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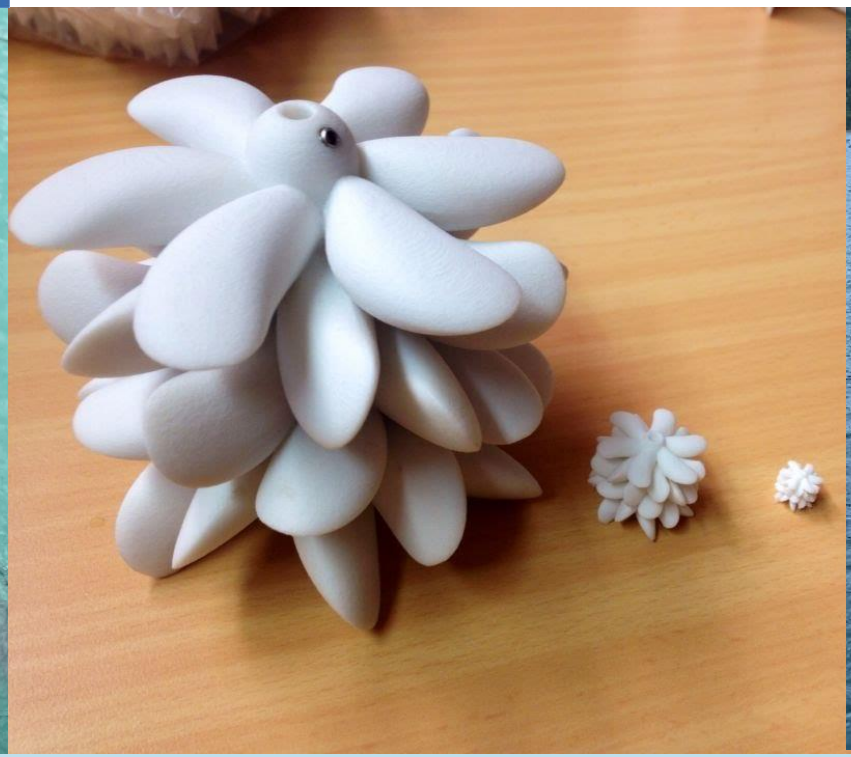
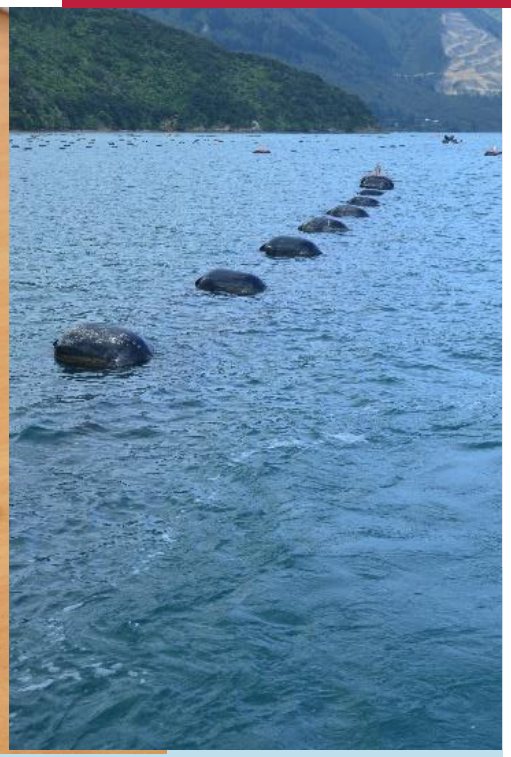




Investigation of aquaculture components for increased efficiency

| Rebekka Gieschen, Jannis Landmann, Nils Goseberg, Arndt Hildebrandt |

| FZK Kolloquium 2019 | 21.03.2019 |

Outline

Basic Research

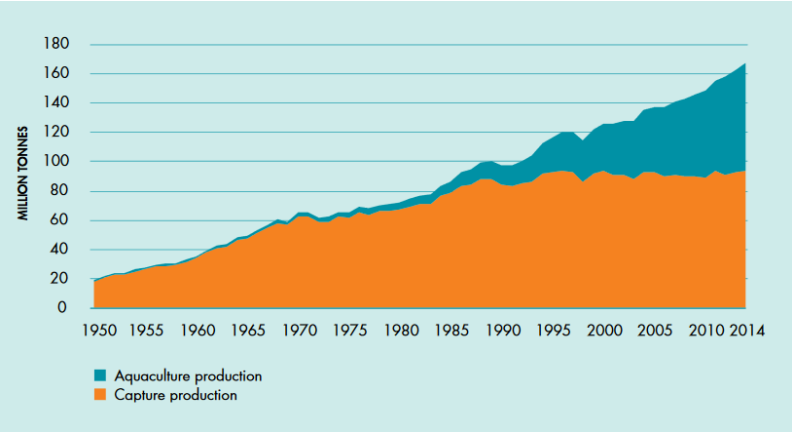
- Live Mussel tests
- Surrogate creation
- Surrogate 1:1 tests
- Surrogate 1:X tests

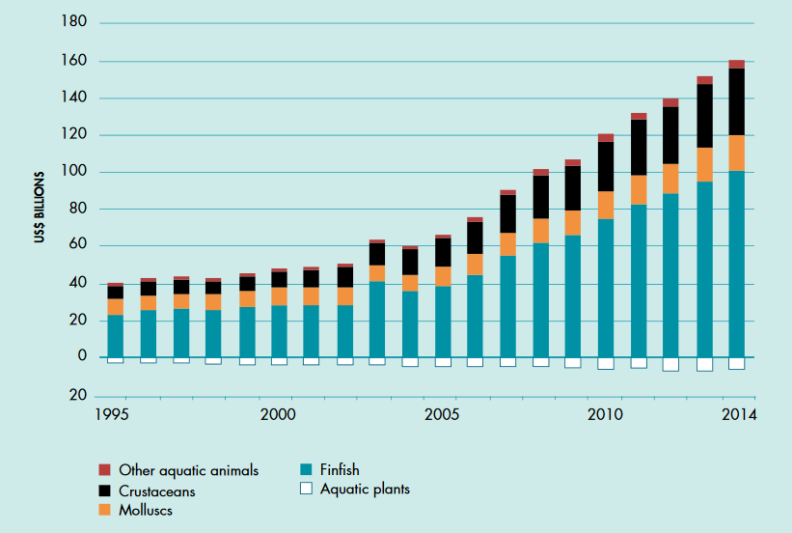
Farm concepts

- Long-Line System

Introduction - Background

- Overall, **increasing demand** for aquatic products
- **Bivalves** an essential source of **proteins**
- **Aquaculture** is one of the **fastest-growing** sectors for protein-based food





FAO; 2016

Introduction - Background

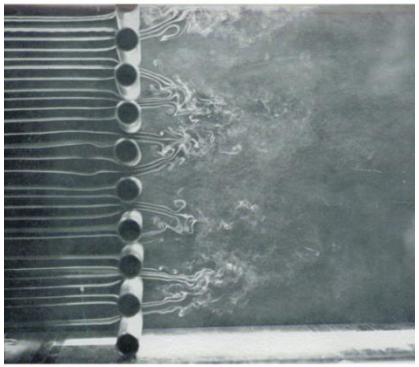
- Aquaculture near-shore faces different **challenges**:
  - Stakeholder conflicts
  - Nutrient depletion
  - Changes in species assemblage
  - Marine litter
- Perspective move to **offshore** location to **offset deficits**
- **Challenging conditions** have to be accounted for

Marlborough District Council; 2018

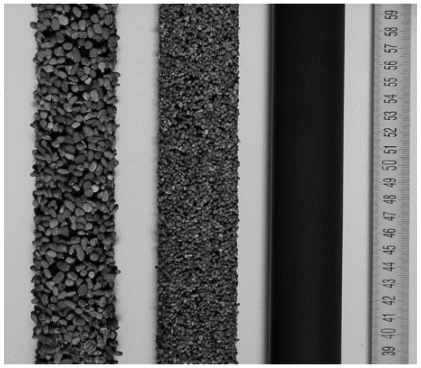
Goseberg, N; 2017

Introduction - Background

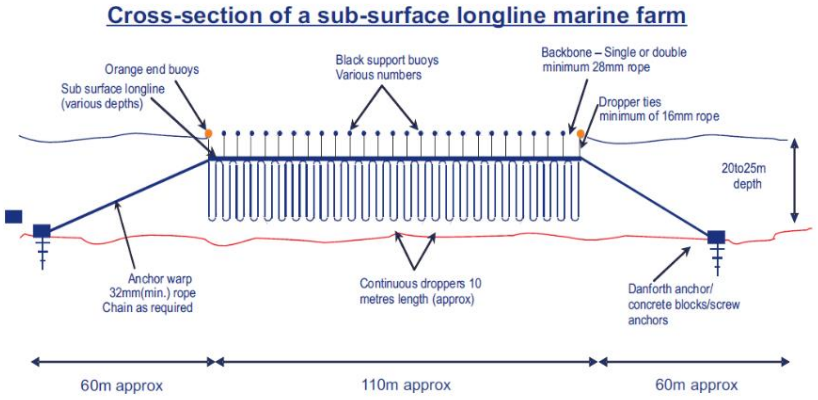
- Hydrodynamic forces acting on fixed and floating structures **commonly** investigated
- **Existing research** related to shellfish aquaculture is **scarce**
  - e.g. Buck, B.H.; Stevens, C.; Plew, D. R.
- **Little research available** regarding physical laboratory tests of shellfish aquaculture



Bradshaw, P; 1965



Plew, D.R.; 2005

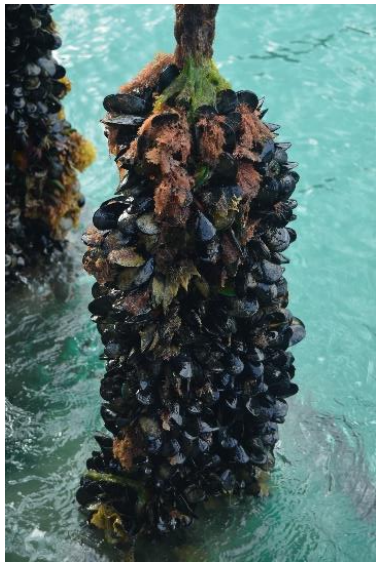


Marine Farming Association; 2017

Introduction - Objectives

- Investigation of wave-current forcing on aquaculture structures
  - **Basic research** regarding motion and forces of **mussels** / mussel-encrusted lines
  - **Project research** of „revolutionary“ aquaculture **designs**
- **Determination of response** of structure to waves and currents
- **Assessment of survivability** of structures in extreme conditions

Vitasovich, P.; 2017



Goseberg, N.; 2017

Outline

Basic Research

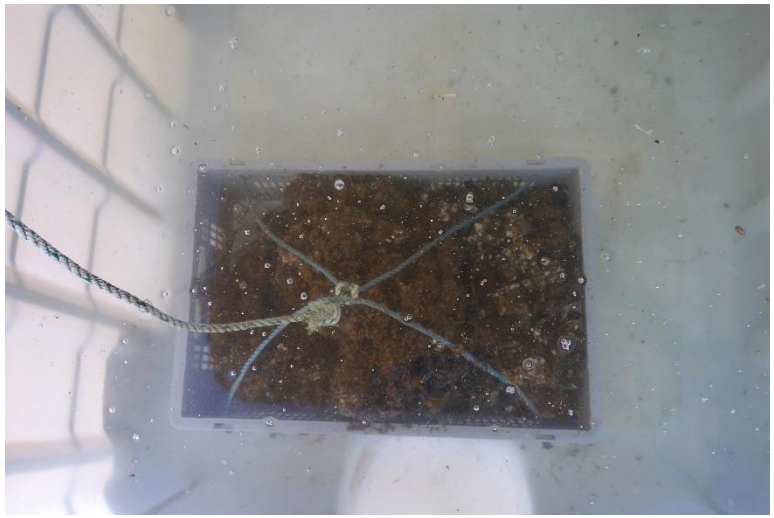
- **Live Mussel tests**
- Surrogate creation
- Surrogate 1:1 tests
- Surrogate 1:X tests

Farm concepts

- Long-Line System

Live Mussel tests

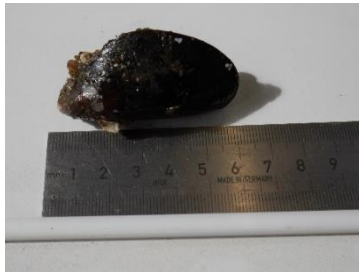
- **Collection** from aquaculture farm close to Kiel,Germany
- **3.62 m dropper line** of Baltic Blue Mussels
- **Transport & storage** in aerated tank with Baltic Sea water



Landmann, J.; 2017

Live Mussel tests

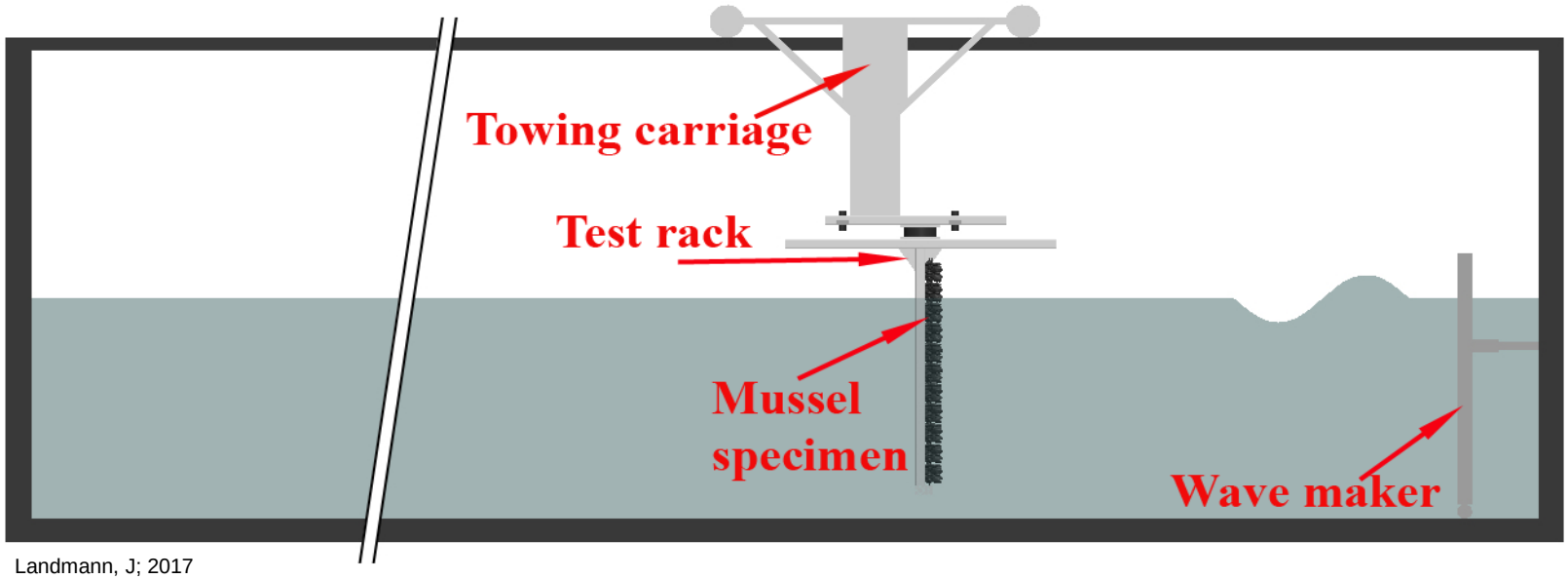
- Portioned in **three specimens** (~1 m)
- **Data acquisition**
  - Per specimen
  - For single mussels
- For **each specimen** determination of
  - Weight
  - Length
  - Width every 5.0 cm
  - Displacement
  - Bending stiffness



Landmann, J.; 2017

Live Mussel tests

- **Methodology**:
  - Determination of **drag and inertia coefficients**
  - Current (Drag) & Wave tests
  - Morison equation: $F = \frac{1}{2}\rho C_D u^2 A + \rho C_M V \dot{u}$

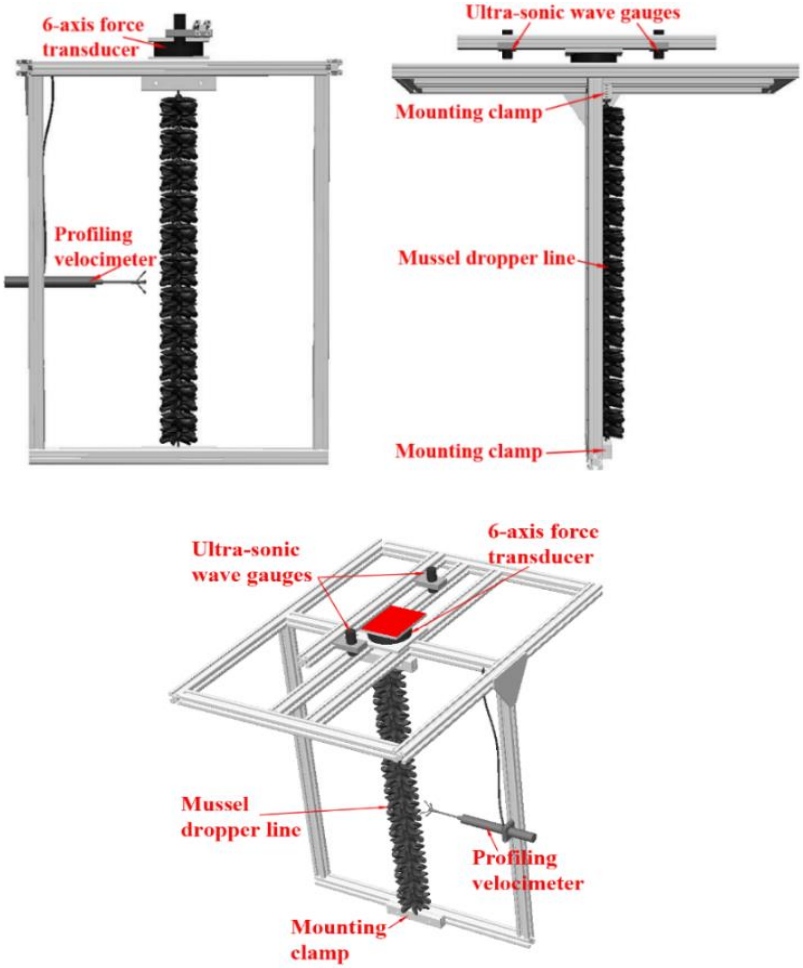


Landmann, J; 2017

Live Mussel tests

- **Mounting frame** fitted with:
  - 6-axis-force transducer
  - Ultra-sonic wave gauges
  - Acoustic Doppler Velocimeter

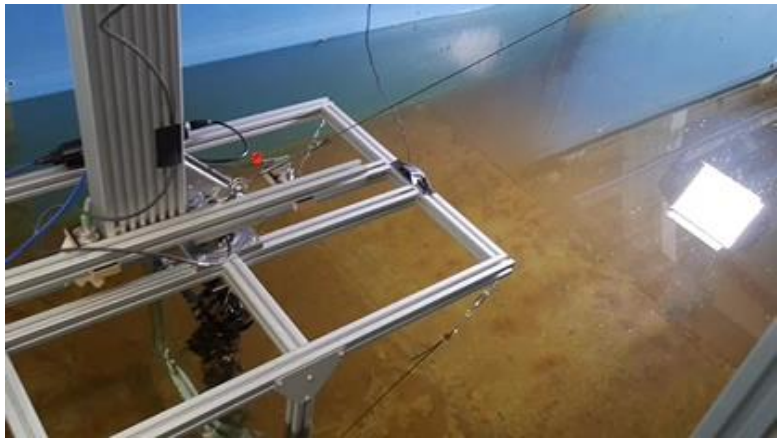
- **Carriage** fitted with:
  - Incremental rotary recorder
  - Webcam
  - Underwater camera

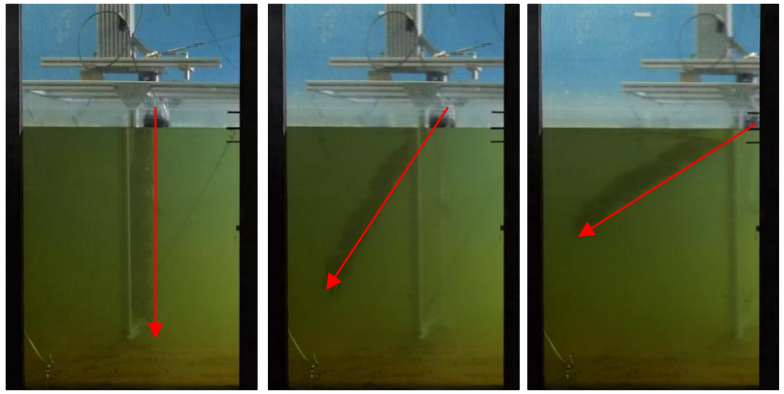


Landmann, J; 2017

Live Mussel tests

- **Drag tests** with **four velocities**
  - $Re = \frac{u * D_i}{\nu}$
  - $Re = 2.0 \times 10^4$ to 1.1×10^5
- **Top- and bottom-mounted**
  - Test for load-evasion potential of dropper lines
  - ~80% force reduction

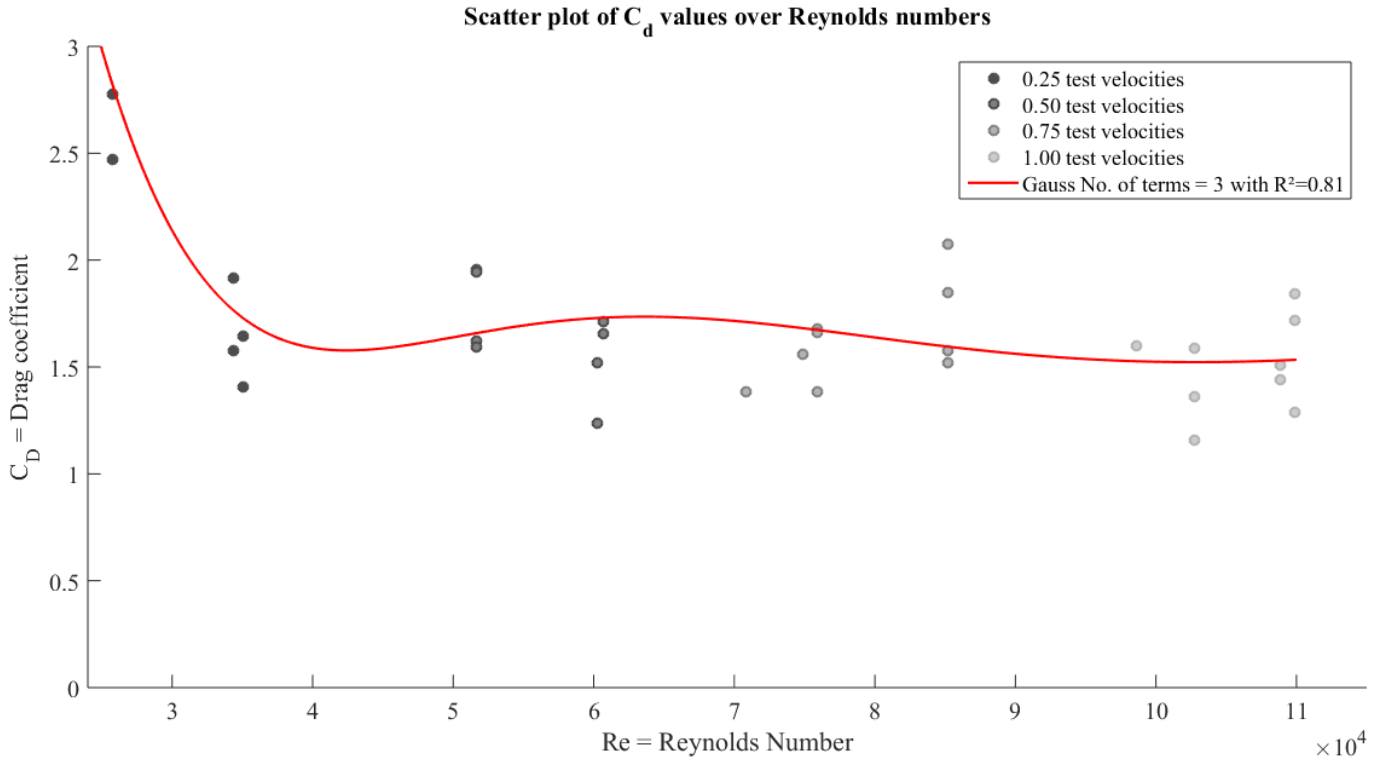




Landmann, J; 2017

Live Mussel tests

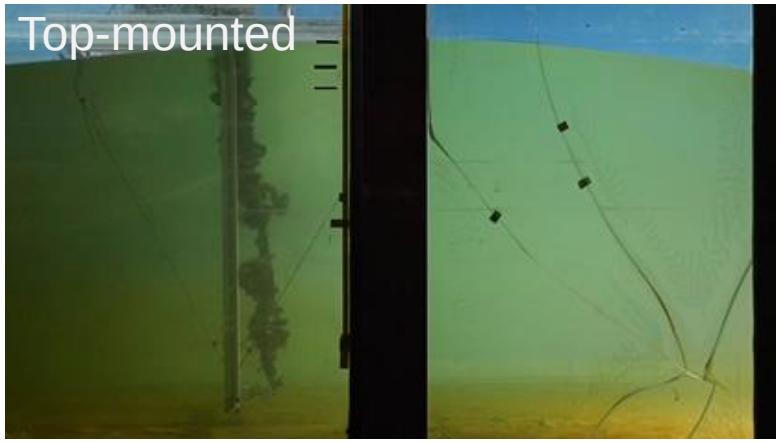
- **Calculation of C_D-values:**
  - Levels about C_D = 1.6 after initial drop
  - Little changes in C_D for higher Re-Numbers



Hildebrandt et al., 2018

Live Mussel tests

- **Inertia tests** with **three waves**
  - $H_s = 0.1\ m, 0.12\ m, 0.15\ m$
  - $T_p = 1.2\ s, 2.4\ s, 1.65\ s$
- **Top- and bottom-mounted**
  - Test for load-evasion potential of dropper lines
  - ~80% force reduction
- C_M**-values: In progress**



Landmann, J; 2017

Outline

Basic Research

- Live Mussel tests
- **Surrogate creation**
- Surrogate 1:1 tests
- Surrogate 1:X tests

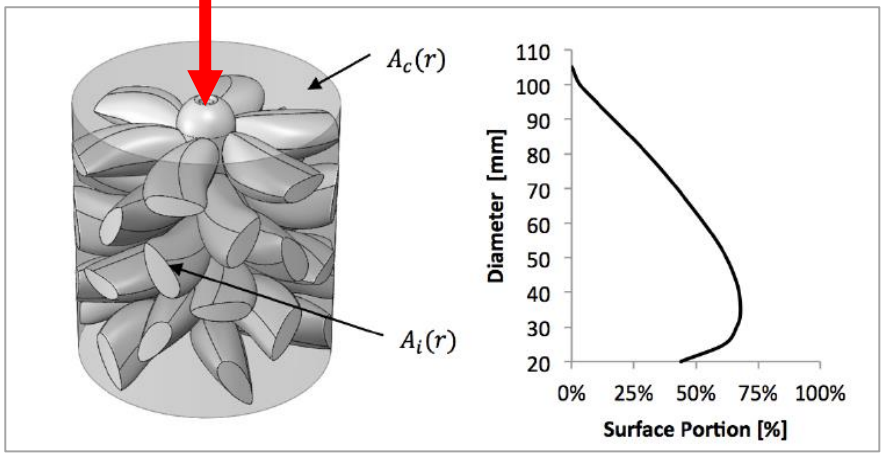
Farm concepts

- Long-Line System

Surrogate creation

- **Aim** is to create **object** with **similar characteristics** in currents and waves as live mussels
- Assuming that **C_D and C_M** are influenced by **surface geometry**
- Evaluation via **Abbot-Firestone-Curve**
  - Describes surface texture of an object
  - Material distribution as a function of depth

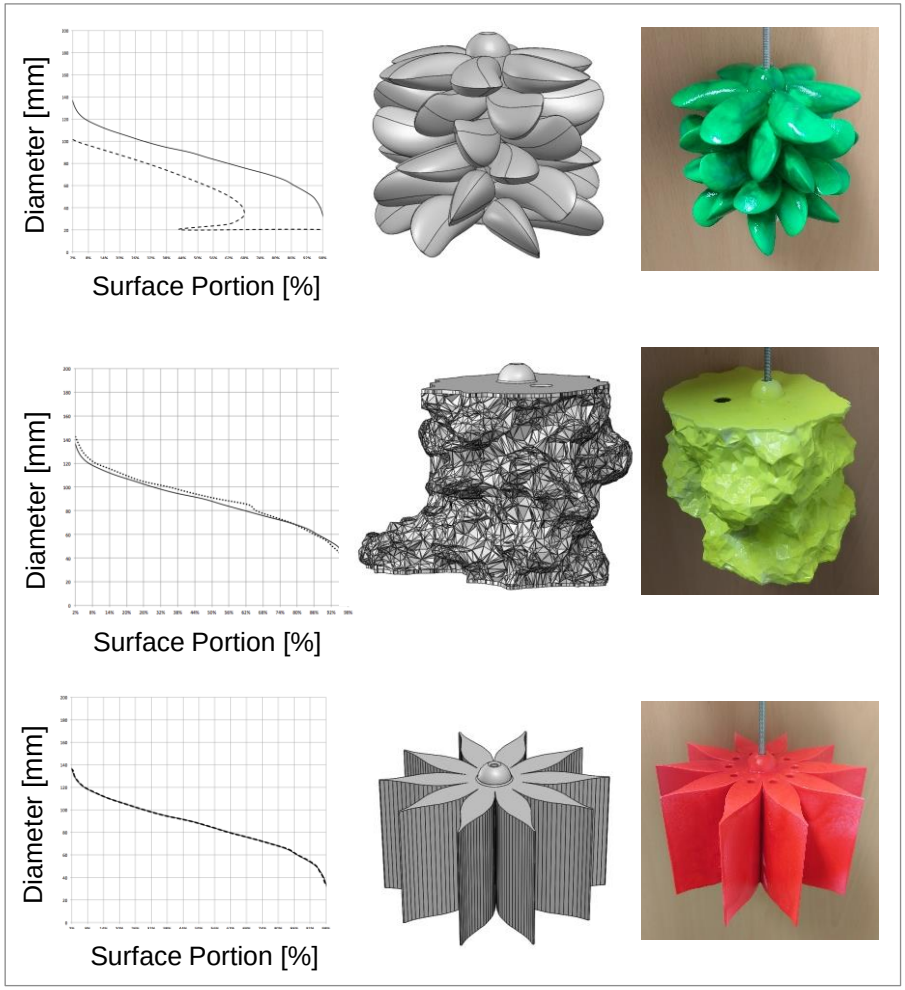
Vitasovich, P.; 2017



Ongsiek, T..; 2017

Surrogate creation

- **Concept 1:**
  - Based on single mussels
- **Concept 2:**
  - Closest fitting 3D-scanned section to mean AFS
- **Concept 3:**
  - Perfect fit to Abbot-Firestone Curve with simplified geometry



Ongsiek, T..; 2017

Outline

Basic Research

- Live Mussel tests
- Surrogate creation
- **Surrogate 1:1 tests**
- Surrogate 1:X tests

Farm concepts

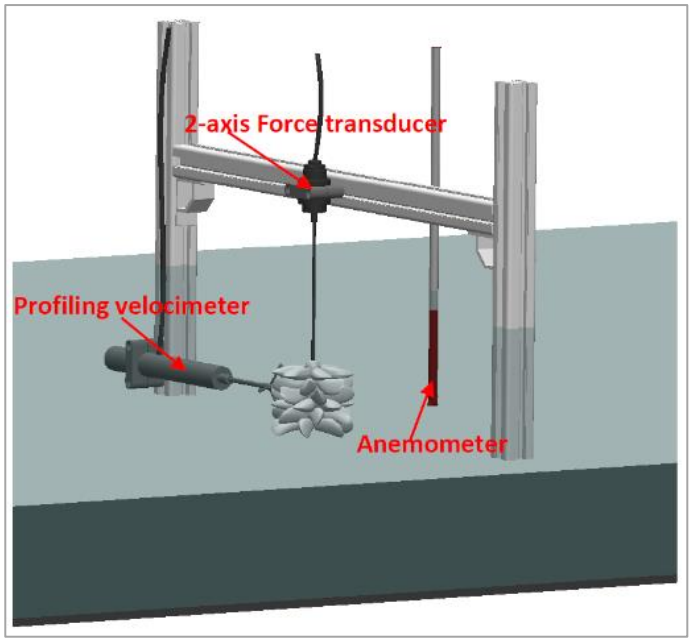
Long-Line System

1:1 Single surrogate tests

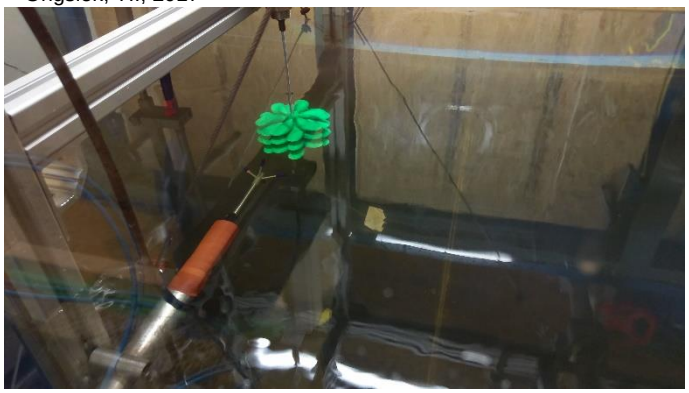
- **Methodology**:
  - Determination of **drag coefficients** via **current tests**

- **Tests with seven velocities:**
  - $0.1\,\frac{m}{s}, 0.25\,\frac{m}{s}, 0.35\,\frac{m}{s}, 0.50\,\frac{m}{s}, 0.75\,\frac{\mathrm{m}}{\mathrm{s}}, 1.00\,\frac{\mathrm{m}}{\mathrm{s}}, 1.20\,\frac{\mathrm{m}}{\mathrm{s}}$

- **C_D-values: In progress**



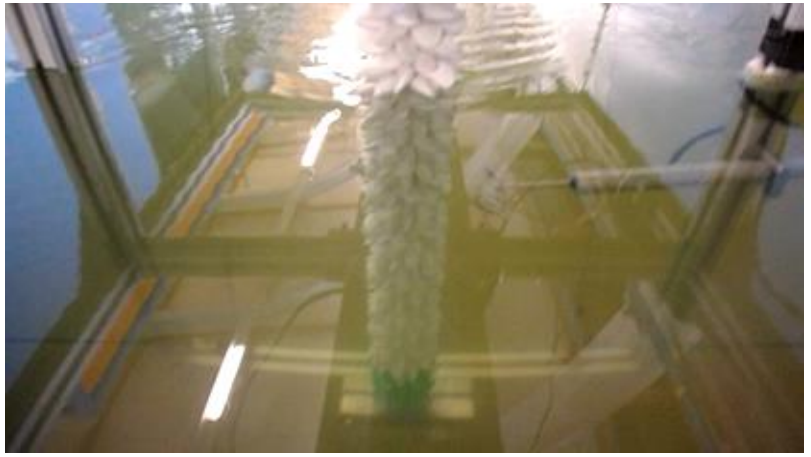
Ongsiek, T..; 2017

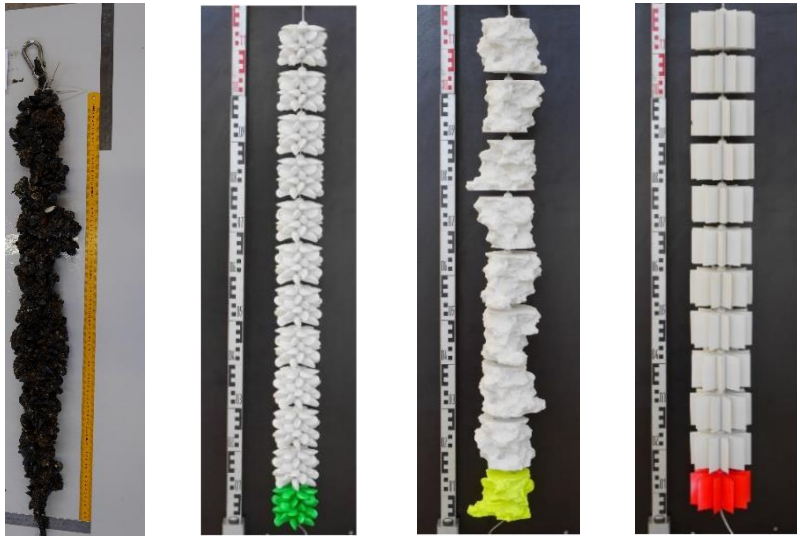


Landmann, J..; 2017

1:1 dropper line surrogate tests

- **Same tests as live mussels**
  - Drag tests with four velocities
  - Inertia tests with three waves
  - Top- and bottom-mounted
- **Evaluation regarding inertia and drag coefficients**
  - Comparison to live-mussel data
- **C_D- and C_M-values: In progress**





Landmann, J.; 2017

Landmann et al., 2019 [in prep.]

Outline

Basic Research

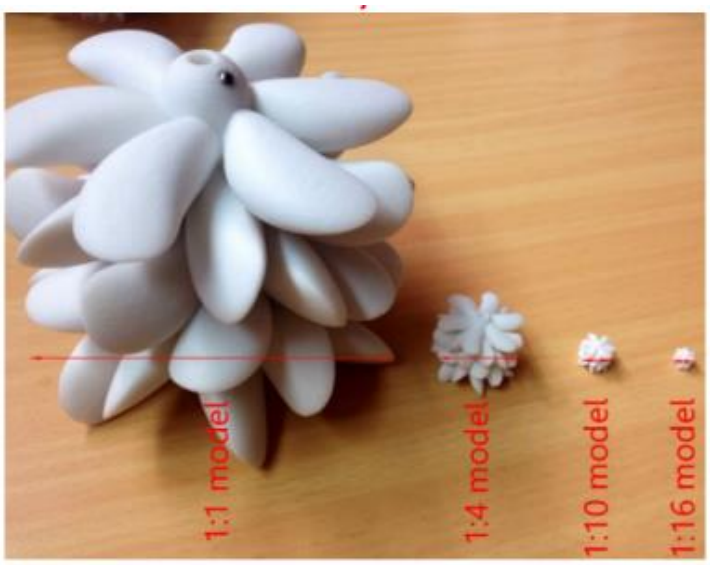
- Live Mussel tests
- Surrogate creation
- Surrogate 1:1 tests
- **Surrogate 1:X tests**

Farm concepts

- Long-Line System

Surrogate 1:X tests

- **Scaled surrogates**
  - 1:4, 1:10 and 1:16 with geometric similarity
  - Concept 2 dismissed



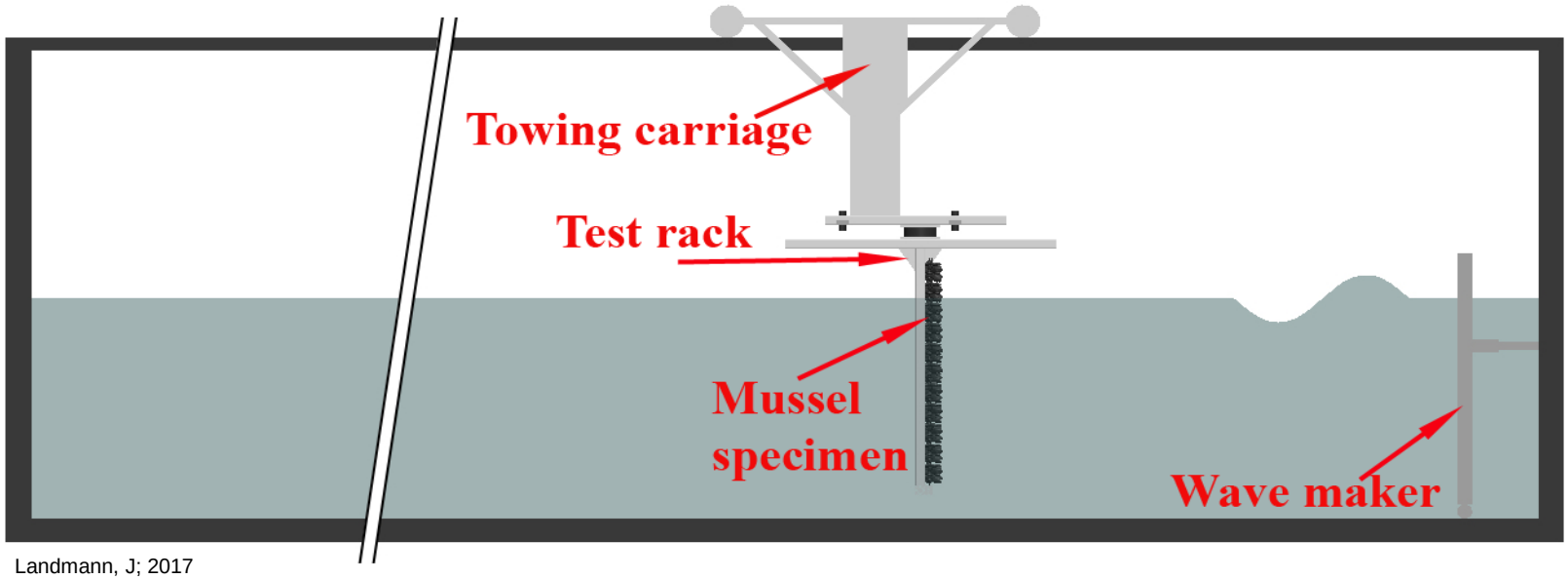
Landmann, J; 2017

Landmann, J; 2017

Gieschen et al., 2019 [in prep.]

Surrogate 1:X tests

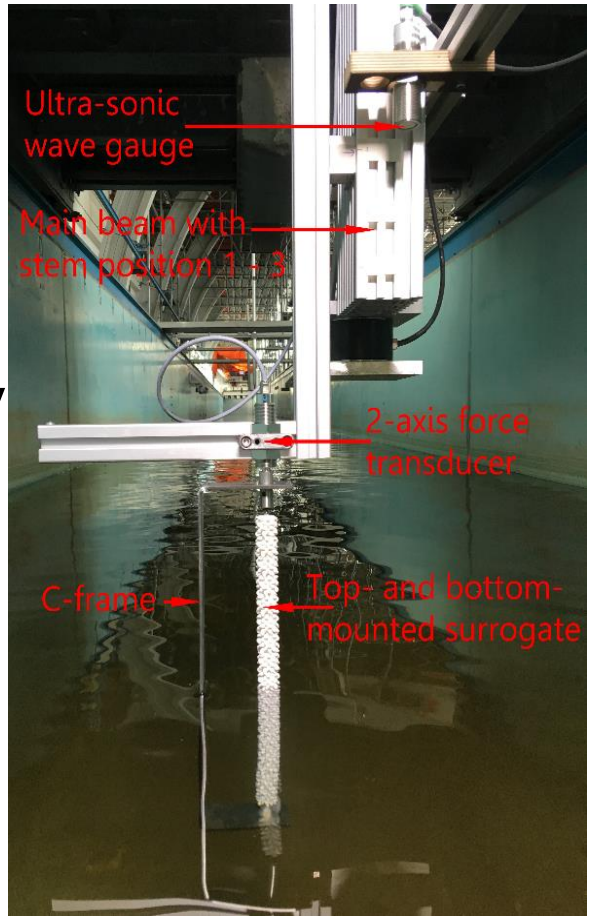
- **Methodology**
  - **Wave tests** only
  - Determination of **drag and inertia coefficients**
  - Investigate **scaling effects** on coefficients
  - Determination of **limits of down scaling**



Landmann, J; 2017

Surrogate 1:X tests

- **Mounting frame** fitted with:
  - 2-axis force transducer
  - Ultra-sonic wave gauge
- **Top- and bottom-mounted**
  - Sensor set-up change for top mounted only
  - Test for load-evasion potential ~90 %
- **Inertia tests** with **5-7 waves** each
  - Froude-Scaling of waves from live mussel tests
- **C_D, C_M and scalability: In progress**



Landmann, J; 2017

Outline

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- Surrogate 1:X tests

Farm concepts

Long-Line System

Long-Line System

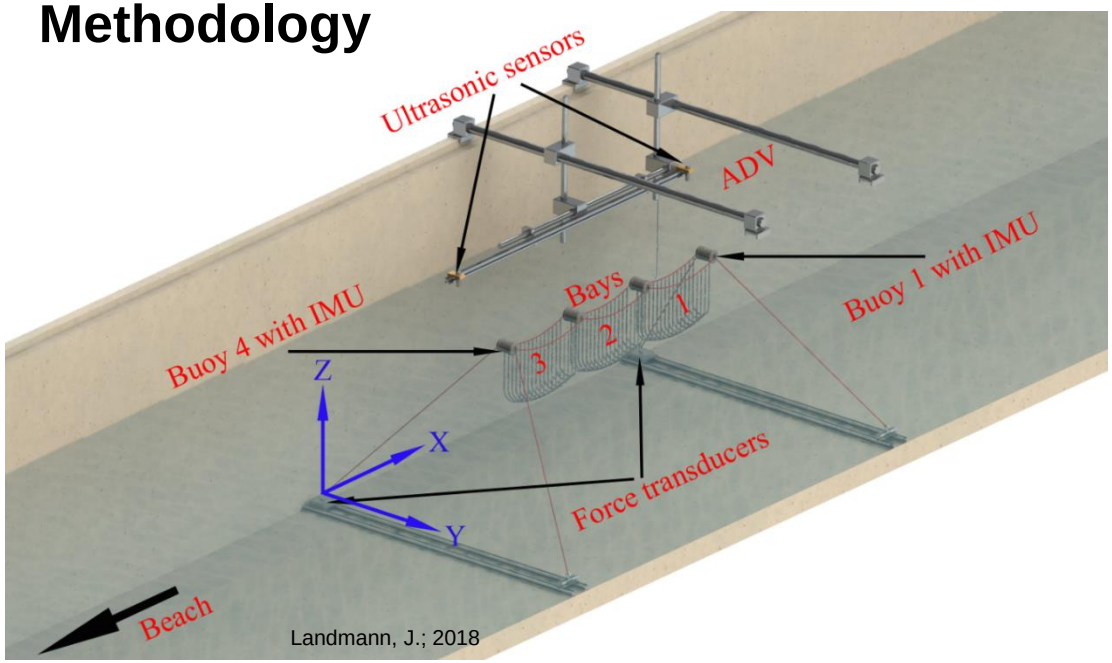
- **Structure**
  - „Traditional“ system in NZ
- **Objective**
  - Novel measurement concept regarding the mooring forces and accelerations
  - Influence of mussel dropper lines on force evolution under waves and currents
  - Motion response of the system under waves and currents

Vitasovich, P.; 2017

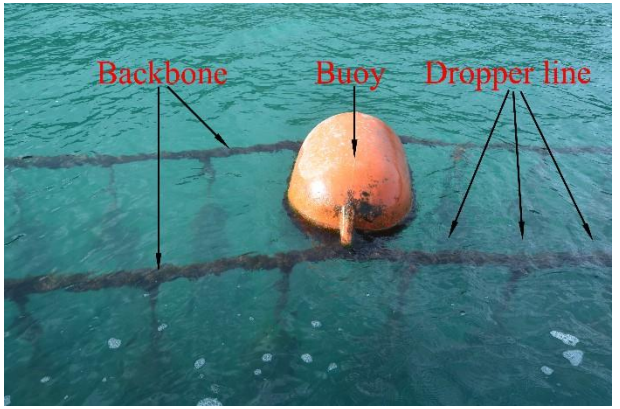
Goseberg, N.; 2017

Long-Line System

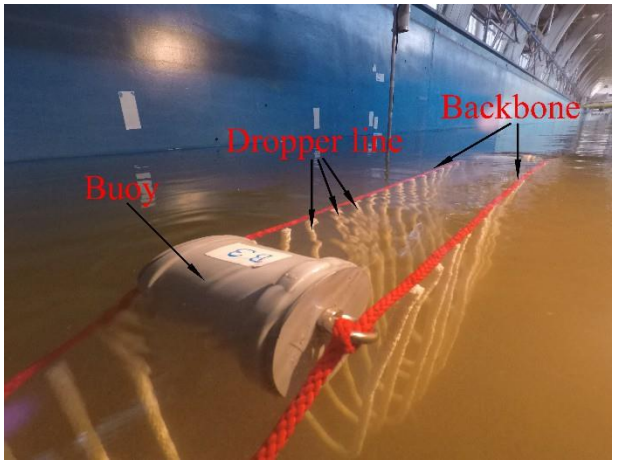
- **Methodology**



Landmann, J.; 2018



Goseberg, N.; 2017

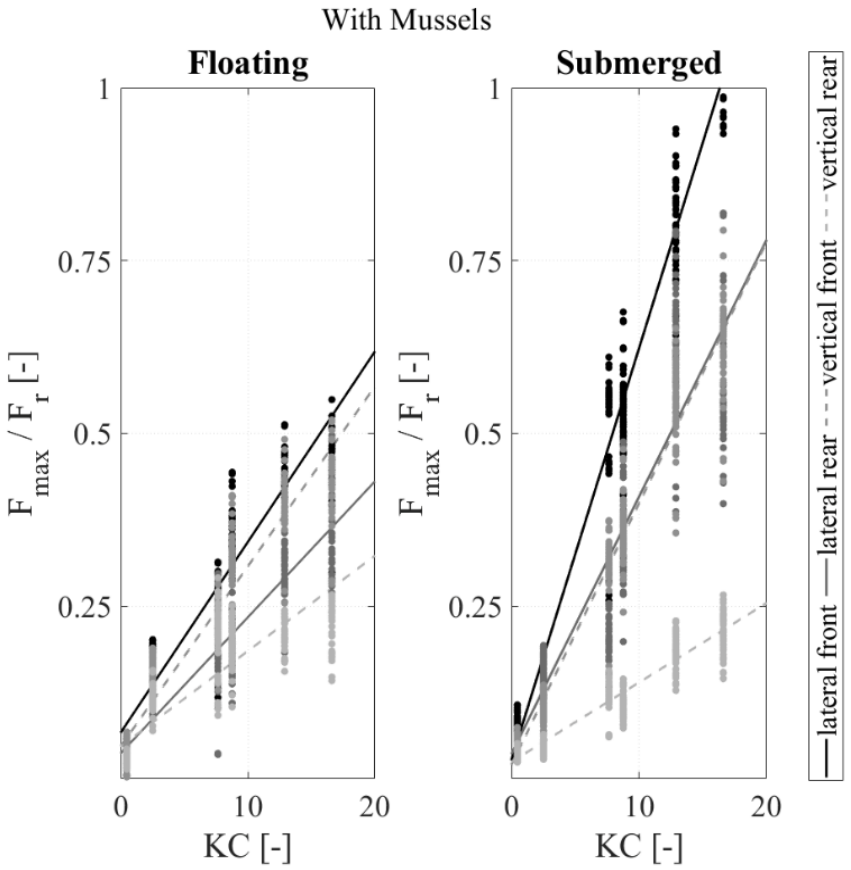


Landmann, J.; 2018

  - Wave spectra and
  - 5 Wave sets:
    - Height 1.2 – 25 cm
    - Period 0.76 – 2.9 s

Long-Line System

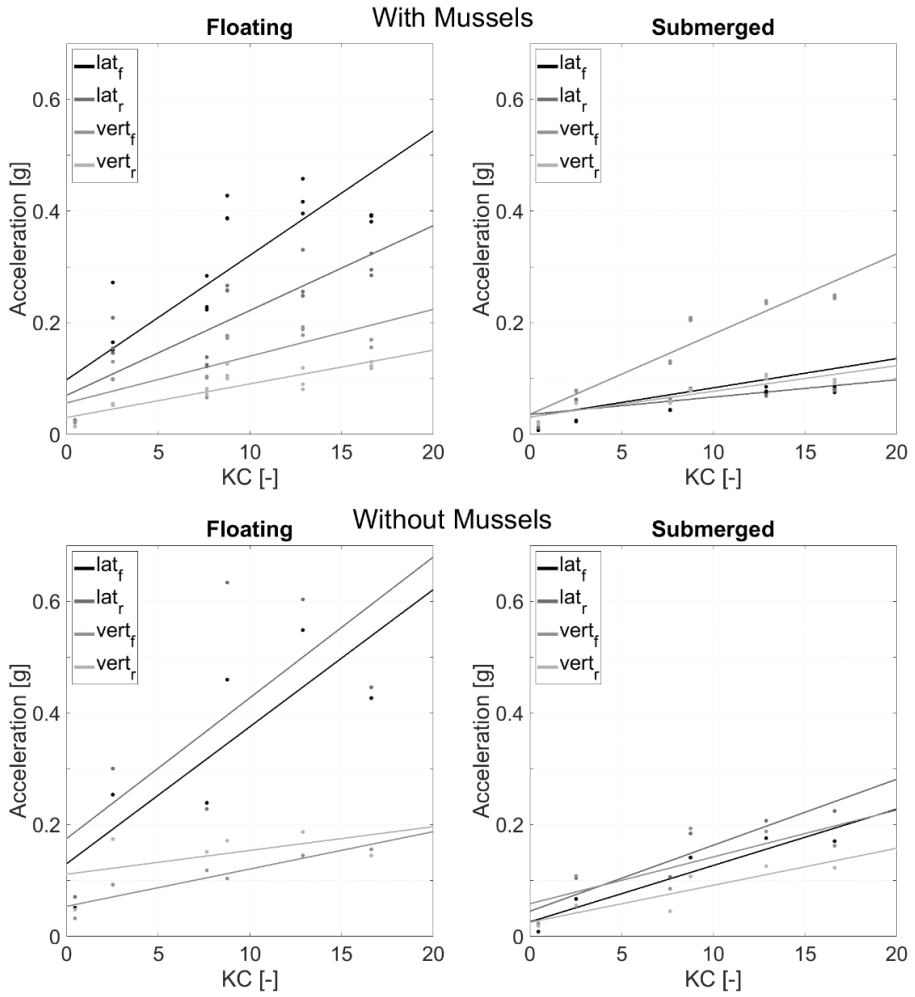
- **Mooring Forces**
  - Added mass of mussels increases tension
  - Submerged system experiences higher loads due to pretension
  - Snapping loads present



Landmann et al., 2019

Long-Line System

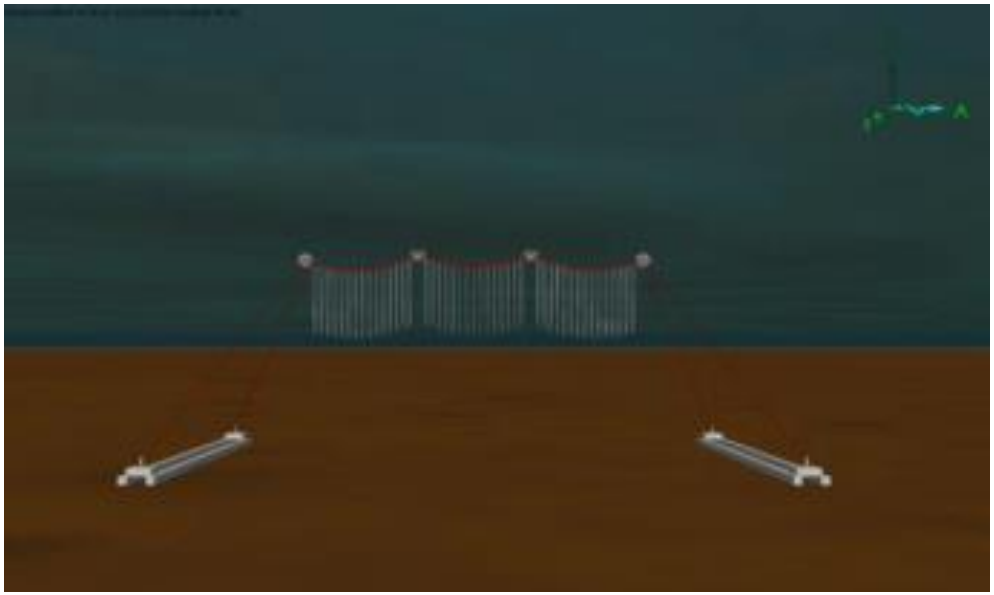
- **Accelerations**
  - Mussels dampen acceleration due to hydrodynamic mass
  - Submerged system experiences lower accelerations
  - Positive implications regarding drop-off



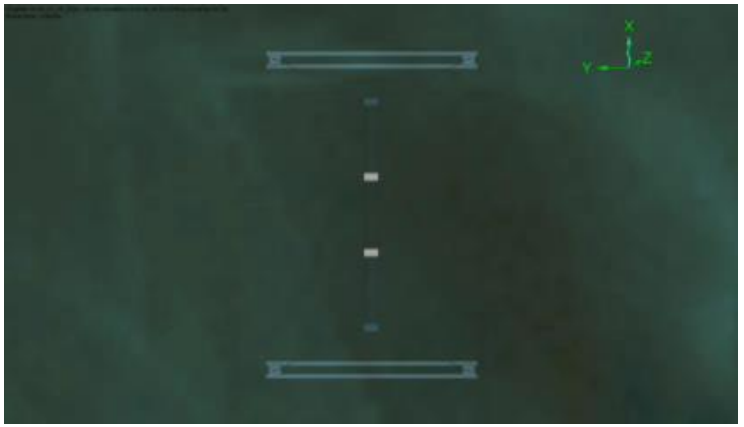
Landmann et al., 2019

Long-Line System

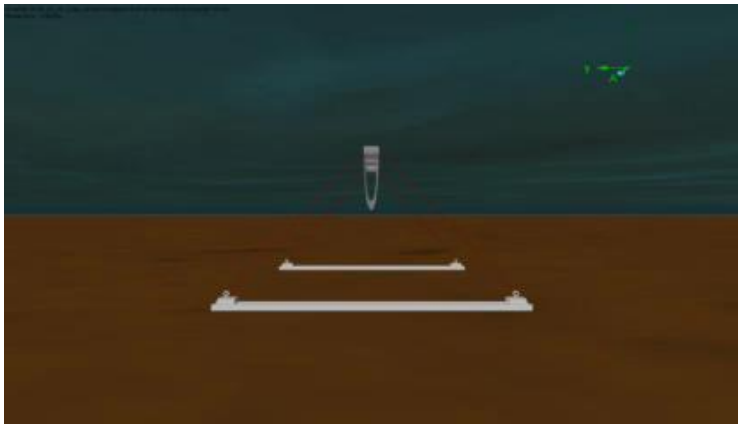
- **Numerical Simulation**
  - OrcaFlex-Model
  - Validation with experimental data
  - Parametric study planned



Fröhling, L.; 2019



Fröhling, L.; 2019



Fröhling, L.; 2019

Discussion