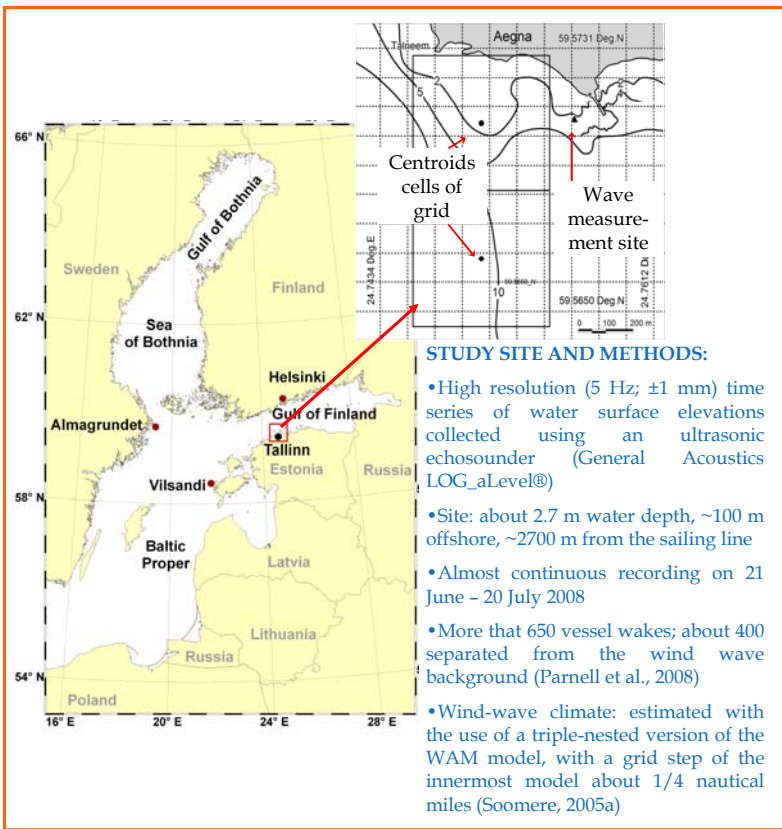


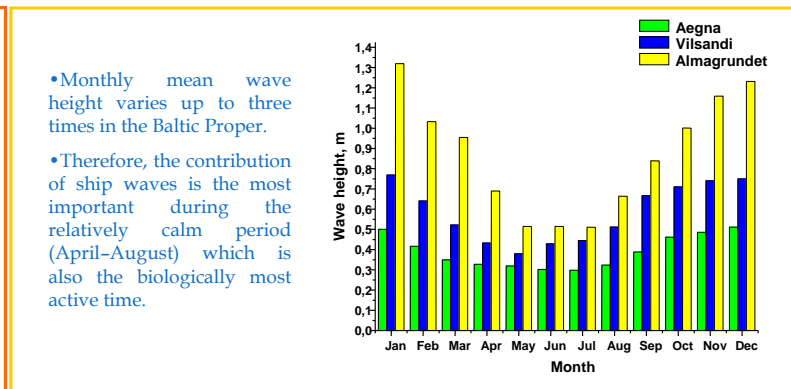
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Vessel-wake effects on the aquatic ecosystem and the coastal environment have received considerable attention in the literature (Madekivi, 1993; Parnell and Kofoed-Hansen, 2001; Soomere, 2007). There has been less attention given to their role as a coastal hazard or as a form of environmental pollution (Soomere, 2005). The first adequately documented case of ship-induced coastal hazards in the open sea, which led to loss of life, seems almost unbelievable. In 1912 in the Gulf of Finland, the Baltic Sea, a boy was washed from a wharf and drowned (Krylov, 2003). The wharf was 2.7 m above water level and was located at a distance of about 10 km from the sailing line of the warship Novik. The nonlinear wave height amplification combined with extensive shoaling of the long waves in shallow water is the probable reason of this event. There have been more recent similar events (Kofoed-Hansen and Mikkelsen, 1997; Hamer, 1999) resulting from the breaking of waves generated by fast ships.

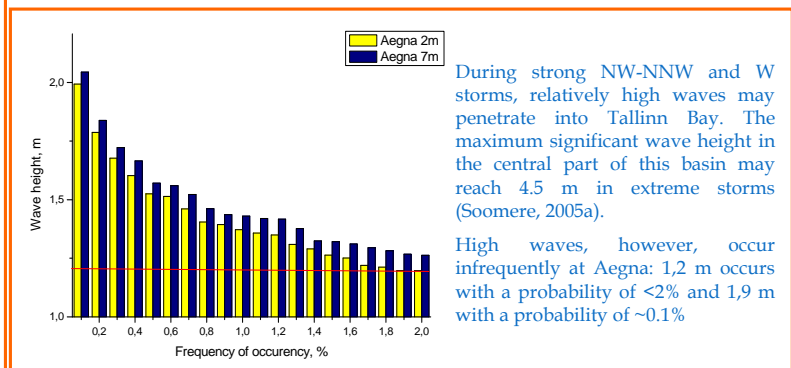


STUDY SITE AND METHODS:

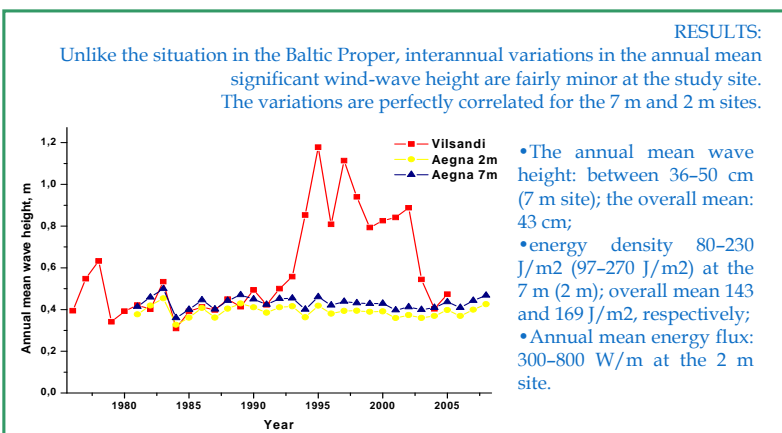
- High resolution (5 Hz; ± 1 mm) time series of water surface elevations collected using an ultrasonic echosounder (General Acoustics LOG_aLevel@)
- Site: about 2.7 m water depth, ~100 m offshore, ~2700 m from the sailing line
- Almost continuous recording on 21 June – 20 July 2008
- More than 650 vessel wakes; about 400 separated from the wind wave background (Parnell et al., 2008)
- Wind-wave climate: estimated with the use of a triple-nested version of the WAM model, with a grid step of the innermost model about 1/4 nautical miles (Soomere, 2005a)



- Monthly mean wave height varies up to three times in the Baltic Proper.
- Therefore, the contribution of ship waves is the most important during the relatively calm period (April–August) which is also the biologically most active time.

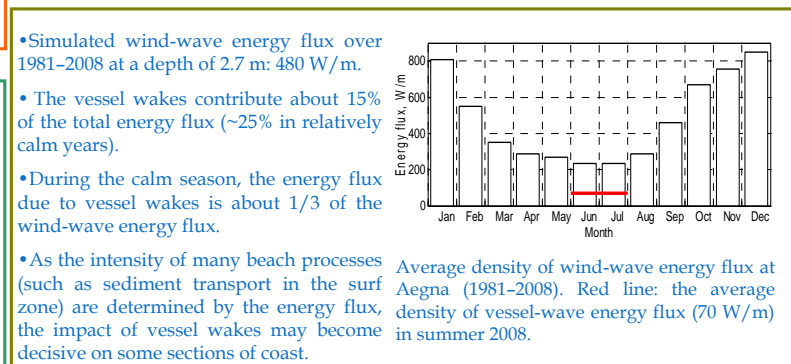


During strong NW-NNW and W storms, relatively high waves may penetrate into Tallinn Bay. The maximum significant wave height in the central part of this basin may reach 4.5 m in extreme storms (Soomere, 2005a). High waves, however, occur infrequently at Aegna: 1.2 m occurs with a probability of <2% and 1.9 m with a probability of ~0.1%



RESULTS:
Unlike the situation in the Baltic Proper, interannual variations in the annual mean significant wind-wave height are fairly minor at the study site. The variations are perfectly correlated for the 7 m and 2 m sites.

- The annual mean wave height: between 36–50 cm (7 m site); the overall mean: 43 cm;
- energy density 80–230 J/m² (97–270 J/m²) at the 7 m (2 m); overall mean 143 and 169 J/m², respectively;
- Annual mean energy flux: 300–800 W/m at the 2 m site.



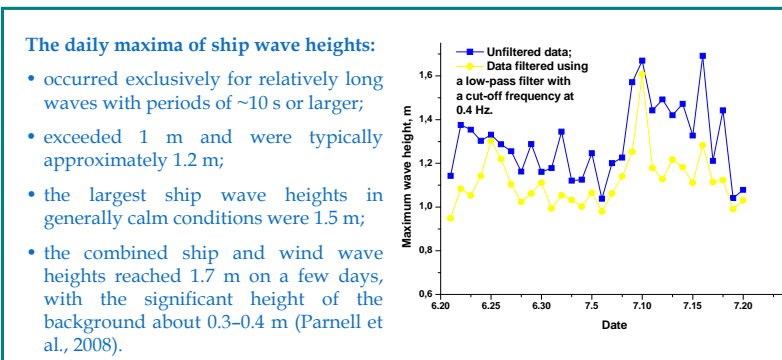
- Simulated wind-wave energy flux over 1981–2008 at a depth of 2.7 m: 480 W/m.
- The vessel wakes contribute about 15% of the total energy flux (~25% in relatively calm years).
- During the calm season, the energy flux due to vessel wakes is about 1/3 of the wind-wave energy flux.
- As the intensity of many beach processes (such as sediment transport in the surf zone) are determined by the energy flux, the impact of vessel wakes may become decisive on some sections of coast.

Average density of wind-wave energy flux at Aegna (1981–2008). Red line: the average density of vessel-wave energy flux (70 W/m) in summer 2008.

CONCLUSION:

The vessel wakes contribute significantly to the energy budget of shorelines during relatively calm periods. Although this contribution is relatively small (~10%) in terms of the energy budget, it is substantial in terms of the highest waves and energy flux. There has been no substantial change to the overall wind wave intensity in Tallinn Bay despite very significant changes occurring in the Baltic Proper. This feature suggests that:

- There have been no large changes to the properties of the W and NW-NNW winds in the surrounding sea areas;
- Increase in storminess does not compensate the impact of the new, anthropogenic component of local hydrodynamic activity.



The daily maxima of ship wave heights:

- occurred exclusively for relatively long waves with periods of ~10 s or larger;
- exceeded 1 m and were typically approximately 1.2 m;
- the largest ship wave heights in generally calm conditions were 1.5 m;
- the combined ship and wind wave heights reached 1.7 m on a few days, with the significant height of the background about 0.3–0.4 m (Parnell et al., 2008).

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