Defining a haul-out indicator for removal of crab-pot-strings in Offshore Windfarms under anticipated adverse weather conditions

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Contents

Summary

Crab-pot-strings with dahns and Bruce anchors have to be taken out of the water once sea conditions get too adverse. But what is exactly considered too adverse? The potential mobilisation of crab-pot-strings with dahns and Bruce anchors is a complex process not easily captured in a single indicator like wind force. An indicator was developed in this project on the base of the mechanisms of mobilisation (currents and waves hauling on the dahn). The $Indicator_{Haul\text{-}out}$ was assembled based on Maximum extra Water Level as compared to Normaal Amsterdam Peil (= wind surge as a measure for currents), Swell and Average Significant Wave Height over 10 min. periods.

A threshold of the $Indicator_{Haul\text{-}out}$ was defined for haul-out. When an $Indicator_{Haul\text{-}out}$ value is predicted of 445 cm using the predictions at Hoek van Holland and Eurogeul 13, the crab-pot-strings will be hauled out before this value will occur. Wageningen Marine Research will calculate this value during the entire experiment planned in PAWP in 2023. As an extra safeguard, two fishermen will also observe the weather and sea condition predictions. They will also give a warning when, based on their experience, sea condition gets too adverse for safe deployment of the strings. In both cases the project leader of Wageningen Marine Research will open a dialogue with the project leader of Eneco on how to proceed. The project leader of Eneco has the final decision on the obligation for haul-out.

1 Introduction

With the rapid upscaling of offshore wind farms (OWFs) on the North Sea, pressures are mounting on e.g. nature and fisheries. Successful development and exploitation of OWFs requires integration in the environment, in terms of ecology and in relation to other users. Multi-use and nature inclusive design are used to meet these wishes and needs.

Passive crab-pot-fisheries (gear code FPO) is considered to be a viable option of multi-use in OWFs. To enable this form of multi-use, several research projects are conducted like the TKI financed Win-Wind project. In Win-Wind a collaboration was established between the Government of the Netherlands, Eneco and the consortium Win-Wind to perform crab-pot-fisheries in Prinses Amalia Wind Park (PAWP). Part of this collaboration agreement was a work method statement (WMS, Rozemeijer et al., 2020). In this WMS the outline, structure and implementation of the proposed experiment were determined, dealing with the risks associated to working in an industrial environment with high voltage and in a dynamic, harsh and unpredictable environment such as the North Sea.

A major risk determined was the mobilisation of crab-pot-strings (Figure **1**) by heavy currents and waves resulting in drifting crab-pot-strings and eventually possibly anchors hitting and damaging infield-electricity-cables (Rozemeijer et al., 2020). Several studies were conducted on the damage and chance aspects of Bruce anchors in relation to this risk of damaging infield-electricity-cables (Rozemeijer et al., 2021a, 2021b, 2022a, 2022b, 2022c). The overall conclusion was that there was a low chance of mobilising the crab-pot-strings and a low damage when a Bruce anchor came in contact with the infield-electricity cables at more than anticipated force resulting in a low Risk (the minimum value of 1 in a range of 1-5 in Risk systematics, International Maritime Organisation, 2018).

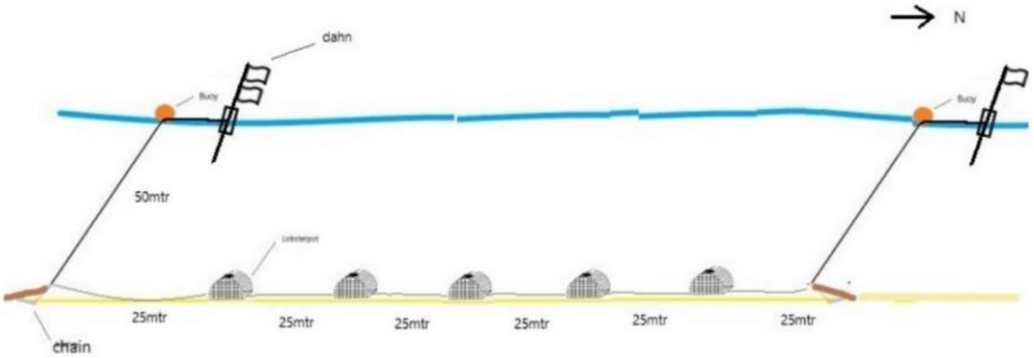


Figure 1 Crab-pot-strings with five pots and two chains. Next to the buoy a dahn is attached (buoy with flag(s), counterweight and radar reflector). The double flag indicates the most southern buoy of the string. A single flag indicates the most northern buoy. In this set up mutual distance between the pots is 25m but 40m is used as well for statistical reasons (Skerrit, 2014).

1.1 Problem statement

In the WMS (Rozemeijer et al., 2020) no conditions were defined to haul out the crab-pot-strings with predicted bad weather. In field experiments different set-ups of crab-pot-strings were tested under different sea conditions during the summer (Rozemeijer et al., 2021a, 2022a). With these results it is now possible to define a first tentative haul-out indicator ($Indicator_{haul\text{-}out}$).

1.1.1 Research question

Define an $Indicator_{haul\text{-}out}$ based on the field experiment with crab-pot-strings results which can be used as a predictor for preventive haul-out of crab-pot-strings to prevent mobilisation of crab-pot-strings and anticipated damage to infield-electricity-cables.

2 Materials and Methods

In general pot fisheries (gearcode FPO) on crab and lobster are performed with chains because anchors have a low holding performance in the stony seabed and hard substrates that are a typical habitat for brown crab. In general fishermen experience that dahns destabilise the crab-pot-strings (C. Meeldijk, pers. obs.). Usually round Polyform A1 buoys (fenders) are used to mark the positions of the crab-pot-strings. Both because of legal requirements (EU 2005, 2011) and better visibility for Crew Transfer Vessels (CTVs) operating in the OWF (Rozemeijer et al., 2020), dahns are obligatory to mark the crab-pot-strings in PAWP.

Accordingly different set-ups were tested with dahns, Polyform A1 buoys, Bruce anchors and chains.

2.1 General set up

Since no assurance was yet achieved on the behaviour of crab-pot-strings with dahns and Bruce anchors, it was decided to test the set-up near wrecks. Several expeditions were performed near wrecks near Scheveningen. Wrecks were chosen as test locations to reduce the risk of being damaged by beam trawls. The vessel Perseverance (SCH61) was used, departing from the harbour of Scheveningen. At the wrecks Adder, Houtrust and Key West different set-ups of crab-pot-strings were deployed. Proximity of wrecks was chosen as a location to reduce the risk of crab-pot-strings being caught by beam trawling. These wrecks were chosen because of their close proximity to Scheveningen. Circumstances in weather and hydrography are most likely similar to PAWP (Caires & Pathirana, 2019). Also the seabed dynamics are comparable (Smaal et al., 2017).

2.2 2019 & 2020 tests

Several tests were performed (Table 1). In October/November 2019, four crab-pot-strings with three pots were tested, with only Polyform A1 buoys and a pick-up marking.

On March 4, 2020, four crab-pot-strings with five pots were put into the sea, now with a buoy and a dahn including lighting and radar reflectors etc.. These were picked up on March 7, 2020.

On March 7, 2020, one crab-pot-string with five pots was put back into the sea. After a severe storm, March 14, 2020 was the first possibility (due to weather conditions) to pick up this crab-pot-string. This crab-pot-string was lost and searched for. The search survey extended maximally 2,778m north eastern direction.

Another test was carried out in August 2020. In the chains weights were doubled to 80 kilos on half of the crab-pot-strings. Four crab-pot-strings with five pots were put into the sea, now with a buoy and a dahn including lighting and radar reflectors. Two crab-pot-strings had Polyform A1 buoys, one with 40 kg chain bunches and one with 80 kg chains. Two crab-pot-strings had dahns, one with 40 kg chains and one with 80 kg chains. First deployment was 04-8-2020 with subsequent checks (haul-out and deployment) on 12-8-2020 and pick up at 18-8-2020 (Table 1).

Table 1 overview of the performed tests and the set-up of the crab-pot-strings.									
Start date	*End date*	*Number of strings*	*Number of pots*	*Dahns*	*Polyform buoys A1*	*Chains 40 kg*	*Chains 80 kg*	*Bruce anchors*	*Displace-ment*
23-10-2019	31-10-2019	4	3		x	x			no
31-11-2019	8-11-2019	4	3		x	x			no
8-11-2019	16-11-2019	4	3		x	x			no
4-3-2020	7-3-2020	4	5			x			yes
7-3-2020	14-3-2020	1	5	x		x			lost
04-8-2020	12-8-2020	4	5	x		x			yes
12-8-2020	18-8-2020	4	5	x	x	x	x		dahns
18-8-2020	24-8-2020	4	5	x	x	x	x		dahns
1-08-2021	18-09-2021	6	5	x				1 or 2	1* 1 anchor

2.3 2021 tests

At the earlier mentioned wrecks each two crab-pot-strings were deployed: one westward and one eastward of the wreck. One of the strings was equipped with one Bruce anchor on each side, the other string was equipped with two Bruce anchors on each side. The positions eastward or westward of the wreck was switched when possible during a sea expedition. The crab-pot-strings were placed parallel to the prevailing current direction at 15 to 50 meters distance to the wrecks.

At each expedition day the displacement of the strings was determined. In addition the strings were hauled for a check on damage of the string and to prevent excessive accumulation of sediment that will prevent any mobilisation by currents or waves. A heavily sedimented string is not representative for crab pot fisheries where the strings are hauled on a regular basis.

3 Results

3.1 Displacement

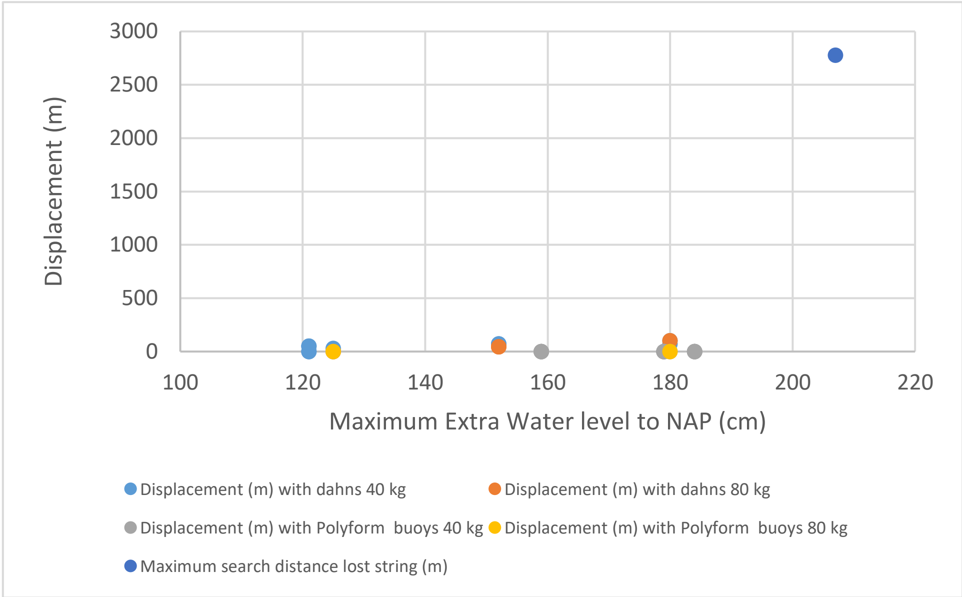
In the tests it appeared that the combination of dahns with chains is an instable setup. At maximal water level as compared to Normaal Amsterdam Peil (NAP, Wind surge, a measure for currents[1]) of 1.21 m and higher, crab-pot-strings with dahns were mobilised (Figure 2A,B). At 2.07 m maximum water level as compared to NAP the tested crab-pot-string disappeared beyond the 2,778 m stretching search survey. Half-moon shaped searches were made of maximally 2,778m extent (1.5 nautical mile) in the direction of the flood current (North East) of the original position but the crab-pot-string was not found (Rozemeijer et al., 2022a).

No difference was found between anchoring chains of 40 kg or 80 kg. The crab-pot-strings setups with fenders (polyform A1 buoys) were stable with water levels as high as a maximal water level as compared to NAP of 1.80m.

With these results, a risk evaluation session was held with the stakeholders (Eneco, CTV services, Ministry of Agriculture, Nature and Food Quality, Rijkswaterstaat and team members, 14-01-2021) where the use of fenders instead of dahns was discussed. Eneco accepted the use of fenders in the assurance that positions of the crab-pot-strings would be made known to all CTV captains (WMS, Rozemeijer et al., 2020). In addition, every time upon redeployment, the new, perhaps slightly deviating, positions were to be reported to both Eneco and the Coast Guard. However, the use of fenders alone is not allowed by EU fisheries legislation and the dahns with registration numbers of the fishery vessel are obligatory (EU 2005, 2011). No exemption on this EU legislation could be made on a national level since granting permission pertains to the European competent authority.

[1] Wind surge (also known as wind set-up, wind effect or storm effect) is the increase in the water level at sea or in a lake because the wind blows the water in one direction. Because the wind blows over the surface of the water, the wind exerts a shear force on the water. This force wants to make the water flow (wind-driven current). In this case it is used as a proxy for currents since current measurement are scare at the North Sea.

A



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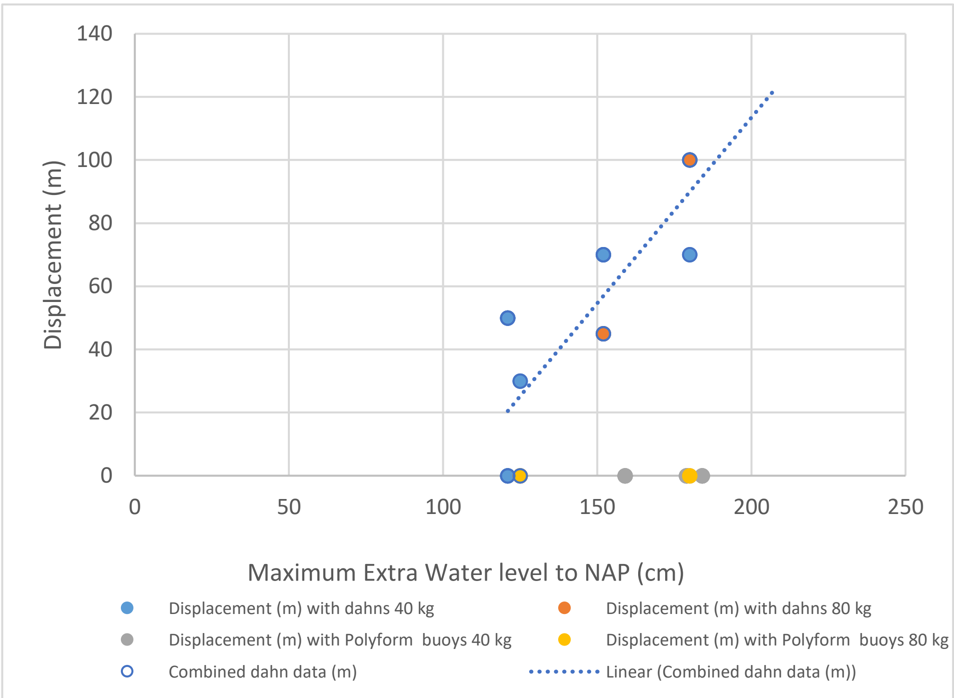


Figure 2 Displacement of the crab-pot-strings with dahns & chains and crab-pot-strings with polyform A1 buoys & chains in relation to Maximum water level compared to NAP (cm). The point 2,778m displacement is an imaginary figure since this string was completely lost and untraceable. The search survey extended maximally 2,778m north eastern direction. The two points of 45 m displacement were averaged over an estimated range of displacement of 40-50 m.

A: with the data point of the lost crab-pot-string.

B: without the data point of the lost crab-pot-string.

3.2 Mechanisms

Crab-pot-strings with dahns have the chance to be mobilised under adverse circumstances whereas crab-pot-strings with A1 polyform buoys have lower chance for mobilisation (Rozemeijer et al., 2022a). In a mechanistic analysis, explanations are found in differences in two different pulling forces: pulling by currents and pulling by waves.

1) Dahns have more surface in the water than A1 polyform buoys (fenders) thereby being subject to the pulling force of currents. The used dahns had a length of 5.80 m and a diameter of the floating body of 0.30m on average. The lateral surface of the combination of floating body/ pole under water/ stabilizing weight is approximately 0.3 m^2. The dahn's own weight is about 15 kg. Upward buoyancy is approximately 20 kg maximum. A1 Polyform buoys have a height of 0.39 m and diameter of 0.32 m. Weight of A1 Polyform buoys is 1 kg. The buoyancy force max. 16 kg. The lateral surface is max. 0.1 m^2 when fully immersed. Simply put, in swell and currents, at least 3 times as much force is exerted on the anchorage of dahns as compared to the polyform buoys by flow resistance as with wind, due to 3 times as much lateral surface area in the water.

2) Also the differences in reaction to waves play an important role. The dahns pull in a vertical direction pulsating with a mass of 15 kg to the anchorage instead of the 1 kg of the polyform buoys.

Of minor importance, the force of the wind on an A1 polyform buoy is also less than the force on the protruding part of a dahn above the water.

3.3 Indicator

So currents and waves should be the main attributes to an indicator for the preventive haul-out of crab-pot-strings in PAWP rather than wind force. Currents are not measured in high resolution. The current is well approximated by Maximum Water Level as compared to NAP. Additionally swell is important in currents and pulling the dahn under water. The wave aspect is well described with the Maximal 10 min. Averaged Wave Height. These three variables are predicted regularly thereby being available for forecasting. The indicator can be defined as:

Equation 1

$Indicator_{Haul\text{-}out}$ = (Maximum Water Level to NAP) + Swell + (Maximal 10 min. Averaged Wave Height)

All in cms (in this case or meters).

3.4 Application

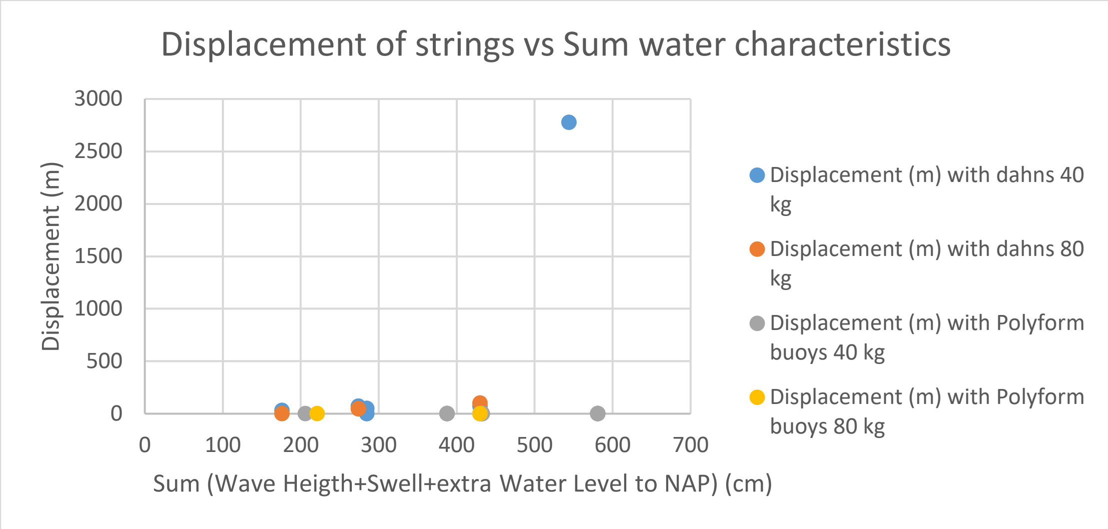
To test the $Indicator_{Haul\text{-}out}$, the results of the displacements of the crab-pot-strings of 2019 and 2020 tests were plotted vs the $Indicator_{Haul\text{-}out}$ (Figure 3A with all results and Figure 3Figure 3B leaving out the most extreme value). The results of the strings equipped with dahns and chains of 40 or 80 kg showed a significant correlation with the $Indicator_{Haul\text{-}out}$. Leaving out the extreme value a correlation was established between displacements (Y) vs $Indicator_{Haul\text{-}out}$ (X):

Equation 2 $Y = 0.265939X - 32.2465$

$R^2 = 0.416671; p : 0.0234$

Note that for the polyform buoys the maximum value was higher than that of the most extreme value of the dahns, confirming the mechanism (Figure 3A,B).

A



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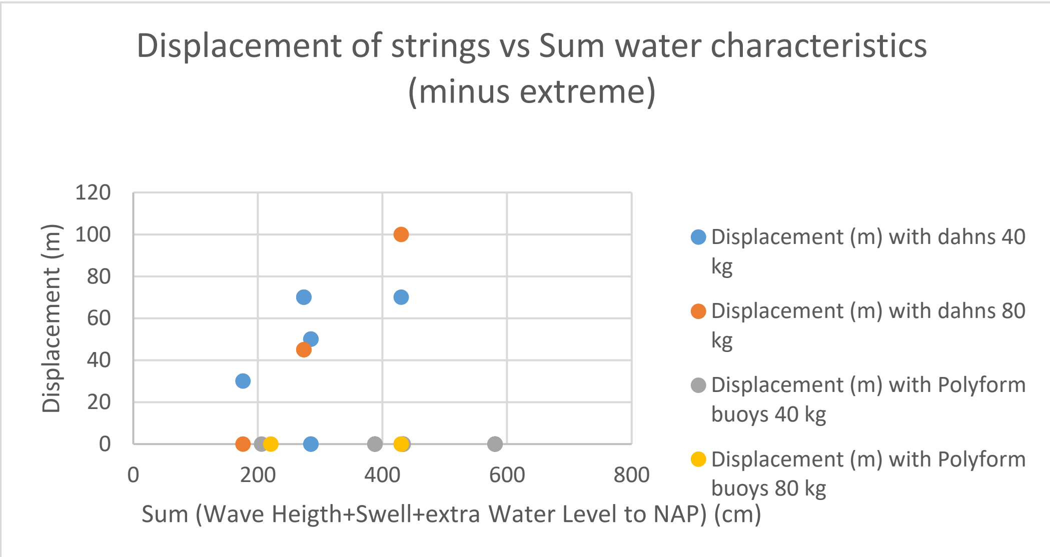

Figure 3 applying the Indicator$_{\text{Haul-out}}$ (Equation 2) on the crab-pot-string displacement results of 2019 and 2020. Strings were equipped with dahns and chains of 40 or 80 kg and with polyform buoys and 40 or 80kg chains. A: all results, B: leaving out the extreme value of 2778 m displacement after 17.5 m/s wind force (8 Bft) (Korving et al., 2021, Rozemeijer et al., 2022a).

3.5 Natural dynamics

In Figure 4 and Figure 5 relations are depicted between the Indicator$_{\text{Haul-out}}$ and wind force with data from 2019 plus 2020 and 2021 respectively. In both cases only the positive values were used in order to simplify information. In both cases there is a positive correlation between the Indicator$_{\text{Haul-out}}$ and wind force with wind being the driving force generating extra water height, swell and waves. Observing e.g. the seemingly two data clouds (two different circumstances) in Figure 4 and three data clouds (two different circumstances) in Figure 5, suggest that local circumstances and specific development are important. For 2019 and 2020 together (encompassing 23-10-2019 to 16-11-19; 4-3-2020 to 14-3-2020 and 4-8-2020 to 24-8-2020; autumn, winter and summer) the Indicator$_{\text{Haul-out}}$

ranges from 0 to 581 cm. In 2021 (just the summer period) the $Indicator_{Haul\text{-}out}$ ranges from 0 to 445 cm.

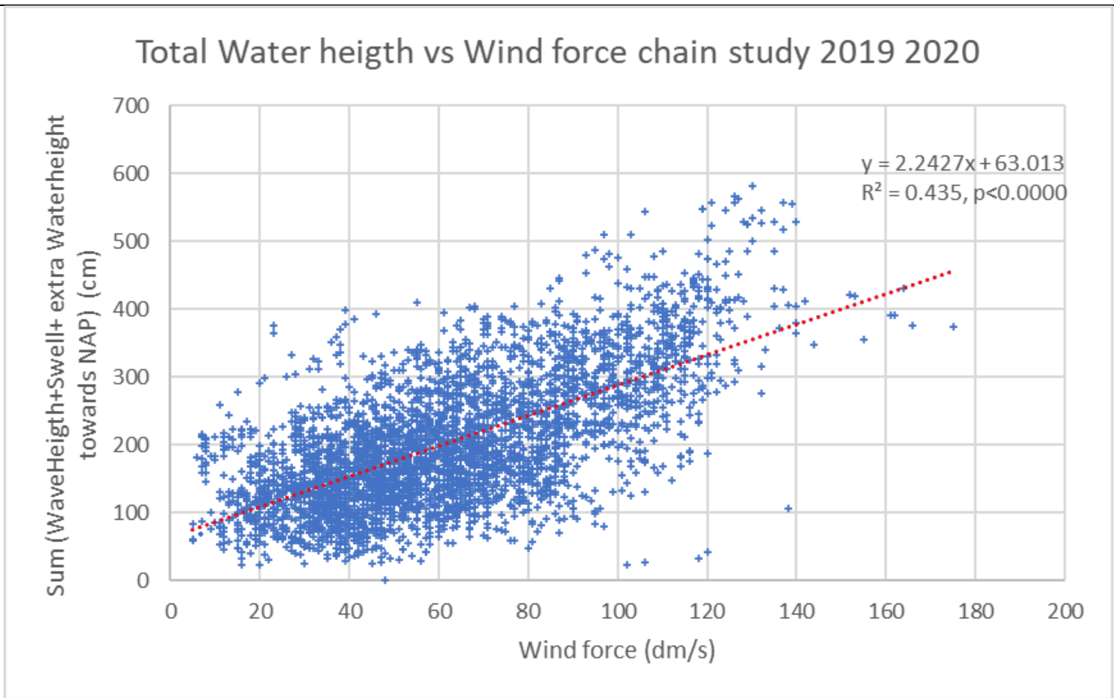

Figure 4 Relation between the $Indicator_{Haul\text{-}out}$ (Equation 1, Sum (Wave Heigth+Swell+extra Water Height towards NAP) (cm)) and wind force for 2019 and 2020 (data from Rozemeijer et al., 2022a).

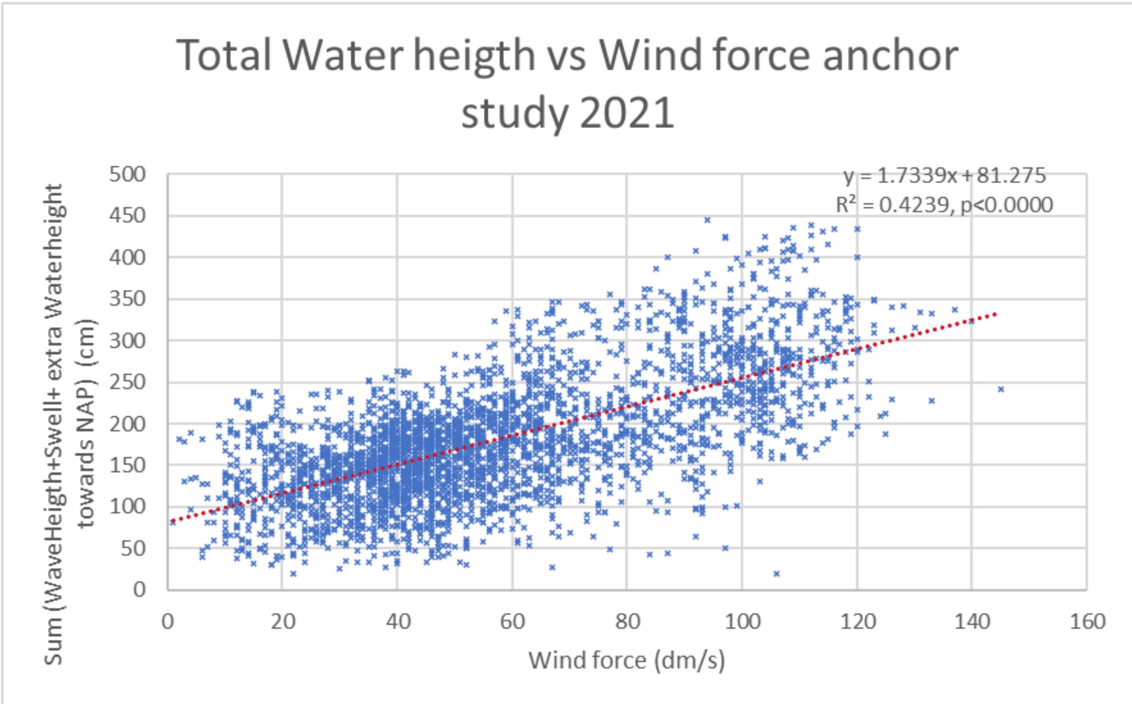

Figure 5 Relation between the $Indicator_{Haul\text{-}out}$ (Equation 1, Sum (Wave Heigth+Swell+extra Water Height towards NAP) (cm)) and wind force for 2021 (data from Rozemeijer et al., 2021b).

3.6 Defining threshold value

A threshold value is needed for preventive haul-out of crab-pot-strings in PAWP, together with a procedure between how to apply the threshold. This section defines the threshold. In the summer of 2021 no crab-pot-string were mobilized with the $\text{Indicator}_{\text{Haul-out}}$ values up to 445 cm. For 2019 and 2020 all the $\text{Indicator}_{\text{Haul-out}}$ values of >445 cm are either November or March. The highest $\text{Indicator}_{\text{Haul-out}}$ value in the summer of 2020 was 440 cm. The strings with polyform buoys and chains were not mobilized by an $\text{Indicator}_{\text{Haul-out}}$ of 581 cm. The strings with dahns and chains were already mobilised at a $\text{Indicator}_{\text{Haul-out}}$ of 176 cm.

Based on this first limited analysis a calculated threshold value for the $\text{Indicator}_{\text{Haul-out}}$ of 445 cm (highest summer value with no mobilisation) seems a first logical approach in combination with the procedure described below.

4 Discussion, conclusions and recommendations

4.1 Procedure

As indicated on the correlations between $Indicator_{Haul-out}$ and wind force (Figure 4, Figure 5) local circumstances and local history in wind force and wind direction are very important. Also the fact that three variables need to be predicted and summed adds to the uncertainty. On the other hand experience with complex dynamics and (un) predictability of the North Sea are part of the knowledge from experience of both fishermen and OWF operators. Therefore it seems better to embed the use of the $Indicator_{Haul-out}$ in a procedure using both aspects of predictions and knowledge from experience.

1) The $Indicator_{Haul-out}$ is continuously calculated by the project leader of Wageningen Marine Research using https://waterberichtgeving.rws.nl. Once the threshold value is predicted, HSE manager Eneco, project leaders Eneco and Wageningen Marine Research, fisherman partner in the Win-Wind consortium and executing fisherman are warned. The predicted situation is discussed for the appropriate action plan.
2) Simultaneously OWF operators, and fishermen are alert and observe weather and circumstances. WMR project leader asks all three every Monday during the fishing period for their evaluation for the coming period at stack whether there is a risk for crab-pot-string mobilizing circumstances.
3) Project leader WMR actively seeks weekly contact with project leader Eneco to evaluate the predictions. If Eneco desires a haul-out it will be done. WMR can decide on haul-out too at lower levels of $Indicator_{Haul-out}$ when the situation urges to such.

4.2 Concluding

An $Indicator_{Haul-out}$ with threshold and evaluating procedure are defined. The WMS (Rozemeijer et al., 2020) can be adapted for this aspect since it was still not defined. This will be done for the crab-pot-string experiment 2023 in PAWP.

4.3 Points to elaborate from this point

The $Indicator_{Haul-out}$ threshold and procedure will be evaluated with the results of crab-pot-string fisheries in Borssele II 2022 and the results of the crab-pot-string fisheries in PAWP (2023).

5 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

The Chemical and Benthos laboratory has an EN-ISO/IEC 17025:2017 accreditation for test laboratories with number L097. This accreditation has been granted by the Dutch Accreditation Council. As a result, the Chemical and Benthos laboratory has demonstrated its ability to provide valid results in a technically competent manner and to work in accordance with the ISO17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

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Justification

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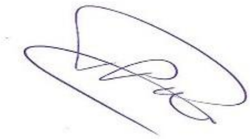
The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Linda Tonk
Researcher

Signature:
Date: 20 december 2022

Approved: dr.ir. TP Bult
Director



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