# MUSSEL HUMMOCKS AFFECT FLOW PATTERNS AND FOOD UPTAKE IN INTERTIDAL MUSSEL BEDS.

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## 1. Problem definition

Shellfish reefs are able to stabilize sediment and attenuate wave forcing (Borsje et al., 2011; Donker et al., 2013). Opportunities for mussel bed restoration in the Dutch Wadden Sea are explored. For this purpose we need a better understanding of the processes that influencemussel bed stability. For coastal protection purposes the type of mussel bed will be important as some beds remain flat while others develop elevations.


**Fig 1:** map of the Wadden Sea

Observations suggest that relief is largest in deeper lying, current dominated mussel beds. Relief develops when sedimentation occurs in irregularly covered mussel beds. High relief is expected to influence flow patterns and thereby transport of food. Variations in food availability can affect the long term stability of the mussel bed.

1. How does an elevated mussel patch (hummock) influence flow patterns, turbulence and vertical mixing?
2. How do hummocks influence food availability and uptake?

**- What is the effect of mussel bed relief on flow patterns and food availability?**

## 2. Methods

### Field observations

- 4 Week experiment around small hummock (~7x3m) (location see Fig 1.)
- Local flow & turbulence conditions
- ADV (32 Hz), 2 above mussel hummock 1 in channel

### Model study

Flow patterns studied using SWASH (zijlema, et. al., 2011)

- Non-hydrostatic model
- Idealized mussel hummock
- Boundary conditions based on field observations
- Prescribed flow on left hand boundary
- 10 m sponge layer at right hand boundary to damp reflections
- Periodic boundary conditions north and south

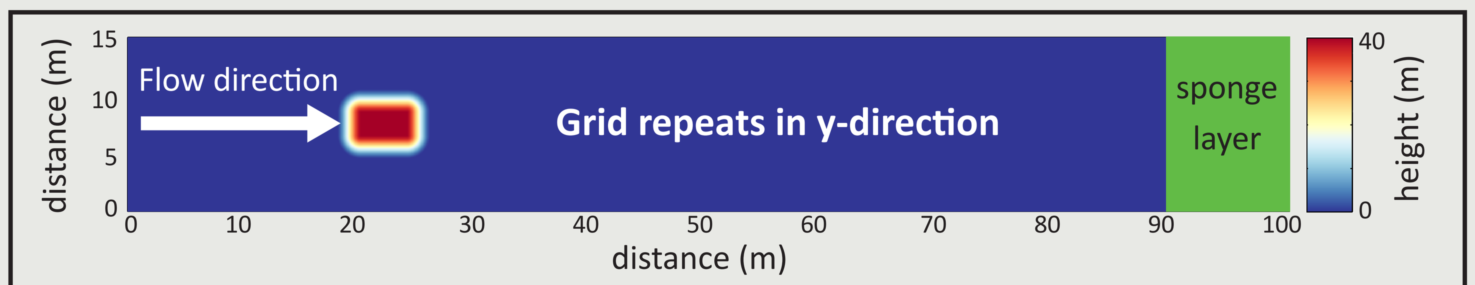


**Fig 2:** The model bathymetry with mussel hummock used in the model study. Hummock, 6 x 4 m base, 0.4 m high, full domain 100 x 15 m.

**Food uptake** is studied using coupled model (based on Simpson et al., 2007)

- Advection-diffusion model with explicit food uptake (in 3D)

## 3. Field observations

### What are typical flow velocities around a mussel hummock?

Observations of flow velocity (Fig 5) reveal:

- Low water: flow over hummock is larger
- High water: velocities are similar (hummock sensor is located closer to bed)
- Large increase in channel velocity when hummock emerges

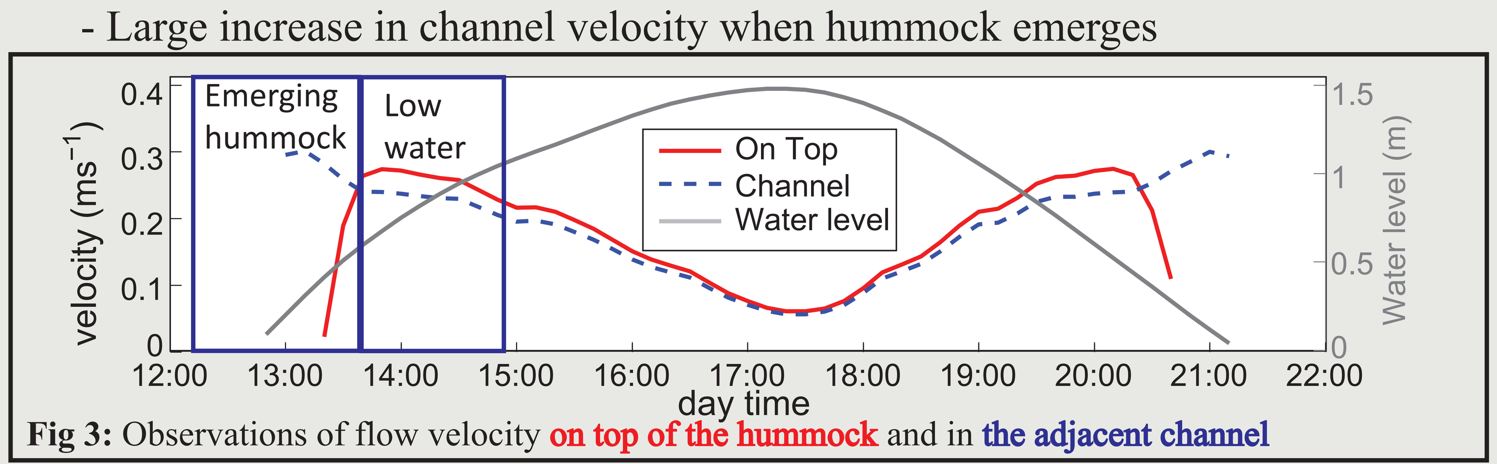


**Fig 3:** Observations of flow velocity on top of the hummock and in the adjacent channel

### How is vertical mixing influenced?

- Turbulent Kinetic Energy (TKE) is increased over hummock
- Vertical mixing is increased

1a. Flow velocities and mixing are increased over hummock.

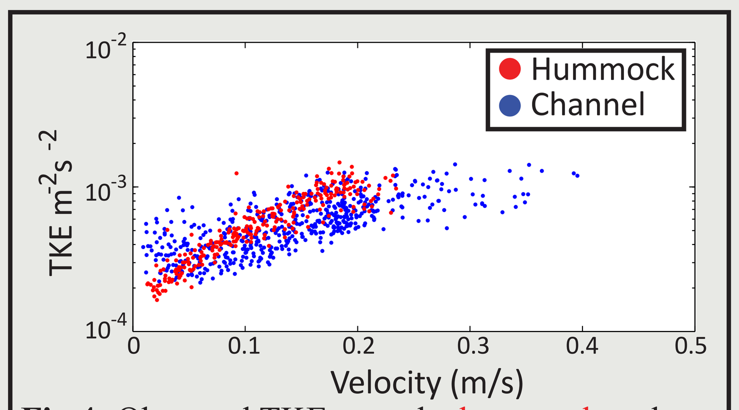


**Fig 4:** Observed TKE over the hummock and in the channel as a function of flow velocity.

## 4. Model Results

### How are flow patterns affected by hummocks?

For water level 0.6 m, flow from the left.

- Large velocity increase:
  - over hummock (+50%)
  - in channel (+25%)
- Wake behind hummock(-25%)
- Reduced velocities in front of hummock (-10%)
- Highest velocities on front and wake side of hummock

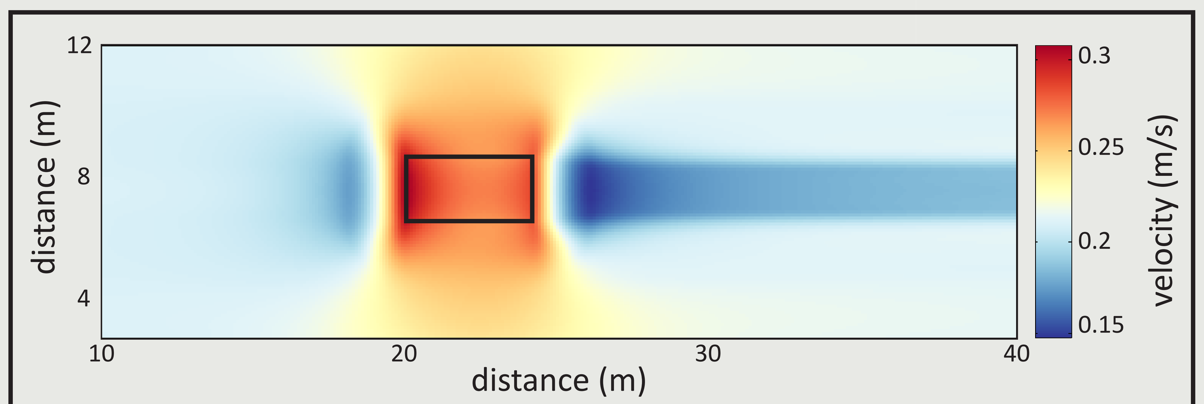


**Fig 5:** Spatial distribution of depth averaged flow velocities for rising tide (0.6 m). Top of the hummock is outlined in black.

1b. Flow is partly accelerated over the hummock and partly routed around the hummock.

### What are the effects of hummock geometry on these flow patterns?

Sensitivity analysis with standard case:

- Hummock length 8m
- Hummock width 2m
- Roughness height of 0.05 m on the hummock
- Roughness height of 0.02 m on the sandy shoal

Increasing hummock length (Fig 7a)

- Gradual change from flow acceleration to flow routing

Increasing hummock width (Fig 7b)

- Flow area decreases, all velocities increase

Increasing surface roughness (Fig 7c)

- Reduces flow acceleration and increases routing

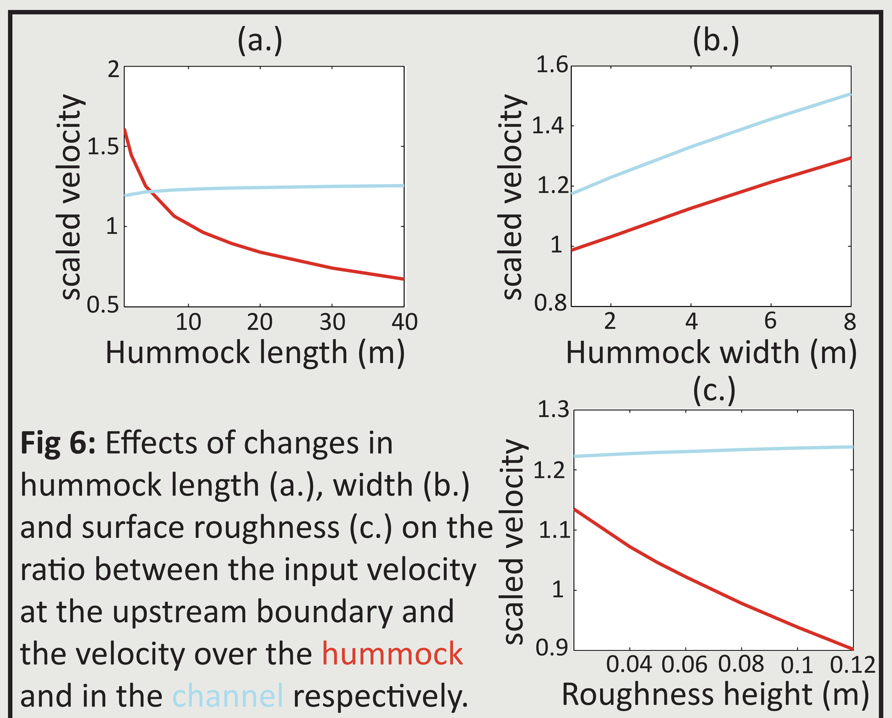


**Fig 6:** Effects of changes in hummock length (a.), width (b.) and surface roughness (c.) on the ratio between the input velocity at the upstream boundary and the velocity over the hummock and in the channel respectively.

### How do spatial patterns influence food uptake?

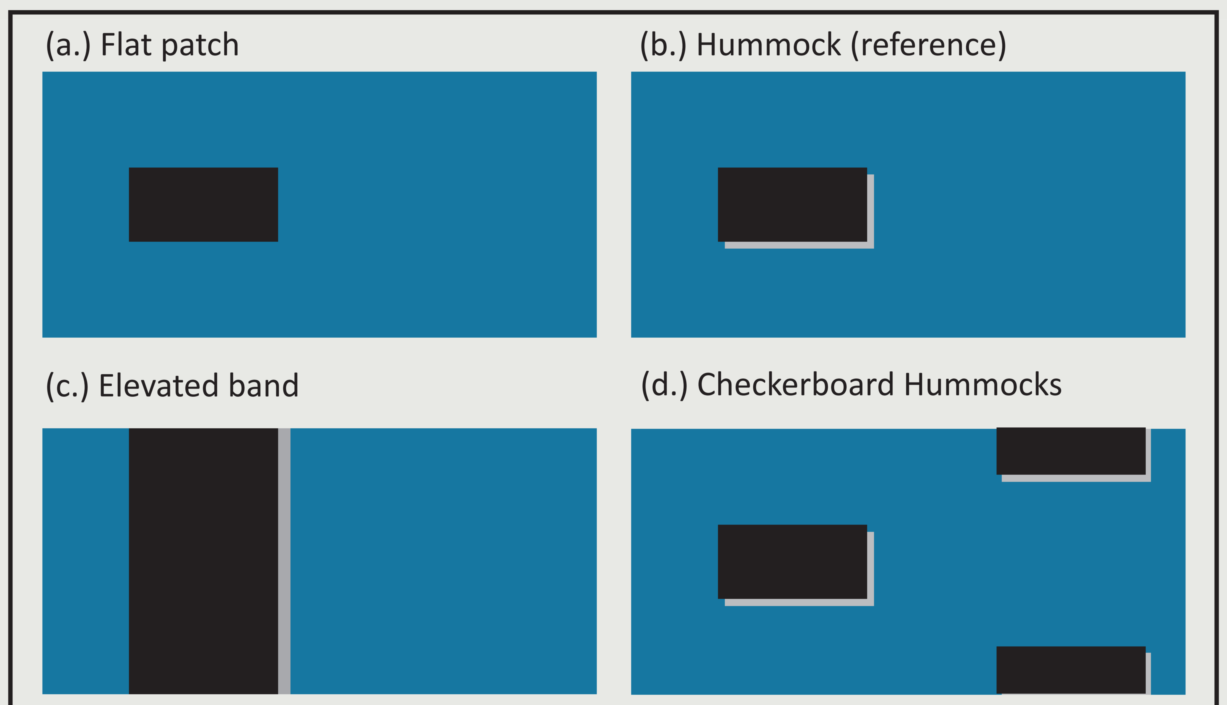


**Fig 7:** Tested mussel bed types: (a.) a mussel patch with no elevation; (b.) a single hummock with a height of 0.4 m; (c.) a mussel band with a height of 0.4 m; (d.) two hummocks of 0.4 m height in a checkerboard formation.

Change in food uptake with respect to hummock (Fig7b).

**Flat patch**
-3%

**Elevated band**
+15% (over same area)

**Checkerboard Hummocks**
First hummock +0%
Second hummock +3.6%

General trend:
More flow routing -> decreased food availability
More flow acceleration -> increased food availability

2. Wide hummocks are beneficial for food uptake.

## 5. Conclusions

- **Mussel hummocks influence flow by accelerating flow over the hummock and routing flow around the hummock.**
- **Geometry influences acceleration and routing, routing increases for more elongated and rougher hummocks.**
- **Wide hummocks are the most beneficial for high food uptake.**

## 6. References & Acknowledgements

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