Hydrographic Survey at the Vesterhav Syd Offshore Wind Farm in July 2025

Scientific note from DCE – Danish Centre for Environment and Energy

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Data sheet

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1 Preface

This technical note contributes to the project "Environmental mapping and screening of areas for offshore wind in Denmark" initiated in 2022 by the Danish Energy Agency. The project aims to support the long-term planning of offshore wind farms by providing a comprehensive overview of the combined offshore wind potential in Denmark. It is funded under the Finance Act 2022 through the program "Investeringer i et fortsat grønnere Danmark" (Investment in the continuing greening of Denmark). The project is carried out by NIRAS, Danish Centre for Environment and Energy (DCE) - Aarhus University and DTU Wind.

The overall project consists of four tasks defined by the Danish Energy Agency (https://ens.dk/energikilder/planlaegning-af-fremtidens-havvindmoelleparker):

1. Sensitivity mapping of nature, environmental, wind and hydrodynamic conditions.

2. Technical fine-screening of areas for offshore wind based on the sensitivity mapping and relevant technical parameters.

3. Assessment of potential cumulative effects from large-scale offshore wind development in Denmark and neighboring countries.

4. Assessment of barriers and potentials in relation to coexistence.

This technical note addresses one component of Task 1 (sensitivity mapping of hydrodynamic conditions). Specifically, the note presents results from a hydrographic survey at the Vesterhav offshore wind farm (North Sea) during early July 2025. Profiles of temperature, salinity, turbidity, fluorescence and PAR (photosynthetically active radiation) were collected along 3 transects inside, west and east of the offshore wind farm. The project management teams at both AU and NIRAS have contributed to the description of the relation to other activities in the preface. This technical note and the work contained within are solely the responsibility of the author.

2 Introduction

A field survey was carried out at the Vesterhav Syd offshore wind farm (OWF) in the North Sea to measure water properties within the OWF as well as conditions at approximately 700 m outside the OWF's eastern and western boundaries. Water column sampling was performed using a Seabird CTD profiler equipped with ancillary sensors collecting vertical profiles of temperature, conductivity, depth (pressure), turbidity, fluorescence and photosynthetically active radiation (PAR) along three transects. The aim of this sampling campaign was to (a) obtain observational data within and around OWFs, where measurements are currently sparse and (b) provide supplementary data for comparison with results from the North Sea hydrodynamic FlexSem model used in the screening project.

3 Sampling and Data Processing

esterhav Syd is an OWF in the Danish North Sea owned and operated by Vattenfall. It is located approximately 9 kilometers off the coast of West Jutland between Søndervig and Hvide Sande (Fig. 1). The wind farm is arranged in a single line comprising 20 turbines orientated in a north-south direction. Vertical profiles of hydrographic parameters temperature, conductivity and depth (pressure) in the water column were collected onboard the FOGA ApS vessel 'Arctic Ocean' using a Seabird SBE 19plus V2 SeaCAT Profiler CTD system. Additional sensors on the CTD were a combined fluorescence and turbidity sensor (WET Labs ECO-AFL/FL) and a PAR sensor (Satlantic). PAR distributions showed little consistency with the fluorescence and turbidity data and are therefore not included in this technical note, as they remain under further examination. CTD profiles (two repeat casts per station) were carried out along three transects: one located within the OWF and two positioned outside the OWF, approximately 700 m from its boundaries on either side (Fig. 1).

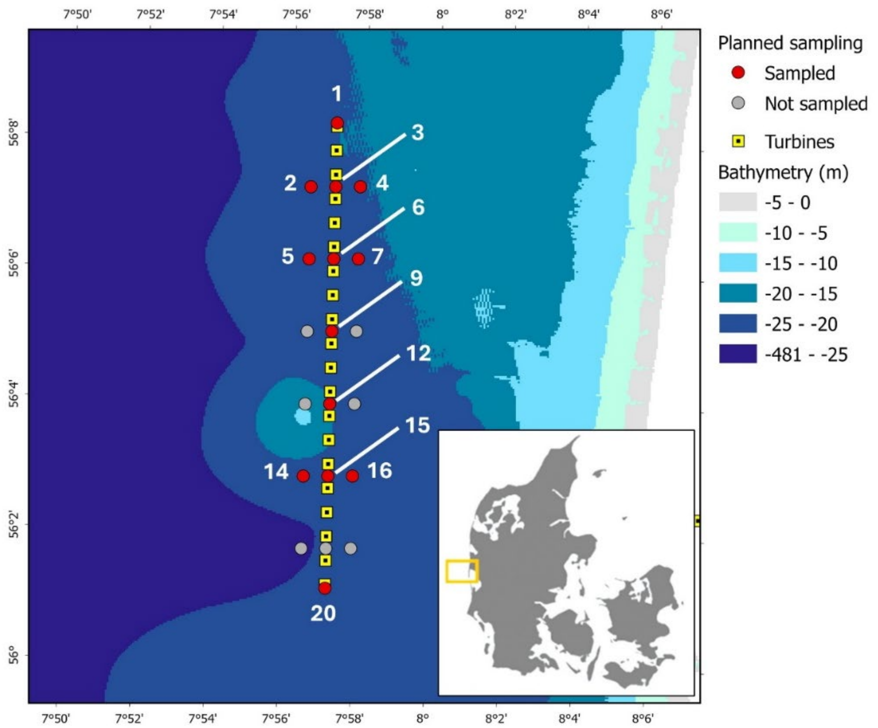

Figure 1. Sampling design and CTD station locations during the July 2025 Vesterhav Syd OWF survey. The location of Vesterhav Syd OWF is shown in the map. The numbers indicate the sampled CTD station numbers based on the original sampling design.

Although the original sampling design specified 20 CTD stations, the total number of CTD stations was reduced to 13 (mainly outside the OWF) because of time constraints associated with additional sampling demands from collaborating research teams and increasingly challenging weather conditions. Despite these adjustments, we successfully managed to cover almost the entire central OWF area (see Fig. 1). Station numbers, positions and times are listed in Table 1 below:

Table 1. CTD station numbers, positions and sampling times. Two CTD casts were conducted at each station within the specified time range.

Station No	Longitude	Latitude	Time (local)
			1-July-2025
1	007° 57’197 E	56° 08’608 N	12.59 – 13.47
2	007° 56’530 E	56° 07’294 N	14.13 – 14.37
3	007° 57’202 E	56° 07’318 N	14.46 – 15.03
4	007° 57’886 E	56° 07’322 N	15.15 – 15.34
5	007° 56’575 E	56° 06’192 N	15.55 – 16.17
6	007° 57’206 E	56° 06’208 N	16.25 – 16.42
7	007° 57’867 E	56° 06’217 N	16.54 – 17.15
			2-July-2025
9	007° 57’214 E	56° 05’102 N	07.30 – 07.39
12	007° 57’230 E	56° 03’984 N	07.53 – 08.15
14	007° 56’537 E	56° 02’873 N	08.34 – 08.57
15	007° 57’223 E	56° 02’886 N	09.07 – 09.30
16	007° 57’890 E	56° 02’877 N	10.03 – 10.20
20	007° 57’239 E	56° 00’833 N	10.49 – 11.31

The CTD data along with data from ancillary sensors were processed using the Seabird SBE data processing software Seasoft V2 (Release 7.26.7) (Seabird, 2014). The main data processing steps are highlighted below (SBE processing modules in parentheses):

- Conversion of raw to text data (Datcnv).
- Low pass filtering of pressure, temperature, conductivity and fluorescence to smooth high frequency data outliers (Filter).
- Mark scans where CTD is moving less than minimum velocity or traveling backwards due to ship roll (Loopedit).
- Derive additional variables potential temperature (°C) and potential density σ_T (kg m^{-3}) (Derive).
- Average data into 0.5 dbar pressure bins (Binaverage).

4 Dataset Description

This section provides an overview of the dataset, summarizing its main characteristics and highlighting key initial findings.

CTD transects inside Vesterhav Syd OWF

The hydrographic and biogeochemical distributions along the transect inside the Vesterhav Syd OWF reveal weakly stratified, but spatially variable, water column properties during both sampling casts (Fig. 2). Temperature shows a distinct vertical gradient, with surface waters reaching around 17.5–18 °C and decreasing to below 16 °C toward the seafloor. Both sampling casts show a similar overall temperature range and spatial variability. The most prominent feature is a wave-like pattern characterized by isothermal doming near the center of the OWF transect, which may reflect localized upwelling of cooler bottom water or the advection of warmer surface waters that become laterally diverted by the OWF structures.

Salinity varies between approximately 31.3 and 32.8 psu, with fresher water near the surface and more saline water at depth, particularly toward the southern stations. Salinity generally follows the temperature pattern, showing higher values in the thermally uplifted zone at the OWF center. Consequently, density increases in this area within the upper 11 m, with less dense waters observed toward the northern and southern OWF boundaries.

Fluorescence intensity is highest within the upper 5–13 m of the water column, reflecting an active subsurface phytoplankton layer confined to the euphotic zone. Localized surface maxima, especially evident in Cast 1, may indicate patchy phytoplankton distributions influenced by small-scale hydrodynamic variability or wake-induced mixing near turbine foundations. Below the surface layer, fluorescence decreases, consistent with reduced light and possible light limitation. Turbidity values remain low throughout both transects (< 2 NTU), with slightly enhanced levels near the seabed and occasional surface peaks that could be linked to resuspension or biological particle aggregation.

Overall, the transects suggest a moderately stratified system typical of summer conditions in the southern North Sea with localized biological variability. Within the OWF, the observed horizontal and vertical gradients may reflect the combined influence of wind forcing, shallow bathymetry, and the hydrodynamic perturbations of local or advected water masses associated with turbine structures.

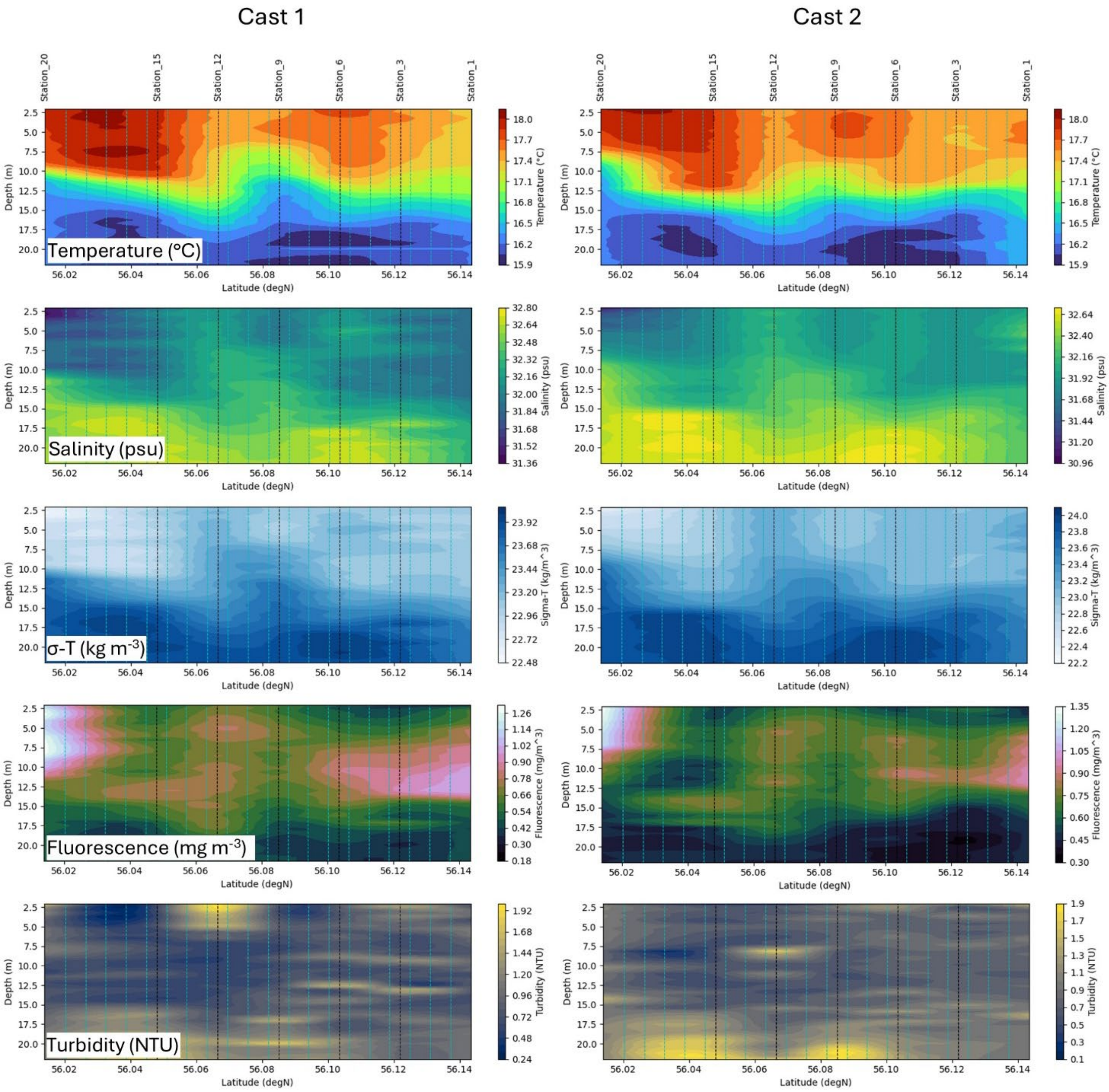

Figure 2. S-N transects of (from top to bottom) temperature (°C), salinity (psu), density σ-T (kg m^{-3}), fluorescence (mg m^{-3}) and turbidity (NTU) during two CTD casts collected within < 1 hour at each CTD station. The black vertical lines indicate station locations, the blue vertical lines indicate OWF turbine locations.

Water mass (T-S) properties

The Temperature–Salinity (T–S) relationships observed west of, inside, and east of the Vesterhav Syd OWF show consistent overall patterns, with small, but notable, differences in water mass characteristics between regions (Fig. 3). Across all locations, temperature decreases with increasing salinity, forming a well-defined inverse T–S gradient typical of weakly stratified North Sea conditions. The data are mainly grouped along a narrow mixing line, suggesting the presence of two principal water mass end members: a warmer, fresher surface layer, and a cooler, more saline subsurface layer.

At the eastern stations (green), salinities are lowest in the temperature range 17 – 18 °C, indicating the influence of relatively fresh and warm coastal or near-shore waters. Within the OWF (dark blue), the T–S curve shifts toward slightly higher salinities at comparable temperatures, indicating enhanced vertical or lateral mixing that brings more saline subsurface water upward, consistent with the doming pattern observed in the hydrographic transects shown in Fig. 2. West of the OWF (light blue), T-S conditions showed the most saline waters, indicating the influence of horizontal advection from the open North Sea.

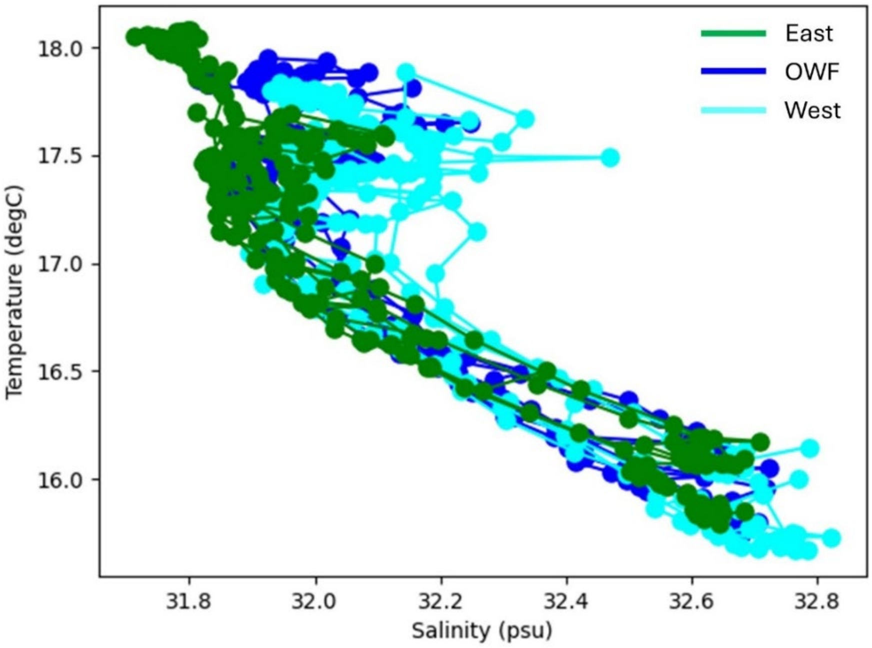

Figure 3. Temperature–Salinity (T–S) relationships derived from all CTD casts conducted at similar latitudes west (cyan), within (dark blue), and east (dark green) of the Vesterhav Syd OWF.

5 Summary and Outlook

The CTD profiles collected across the offshore wind farm (OWF) region have great potential to provide valuable insights into the hydrographic structure and short-term variability of the local water column, both inside and outside the OWF. The measurements revealed clear spatial gradients in temperature and salinity, as well as indications of localised mixing and stratification patterns within and around the OWF. These observations suggest that the presence of the turbine array may influence small-scale hydrographic features, either through enhanced vertical mixing or local changes in circulation and water mass propagation. Additionally, fluorescence and turbidity data highlight variations in biogeochemical conditions that could be linked to hydrodynamic modifications or biological responses in the OWF environment.

While the dataset represents a robust snapshot of conditions during the survey period, it also illustrates a key limitation of such measurements. CTD casts capture instantaneous states of the water column, which can vary considerably due to tides, meteorological forcing and seasonal stratification. Consequently, single-survey observations provide essential baseline information, but are insufficient to fully characterise dynamic OWF-driven processes or their long-term ecological implications.

Continuous monitoring efforts inside and around OWFs are crucial to separate natural variability from OWF effects. Repeated or autonomous CTD profiling, complemented by moored sensors and numerical modelling, would allow resolving the temporal evolution of hydrographic structures and quantifying the cumulative impacts of turbine-induced mixing. Such integrated approaches are fundamental for advancing our understanding of how offshore wind developments interact with the surrounding marine environment and for supporting environmentally sustainable expansion of offshore renewable energy.

6 References

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7 Acknowledgements

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