SHIPPING-INDUCED SEDIMENT RESUSPENSION IN THE VENICE LAGOON, ITALY

John Rapaglia [1]*, Luca Zaggia [2], Klaus Ricklefs [3] and Morgan Gelinas [1]
[1] Christian Albrechts University of Kiel - john.rapaglia@geographie.uni-kiel.de
[2] 2. National Research Council of Italy: Institute of Marine Science (CNR-ISMAR)
[3] 3. West Coast Research and Technology Center of Kiel University

Abstract

Sediment remobilization induced by the passing of commercial tankers and cargo vessels in the Venice Lagoon, Italy was investigated during two sampling campaigns in March and July, 2009. A suite of instruments was utilized to measure suspended sediment concentration (SSC), water depth, and water velocity on the shoals alongside the shipping canal. SSC concentrations above 500 mg L^{-1}, much higher than the background concentration of 7 mg L^{-1}, were recorded at 50 cm above the sediment surface for several minutes after the passage of large ships. A threshold based on the Froude number and the size of the ship was calculated below which large waves directly linked to large SSC events do not form, thereby preventing previously isolated contaminated sediments to be reintroduced into the marine environment.

Keywords: Estuaries, Coastal Management, Sediment Transport, Waves

Introduction/Methods

Given their geographical orientation as a natural barrier to the open seas, coastal lagoons provide prime locations for shipping ports. Although the shipping industry is beneficial to the world's economy, it is important to discuss the possible negative impacts shipping can have on local ports, such as pollution from ship ballast water, introduction of invasive species and sediment resuspension and redistribution [1]. Herein, we investigate how shallow water waves produced by ships influence suspended sediments upon extended shoals in the Venice Lagoon, Italy. The sediments in the vicinity of the shipping channel are contaminated and therefore we aim to ascertain which parameters (i.e. vessel velocity, draft, width, tidal level etc.) influence the formation of powerful waves from shipping vessels outside the channel in the Venice Lagoon, and how much resuspension these waves produce. Among the variables that determine the formation of large waves, only vessel velocity and the timing of transit in relation to tidal levels can be controlled.

As the vessel velocity increases and as the size of the vessel increases the amplitude of the wave increases and therefore the probability for the formation of a shallow-water wave increases. When the shallow water wave breaks it generates high near-bottom current velocities (U_{max}; m s^{-1}) along the sediment surface leading to re-suspension events [2].

$$U_{max} = \frac{\pi H}{T * \sinh \frac{2\pi h}{\lambda}}$$

Fig. 1. Equation 1

(1) where H is the wave height (m), T the wave period (s), h the water depth (m) and λ the wavelength (m). The larger the U_{max}, the greater the amount of resuspension will occur. Therefore, as expected, larger resuspension events will develop in the presence of high waves. An acoustic Doppler current profiler (ADCP) was utilized to measure SSC in the canal while two optical backscatter sensor (OBS) arrays were placed 50 m onto the shoals alongside the canal at a mean depth of 1.5 m. An S4 electromagnetic current meter with an internal OBS was also placed alongside one of the OBS arrays to measure water depth and velocity. Meanwhile a canal-normal transect of pressure sensors was spaced at 100 m intervals away from the canal to reproduce the propagation length and shape of the shallow water waves. An automated identification system (AIS) was used to collect vessel size, velocity and heading data.

Results

More than 100 ships generated waves associated with SSC change as recorded by the OBS arrays, however only 10 waves were sufficiently large and steep to cause extensive resuspension events. An extensive SSC event was considered to be one in which the change in SSC was over 300 mg L^{-1} and in which the sediment remained in suspension longer than 6 minutes. Schoellhamer relates the product of the Froude number and the size of the ship to wave height [3]. Using a modified version of the Schoellhamer relationship including the water level on the shoals, we are able to determine a critical threshold of these parameters below which the shallow water waves will not attain the height or steepness necessary to create large SSC events (Figure 1). The knowledge of this threshold can help in the management practice of the lagoon.

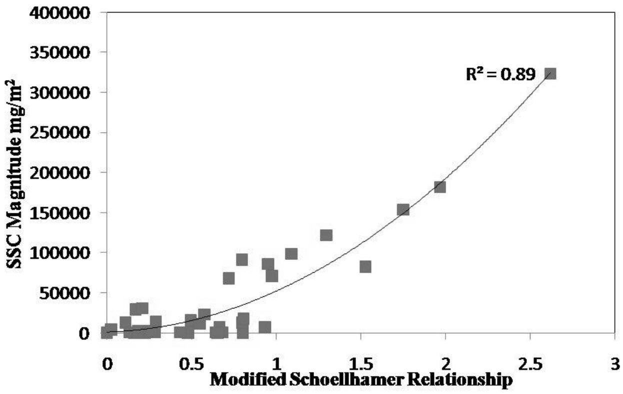

Fig. 2. SSC event magnitude versus the modified Schoellhamer parameter. Large resuspension events do not occur below the threshold of 0.75.

Pressure sensor data shows the length of wave propagation along the shoals. Though there was significant dissipation of energy with distance from the channel, large waves are still recorded at least 1000 m onto the shoal, and are likely to be the one of the primary cause of extensive subsurface erosion seen in the central lagoon over the last 30 years [4].

References

1 - Hayes K.R., and Sliwa C., 2003. Identifying potential marine pests—a deductive approach applied to Australia. *Marine Pollution Bulletin*, 46: 91-8.

2 - Hofmann H., Lorke A., Peeters F., 2008. The relative importance of wind and ship waves in the littoral zone of a large lake. *Limnology and Oceanography*, 53: 368-380.

3 - Schoellhamer D.H., 1996. Anthropogenic sediment resuspension mechanisms in a shallow microtidal estuary. *Estuarine, Coastal and Shelf Science*, 43: 533-548.

4 - Molinaroli E., Guerzoni S., Sarretta A., Masiol M., and Pistolato M., 2009. Thirty-year changes (1970 to 2000) in bathymetry and sediment texture recorded in the Lagoon of Venice sub-basins, Italy. *Marine Geology*, 258: 115-125.