable trend in order to eventually bring the value above the reference value;

2 **Current value is worse than reference value and trend is improving:** These indicators require immediate attention regarding policy and management (as values are too low) including an exploration of whether the value of the indicator can exceed the reference value over time without additional measures;

3 **Current value is better than reference value and trend is worsening or uncertain:** The current value indicator is better than the reference value but the difference is decreasing. These indicators do not require immediate attention regarding policy and management, but do require exploration of possible causes of the decline (to prevent the value of the indicator from falling below the reference value over time);

4 **Current value is better than reference value and trend is improving or stable:** These indicators do not require immediate attention regarding policy and management, other than monitoring to check that the trend does not start to reverse.

5 **Current value in relation to the reference value is uncertain:** These indicators require attention regarding policy and management because, according to the precautionary principle, it cannot be excluded that the current value is below that of the reference value.

Wadden Circle
The outcomes can be used to explore how many of the indicators for the variables are situated in the five different situations, for the Dutch part of the Wadden Sea as a whole and within the various themes and groups (right panel Figure 2). It can also indicate how ecological assignments are distributed and which indicators are involved.

Wadden Dashboard
The Wadden Dashboard is an overview of the outcomes of the state for the entire Dutch part of the Wadden Sea, those of the different themes (weather & climate, environment, and species) and those of the further breakdown of the groups of each theme (Table 2).

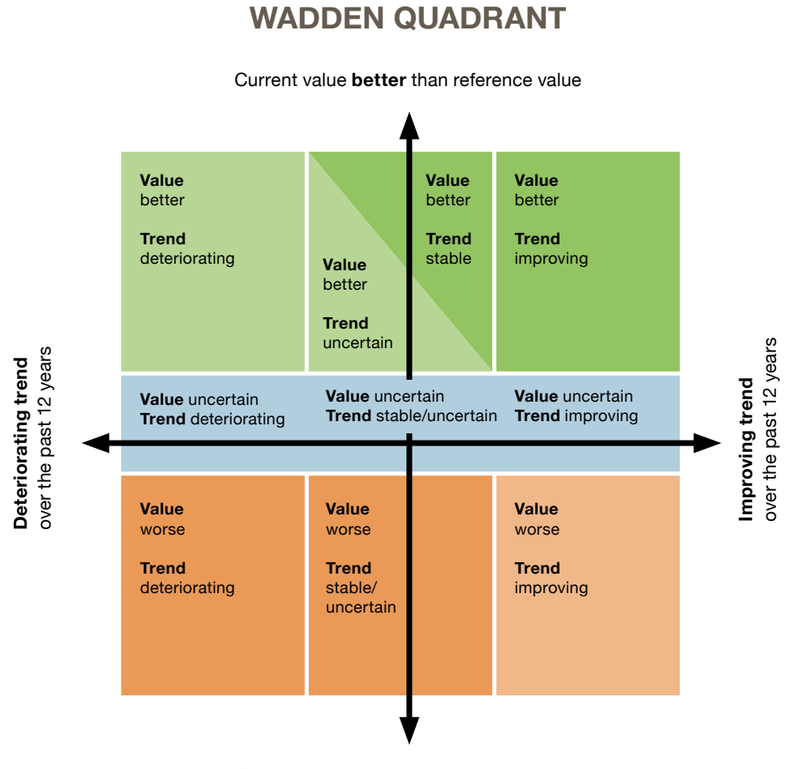


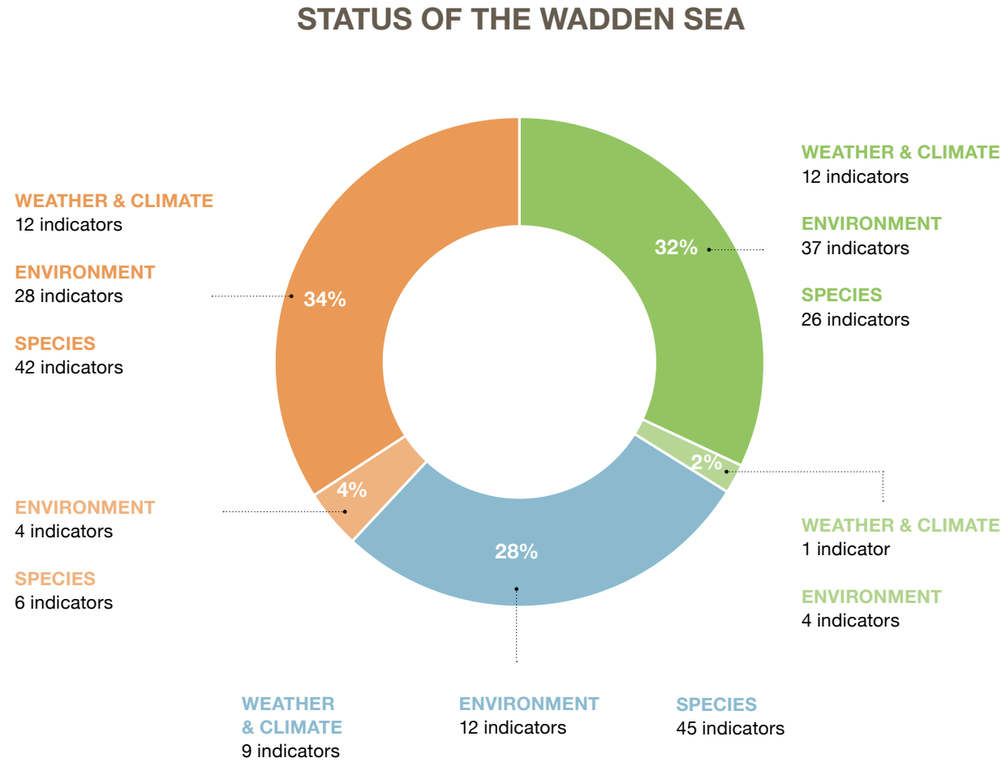
Figure 2. *Wadden Quadrant (above) and Wadden Circle (below) with a classification of indicators based on their current value (compared to a reference value) and recent trend (over the past 12 years).*

3 STATUS AND TRENDS IN THE DUTCH PART OF THE WADDEN SEA

The 'State of the Wadden Sea' is composed of **238 indicators**, of which 34 pertain to the theme 'Weather & Climate', 85 to the theme 'Environment', and 119 to the theme 'Species' (Figure 3). For the Dutch part of the Wadden Sea as a whole, the current value of **92** out of the 238 **(39%)** indicators is '**worse**' than the reference value, of which 82 (34%) have been 'stable', 'uncertain' or 'worsening' over the past 12 years (Figure 3). For **80** of the 238 **(32%)** indicators, the current value is **'better'**, of which 75 (32%) have a trend that is 'stable' or 'improving', and for 5 (2%), there is a 'better' value combined with a 'worsening' trend. For **66** of the 238 indicators (**28%**), the current value is **'uncertain'**.

Most of these situations contain indicators of the themes weather and climate, environment, and species, with the exception of the situation 'value better/trend worsening or uncertain' (light green), which has no indicators from the theme 'species', and the situation 'value worse/trend improving or uncertain' (light orange), which lacks indicators from the theme 'weather & climate' (Figure 3).

Based on these findings, it can be cautiously concluded that, despite the existence of a large number of protection regimes, the Dutch part of the Wadden Sea ecosystem cannot yet be considered healthy in 2025 and that additional efforts are needed to get there. This outcome is consistent with those in previous reports, but now, as noted earlier, it is based on a more comprehensive assessment of this area.



Themes
Weather & Climate (34 indicators)
Environment (85 indicators)
Species (119 indicators)

Sampling frequency
Variable

Spatial coverage
Wadden Sea & Ems-Dollard

Number of indicators
238

Units
Variable

Reference values (RV)
Natura2000 Directive, Water Framework Directive, OSPAR Directive, RIVM Directive, Values at the start of time series, Average values of time series, Maximum values of time series, Historical value (before time series)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	50	10	17
Stable	25	17	13
Deteriorating	1	37	9
Uncertain	4	28	27

Figure 3. *Score of indicators based on their current value and recent trend (past 12 years) in the Wadden Quadrant for the Dutch part of the Wadden Sea as a whole, and for the individual themes.*

4 WEATHER & CLIMATE

The state of 'Weather & Climate', as part of the state of the Dutch part of the Wadden Sea, is composed of **34 indicators**, of which 11 relate to atmospheric conditions (4 for air temperature, 3 for precipitation, 3 for wind, 1 for solar radiation) and 23 for seawater conditions (3 for water temperature, 9 for sea level height, 10 for freshwater supply to the Wadden Sea via sluices, 1 for salinity) at various measuring locations in the Dutch parts of the Wadden Sea and the Ems-Dollard estuary (Table 2, Figures 4 & 5). There are **no** legally established **reference values** for these indicators, which are therefore based on measurements taken at the **start of the time series** (Table 3).

For **12** of the 34 (**35%**) indicators, the current values are **'worse'** than the reference values, of which 2 indicators have been 'stable' over the past 12 years and 10 indicators have shown a further **'deterioration'** (Figure 5). The indicators showing a 'deteriorating' trend mainly concern **rising air temperatures** (2 indicators) and **rising sea levels** (5 indicators) compared to the values in the early years of the time series.

For **13** of the 34 (**38%**) indicators, the current values are **'better'** than the reference values, of which 12 indicators have been 'stable' over the past 12 years and 1 indicator has deteriorated (Figure 5). The indicators with a **'stable'** trend mainly concern averages and days with extreme values in **precipitation** per year (3 indicators), days with extreme values in **water temperature** and **wind speeds** during the year, and the average values of **freshwater discharge** during the growing season (April-September) and during the year (January-December).

For **9** of the 34 indicators (**26%**), the current value is '**uncertain**', of which 2 indicators show a stable trend and 7 show a deteriorating trend. The indicators with a '**deteriorating**' trend include an increase in the **number of summer days** and **solar radiation** at De Kooy Airport (Den Helder), and an annual average decrease in **freshwater discharge** via the sluices at Den Oever (Afsluitdijk) and an annual average increase in freshwater discharge via the Cleveringsluizen (sluices of Lauwersmeer).

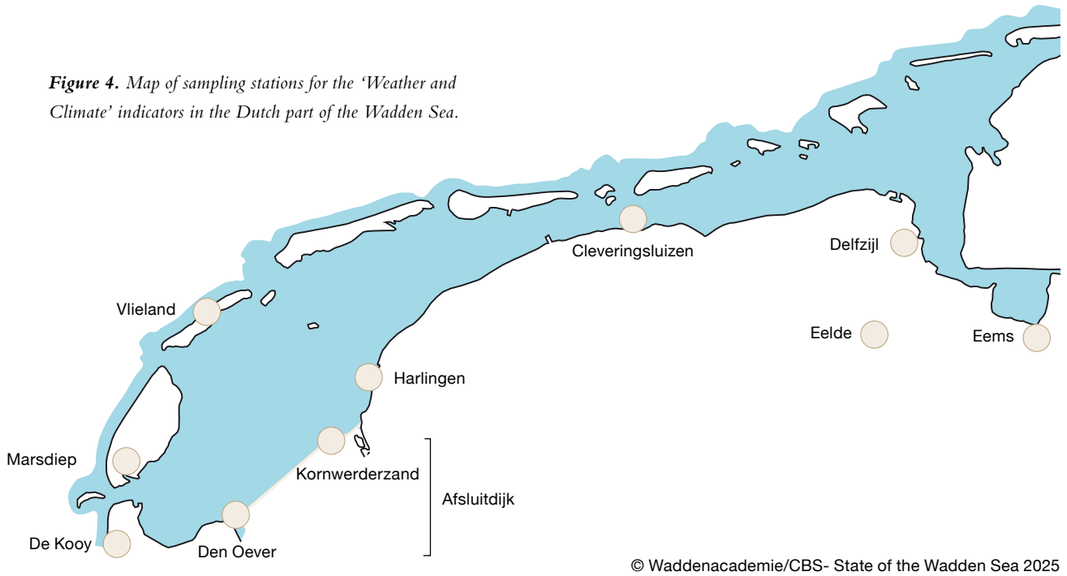
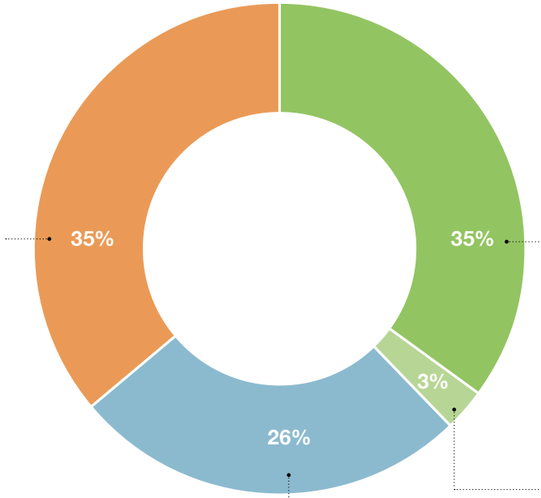


Figure 4. *Map of sampling stations for the 'Weather and Climate' indicators in the Dutch part of the Wadden Sea.*

WEATHER & CLIMATE



AIR TEMPERATURE
Average De Kooy
Warm days De Kooy

WATER TEMPERATURE
Average Marsdiep

WIND
Average Eelde

SEA LEVEL
Average Delfzijl
Average Den Helder
Average Harlingen
High tide Delfzijl
High tide Den Helder
High tide Harlingen
Low tide Harlingen

SALINITY
Average Marsdiep

PRECIPITATION
Sum De Kooy
Days >20mm De Kooy
Days >50mm De Kooy

WATER TEMPERATURE
Days >21°C Marsdiep

WIND
Days >8Bft Eelde
Days >8Bft Vlieland

FRESHWATER DISCHARGE
Afsluitdijk & Ems (growing season)
Afsluitdijk & Ems (year)
Ems (growing season)
Ems (year)
Kornwerderzand (growing season)
Kornwerderzand (year)

AIR TEMPERATURE
Frost days De Kooy

AIR TEMPERATURE
AIR TEMPERATURE
Summer days De Kooy

WATER TEMPERATURE
Days >18°C Marsdiep

SEA LEVEL
Low tide Delfzijl
Low tide Den Helder

SOLAR RADIATION
De Kooy

FRESHWATER DISCHARGE
Cleveringsluizen (growing season)
Cleveringsluizen (year)
Den Oever (year)
Den Oever (growing season)

Data sources
KNMI (atmosphere, 1906/1965-2024)
RWS (sea level, 1851/1922-2024)
RWS (freshwater discharge, 1976-2024)
NIOZ (water quality Marsdiep, 1861-2022)

Sampling frequency
From once every 10 minutes to once a day

Spatial coverage
Wadden Sea & Ems-Dollard
NIOZ: 1 sampling station
KNMI: 3 sampling stations
RWS: 3 sampling stations (freshwater discharge)
RWS: 3 sampling stations (sea level)

Number of indicators
34

Units
Variable

Reference values (RV)
Values at the start of the time series

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	0	0	0
Stable	12	2	2
Deteriorating	1	10	7
Uncertain	0	0	0

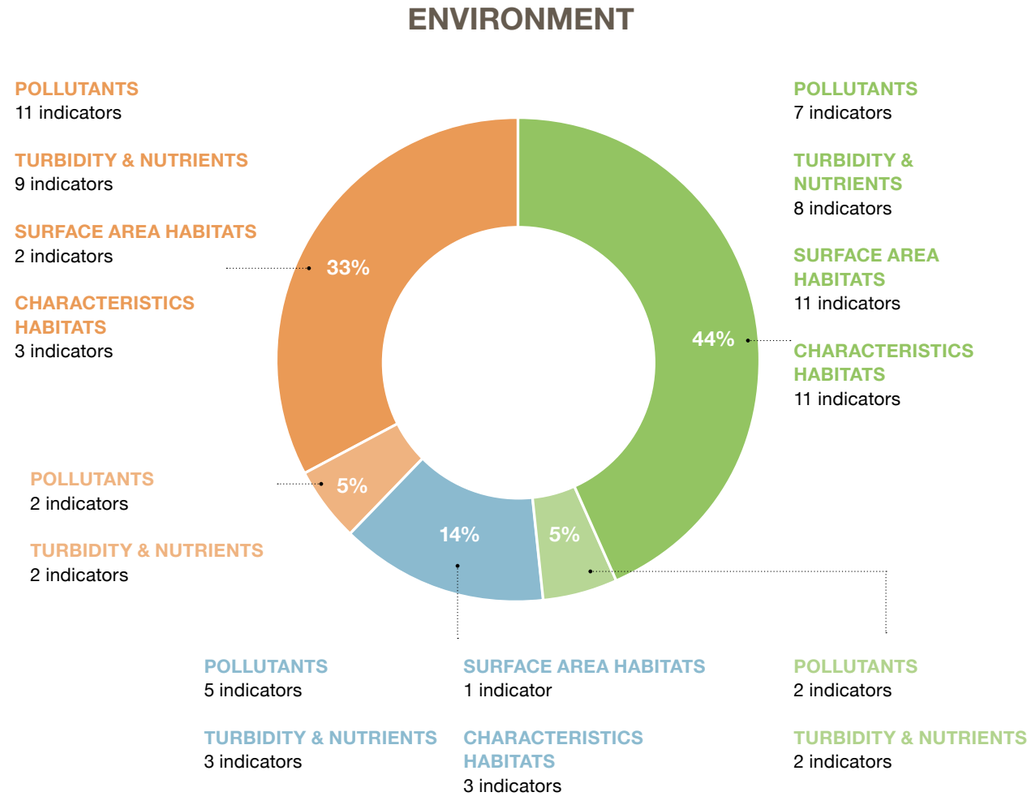
Figure 5. *Scores of the 'Weather & Climate' indicators positioned in the Wadden Quadrant based on their values and trends.*

5 ENVIRONMENT

The state of the 'Environment' is, as part of the state of the Dutch part of the Wadden Sea, composed of 85 indicators, of which 30 for pollutants, 24 for turbidity & nutrients, 14 for the surface area of habitats, and 17 for characteristics of habitats (Table 2, Figure 6).

For many of these indicators, the **reference values** are based on treaties (**WFD, Natura 2000, OSPAR, and RIVM** guidelines). Where that was not the case, the reference values were based on conditions at the **beginning of a time series**, the **average value** of a time series, or **a value from the literature** (only for transparency) (see Table 3).

For **32** of the 85 (**38%**) indicators, the current values are '**worse'** than the reference values, with trends in 13 indicators worsening further over the past 12 years, those in 15 indicators being 'stable' or 'uncertain,' and those in 4 indicators 'improving' (Figure 6). For **41** of the 85 (**49%**) indicators, the current values are **'better,'** with trends in 32 indicators improving over the past 12 years, those in 5 indicators being 'stable,' and those in 4 indicators uncertain (Figure 6). For **12** of the 85 indicators (**14%**), the current value is '**uncertain**' (Figure 6).



Data sources
Polluting substances
Turbidity & Nutrients
Surface area of habitats
Characteristics of habitats

Sampling frequency
From once every 10 minutes to once a day

Spatial coverage
Wadden Sea & Ems-Dollard

Number of indicators
85

Units
Variable

Reference values (RV)
Natura2000 Directive, Water Framework Directive, OSPAR Directive, RIVM Directive, Average values of time series, Historical value (before time series)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	32	4	5
Stable	5	7	3
Deteriorating	0	13	0
Uncertain	4	8	4

***Figure 6**. Scores of 'Environment' indicators in the Wadden Quadrant based on their values and trends.*

5.1 Pollutants

The group of 'Pollutants', as part of the theme 'Environment' of the State of the Dutch part of the Wadden Sea, consists of **30 indicators**, of which 3 are for the concentrations of pesticides (imidacloprid), 4 for non-ubiquitous substances (very harmful priority substances, in this case fluoranthene), 11 for specific pollutants (substances that can pose a problem in large rivers or regional waters, in this case arsenic, benzo(a)anthracene, and chrysene), 3 for ubiquitous substances (i.e. substances that are no longer discharged but still present in the environment because they were widely used in the past and hardly broken down, in this case tributyltin), and 9 for heavy metals (cadmium, mercury, and lead) as measured at 4 different locations in the Wadden Sea (Table 2, Figures 7 & 8).

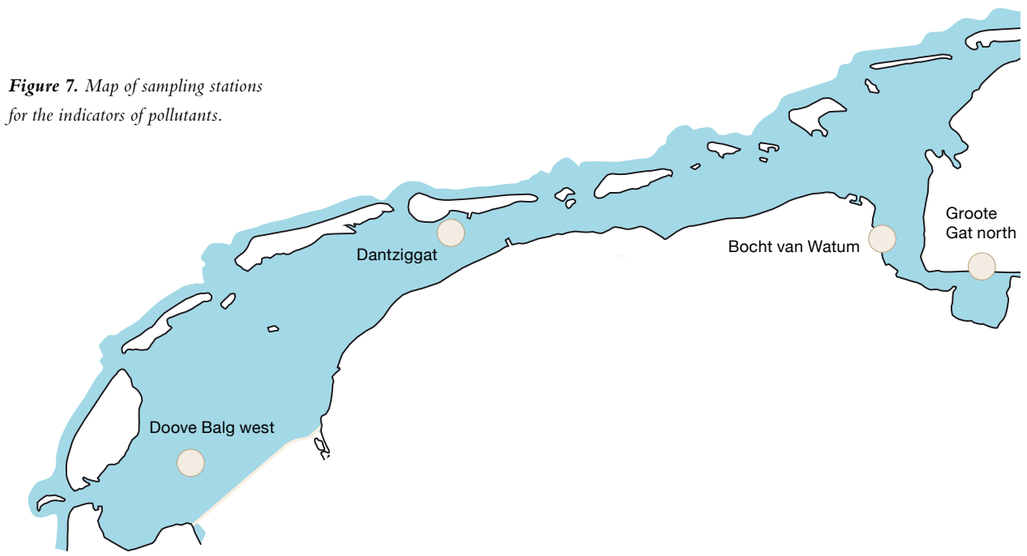
For all of these indicators, legally set **reference values** exist that have been published as 'risks of substances' by the RIVM (see Table 3). For the present state report, not all pollutants and other parameters for which there is an objective for the Dutch part of the Wadden Sea under the Water Framework Directive (WFD) have been included. Furthermore, for the present state report, the pollutants have been mapped individually, while the WFD employs the 'one out, all out' principle, whereby a water body only receives a 'good' classification if all parameters are in order. This state report offers, therefore, a more favourable view than the assessment of pollutants according to the formal WFD reporting.

For **16** out of 30 (**54%**) indicators, the current values are **'worse**' than the reference values, of which 2 indicators have been 'stable' over the past 12 years and 7 indicators showed further 'deterioration' (Figure 7). Regarding the indicators with a **'deteriorating**' trend, this particularly concerns the increase in the concentrations of **arsenic, benzo(a) anthracene, fluoranthene,** and **mercury.**

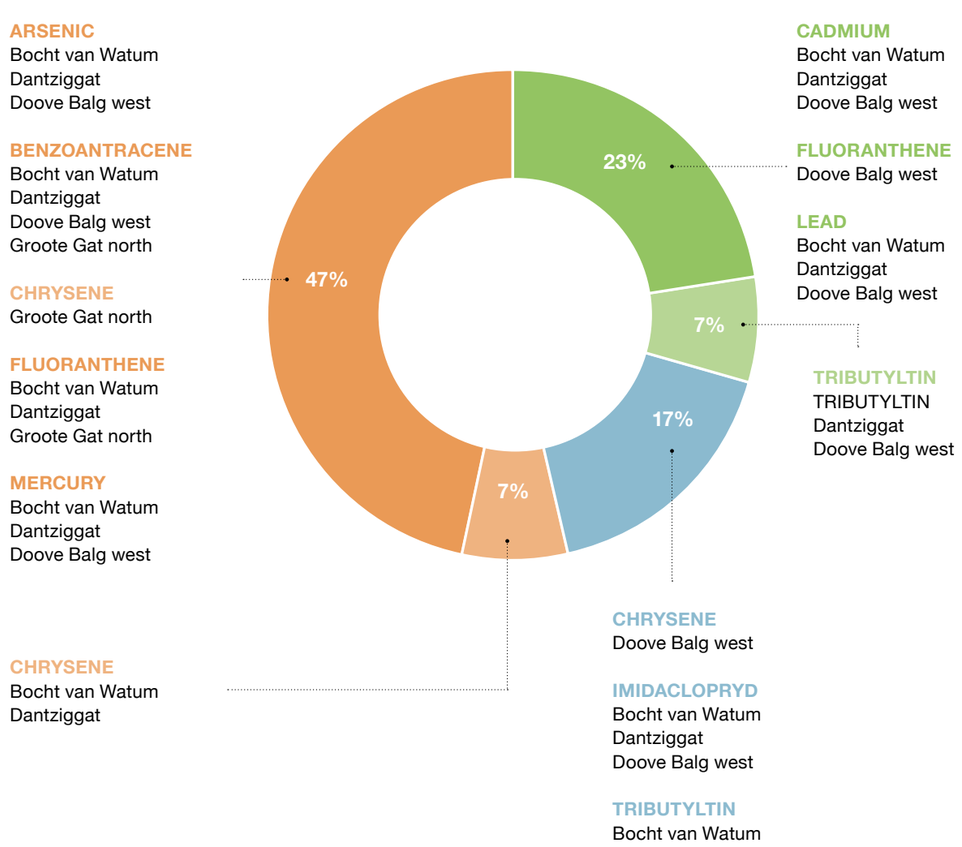
For **9** out of 30 (**30%**) indicators, the current values are '**better**', with the trend of 6 indicators having been **'improving'** over the past 12 years and for 1 indicator 'stable' (Figure 7). Regarding the indicators with an 'improving' trend, it concerns the decrease in concentrations of **cadmium and lead** at all three stations where this is measured.

For 5 out of the 30 indicators (17%), the current value is **'uncertain'** compared to the reference value, of which 3 indicators have an uncertain trend and 2 have an improving trend (Figure 7). Regarding the indicators with an **'uncertain**' trend, it concerns the concentrations of the pesticide **imidacloprid** at all three locations where this is measured.

Figure 7. *Map of sampling stations for the indicators of pollutants.*



POLLUTANTS



Data sources
RWS (1996/2015-2024)

Sampling frequency
4 to 19 times per year

Spatial coverage
Wadden Sea & Ems-Dollard
4 sampling stations

Number of indicators
30

Units
Concentration (µg/l)

Reference values (RV)
RIVM Directive (risks of substances)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	6	2	2
Stable	1	2	0
Deteriorating	0	7	0
Uncertain	2	5	3

Figure 8. *Scores of 'pollutant' indicators in the Wadden Quadrant based on their values and trends.*

5.2 Turbidity & Nutrients

The group of 'Turbidity & Nutrients', as part of the theme 'Environment' of the state of the Dutch part of the Wadden Sea, consists of **24 indicators**, of which 6 for turbidity, 6 for the concentrations of dissolved phosphorus (P; phosphate PO4), 6 for the concentrations of dissolved nitrogen (N; the sum of the concentrations of nitrate NO3, nitrite NO2, and ammonium NH4) and 6 for the ratio between N:P as measured at 4 different locations in the Wadden Sea (Table 2, Figures 9 & 10). The annual values for turbidity are based on the average light attenuation during the growing season (May-September) of eelgrass (Zostera marina), while the annual values for nutrients are based on the average concentrations during the winter months (December–February).

For nutrient concentrations, the reference values for the coastal zone of the North Sea, as defined in the OSPAR Directive, have been used. The reference values for the N:P ratio (16) in the water and for water turbidity are both based on those in an undisturbed situation, with those for turbidity based on the situation prior to the closure of the Zuiderzee (see Table 3).

For **11** of the 24 (**46%**) indicators, the current values are **'worse'** than the reference values, of which 5 indicators have been 'stable' over the past 12 years and 4 indicators have shown a further 'deterioration' (Figure 10). With regard to the indicators showing a '**stable**' or '**deteriorating**' trend, this concerns an increase in the **N:P ratio** (for all 6 measuring stations) and a decrease in **water turbidity** at 3 of the 6 measuring stations, namely at Groote Gat north, Bocht van Watum and Doove Balg west (Figure 9).

For **10** of the 24 (**41%**) indicators, the current values are **'better'**, with the trend for 4 indicators having 'improved' over the past 12 years and for 4 indicators having remained 'stable' (Figure 10). The indicators with a '**stable**' or '**improving**' trend relate to the decrease in concentrations of **phosphorus (P)** and **nitrogen (N)** at four of the six stations where these are measured.

For **3** of the 24 indicators (**13%**), the current value is '**uncertain**' compared to the reference value, with each of these 3 indicators showing an improving trend (Figure 9). The indicators with an '**improving**' trend are a decrease in the concentration of nitrogen (N) in the Bocht van Watum and an increase in turbidity at Marsdiep north and Vliestroom (Figure 9)

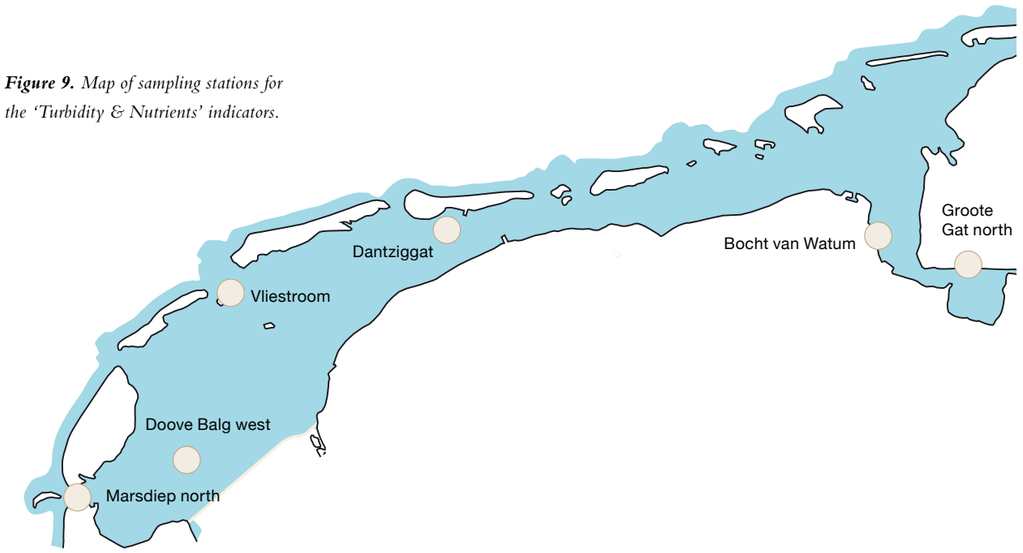
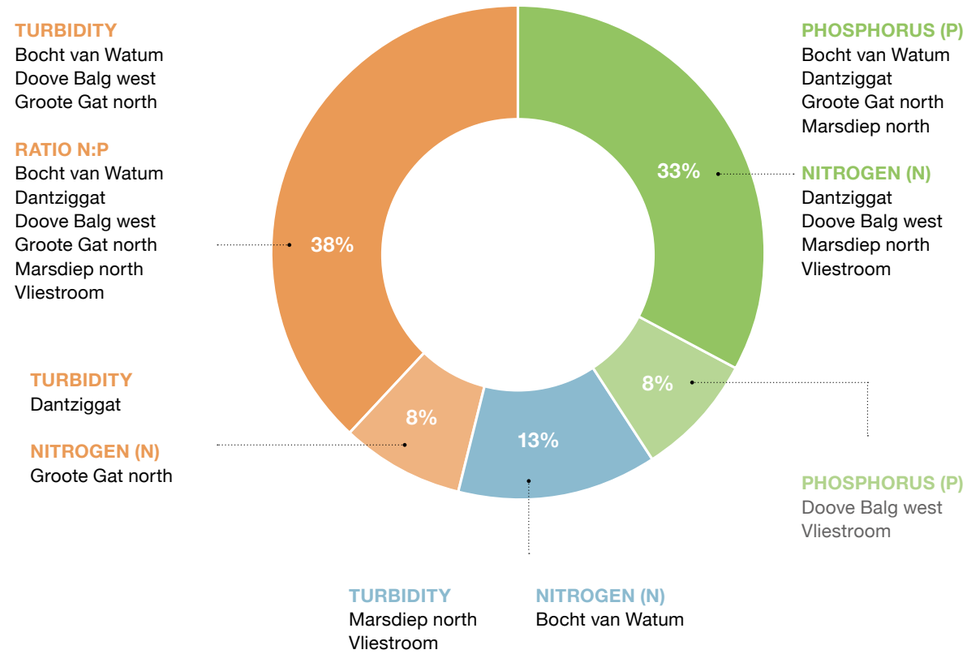


Figure 9. *Map of sampling stations for the 'Turbidity & Nutrients' indicators.*

TURBIDITY & NUTRIENTS



Data sources
MWTL/RWS (1988-2024)

Sampling frequency
12-24 times a year

Spatial coverage
Wadden Sea & Ems-Dollard
6 sampling stations

Number of indicators
24

Units
Light attenuation (m^{-1})
Nutrient concentrations ($mmol/m^3$)

Reference values (RV)
OSPAR Directive (nutrients), Historical value (turbidity)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	4	2	3
Stable	4	5	0
Deteriorating	0	4	0
Uncertain	2	0	0

Figure 10. *Scores of 'Turbidity & Nutrients' indicators in the Wadden Quadrant based on their values and trends.*

5.3 Surface area habitats

The group of 'Surface area habitats', as part of the 'Environment' theme of the state of the Dutch part of the Wadden Sea, consists of **14 indicators**, of which 3 are for the Wadden Sea, 5 for saltwater vegetation inside and outside the dykes, and 6 for dune areas (Table 2, Figure 11). The measurements cover the entire Dutch part of the Wadden Sea, including the Ems-Dollard, and the Dutch Wadden Sea islands.

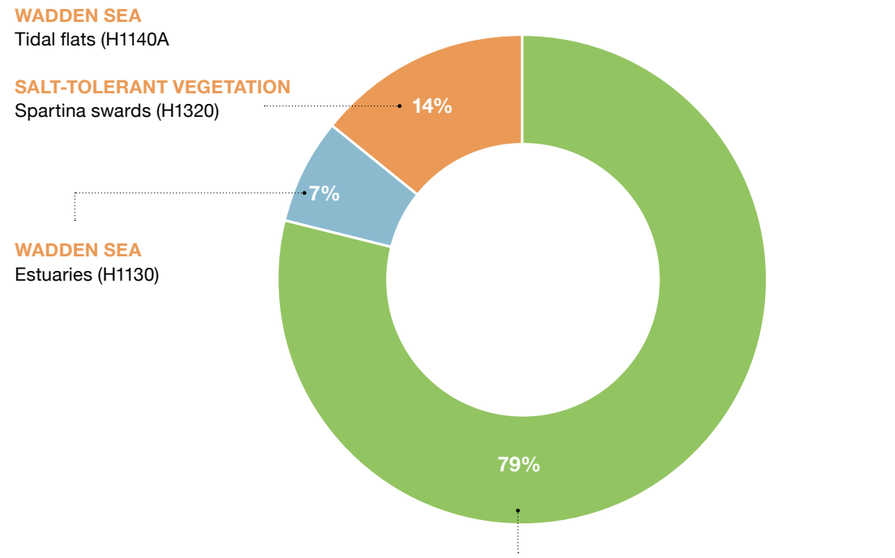
The reference values for these habitats are based on an N2000 conservation objective, which states that the surface area of each of these areas must not have deteriorated since the area was designated. In practice, this is assessed on the basis of the changes between initial mapping efforts in 2005 and second mapping efforts in 2018 (see Table 3).

For **2** of the 14 (**14%**) indicators, the current values are '**worse**' than the reference values, with both indicators showing further 'deterioration' (decline in surface area) over the past 12 years (Figure 11). This '**deterioration**' concerns the surface area (hectares) of **mudflats and sandbanks** that fall dry at low tide, and the surface area of **salt marshes** located between the mudflats and areas that are partly covered with English cordgrass.

For **11** of the 14 (**79%**) indicators, the current values are '**better**', with all of these indicators showing an 'improvement' (expansion of the area) over the past 12 years (Figure 11). This '**improvement**' concerns the area (hectares) of **permanently flooded sandbanks** (which do not emerge at low tide), the area of **most salt marsh zones** (with the exception of the areas covered by English cordgrass) and **all dune zones**.

For **1** of the 14 indicators (**7%**), the current value is '**uncertain**' relative to the reference value. This concerns the surface area of **estuaries** (defined within N2000 as the downstream section of a river that is influenced by the tidal action of the sea). Within the Wadden Sea, this specifically concerns the Ems-Dollard area.

SURFACE AREA HABITATS



Data sources
Mapping T0 (2004-2010)
Mapping T1 (2012-2019)

Sampling frequency
Once every 6 years

Spatial coverage
Wadden Sea & Ems-Dollard Islands (dunes)

Number of indicators
14

Unit
Surface area (hectares)

Reference values (RV)
N2000 Directive (Habitat Directive)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	11	0	0
Stable	0	0	1
Deteriorating	0	2	0
Uncertain	0	0	0

Figure 11. *Scores of 'Surface Area of Habitat' indicators in the Wadden Quadrant based on their values and trends.*

5.4 Characteristics Habitats

The group of 'Characteristics habitats', as part of the 'Environment' theme of the state of the Dutch part of the Wadden Sea, consists of **17 indicators**, of which 5 are for biogenic structures (seagrass and shellfish beds), 3 for sediment coarseness (measured as median grain size in µm), 3 for the silt content of the sediment (measured as the fraction of the sediment with a median grain size smaller than 62 µm) and 3 for the zonation of salt marshes. The measurements were carried out across the entire Wadden Sea (including the Ems-Dollard estuary). For the analyses of the values and trends in sediment characteristics and the zonation of salt marshes, the data were combined within three sub-areas (western Wadden Sea, eastern Wadden Sea and Ems-Dollard, Figure 12).

The reference values for seagrass are based on the Water Framework Directive, while those for mussel beds are based on the Habitats Directive (Table 3). There are no externally defined reference values for other shellfish beds (oyster beds, mixed beds) and for the composition of the sediment (coarseness, silt content). Furthermore, the time series on sediment characteristics are too short to define a starting period as a reference. We have, therefore, taken the average values of these entire time series as reference values for these indicators. The reference values for salt marsh zonation are based on the Water Framework Directive, which aims to achieve a balanced distribution of different vegetation zones (pioneer, low, middle, high and brackish).

For **3** of the 17 (**18%**) indicators, the current values are '**worse**' than the reference values, with the trend for all 3 indicators (**mussel beds, mixed mussel beds and seagrass beds**) being '**uncertain**' (Figure 13).

For **11** of the 17 (**65%**) indicators, the current values are '**better**', with 10 of those 11 indicators showing a 'stable' trend over the past 12 years (Figure 13). This '**stable**' trend concerns the coarseness and silt content of the **sediment** in the western and eastern parts of the Dutch part of the Wadden Sea, and a **balanced salt marsh zonation** in all three sub-areas.

For **3** of the 17 indicators (**18%**), the current value is '**uncertain'**. Of these, the trend for **oyster beds** is 'uncertain' and that for the coarseness and silt content of the **sediment** in the Ems-Dollard is '**stable**'.

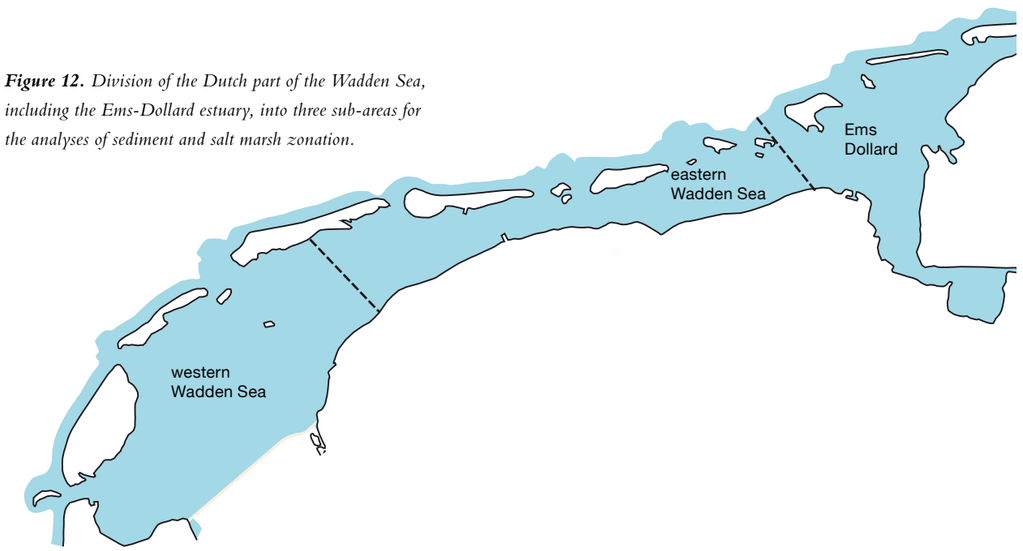
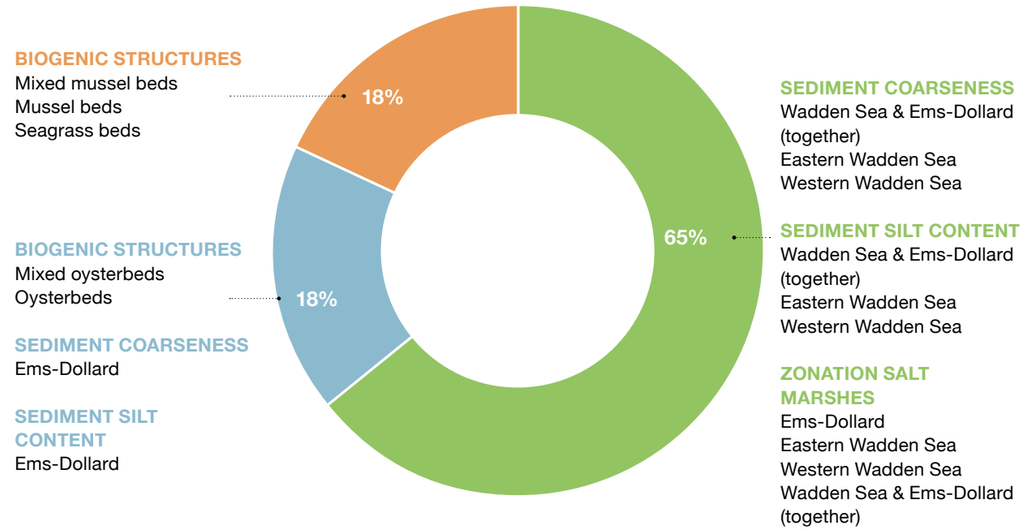


Figure 12. *Division of the Dutch part of the Wadden Sea, including the Ems-Dollard estuary, into three sub-areas for the analyses of sediment and salt marsh zonation.*

CHARACTERISTICS HABITATS



Data sources
SIBES: NIOZ commissioned by RWS (2009-2019)
VEGWAD/MWTL: RWS (2003, 2009, 2015, 2022)
Seagrass/MWTL: RWS (1972-2022)
WOt: WMR commissioned by LVVN (1995-2024)

Sampling frequency
Once a year to once every six years

Spatial coverage
Wadden Sea & Ems-Dollard

Number of indicators
17

Units
Variable

Reference values (RV)
Average values of time series, (sediment & shellfish beds), Water Framework Directive, (saltmarshes & seagrass beds)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	11	0	0
Stable	0	0	2
Deteriorating	0	0	0
Uncertain	0	3	1

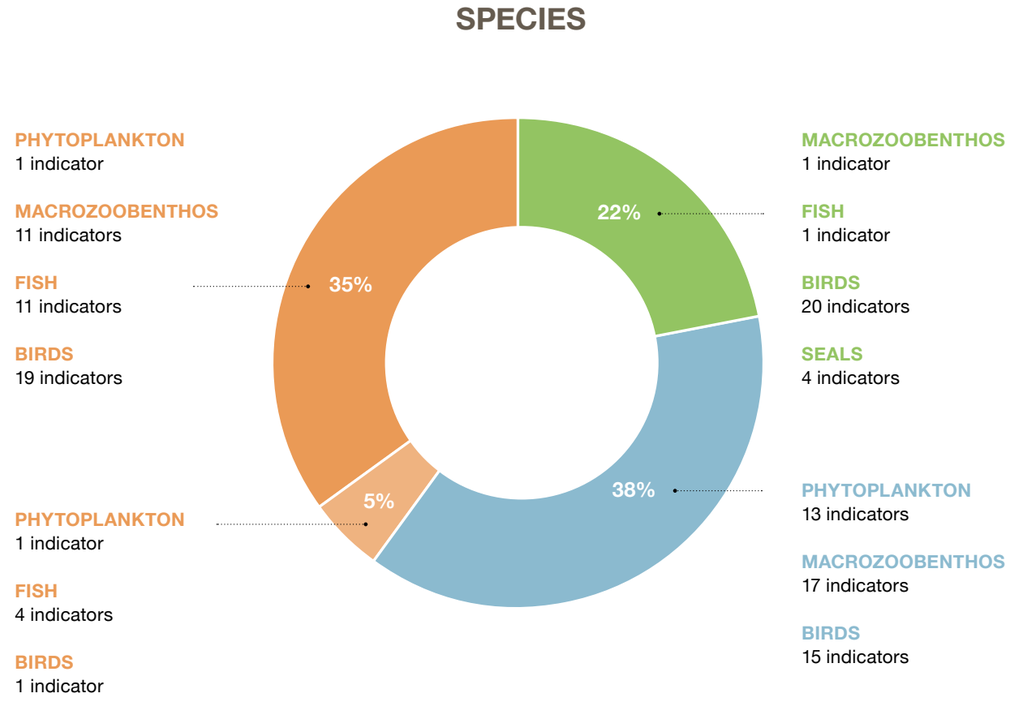
Figure 13. *Score of 'Habitat Characteristics' indicators in the Wadden Quadrant based on their values and trends.*

6 SPECIES

The state of 'Species', as part of the state of the Dutch part of the Wadden Sea, is based on **119 indicators**, including 15 for phytoplankton (microscopic pelagic algae), 29 for macrozoobenthos (such as bivalves and worms), 16 for fish, 55 for birds and 4 for seals (Table 2, Figure 14).

For many of these **indicators**, the reference values were derived from legal sources (**WFD** for **phytoplankton, N2000** for birds and seals). Where such values were not available, the reference values were taken from the **average values** (benthic animals) or **maximum values** (fish) of a time series (see Table 3). With regard to birds, only the population size or number of breeding pairs in the Wadden Sea was considered. This means that the assessment does not correspond to the assessment of the 'conservation status' of a species at national level, which takes not only population size, but also distribution area, habitat quality and future prospects into account. This explains, for example, why certain species may be in a (very) unfavourable state nationally, whilst within the state of the Dutch part of the Wadden Sea these are classified as 'better' or 'uncertain'.

For **48** of the 119 (**40%**) indicators, the current values are '**worse**' than the reference values, with trends in 14 indicators deteriorating further over the past 12 years, those in 28 indicators remaining 'stable' or 'uncertain', and those in 6 indicators improving (Figure 14). For **26** of the 119 (**22%**) indicators, the current values are '**better**', with trends improving in 18 indicators over the past 12 years, 'stable' in 8 indicators (Figure 6). For **45** of the 119 indicators (**38%**), the current value is '**uncertain**' (Figure 14).



Data sources
Phytoplankton (15 indicators)
Macrozoobenthos (29 indicators)
Fish (16 indicators)
Birds (55 indicators)
Seals (4 indicators)

Sampling frequency
Variable

Spatial coverage
Wadden Sea & Ems-Dollard

Number of indicators
119

Units
Variable

Reference values (RV)
Natura2000 Directive, Water Framework Directive, Average values of time series, Maximum values of time series

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	18	6	12
Stable	8	18	8
Deteriorating	0	14	2
Uncertain	0	20	23

Figure 14. *Scores of 'Species' indicators in the Wadden Quadrant based on their values and trends.*

6.1 Phytoplankton

The 'Phytoplankton' group, as part of the 'Species' theme of the state of the Dutch part of the Wadden Sea, consists of **15 indicators**, 14 of which are indicators for the average total biomass of microscopic pelagic algae (measured as mg chlorophyll-a per m3) during the growing season (March–September) and during the year (January-December), and 1 indicator for the bloom frequency of *Phaeocystis globosa* (determined as the number of months per year in which densities of more than 1000 cells per ml occurred). The measurements were carried out at seven sampling stations in the Wadden Sea, including the Ems-Dollard estuary (Figure 15).

The reference values for phytoplankton (biomass and blooms) are based on the Water Framework Directive, which specifies different reference values for different sub-areas (Table 3).

For **2** of the 15 (**14%**) indicators, the current values are '**worse**' than the reference value, with the trend in the percentage of Phaeocystis blooms per year at the Marsdiep sampling station '**deteriorating**' and that of phytoplankton biomass during the growing season at the Dantziggat sampling station 'improving' (Figure 16).

For the remaining **13** of the 15 indicators (**87%**), the current values are '**uncertain**' compared to the reference values. Of these, the trend for 7 indicators is '**improving**' and that for 6 indicators is '**uncertain**' (Figure 16). The '**improvement**' mainly concerns (6 of the 7 indicators) the decrease in **phytoplankton biomass** during the growing season and throughout the year at the Bocht van Watum, Huibertgat east and Marsdiep north measuring stations (Figure 15).

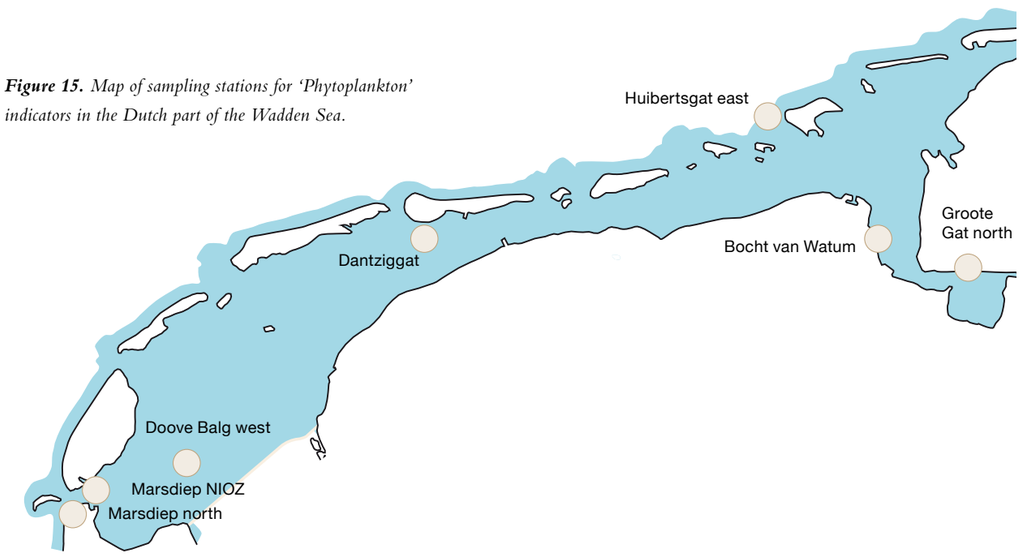
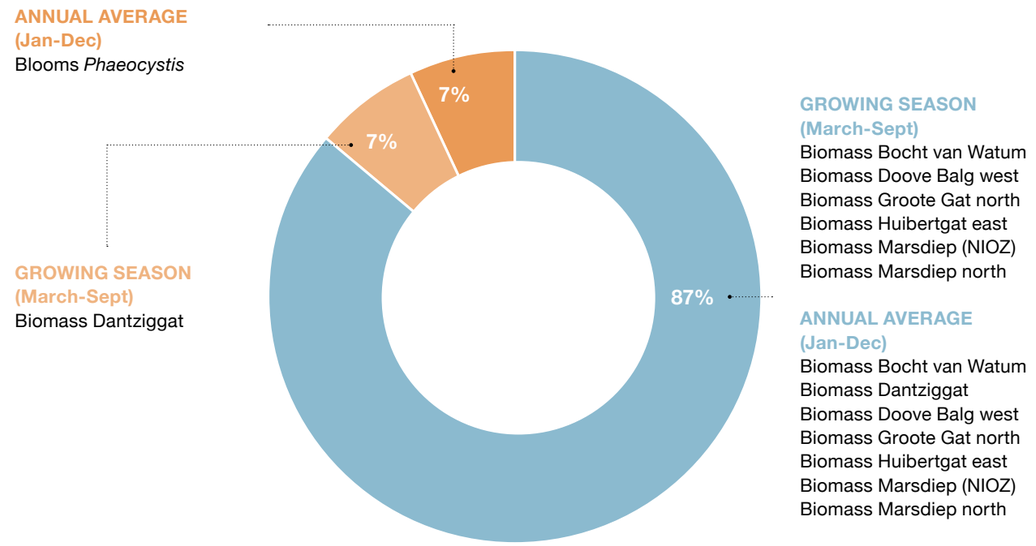


Figure 15. *Map of sampling stations for 'Phytoplankton' indicators in the Dutch part of the Wadden Sea.*

PHYTOPLANKTON



Data sources
Jetty: NIOZ (1974-2020)
MWTL: RWS (1990-2023)

Sampling frequency
Jetty: 20-60x per year
MWTL: 12-24x per year

SPATIAL COVERAGE
Wadden Sea & Ems-Dollard
Jetty: 1 sampling station (Marsdiep)
MWTL: 6 sampling stations

Number of indicators
15

Units
Biomass (mgCHLa/m³)
Frequency (number of months with bloom/year)

Reference values (RV)
Water Framework Directive (WFD)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	0	1	7
Stable	0	1	0
Deteriorating	0	0	0
Uncertain	0	0	6

Figure 16. *Scores of 'phytoplankton' indicators in the Wadden Quadrant based on their values and trends.*

6.2 Macrozoobenthos

The group of 'Macrozoobenthos', as part of the 'Species' theme of the state of the Dutch part of the Wadden Sea, consists of **29 indicators**. The data originate from two different measurement programmes (with different protocols for sampling and laboratory analysis), namely the 'Synoptic Intertidal BEnthic Survey (SIBES)' conducted by the Royal Netherlands Institute for Sea Research (NIOZ), and the shellfish survey focused on commercial shellfish species conducted by Wageningen Marine Research as a Statutory Research Task (WOt). Of the 29 indicators for benthic animals, 8 originate from WOt and 21 from SIBES (Figure 17).

In addition to this subdivision into sampling programmes (SIBES, WOt), a distinction has also been made between crustaceans (4 indicators), shellfish (13 indicators) and worms (12 indicators), as well as biomass of species groups (the total weight per m2 of worms and shellfish from the SIBES sampling, and that for shellfish from the WOt sampling) and densities of species or species groups for the remaining 26 indicators (Figure 17). The measurements are carried out annually at approximately 6,000 measuring stations (SIBES and WOt combined) in the Wadden Sea, including the Ems-Dollard estuary (Figure 17).

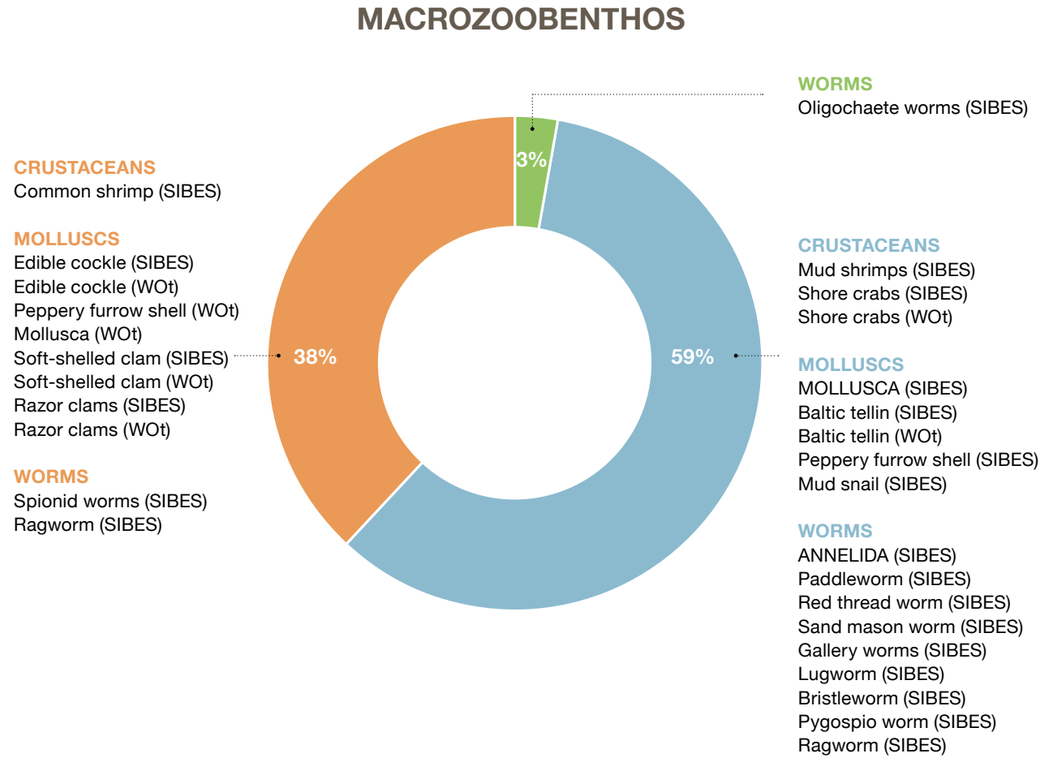
The Water Framework Directive (WFD) describes reference classes for each species, but these references are based on another Dutch monitoring program (MWTL) that samples at a very limited number of stations. Due to differences in sampling methods, this is difficult to apply to the data from the WOt and the SIBES. In addition, the WFD does not specify whether the densities refer to the littoral zone (areas that emerge during low tide) or the sublittoral zone (areas that are always submerged). Therefore, it has been decided to use the average values of the densities and biomass of the macrozoobenthic species from the SIBES and WOt time series for the same period (2008-2022) as reference values.

For **11** of the 29 (**38%**) indicators, the current values are '**worse**' than the reference values, with 3 indicators showing a '**deteriorating**' trend (decrease in densities of bristle worms *Spio* spp. and the common shrimp *Crangon crangon* as sampled within SIBES, decrease in the biomass of shellfish as sampled as WOt), 1 indicator is '**stable**' (razor clams *Ensis* spp. as sampled within WOt) and 6 indicators are '**uncertain**' (Figure 17).

For **1** of the 29 (**3%**) indicators, the current value is '**better**'. This concerns *Oligochaeta* (as sampled within SIBES), whose densities have increased over the last 12 years (Figure 17).

For **17** of the 29 indicators (**59%**), the current values are '**uncertain**' compared to the reference values. Of these, the trend for 3 indicators is '**improving**', for 12 indicators 'uncertain' and for 2 indicators '**stable**' (Figure 17).

Of the seven species or species groups sampled in both SIBES and WOt, three have the same value and trend (cockle, soft-shell clam and European green crab), while the other four (densities of Baltic tellin, peppery furrow shell, razor clams and biomass of mollusca) differ in value and/or trend.



Data sources
SIBES: NIOZ commissioned by RWS (2008-2022)
WOt: WMR commissioned by LVVN (1998-2023)

Sampling frequency
SIBES: once a year (summer)
WOt: once a year (spring)

Spatial coverage
Wadden Sea & Ems-Dollard
SIBES: 4500 sampling stations
WOt: 1500 sampling stations

Number of indicators
29

Units
Density (number/m²)
Biomass (gADW/m²; Mollusca & Annelida)

Reference values (RV)
Average values of time series (2008-2022)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	1	0	3
Stable	0	1	2
Deteriorating	0	3	0
Uncertain	0	7	12

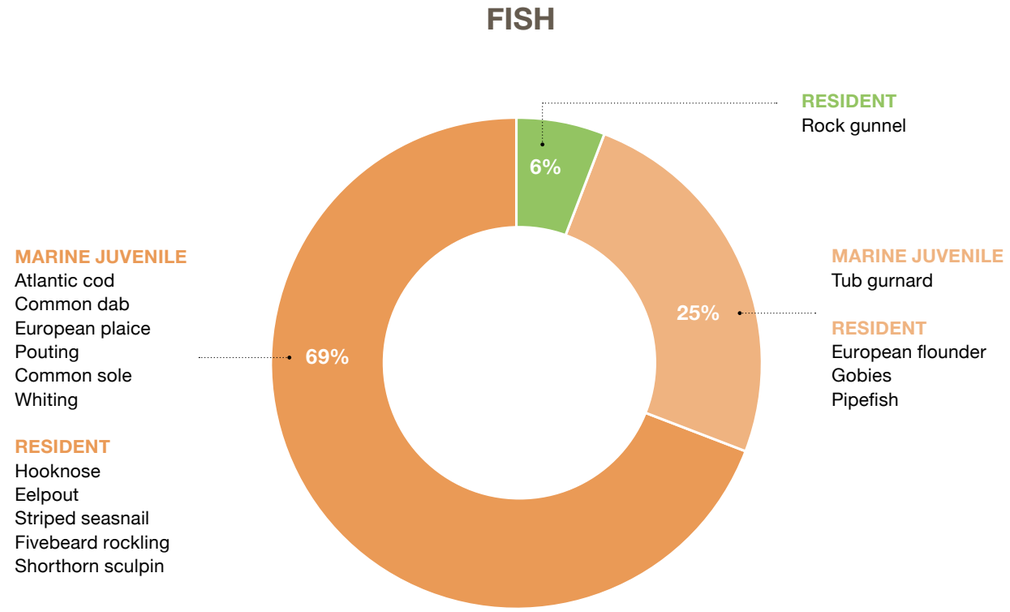
Figure 17. *Scores of 'Macrozoobenthos' indicators in the Wadden Quadrant based on their values and trends.*

6.3 Fish

The 'Fish' group, part of the 'Species' theme of the state of the Dutch part of the Wadden Sea, consists of **16 indicators**, divided into marine juveniles (7 indicators) that mainly use the Wadden Sea as a nursery and resident species (9 indicators) that spend most of their lives in the Wadden Sea. The measurements are carried out at 120 locations in the Wadden Sea, including the Ems-Dollard estuary (Figure 18).

Since there aren't any legally established reference values for most species, the **maximum values** of the numbers per catch (catch per unit effort; CPUE) within the study period (1985-2024) were used as reference values. This approach is most consistent with the reference values for species (flounder, common sole) for which values are available within the Water Framework Directive. The three fish species for which N2000 targets have been formulated for the Wadden Sea (sea lamprey, river lamprey and twait shad) could not be included in the analysis because of insufficient long-term monitoring data.

For **15** of the 16 (**94%**) indicators, the current values are '**worse**' than the reference values, with the trend for 2 indicators (cod, common sole) '**deteriorating**' and for 4 indicators (flounder, gobies, tub gurnard, pipefish) 'improving' (Figure 18). The value of the remaining indicator, the butterfish *Pholis gunnellus,* is '**better**'. This species is increasing in numbers, resulting in an '**improving**' trend (Figure 18). Within the current selection of species and species groups, there are no fish for which the value is 'uncertain', and there are no obvious differences in the distribution of marine juveniles and resident species across the three observed situations.



Data sources
Demersal Fish Survey (1985-2024):
WMR commissioned by LVVN / ICES

Sampling frequency
Once a year (spring)

Spatial coverage
Wadden Sea & Ems-Dollard
120 sampling stations (start of fishing tracks)

Number of indicators
16

Unit
Density (numbers/track/depth-class)

Reference values (RV)
Maximum value of time series (1985-2024)

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	1	4	0
Stable	0	3	0
Deteriorating	0	2	0
Uncertain	0	6	0

Figure 18. *Scores of 'Fish' indicators in the Wadden Quadrant based on their values and trends.*

6.4 Birds

The 'Birds' group, part of the 'Species' theme of the state of the Dutch part of the Wadden Sea, consists of **55 indicators**, divided between species that breed in the Wadden Sea (13 indicators), those that mainly forage there (36 indicators) and those that roost there (6 indicators). The measurements are carried out throughout the Wadden Sea, including the Ems-Dollard estuary (Figure 19).

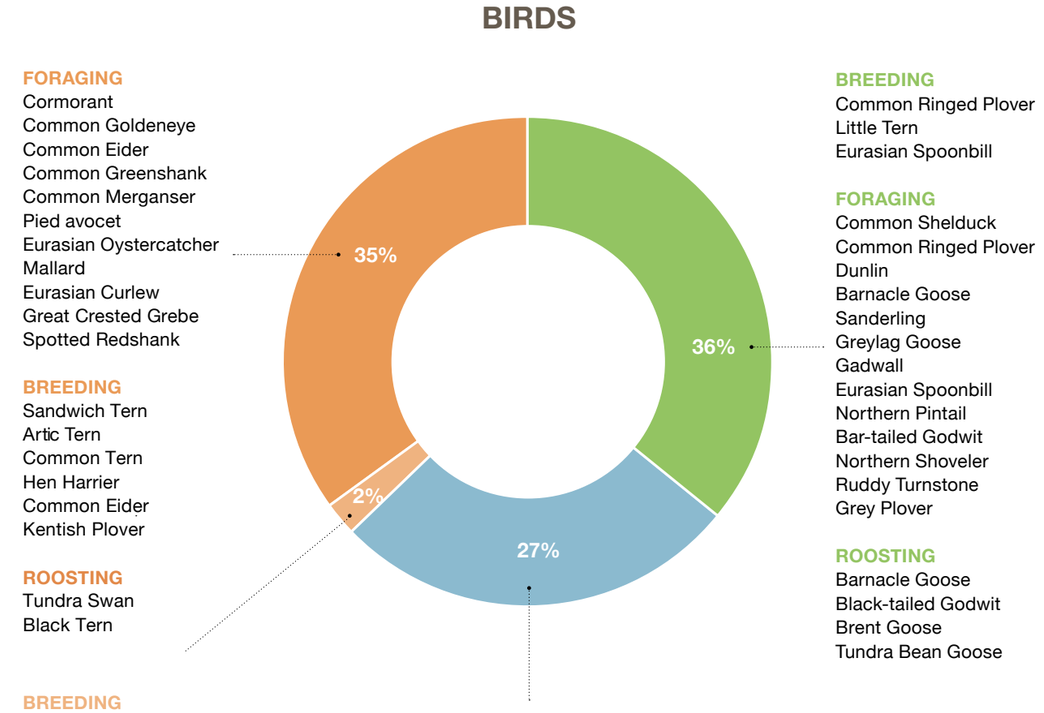
The reference values against which the abundance of birds are assessed are derived from the conservation objectives for the Wadden Sea set out in Natura 2000 (Table 3). These reference values have different units, namely number of breeding pairs (for breeding birds) and the average or maximum numbers of non-breeding birds (birds that forage and/or roost in the Wadden Sea). No exact reference value was available for the tundra bean goose, but 'conservation' was specified within Natura2000. Therefore, the trend value from 2009 (when the N2000 targets were set) was used as the reference value for this species.

These reference values are only **part of** the formal legal assessment of birds within **N2000**, which also assesses the distribution area, habitat quality and future prospects in addition to population size. For each of the four aspects, the assessment can be favourable, moderately unfavourable, very unfavourable or unknown, with the final assessment being determined by the **least favourable outcome** of the four tests.

For **20** of the 55 (**37%**) indicators, the current values are '**worse**' than the reference values, of which for 1 indicator (the Pied Avocet) as a breeding bird) the numbers increased and the trend was therefore 'improving', for 3 indicators (common tern as a breeding bird, Cormorant and Pied Avocet as foraging birds) the numbers were '**stable**', for 7 indicators '**uncertain**' and for 9 indicators '**deteriorating**' (including the Sandwich Tern and Arctic Tern as breeding birds).

For **20** of the 55 (**35%**) indicators, the current values are '**better**', of which for 13 indicators (2 species of breeding birds and 11 species of foraging birds) the numbers increased and the trend is therefore '**improving**', and for 7 indicators (1 breeding bird, 4 foraging birds and 2 roosting birds) the numbers are '**stable**'.

For **15** of the 55 indicators (**27%**), the current values are '**uncertain**' compared to the reference values, of which 3 species are breeding birds (Marsh Harrier, Lesser Black-backed Gull, Short-eared Owl) and 12 species are foraging birds.



Data sources
Sovon / Ecological Monitoring Network
Breeding birds (1990-2023)
Non-breeding birds (1976-2023)

Sampling frequency
Breeding birds: breeding season
Non-breeding birds: season (July-June)

Spatial coverage
Wadden Sea & Ems-Dollard

Number of indicators
55

Units
Breeding birds: number of breeding pairs
Non-breeding birds: number of individuals

Reference values (RV)
Natura2000 Directive

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	13	1	2
Stable	7	3	6
Deteriorating	0	9	2
Uncertain	0	7	5

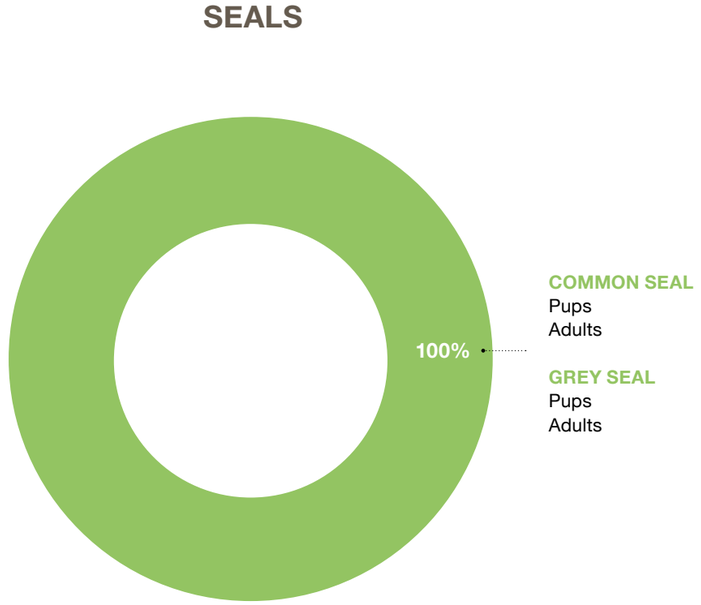
Figure 19. *Scores of 'Bird' indicators in the Wadden Quadrant based on their values and trends.*

6.5 Seals

The ‘Seals’ group, part of the ‘Species’ theme of the state of the Dutch part of the Wadden Sea, consists of **4 indicators**, being two species (common and grey seals) and two age categories (pups and adults) of each species. The measurements are carried out throughout the Wadden Sea, including the Ems-Dollard estuary (Figure 20).

There are no specific N2000 reference values available for seals, but there is a ‘**conservation objective**’ for the common seal (the species must not decline in number) and an ‘**improvement objective’** for the grey seal (the number of the species must increase over time). Because the N2000 targets were finalised in 2009, the average trend values for the period 2009-2023 for the numbers of adult grey seals and seal pups have been used as reference values.

For all four indicators, the current values are ‘**better**’ than the reference values, with the trend for adult harbour seals being ‘**stable**’ and that for adult grey seals and pups of both seal species being ‘**improving**’.



Data sources
WOt (WMR commissioned by LVVN)

Sampling frequency
Once a year
Adults of common seal (Aug)
Adults of grey seal (March/April)
Pups of common seal (June/July)
Pups of grey seal (December/January)

Spatial coverage
Wadden Sea & Ems-Dollard

Number of indicators
4

Unit
Number

Reference value (RV)
N2000 Directive or guideline:
‘conservation’ for grey seals
‘expansion’ for common seals

TREND past 12 years	Current value relative to RV		
	Better	Worse	Uncertain
Improving	3	0	0
Stable	1	0	0
Deteriorating	0	0	0
Uncertain	0	0	0

Figure 20. *Scores of ‘Seal’ indicators in the Wadden Quadrant based on their values and trends.*

7 CONCLUSIONS

Wadden Dashboard
For **66 of the 238** indicators (**28%**) investigated in the state of the Dutch part of the Wadden Sea, the current values are '**uncertain**' in relation to the reference values (Figure 21). As it cannot be ruled out that the current values for these indicators are 'worse' than the reference values, they require attention from policy and management. The proportion of indicators with an 'uncertain' value is highest within the theme '**Species**' (45 indicators), specifically for **phytoplankton** (13 indicators), **macrozoobenthos** (17 indicators) and **birds** (15 indicators). Because this uncertainty may arise, among other factors, from **large spatial variation in numbers and trends** of plants and animals within the Dutch part of the Wadden Sea, a more detailed analysis, breaking down the data into sub-areas (e.g. tidal basins), could provide a clearer picture with less uncertainty. Expanding it to the entire Wadden Sea may also be an option as this will increase the data availability and, amongst others, subsequently increase the statistical power of the trend analyses.

The results of the present state report further indicate that for the Dutch part of the Wadden Sea, the current values of **92 of the 238** indicators (**38%**) are '**worse**' than the reference values, of which **37 of the 238** (**16%**) have shown further '**deterioration**' over the past 12 years (Figure 21). This means that the current state of the Dutch part of the Wadden Sea is unsatisfactory in many respects, which calls for policy and management measures.

This state report does not indicate the possible causes for these developments, nor does it indicate which measures could be taken to turn the tide. The current overview provided by the state report can be helpful in this regard, as it provides an overview of the 50 indicators for which the current values are '**better**' and the trend is '**improving**' (**21%**), and thus possibly provides indications as to which previously taken ecological restoration measures (e.g. in the field of nature management, design and pressure reduction) have proven effective.

Climate change
Climate change must be taken into account in order to ensure the effectiveness of any future measures.

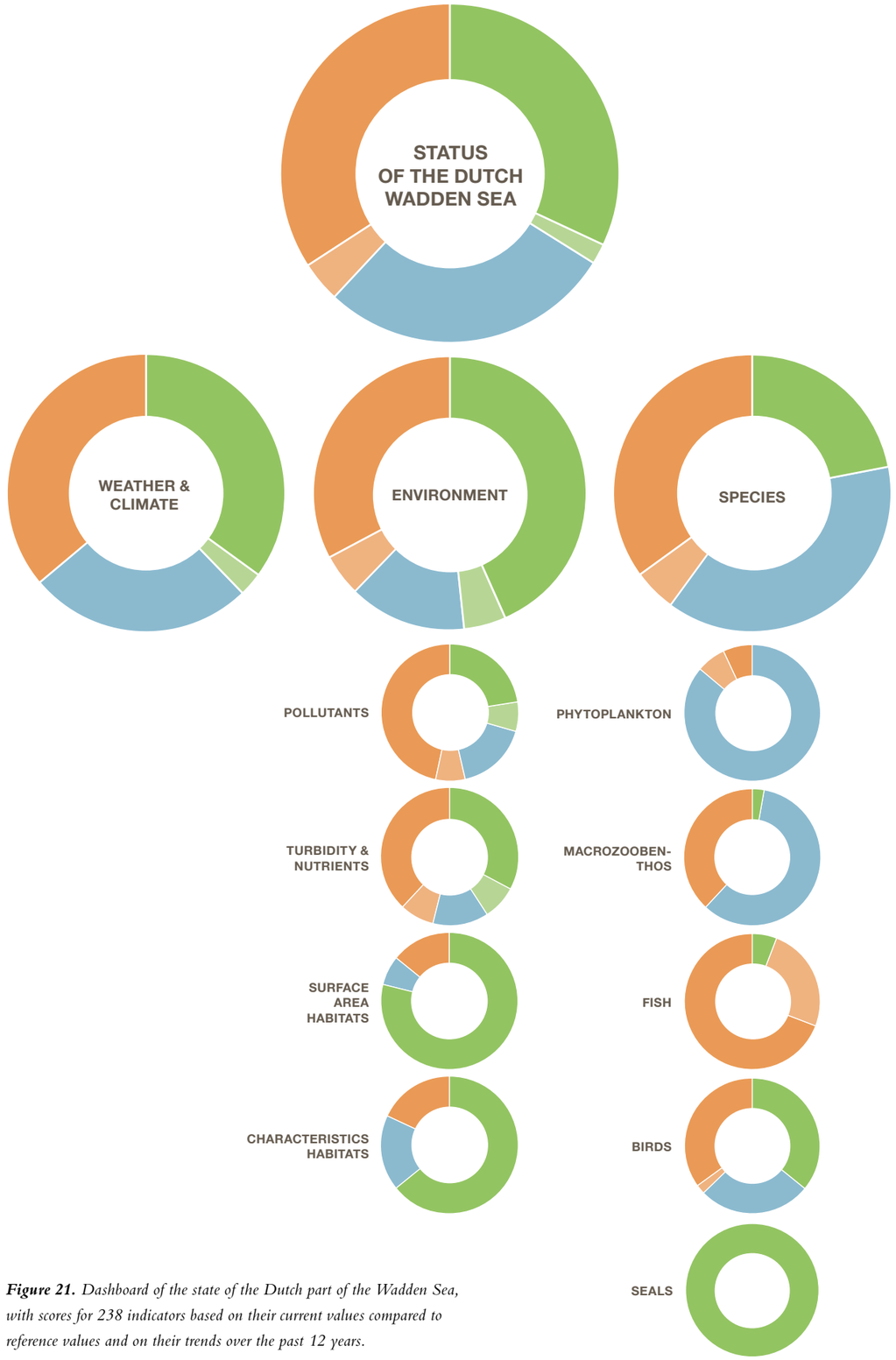


Figure 21. *Dashboard of the state of the Dutch part of the Wadden Sea, with scores for 238 indicators based on their current values compared to reference values and on their trends over the past 12 years.*

The present state report shows that the average air- and water temperatures are rising. Based on recent scenarios of the Royal Netherlands Meteorological Institute, this trend will continue in the coming decades, even if immediate action is taken to reduce greenhouse gas emissions.

Because **warming** has consequences for biological processes (such as the reproductive success of shellfish and the timing of seasonal migration of migratory birds), it cannot be ruled out that this will have an impact on the numbers (increase or decrease) of various species in the Wadden Sea. In addition, if the height of coastal ecosystems (such as tidal flats and salt marshes) cannot keep pace with **enhanced sea level rise** and if these can also not move inland (so-called 'coastal squeeze) than these habitats and their biodiversity might become lost.

Cumulation may also occur, whereby the effects of climate change add to the pressures from other human activities. This development calls for further investigation of the possible consequences of climate change for the natural values of the Wadden Sea, for example by taking into account **climate-related characteristics** of plants and animals (such as temperature sensitivity).

Next steps

The current list of indicators consists of variables that are considered relevant to the functioning of the Wadden Sea as an integral ecosystem, and for which data and reference values were available. The present state report provides a broad picture of developments in natural values in this area and clear indications of which indicators require attention from policy and management. In a subsequent phase, the state report should be further expanded with more (possibly all) parameters that are currently used for formal legal assessments (N2000, WFD, OSPAR). In addition, variables for which indicators are currently being developed, such as the **pillars underpinning the Wadden Sea as a World Heritage Site** and the **core values of the landscape**, could be added.
Furthermore, the values and trends of **other pressure factors deemed most relevant** (in addition to those of weather and climate) could be included. This would provide insight into whether and, if so, to what extent additional measures actually lead to a reduction in pressure and have an impact on the State of the Wadden Sea.

In addition, this analysis could be performed in different parts of the trilateral Wadden Sea to explore how similar or how different the state, trends and pressures are. This information could be then be used for identification of generic and/or local pathways to adapt to climate change.

Implementation

The '**State of the Wadden Sea'** provides a **comprehensive picture of the current state and trends in natural values** of the Dutch part of the Wadden Sea, based on a standardised system for extracting and linking information about current values relative to reference values and trends over the past 12 years from 238 long-term time series.

The use of the state of the Dutch part of the Wadden Sea is most effective **when structurally imbedded into a policy cycle**, in which the results are used for policy-making (as intended in the Policy Framework for Nature of the Dutch part of the Wadden Sea) and the effects of the implementation of that policy are regularly assessed and evaluated (e.g. once every three to four years).

It could also be considered by the Wadden Sea Board to expand the present state report to the trilateral Wadden Sea area. As such, it could function as a synthesis of the thematic chapters of the **Wadden Sea Quality Status Report**. Most (if not all) of the selected indicators for the Dutch part of the Wadden Sea are available for the German and Danish parts as well. Results could then be presented and discussed during each International Scientific Wadden Sea Symposium, and outcomes taken into account during each Trilateral Governmental Conference (once every four years).

This would require structural cooperation within the **Trilateral Monitoring and Assessment Programme (TMAP)** to make all data and information FAIR and open, and with the **Common Wadden Sea Secretariat** to connect these efforts to trilateral meetings (symposia, conference) and the QSR. This will be advantageous for both, getting a better understanding on current values and trends within the trilateral Wadden Sea, and for interpretation of the status and trends in particular areas (e.g., the Dutch part of Wadden Sea) from a trilateral perspective (e.g., local declines may point to local pressures).

ACKNOWLEDGEMENTS

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APPENDIX

1 Names of macrozoobenthic species and groups

Species name	Taxonomic group*	Common name		Sampling program	
		Dutch*	English**	SIBES	WOT
Alitta virens	ANNELIDA	Zager	Sandworm	X	
Arenicola marina	ANNELIDA	Wadpier	Lugworm	X	
Capitella sp.	ANNELIDA	Slangpieren	Gallery worms	X	
Carcinus/Liocarcinus	CRUSTACEA	Strandkrabben	Shore crabs	X	X
Cerastoderma edule	MOLLUSCA	Kokkel	Edible cockle	x	X
Corophiidae	CRUSTACEA	Slijkgarnalen	Mud shrimps	X	
Crangon crangon	CRUSTACEA	Garnaal	Common shrimp	X	
Ensis sp	MOLLUSCA	Zwaardschedes	Razor clams	X	X
Eteone longa	POLYCHAETA	Groengele wadpier	Paddleworm	X	
Hediste diversicolor	POLYCHAETA	Zeeduizendpoot	Ragworm	X	
Heteromastus filiformis	POLYCHAETA	Rode draadworm	Red thread worm	X	
Lanice conchilega	POLYCHAETA	Schelpkokerworm	Sand mason worm	X	
Macoma balthica	MOLLUSCA	Nonnetje	Baltic tellin	X	X
Mya arenaria	MOLLUSCA	Strandgaper	Soft-shelled clam	X	X
Oligochaeta	ANNELIDA	Ringwormen	Oligochaete worms	X	
Peringia ulvae	MOLLUSCA	Wadslakje	Mud snail	X	
Pygospio elegans	ANNELIDA	Zandkokerworm	Pygospio worm	X	
Scoloplos amriger	ANNELIDA	Wapenworm	Bristleworm	X	
Scrobicularia plana	MOLLUSCA	Platte slijkgaper	Peppery furrow shell	X	X
Spio sp.	ANNELIDA	Borstelwormen	Spionid worms	X	

* See Dutch ‘Staat van de Waddenzee 2025’ (Bogaart et al., 2025)

** World Register of Marine Species (WoRMS), http://www.marinespecies.org

2 Names of fish species

Species name	Fish guild*	Common name	
		Dutch*	English**
Agonus cataphractus	Resident	Harnasmannetje	Hooknose
Chelidonichthys lucerna	Marine juvenile	Rode poon	Tub gurnard
Ciliata mustela	Resident	Vijfdradige meun	Fivebeard rockling
Gadus morhua	Marine juvenile	Kabeljauw	Atlantic cod
Gobiidae	Resident	Grondels	Gobies
Limanda limanda	Marine juvenile	Schar	Common dab
Liparis liparis	Resident	Slakdolf	Striped seasnail
Merlangius merlangus	Marine juvenile	Wijting	Whiting
Myoxocephalus scorpius	Resident	Zeedonderpad	Shorthorn sculpin
Pholis gunnellus	Resident	Botervis	Rock gunnel
Platichthys flesus	Resident	Bot	European flounder
Pleuronectes platessa	Marine juvenile	Schol	European plaice
Solea solea	Marine juvenile	Tong	Common sole
Syngnathidae	Resident	Zeenaalden	Pipefish
Trisopterus luscus	Marine juvenile	Steenbolk	Pouting
Zoarces viviparus	Resident	Puitaal	Eelpout

* See Dutch ‘Staat van de Waddenzee 2025’ (Bogaart et al., 2025)

** FishBase, www.fishbase.se

3 Names of bird species

Species name	Common name		Habitat Use***		
	Dutch*	English**	B	F	R
Anarhynchus alexandrinus	Strandplevier	Kentish Plover	X		
Anas acuta	Pijlstaart	Northern Pintail		X	
Anas crecca	Wintertaling	Green-winged Teal		X	
Anas platyrhynchos	Wilde eend	Mallard		X	
Anser anser	Grauwe gans	Greylag Goose		X	
Anser serrirostris	Toendrarietgans	Tundra Bean Goose			X
Arenaria interpres	Steenloper	Ruddy Turnstone		X	
Asio flammeus	Velduil	Short-eared Owl	X		
Aythya marila	Topper	Greater Scaup		X	
Branta bernicla	Rotgans	Brant Goose		X	X
Branta leucopsis	Brandgans	Barnacle Goose		X	X
Bucephala clangula	Brilduiker	Common Goldeneye		X	
Calidris alba	Drieteenstrandloper	Sanderling		X	
Calidris alpina	Bonte strandloper	Dunlin		X	
Calidris canutus	Kanoet	Red Knot		X	
Calidris ferruginea	Krombekstrandloper	Curlew Sandpiper		X	
Charadrius hiaticula	Bontbekplevier	Common Ringed Plover	X	X	
Chlidonias niger	Zwarte stern	Black Tern			x
Circus aeruginosus	Bruine kiekendief	Western Marsh Harrier	X		
Circus cyaneus	Blauwe kiekendief	Hen Harrier	X		
Cygnus columbianus	Kleine zwaan	Tundra Swan			X
Falco peregrinus	Slechtvalk	Peregrine Falcon		X	
Haematopus ostralegus	Scholekster	Eurasian Oystercatcher		X	
Larus fuscus	Kleine mantelmeeuw	Lesser Black-backed Gull	X		
Limosa lapponica	Rosse grutto	Bar-tailed Godwit		X	
Limosa limosa limosa	Grutto	Black-tailed Godwit		X	X
Mareca penelope	Smient	Eurasian Wigeon		X	
Mareca strepera	Krakeend	Gadwall		X	
Mergus merganser	Grote zaagbek	Common Merganser		X	
Mergus serrator	Middelste zaagbek	Red-breasted Merganser		X	
Numenius arquata	Wulp	Eurasian Curlew		X	
Phalacrocorax carbo	Aalscholver	Cormorant		X	

Names of bird species (Continuation)

Species name	Common name		Habitat Use***		
	Dutch*	English**	B	F	R
Platalea leucorodia	Lepelaar	Eurasian Spoonbill	X	X	
Pluvialis apricaria	Goudplevier	European Golden Plover		X	
Pluvialis squatarola	Zilverplevier	Grey Plover		X	
Podiceps cristatus	Fuut	Great Crested Grebe		X	
Recurvirostra avosetta	Kluut	Pied Avocet	X	X	
Somateria mollissima	Eider	Common Eider	X	X	
Spatula clypeata	Slobeend	Northern Shoveler		X	
Sterna hirundo	Visdief	Common Tern	X		
Sterna paradisaea	Noordse stern	Arctic Tern	X		
Sternula albifrons	Dwergstern	Little Tern	X		
Tadorna tadorna	Bergeend	Common Shelduck		X	
Thalasseus sandvicensis	Grote stern	Sandwich Tern	X		
Tringa erythropus	Zwarte ruiter	Spotted Redshank		X	
Tringa nebularia	Groenpootruiter	Common Greenshank		X	
Tringa totanus	Tureluur	Common Redshank		X	
Vanellus vanellus	Kievit	Northern Lapwing		X	

* See Dutch ‘Staat van de Waddenzee 2025’ (Bogaart et al., 2025)

** Avibase - The World Bird Database, avibase.bsc-eoc.org

*** B means breeding, F means foraging, and R means roosting