Small vessels for large waves

The daughter craft for wind farms far from shore

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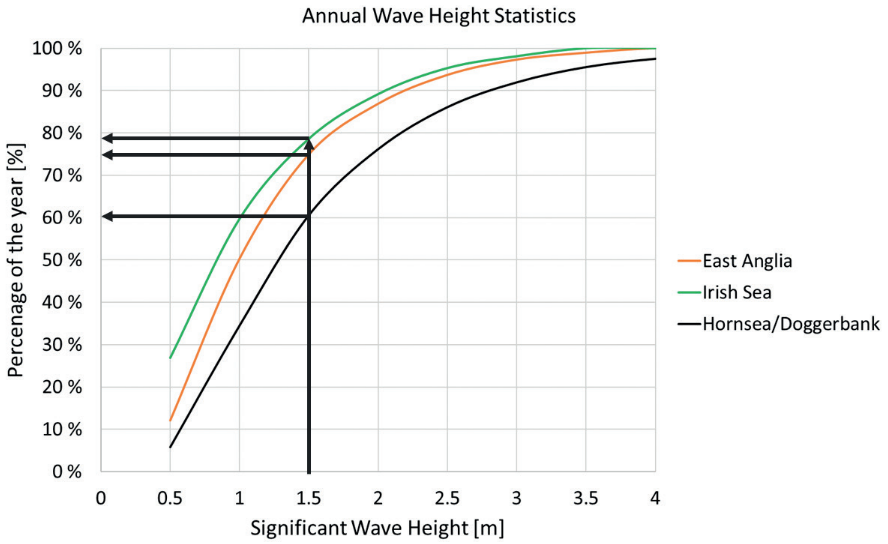
Over the last three years we have seen the introduction of purpose-built Service Offshore Vessels (SOV). These 70-100 m long vessels service wind farms, where a long distance to shore makes a land-based service organization impractical. Typically, 40-60 technicians live onboard the vessels and are transferred to the wind turbines with motion compensated walk-to-work gangways. A challenge for this operation is the efficiency of getting the technicians around the wind farm. The SOV transits at typically 10 knots and needs time for accurate positioning, to set out and also collect the personnel.

This is the background for using daughter craft. Deployed and retrieved by a davit system onboard the SOV, she can complement the gangway, shuttle between the SOV and turbines near and far throughout the wind farm. So far these daughter craft have been of similar type to existing small rescue crafts. Monohull, 10-12 m in length and weight 8-15 tons. But these small vessels can transfer to the turbines in limited wave height, typically up to 1 to 1.2 m significant wave height and will therefore get limited weather windows. An alternative is to use larger Crew Transfer Vessels (CTV) of 25-30 meter length that can stay 24/7 in the wind farm, however, with significantly increased cost, due to larger vessels with more manning and the need for transfer to the shore far away.

A daughter craft needs to be lightweight and small to operate from an SOV. But at the same time she should be able to operate in a large weather window. An offshore wind trend is that near-shore CTVs are getting larger. Many of the first CTVs were catamarans of 15-16 meter length, while now most newbuilds are 20-28 meter length. The most evident reason for this is the required increased operational weather window with increased operational wave height. This is illustrated in the following figure.

Significant wave height [m]	Wave height operability	
	Near shore wind farm	Far shore wind farm
1.0	50-60%	35%
1.5	75-80%	60%
2.0	85-90%	75%

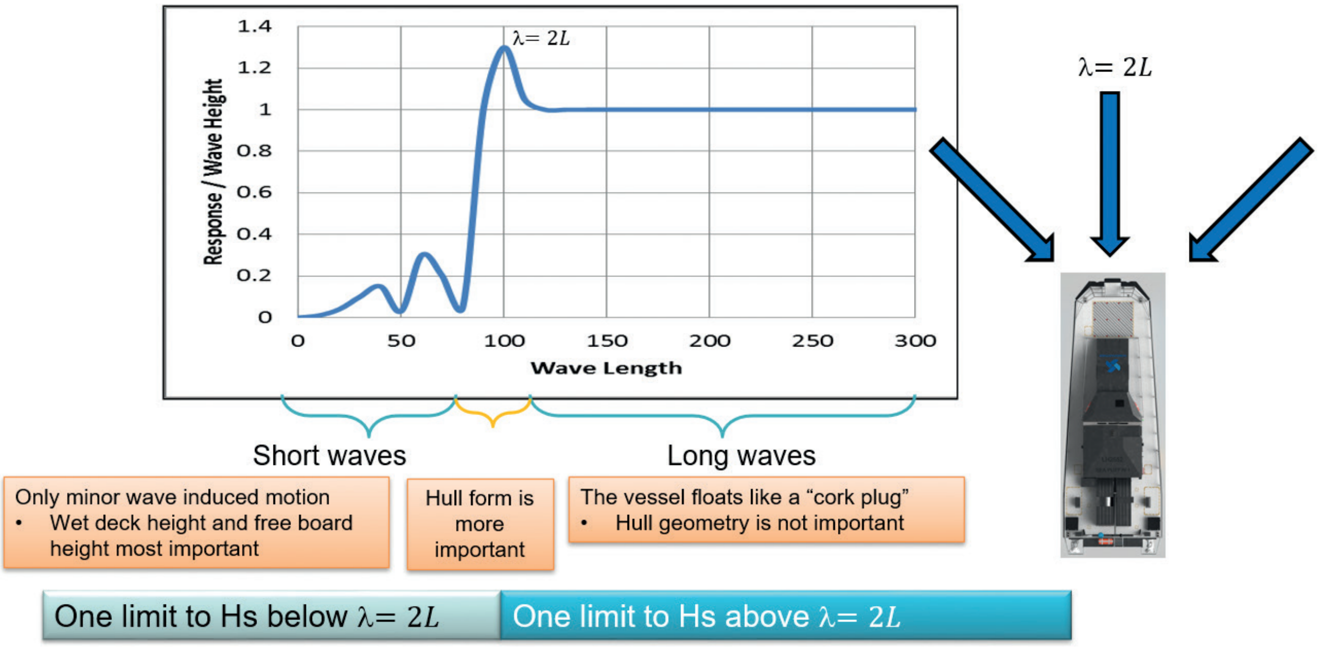
Using the mentioned wind farms as an example, this table shows typical weather windows for different operational wave heights.



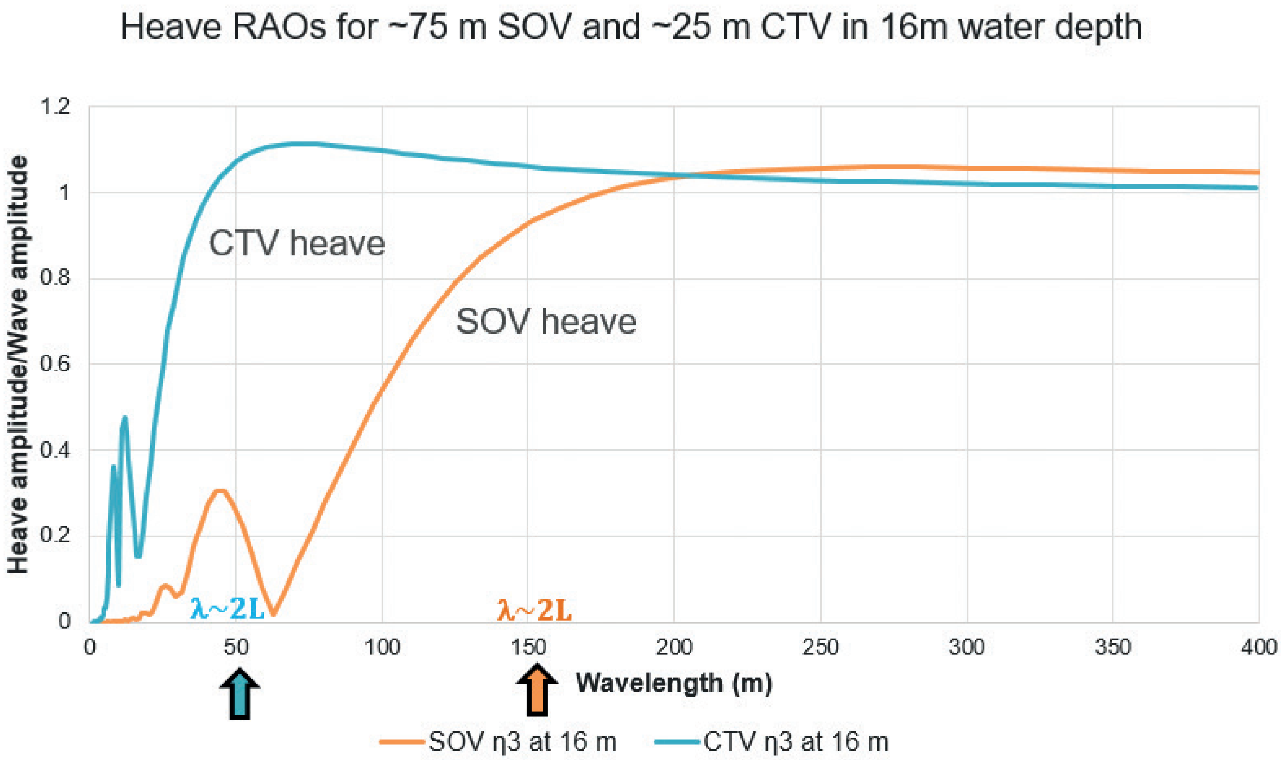
The figure shows yearly statistics of wave height for some European wind farm locations. East Anglia and Irish Sea wind farms are mostly served by land-based CTVs, while Hornsea and Doggerbank are further offshore and served by SOVs. The plots show that if a vessel can operate at average 1.5 m significant wave height, she will offer 75-80% operability in the near shore wind farms and 60% at Hornsea/Doggerbank.

Wavelength and vessel motions

The operational wave height for a vessel is all about the seakeeping of the vessel, how it reacts with different types and directions of waves. It is especially important to understand how the wavelength compares to the vessel size, as this is defining for the physics of the vessel motions. This should be considered when selecting a vessel type. Doing this we are able to distinguish between 'short waves' and 'long waves', where 'long waves' are when the wavelength is longer than twice the length of the vessel. The next figure illustrates this for vertical vessel motions with an RAO plot.



The figure shows a typical RAO plot for vertical vessel motions. λ means wavelength and L means length of hull. The curve shows how much vertical motions the vessel gets compared to the height of the wave. If the value is 1 the vessel moves 1 meter if the wave height is 1 meter. This is typical for swell; long waves where the vessel floats like a cork plug. If the waves are short compared to the vessel the vessel moves little. If the waves are typically exactly twice the length of the vessel the motions can be exaggerated. These types of motions are typical for all kinds of floating vessels and shapes.



The figure shows vertical motions of a typical 25 m CTV and 75 m SOV for different wavelengths. It clearly shows that at wavelengths that are typically 2 x vessel length the vessels float with the waves, e.g. value 1.0. It also shows that the SOV motions are favorable especially for wavelengths less than 100 meters.

In the following RAO curves are calculated for a typical 25 m CTV and a 75 m SOV.

The typical way of describing waves is with a significant wave height and a wave period. The significant wave height is the average of the ⅓ highest waves, and the wave period can be understood as the average time between each wave crest. This can be used to calculate the average wavelength, which also depends on depth. This is shown in the following figure.

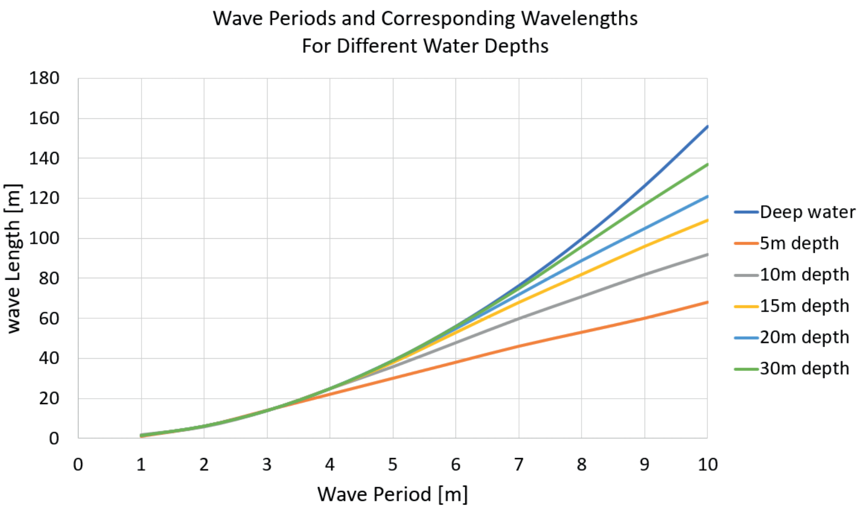
Generally near-shore wind farms are dominated by shallow draft and short periods of 4-6 s for relevant wave heights. The figure shows that this corresponds typically to 20-50 m wavelength, which has been shown in the calculation is favourable for > 25 m CTV, but might prove challenging for smaller vessels. Far from shore wind farms are dominated by longer periods 6-8 s and deep water, corresponding to 50-100 m wave length, which is more demanding for the 25 m CTVs but excellent for > 75 m SOVs.

Daughter craft for large waves

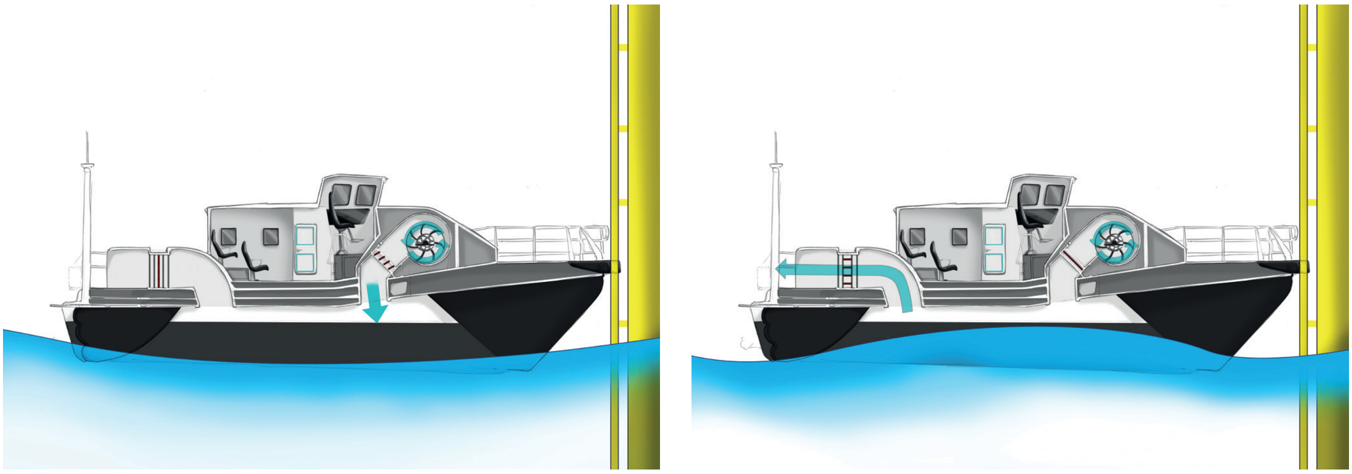
A main challenge for the offshore wind daughter craft is to safely access the offshore wind turbines in a wave climate that forces large vertical motions on the vessel.

As shown in the previous figures, the dominating wave is 'long', meaning the vessels will primarily float up and down with the wave period and with the same elevation as the waves.

ESNA has developed the Sea Puffin SES daughter craft especially for this, as the active SES motion damping can work very efficiently



The figures show how the wave period matches with wavelength. Most wind farms have been built in relatively shallow water, while the floating wind farms and far from shore wind warms typically are in deeper water. With a wave period of 7 seconds the wavelength in deep water is close to 80 meters. If just 5 meter depth the same wave is however shorter than 50 meters.

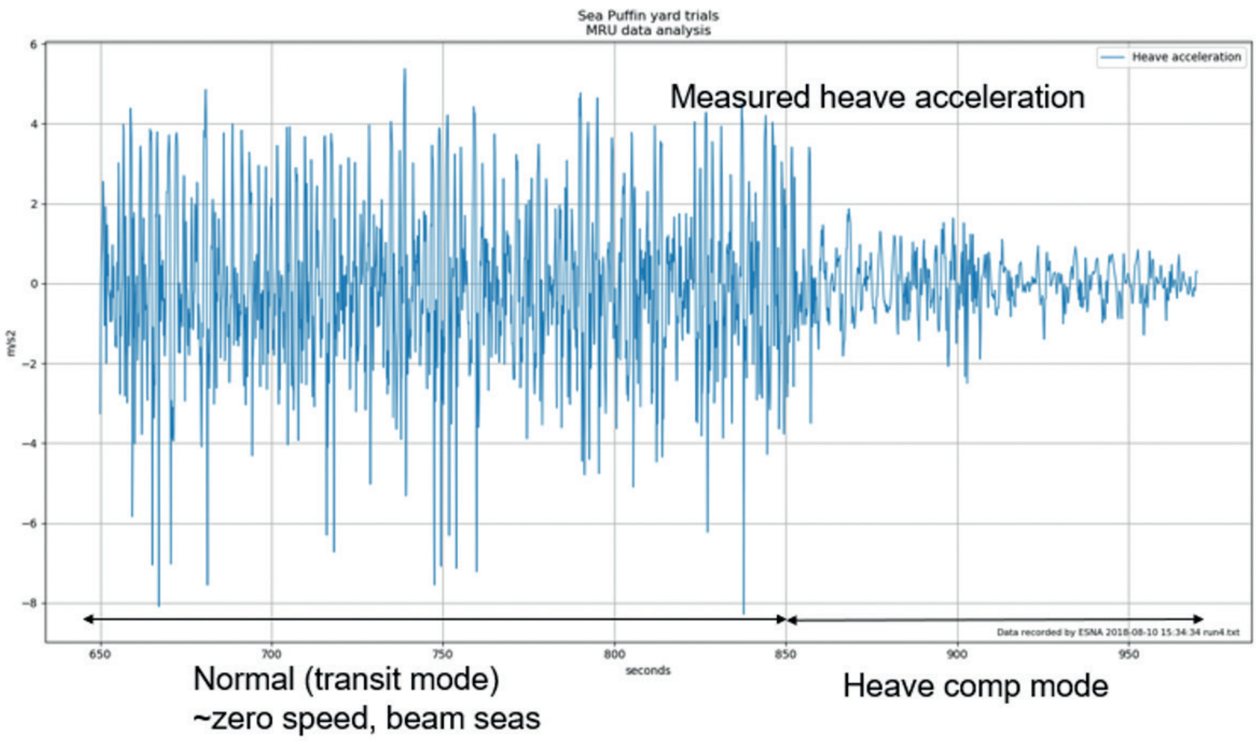


The figure shows SES motion damping. Side view, with the vessel pushing on to the yellow boat landing. Safe access means that the bow does not slide along the boat landing. The fan in the 'nose' blows air into the air cushion. The arrows show direction of airflow. In the wave through the outlet damper is closed and air pressure is increased in the air cushion to compensate for reduced buoyancy. At the right with the wave crest the inlet damper is closed to shut off air supply, while the outlet damper is opened to reduce the air cushion pressure. This system effectively removes 0.5-1.0 m vessel elevation and allows safe turbine access in larger wave heights.

in such conditions. The vessel is 15 meters long and can be launched and recovered using conventional single-hook davits.

The SES (Surface Effect Ship) has an air cushion between the two catamaran hulls, and with rubber sealing fore and aft between the hulls. An air fan creates an overpressure in this air cushion, that can lift up to 80% of the vessel weight. With an actively controlled air damper the air cushion pressure can be varied between 0 and 80%, and this is used for active motion control when accessing the wind turbines. The vessel design was started in 2015, with the first of class Sea Puffin 1 delivered by Esbjerg Shipyard A/S to owner WindPartner in 2018. Since then the vessel has proven very high operational efficiency. The motion damping concept is illustrated in the above figures.

The Sea Puffin 1 has successfully demonstrated safe turbine access in 1.75 m significant wave height. Measurements were made by ESNA, and the trials were



The figure shows measurements of vertical accelerations from zero speed sea trials with the Sea Puffin 1 in 1.5 m significant wave height. First the vessel floats normally, before the heave motion damping system is activated. The motions are significantly reduced.

The Sea Puffin 1 demonstrating full air cushion lift. Without the air cushion the draught is just where the black antifouling meets the white side paint.

financed by the Carbon Trust Offshore Wind Accelerator. Below table shows typical trial results, clearly illustrates the differences in wavelength. Both trials are at similar wave height, but with wavelengths corresponding to shallow near shore wind farms and far from shore deep water. The slip % is calculated using OWA's P-Plot criteria. For the long waves the vessel's bow was almost still, while for short waves the motions were just within the OWA criteria for safe transfer.

With an operational wave height of up to 1.75 m the expected annual operability in wind farms as Doggerbank and Hornsea for the Sea Puffin Daughter craft is around 70%. This is twice the operability of a conventional daughter craft that can transfer at 1.0 m Hs, and matches with the performances of

Wind farm	Significant Wave Height [m]	Wave peak period [s]	Water depth [m]	Wavelength [m]	Slip % (max 10)
Hywind Scotland	1.70	7.0	Deep	76	2 %
Horns Rev 2	1.75	4.7	9 - 17	Ca. 33	9 %

significantly larger CTVs of 22+ meters length. She is in addition classed and can transit to and from shore, providing both high performances and flexibility for the offshore wind farm operations.

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The Sea Puffin 1 pushing on to an offshore wind turbine. View from the wheelhouse.