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Damping of ship-induced primary waves in groyne fields

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Introduction

Recent ecological studies (Collas et al., 2018) show that ship-induced waves can reduce suitability of fish habitats along the river banks between groynes. Specifically eggs and young fish are vulnerable to these waves (Wolter & Arlinghaus, 2003). For the river Waal in the Netherlands the breeding and growing season of this fauna is from April to September, which generally corresponds to flow conditions where the groynes in the river are not completely submerged. The preferred habitat of fish is in the shallow zones close to the bank, which experience a high degree of hydrodynamic variability due to ship-induced waves. The goal of this research is to explore whether fish habitat during the growing and breeding season can be improved by reducing the flow impact of passing ships through structural modifications ("notching") of groynes.

Method

The 2D hydrodynamic model XBeach is used to simulate ship-induced wave dynamics (Roelvink et al., 2015). The model consists of a straight river channel with groynes along the banks. In the main channel, a steady flow is imposed. Passing ships are included in the model by defining a moving pressure field. Various groyne geometries are considered to study the flow properties in the groyne field. Two hydro-ecologic parameters are defined for the assessment of habitat suitability in-between the groynes:

1. Water level range: the difference between the highest water level and the lowest water level when a ship is passing.
2. Flow velocity range: the maximum change of the velocity vector during a ship is passing.

Both parameters are calculated for a 60-second time interval centred around the passing of a ship. The 'Flow velocity range' takes into account the magnitude as well as the direction of the flow field, as illustrated in Figure 1.

The figure shows the two horizontal components of the velocity vector (u and v-velocity), for a specific fixed location in the groyne field during the 60 second time interval. A circle is fitted around these velocity points, of which the diameter is the 'Flow velocity range'. This calculation is carried out for each location in the groyne field.

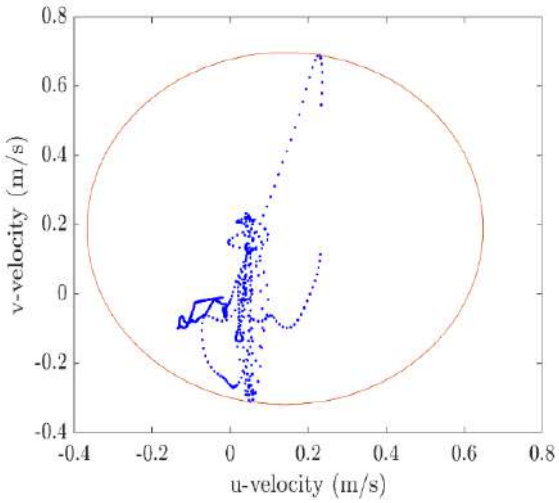

Figure 1. plot of the u- and v- directed velocity values during ship passing to determine the maximum velocity range.

Results

Figure 2 shows the results of the 'Flow velocity range' for two different groyne-configurations. The top plot shows the velocity range for a sequence of traditional impervious groynes. The middle plot shows the velocity range when the groynes are "notched", i.e. when a 10 m opening is created in the groynes. The bottom plot shows the difference in 'Flow velocity range' between the two situations. Herein, a negative value (blue) indicates regions where the notching has reduced the flow velocity range, and, hence, where fauna habitability has improved. In general, the velocity range has improved near the tips of the groynes, the center of the groyne field and close to the river banks, which is the area of interest for fauna habitat. When a ship passes the modified groyne field, the largest flow velocities occur within the notches (see

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middle plot). Immediately next to the notch, the velocity range improves the most. Additional simulation runs with changes in notch location and notch size have shown that shallow wide notches close to the river bank appear to be most effective in reducing the 'Flow velocity range' in the groynes field (see Pasman 2020, results not shown here).

Conclusions

Results from the modelling study show that a notched groyne can have a positive influence on the fish habitat in rivers. Close to the notch, the fish habitat may locally become less suitable because of the higher flow velocities associated with flow through the notch. However, in large parts of the groyne field the flow variability is reduced, because of the inter-connection between neighbouring groyne fields. This makes most of the areas in the groyne fields more suitable for fish habitats. An optimal location of the notch for creating hospitable fish habitat appears to be close to the bank with a wide but shallow notch shape. This suggests that with relatively simple modifications the ecological value in the groyne fields can be improved significantly.

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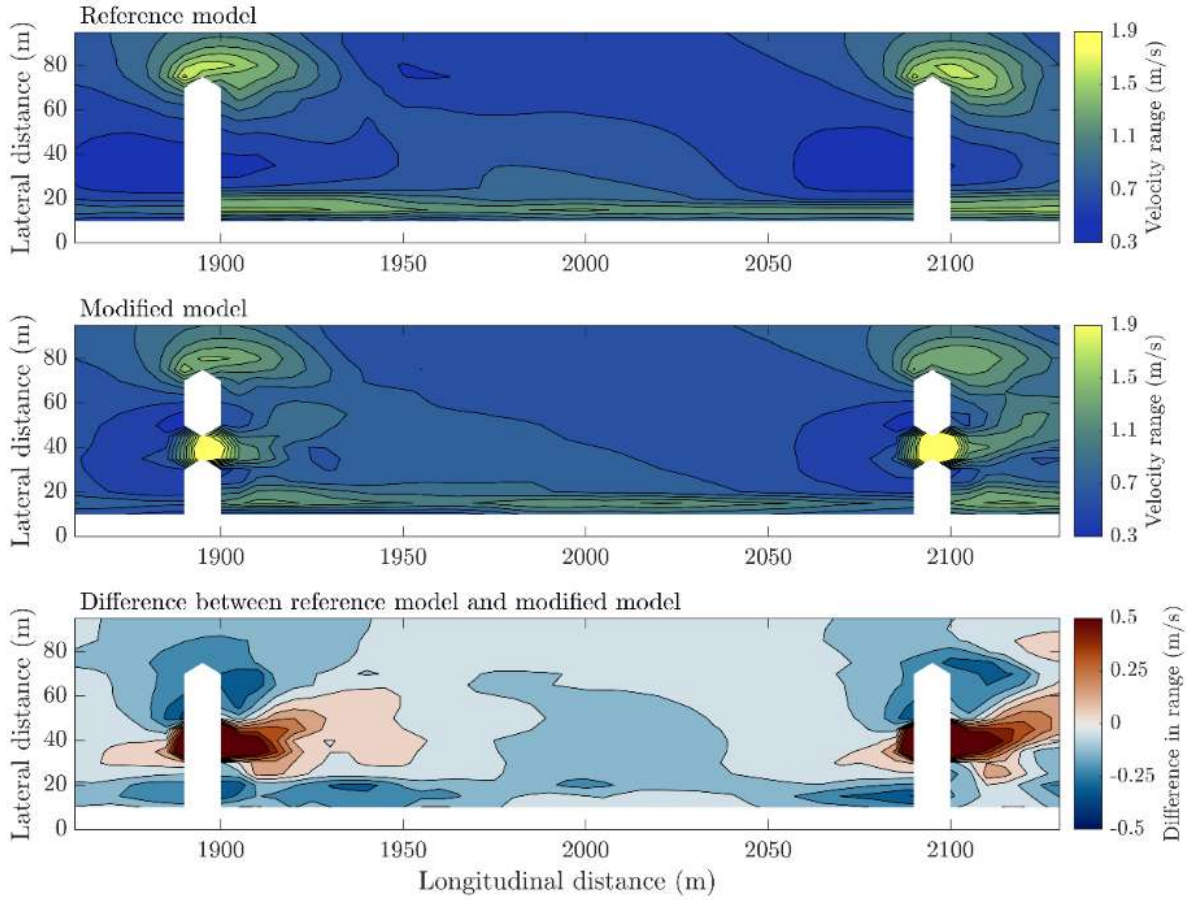

Figure 2. Flow velocity range during passing of a ship (travelling upstream). The base flow in the main channel is from left to right.