

# Hananui

Assessment of seabed effects





### Habitat type predictions

- Sand
- Sandy shell hash
- Coarse gravel shell and sand
- Bushy bryozoan thickets
- Bryozoan-sponge 'reefs'



8442 habitat data points

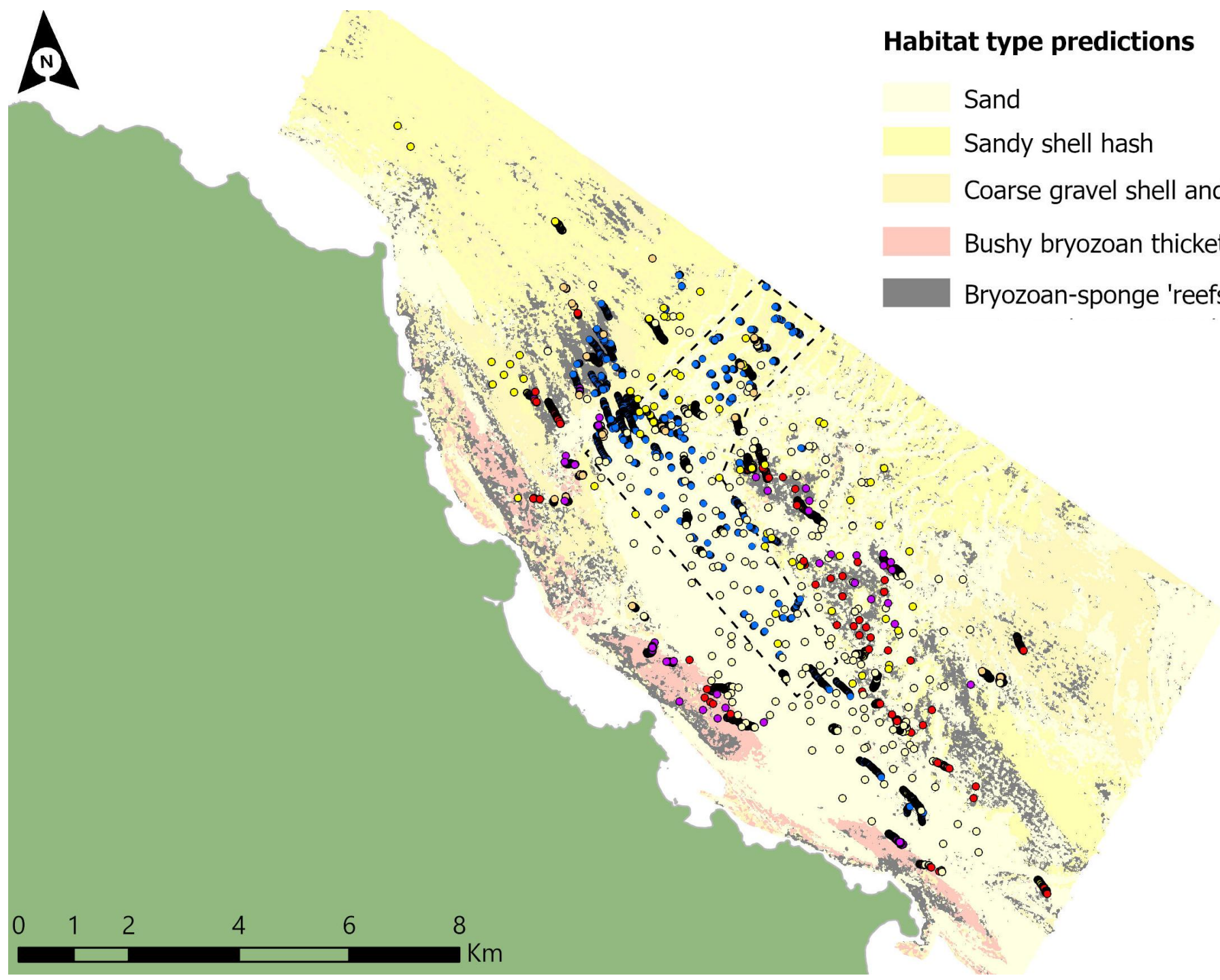
# Previous habitat map





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**New data**





### Habitat type predictions

- Sand
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- Bushy bryozoan thickets
- Bryozoan-sponge 'reefs'
- Patchy low-relief bryozoan-sponge



10,531 habitat data points



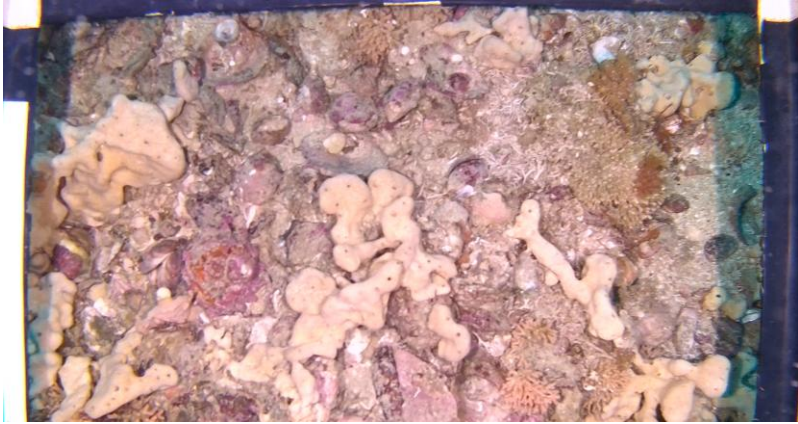
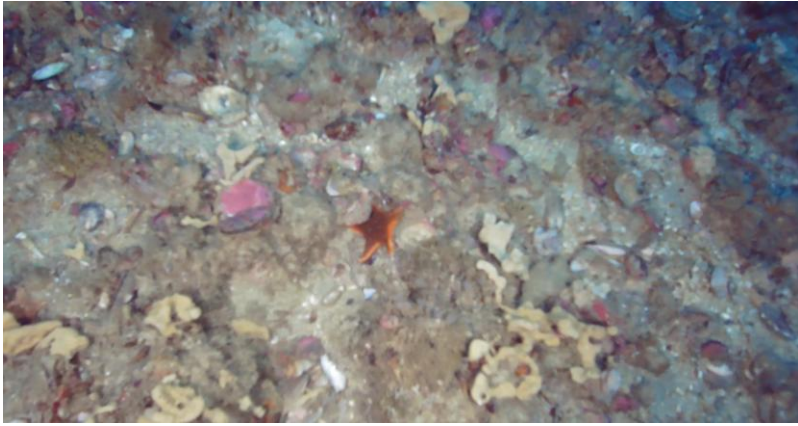
# Updated habitat map



- Biogenic clumps formed by massive encrusting bryozoan (*Celleporaria agglutinans*) and erect bryozoan (*Cinctapora elegans*)
- Other erect and encrusting bryozoans e.g. *Hornera foliacea* and possibly *Hornera robusta*.
- encrusting and erect sponges (likely *Chondropsis* cf. *kirkii* and possibly *Dactylia varia*, *Iophon minor*, *Crella incrustans*).
- Colonial ascidians (*Botrylloides* sp., *Botryllus* sp. and *Eudistoma circumvallatum*).
- Calcareous tubeworms (likely *Galeolaria hystrix*).
- Sea anemones (*Anthothoe albocincta*)
- Some bushy bryozoan and feather hydroids.
- Occasional individual or small patches of brachiopods and large bivalves including dredge oysters, scallops, bearded horse mussels and dog cockles.
- Occasional kina, sea tulips, sea cucumbers, brittle stars, cushion stars, 11-armed sea stars and gastropods including saw shells.
- Sparse foliose and encrusting red algae.
- Blue cod (*Parapercis colias*), leather jacket (*Parika scaber*), triplefin

## Bryozoan-sponge 'reefs'

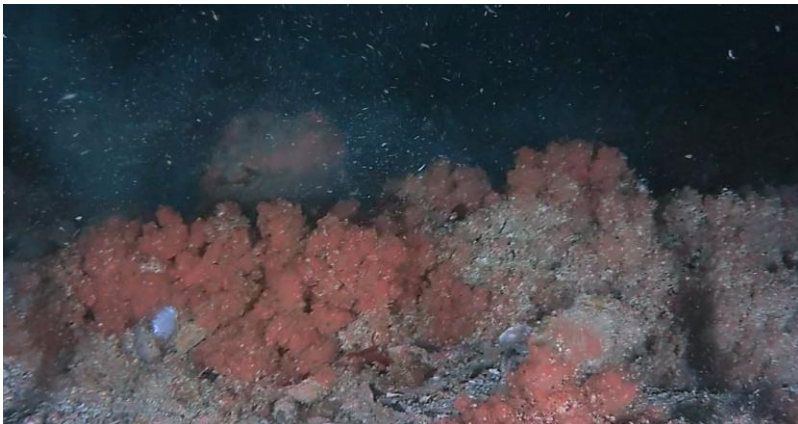
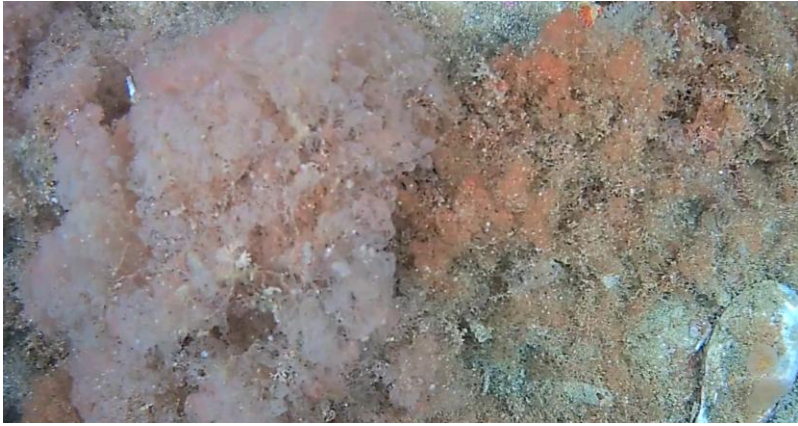
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- Small 'massive' encrusting bryozoan (*Celleporaria agglutinans*)
- Small erect bryozoan (*Cinctapora elegans*)
- Small erect / encrusting sponges (e.g. *Chondropsis cf. kirkii*)
- Occasional kina, sea cucumbers, brittle stars, cushion stars, 11-armed sea stars and gastropods including saw shells
- interspersed with areas of 'coarse gravel, shell and sand habitat.
- Where biogenic clumps occurred, observed biota were as for 'bryozoan-sponge reef' habitat.

## Patchy low-relief bryozoan-sponge habitat

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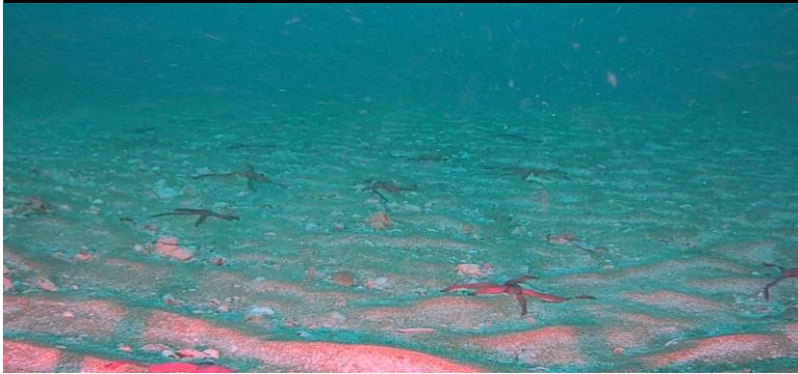


- Abundant bushy ('clown-hair') bryozoans (*Orthoscuticella innominata*)
- Mounds of calcareous tube-worms (likely *Galeolaria hystrix*),
- moderate abundance of small erect bryozoans (mainly *C. elegans*), sponges and feather hydroids.
- Sparse foliose red algae.
- Some red and brown drift algae.
- Occasional individual or small patches of large bivalves including dredge oysters, scallops, bearded horse mussels and dog cockles.
- Occasional patches of brachiopods.
- Occasional kina (*Evechinus chloroticus*), sea tulips, sea cucumbers. Gastropods, including saw shells. Occasional brittle stars, cushion stars and 11-armed sea stars.

## Bushy bryozoan thickets

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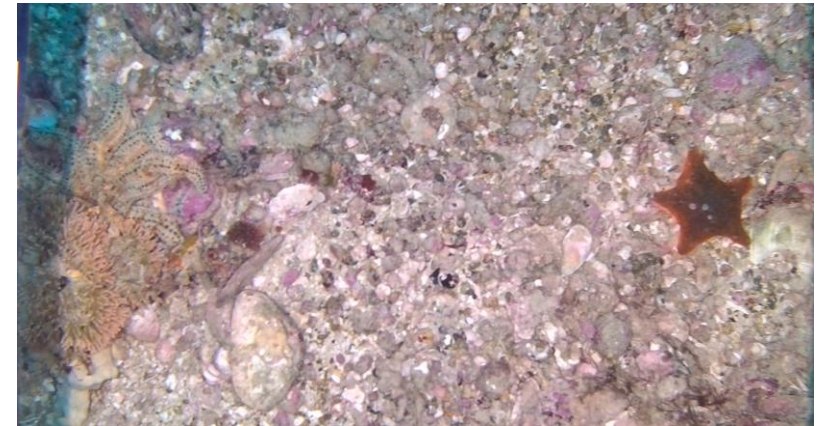
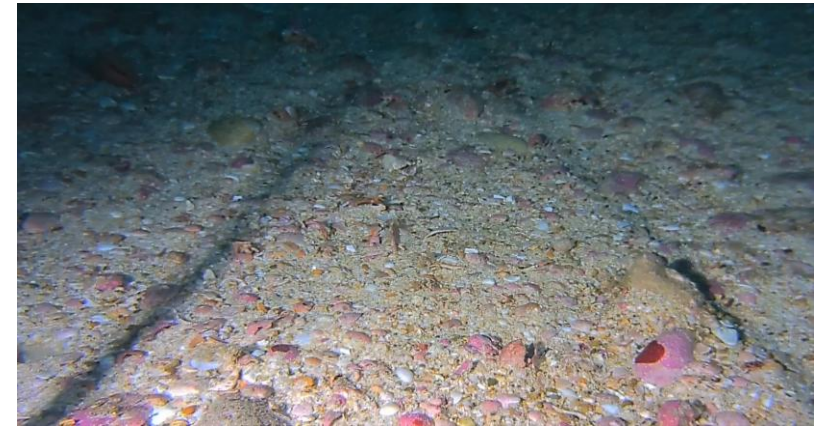
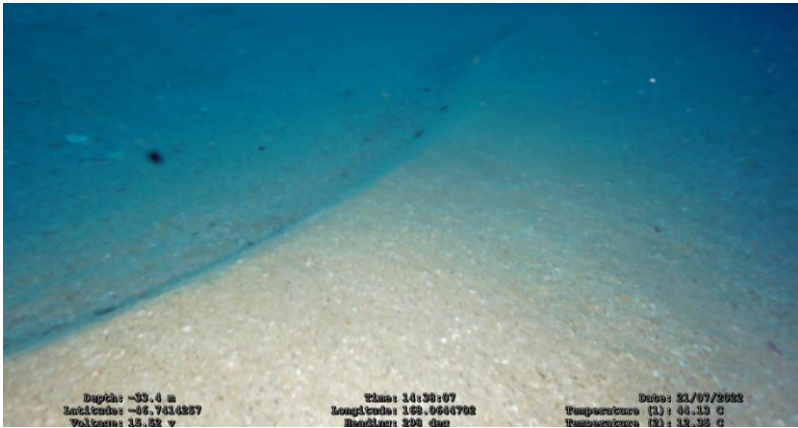
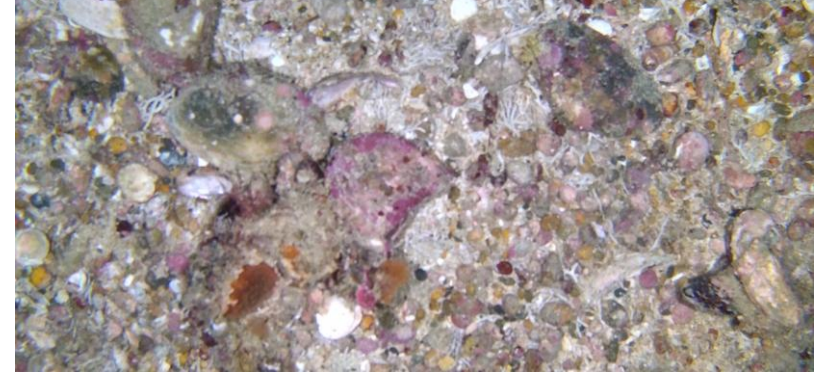
Sand



Sandy shell hash

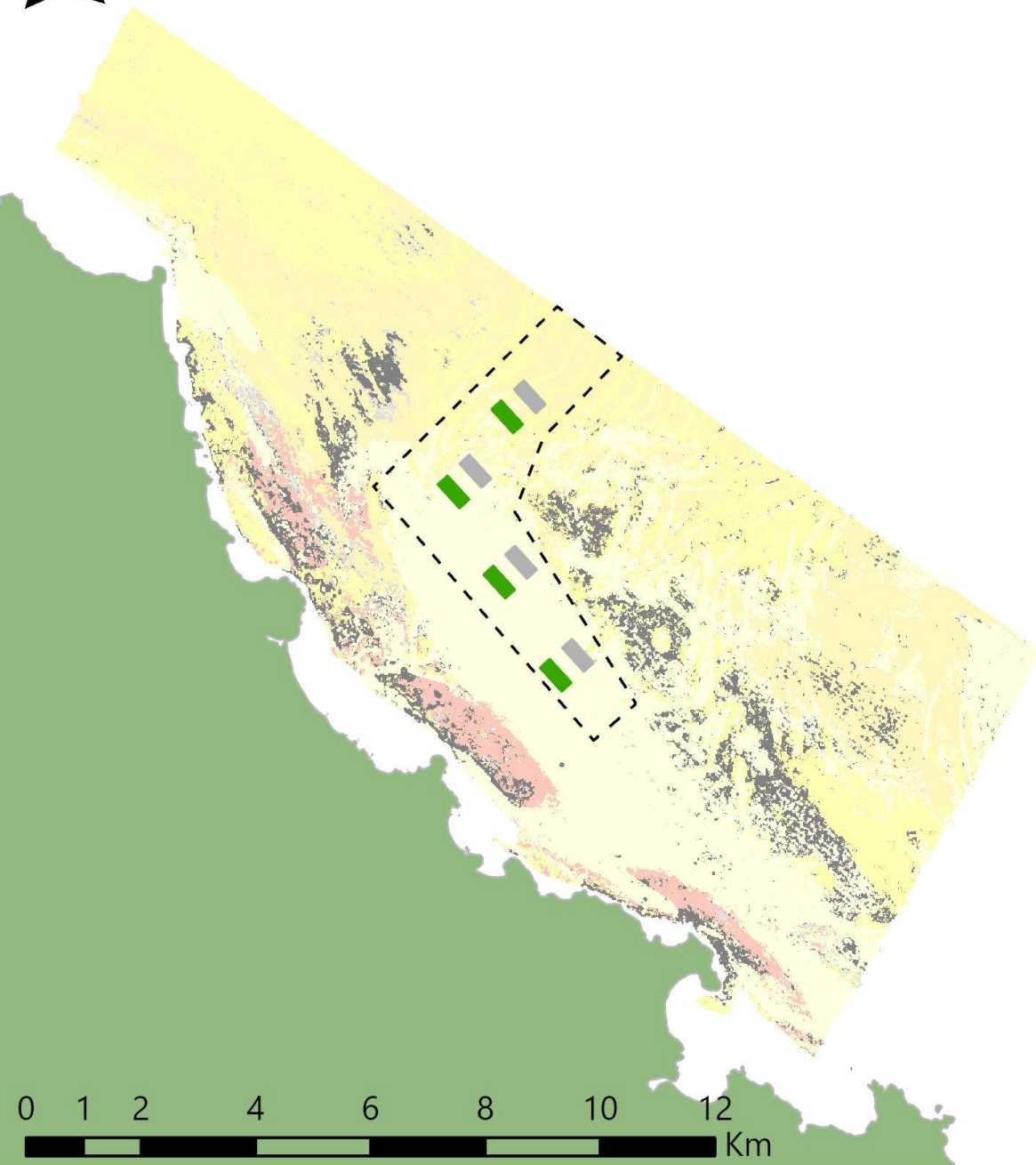


Coarse gravel sand and shell





# Hananui survey area



### Habitat type predictions

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- Bushy bryozoan thickets
- Bryozoan-sponge 'reefs'
- Patchy low-relief bryozoan-sponge
- Stage 1 blocks
- Stage 2 blocks

# Seabed effects from salmon farming

## Installation (anchors & moorings)

- Seabed disturbance & species displacement
- Short-term sediment resuspension
- Reduced impacts in sandy, high-current areas

*avoid sensitive habitats, staged development, skilled installation*

## Presence of farm structures

- Shading - minimal (few photosynthetic taxa)
- Habitat for fouling organisms, potential pest risk
- Possible protection from dredging impacts

*monitoring, biosecurity plan, regular inspection*

## Seabed Effects of Salmon Farming

- **Sediment:** Oxygen depletion, sulphides ↑, nutrients ↑; mitigated by high-flow sandy site.
- **Macrofauna:** Predictable succession → opportunists ↑, diversity ↓ at high loads.
- **Epifauna:** Little known. Assume high levels of farm waste = smothering clogging feeding apparatus. With lower levels, consumption of farm waste = ↑ food supply = ↑ growth or ↓ growth due to reduction in food quality.



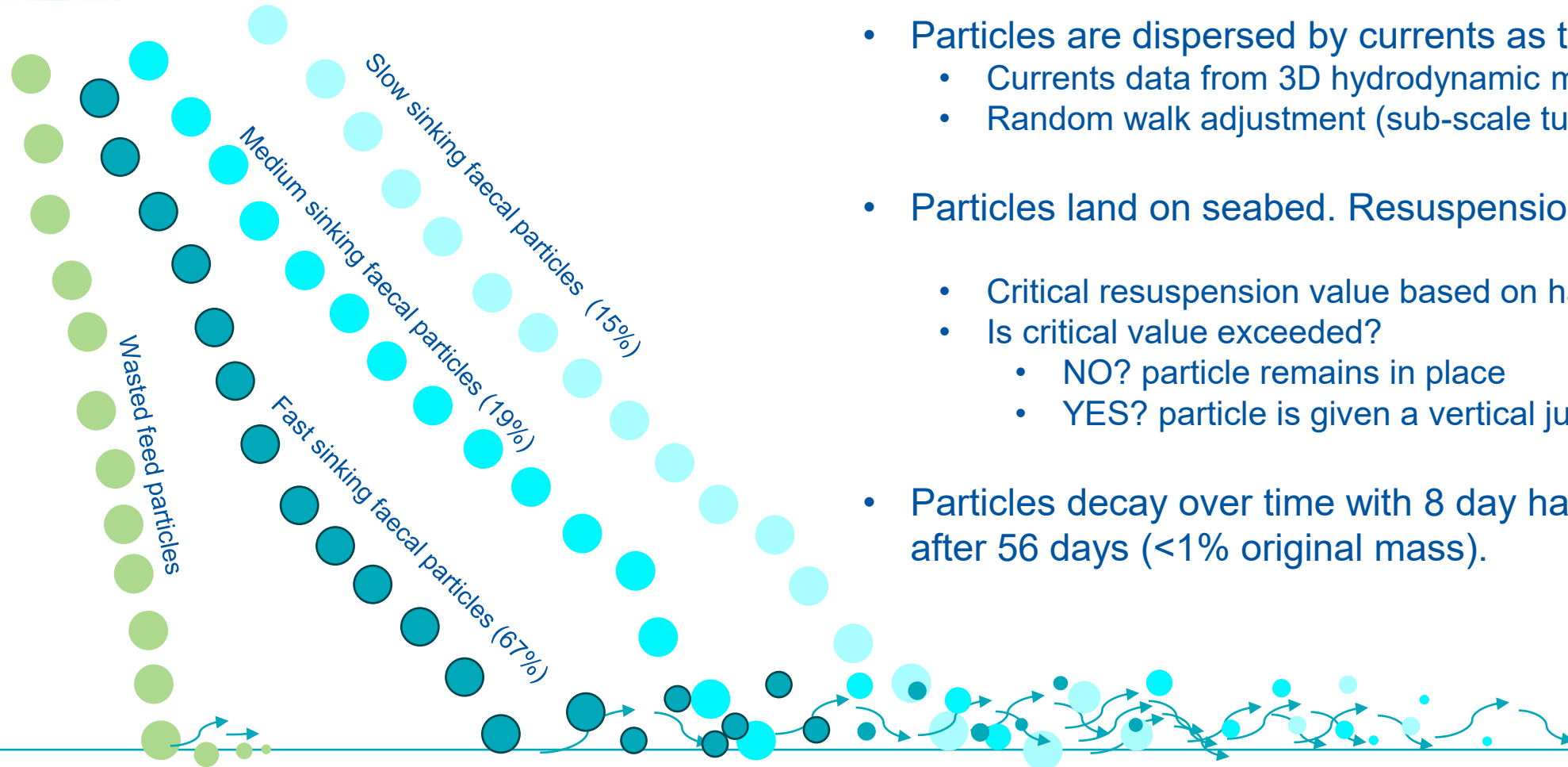
# Depositional modelling methods

**Approach and how / why this differs to the  
previous application**

# Improvements made to modelling

- New hydrodynamic model (3D time history of water currents)
  - 2-year duration (previously 2 months)
  - Effects of habitat on near-seabed currents included
- This modelling uses variable feed inputs that mirror production cycle
- Effect of benthic habitat built into resuspension dynamics
  - Resuspension thresholds determined by habitat using latest information in literature.
- Three different sizes of particles modelled with different sinking rates
  - Past modelling used one faecal particle size with one sinking rate

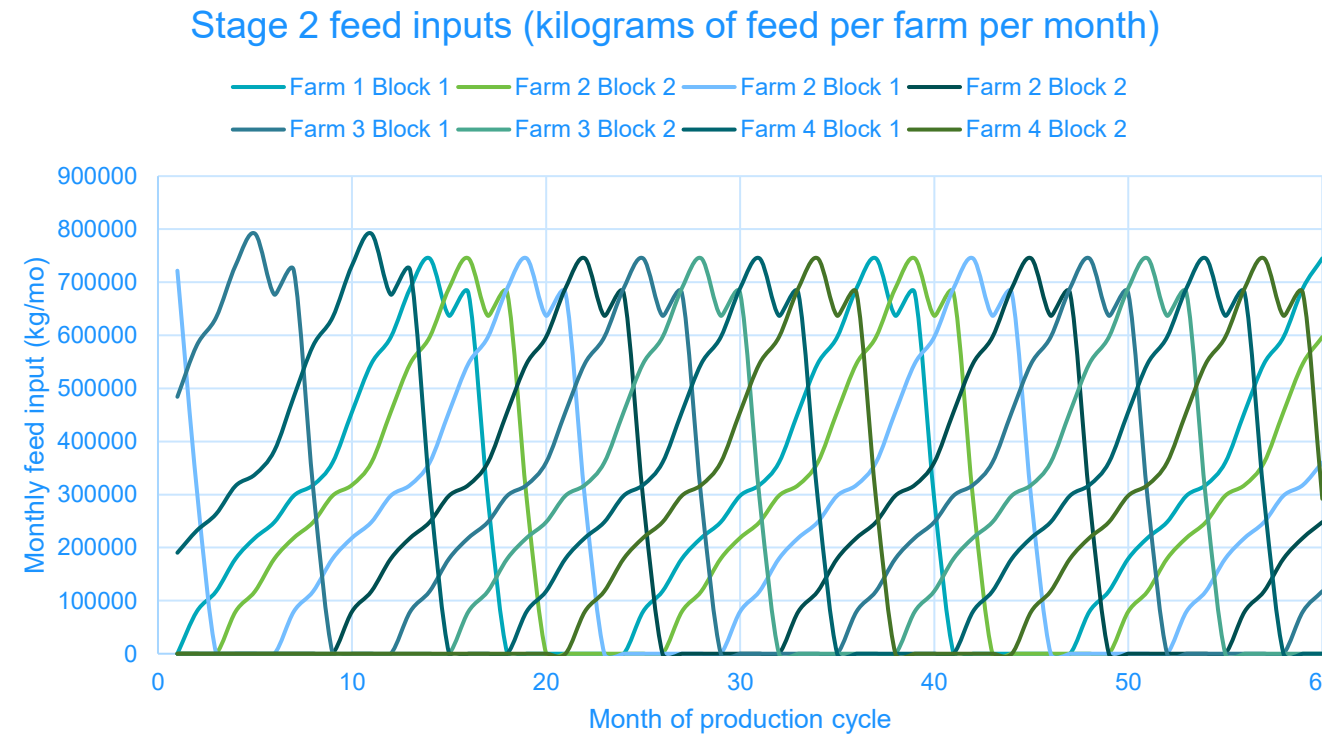
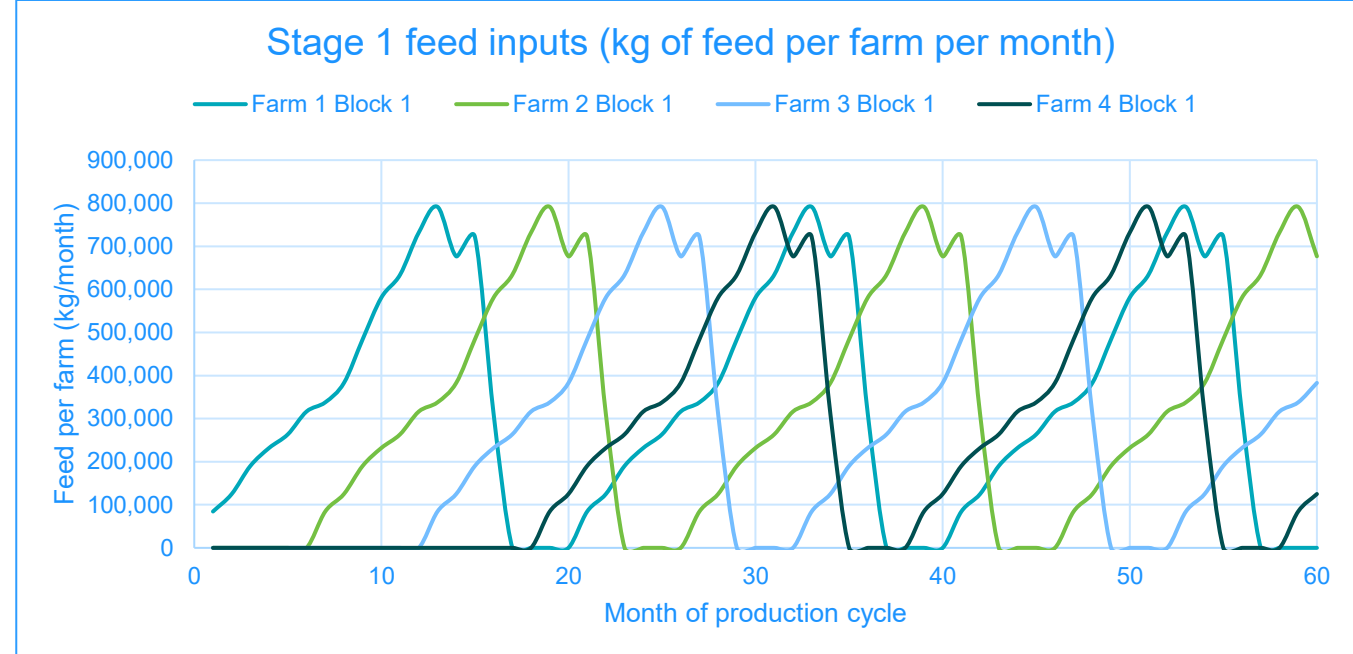
# How the model works



- Continuous release of virtual faecal particles and wasted feed pellets
- Particles are dispersed by currents as they sink
  - Currents data from 3D hydrodynamic model
  - Random walk adjustment (sub-scale turbulence)
- Particles land on seabed. Resuspension?
  - Critical resuspension value based on habitat + particle type
  - Is critical value exceeded?
    - NO? particle remains in place
    - YES? particle is given a vertical jump
- Particles decay over time with 8 day half life. Removed after 56 days (<1% original mass).

# Feed cycle

- Scenarios used here:
  - Each simulation is 24 months long
  - Modelled at full production (start up period excluded)
  - Statistics for each farm (block of pens) taken during highest three months of feed inputs.
- First three months of simulation thrown out while mass in simulation becomes 'steady'
- Stage 1:
  - 1 period of 24 months covers all peaks
- Stage 2:
  - 2 x 24 months required
  - 6 peaks captured in period 1
  - 2 remaining peaks captured in period 2



# Habitat used to determine resuspension criteria

Mud –  $u_{crit}^* = 0.008$  m/s (Carvajalino-Fernandez et al. 2020)

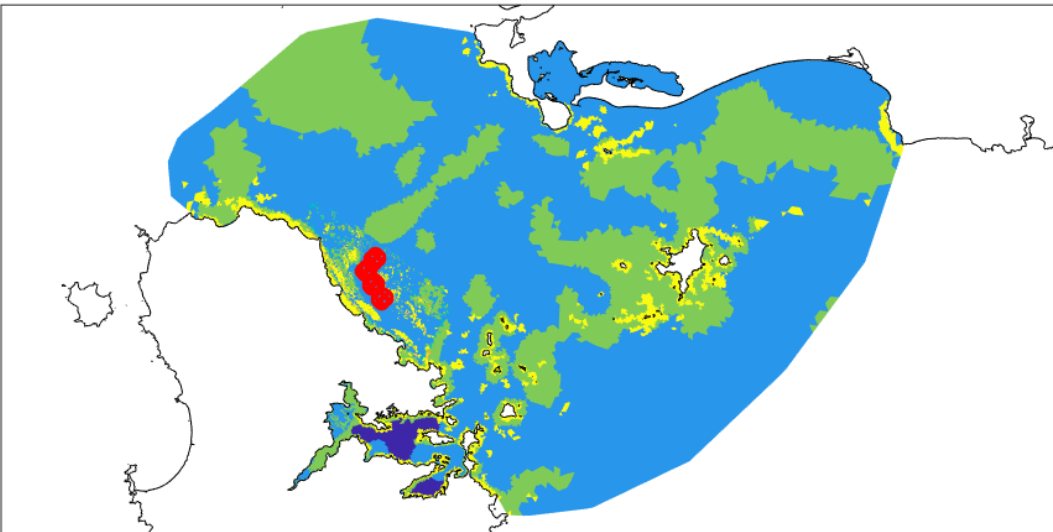
Sand –  $u_{crit}^* = 0.0105$  m/s (CF et al. 2020)

Gravel –  $u_{crit}^* = 0.013$  m/s ^^

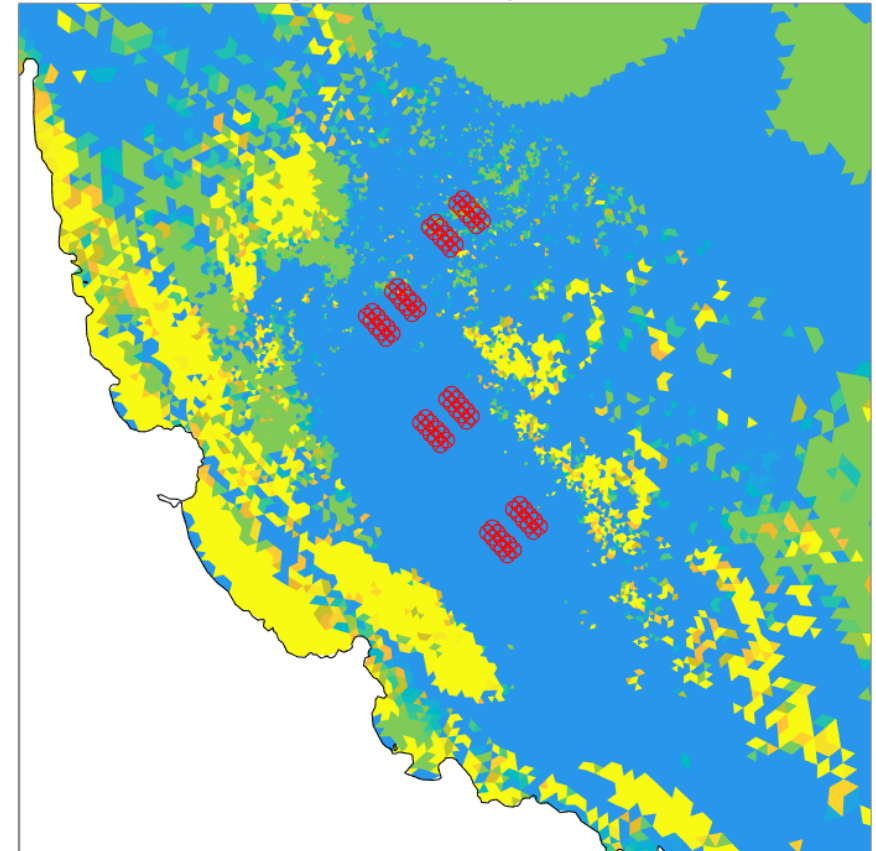
Reef –  $u_{crit}^* = 0.0163$  m/s (CF et al. 2020)

c.f. past modelling used single  $u_{crit}^*$  of 0.009 m/s throughout

Drag formulation in hydro model



Drag formulation in hydro model



^^ no direct value available, took mid-point of sand and reef

# Solids flux modelling

- “*mass flux*”, “*primary deposition*”, “*depositional flux*”
  - Rate of deposition to the seabed
  - Units:  $\text{g m}^{-2} \text{mo}^{-1}$ ,  $\text{g m}^{-2} \text{d}^{-1}$ ,  $\text{kg m}^{-2} \text{yr}^{-1}$ )
  - No resuspension
  - “Like checking a rain gauge’
- Traditional metric of deposition that works well at low flow farms
- Established relationships to estimate ecological enrichment via Enrichment Stage (ES) in Marlborough Sounds
- Relationships often applied outside of Marlborough Sounds

# Residual solids modelling

- Accumulation of solids on seabed
  - Units:  $\text{g m}^{-2}$
  - Particles resuspended and decayed
  - “A snapshot of the seabed” or “what you’d most likely see if you went down and took a look”
- Mean residual solids = average accumulation during three-month period
- Relationships derived from a Tory Channel study for
  - soft sediment:  $12.5 \text{ g m}^{-2}$
  - reef habitats:  $9 \text{ g m}^{-2}$

# Ecological effects ‘thresholds’

## Solids flux - Predicted effects footprint for soft-sediment habitats

1 kg m<sup>-2</sup> yr<sup>-1</sup> corresponds to ‘*moderate*’ enrichment effects (Keeley et al. 2013)

- Based on footprint mapping exercise in Marlborough Sounds (Keeley et al. 2013).
- Relationships between flux and effects may vary by site e.g. sandy seabed here differs from sandy-muddy habitats of Marlborough Sounds and very different flow regimes (currents at Hananui = 2 x Tory Channel)
- Derived using a very simple model (DEPOMOD) compared to the model used here (OceanTracker)
- Here we use a **more conservative 0.5 kg m<sup>-2</sup> yr<sup>-1</sup>**, as enrichment may be noticeable at lower levels due to naturally low organic content.

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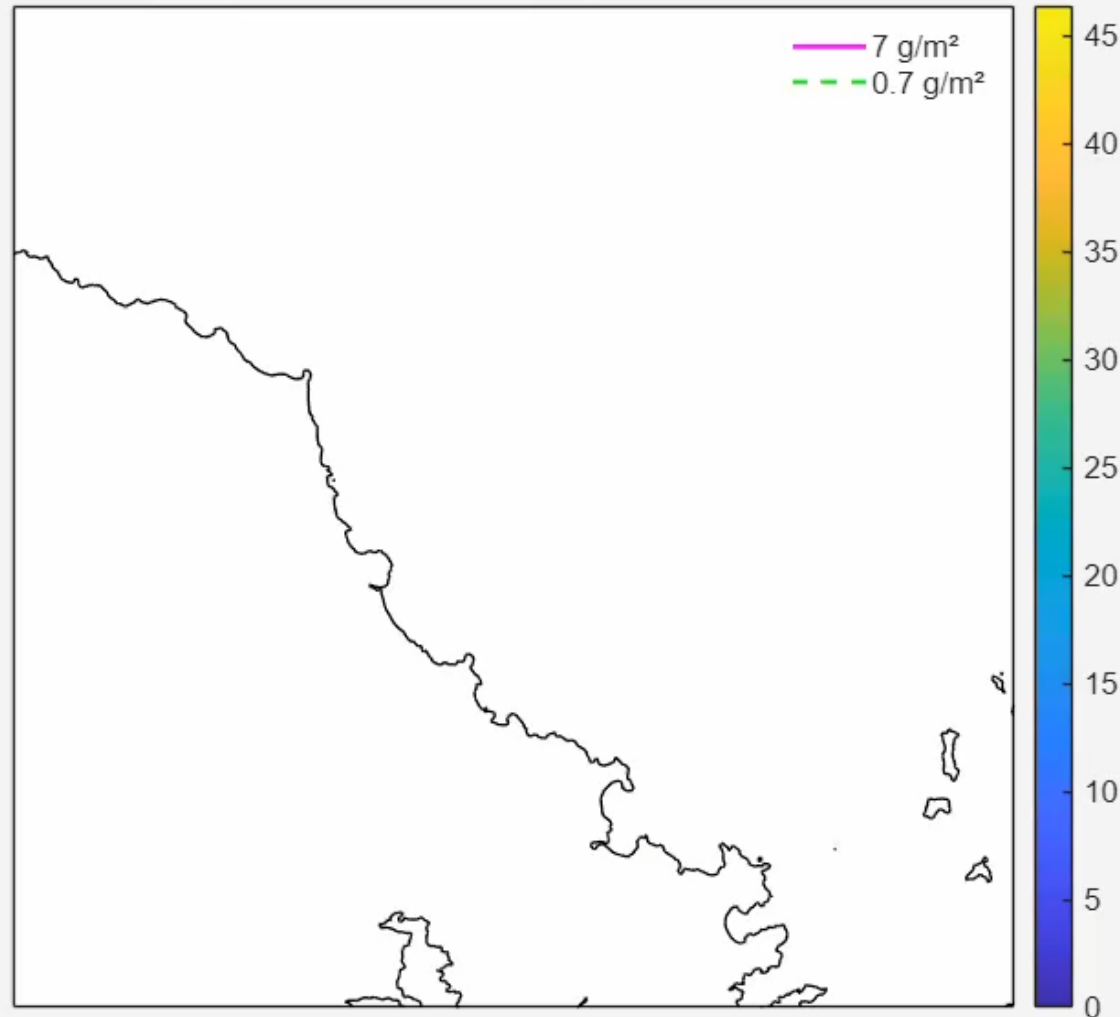
## Residual solids

Based on footprint mapping exercise in Tory Channel (Elvines et al. 2021) that used similar model to here although less sophisticated.

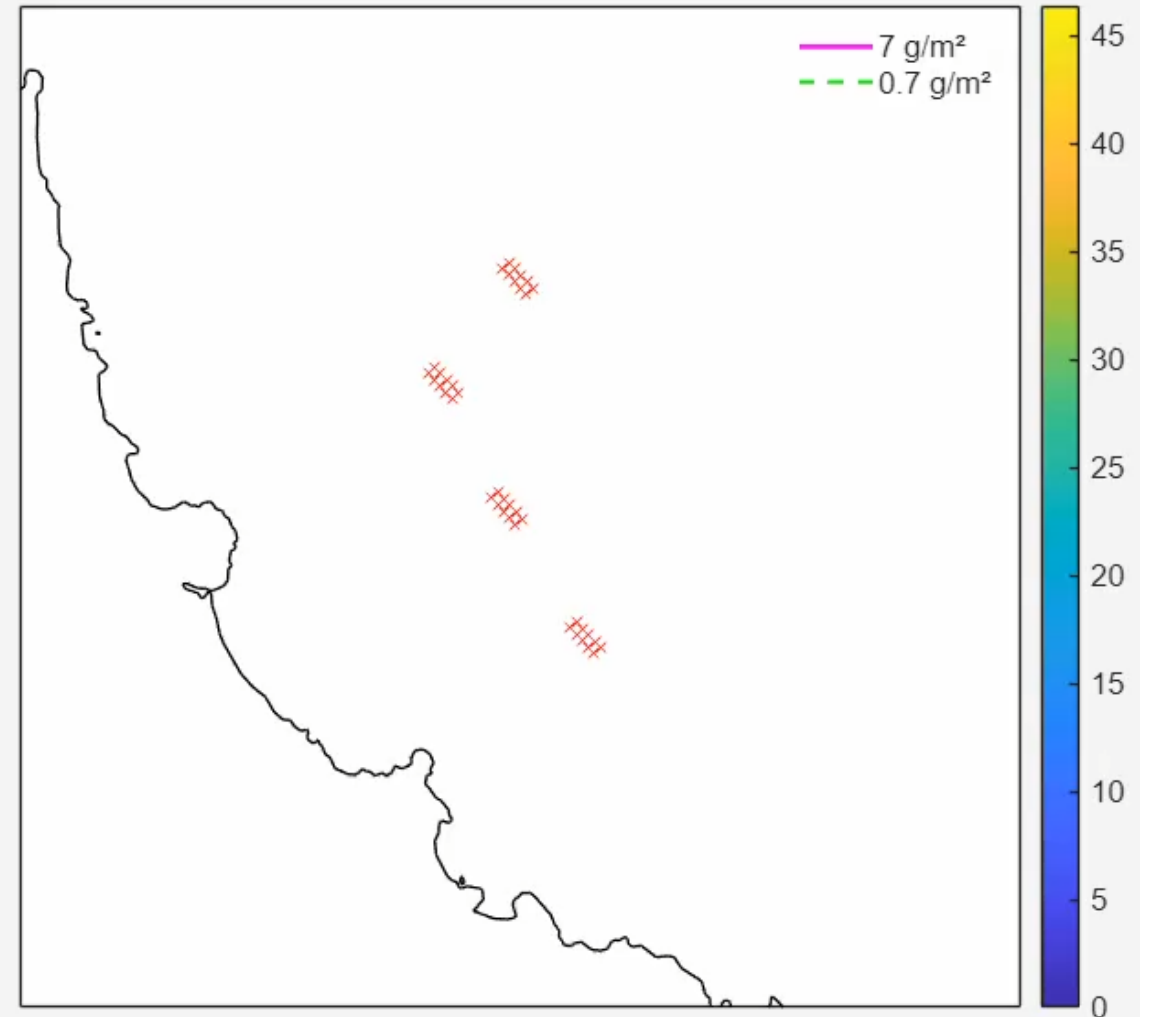
- Threshold determined for moderate enrichment in soft sediment ~12.5 g·m<sup>-2</sup>
  - Moderate enrichment seen at soft sediment stations where modelled residual solids was 7-18 g·m<sup>-2</sup> (12.5 is midpoint)
- Threshold for rocky reef communities 9 g·m<sup>-2</sup>
  - No enrichment detected at reef habitats, but model showed residual solids of 0.15 to 9 g·m<sup>-2</sup> at reef stations
- Here we use **more conservative thresholds of 7 g·m<sup>-2</sup> for primary footprint and 0.7 g·m<sup>-2</sup> for outer limit of effects**

# Stage 1: Residual Solids

Daily residual solids (g/m<sup>2</sup>) on 01-Jun-2018

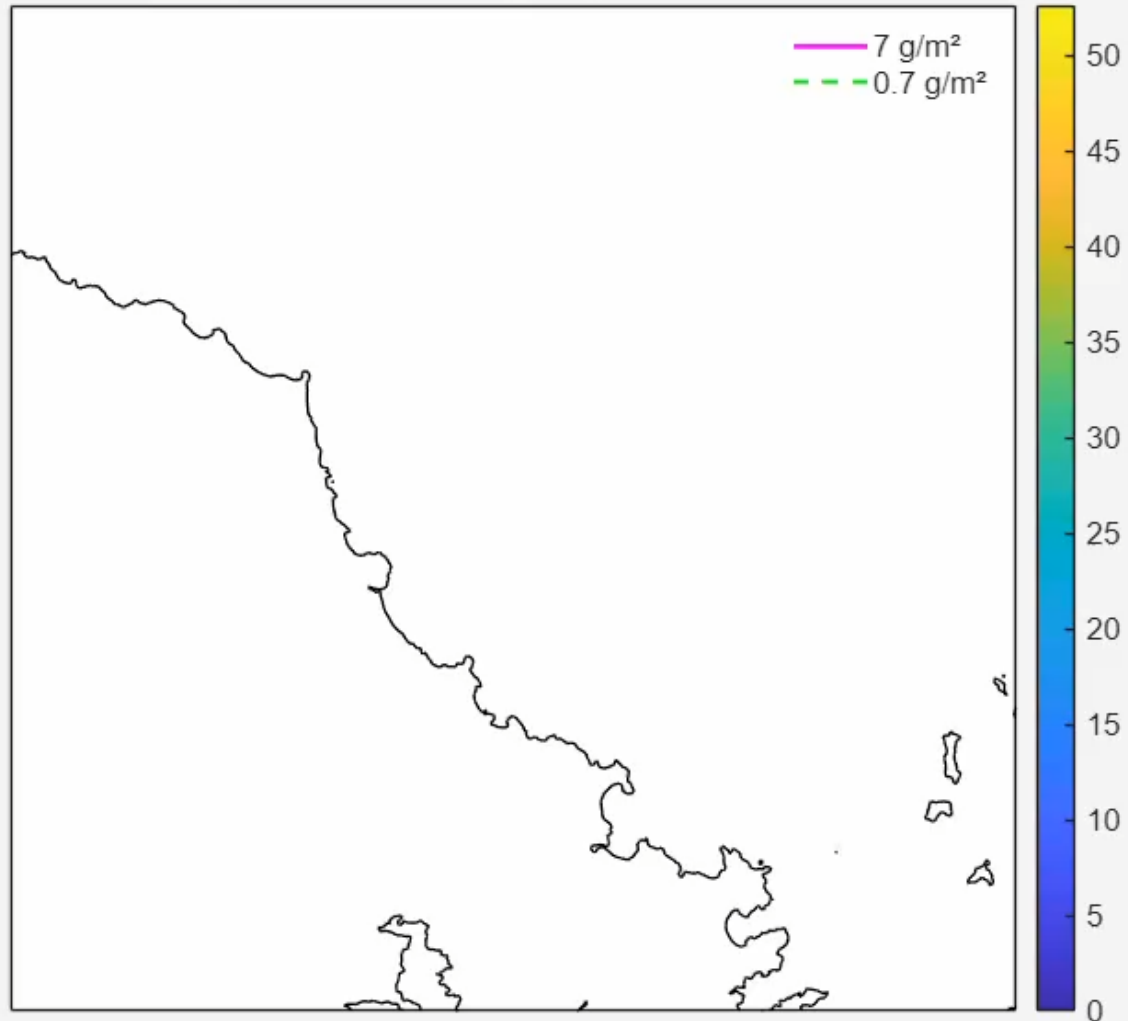


Zoomed area (g/m<sup>2</sup>)

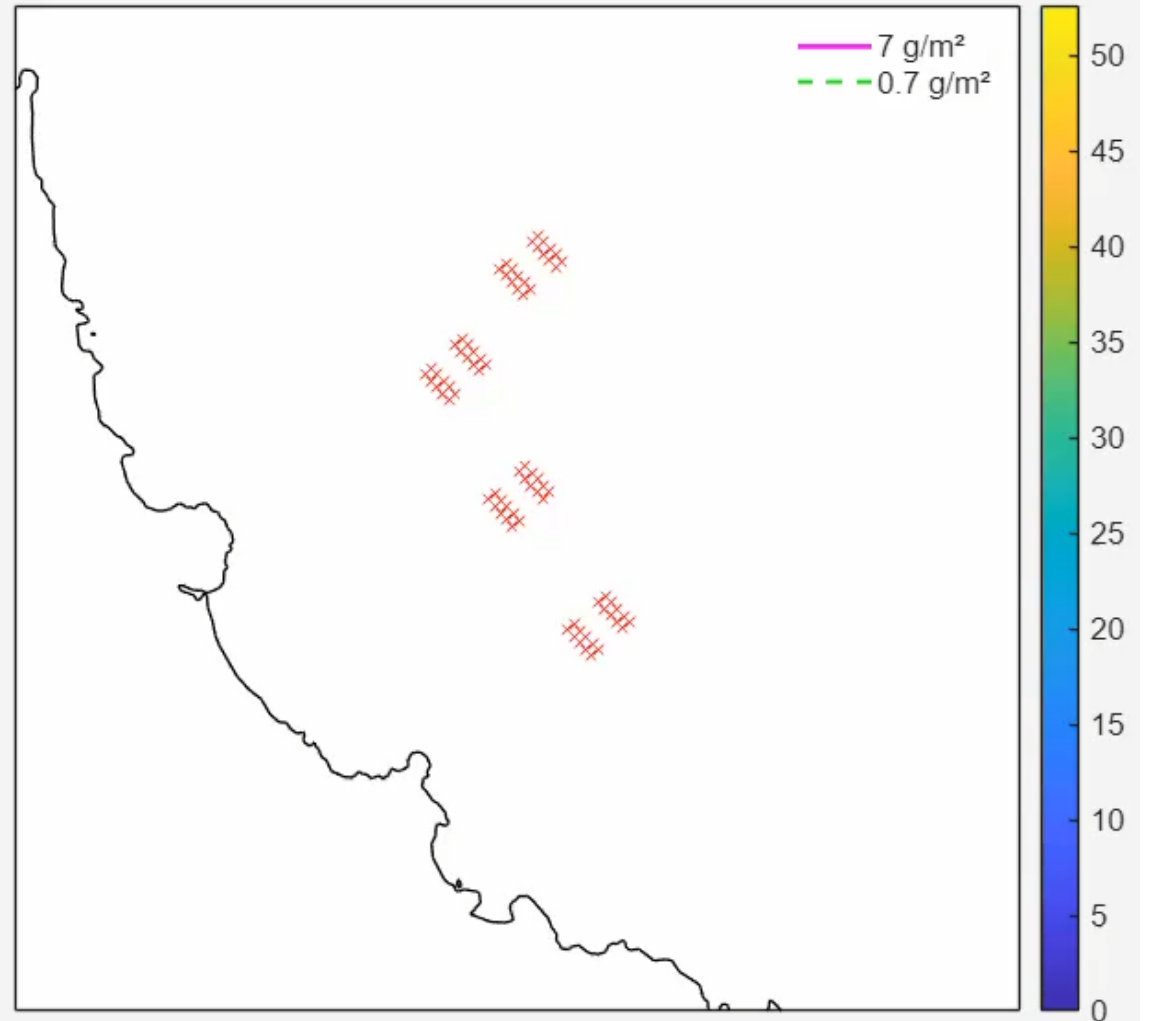


# Stage 2: Residual Solids

Daily residual solids ( $\text{g/m}^2$ ) on 01-Jun-2018

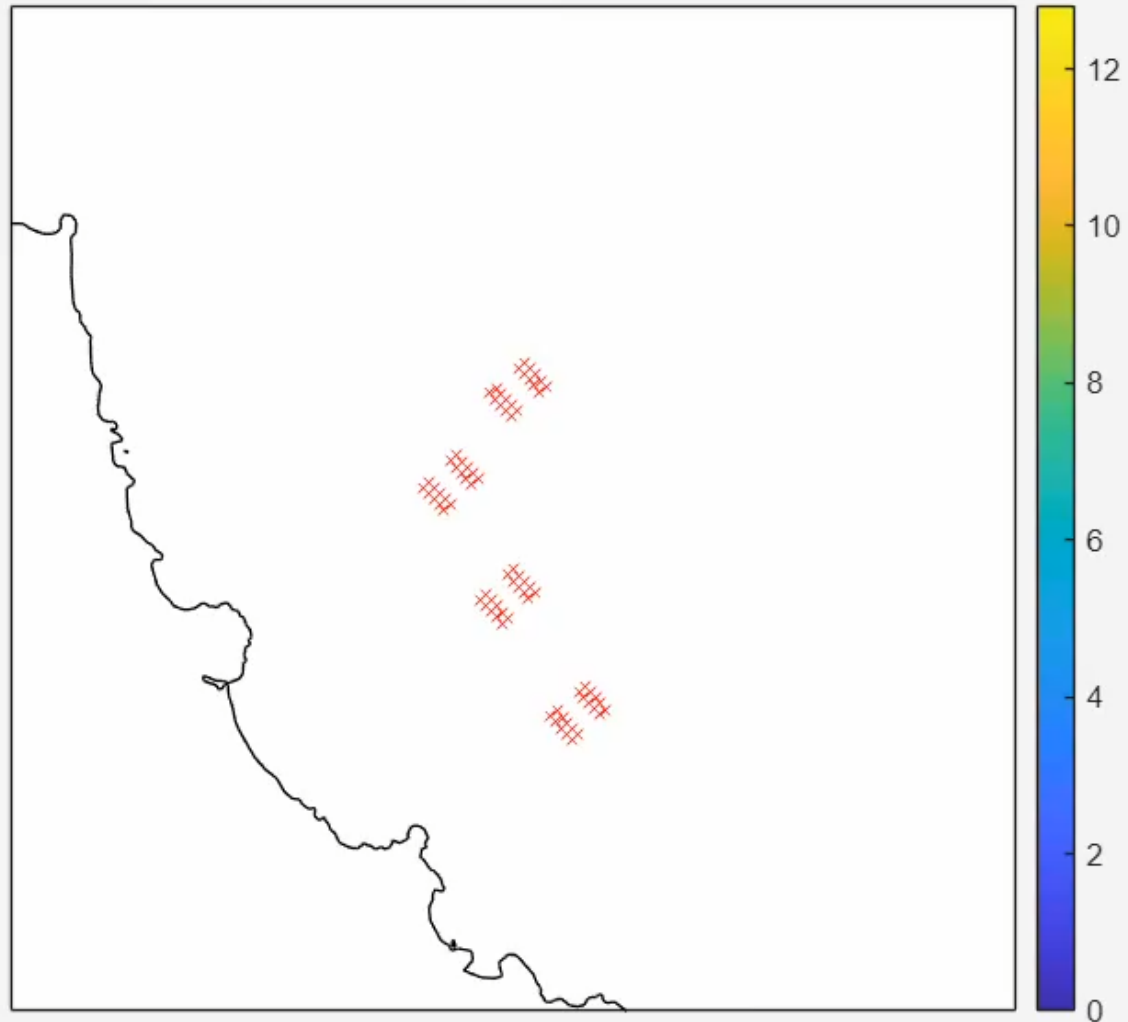


Zoomed area ( $\text{g/m}^2$ )

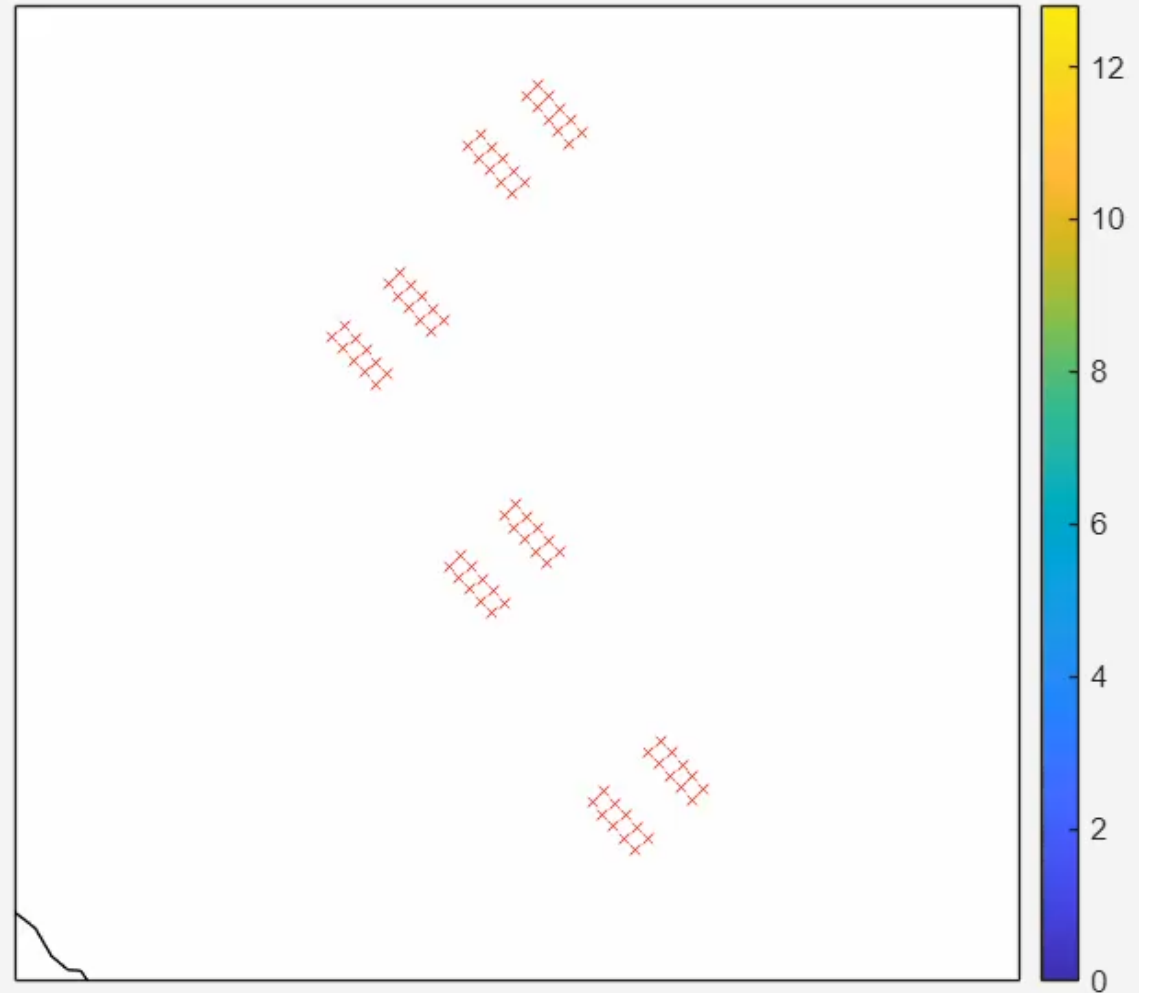


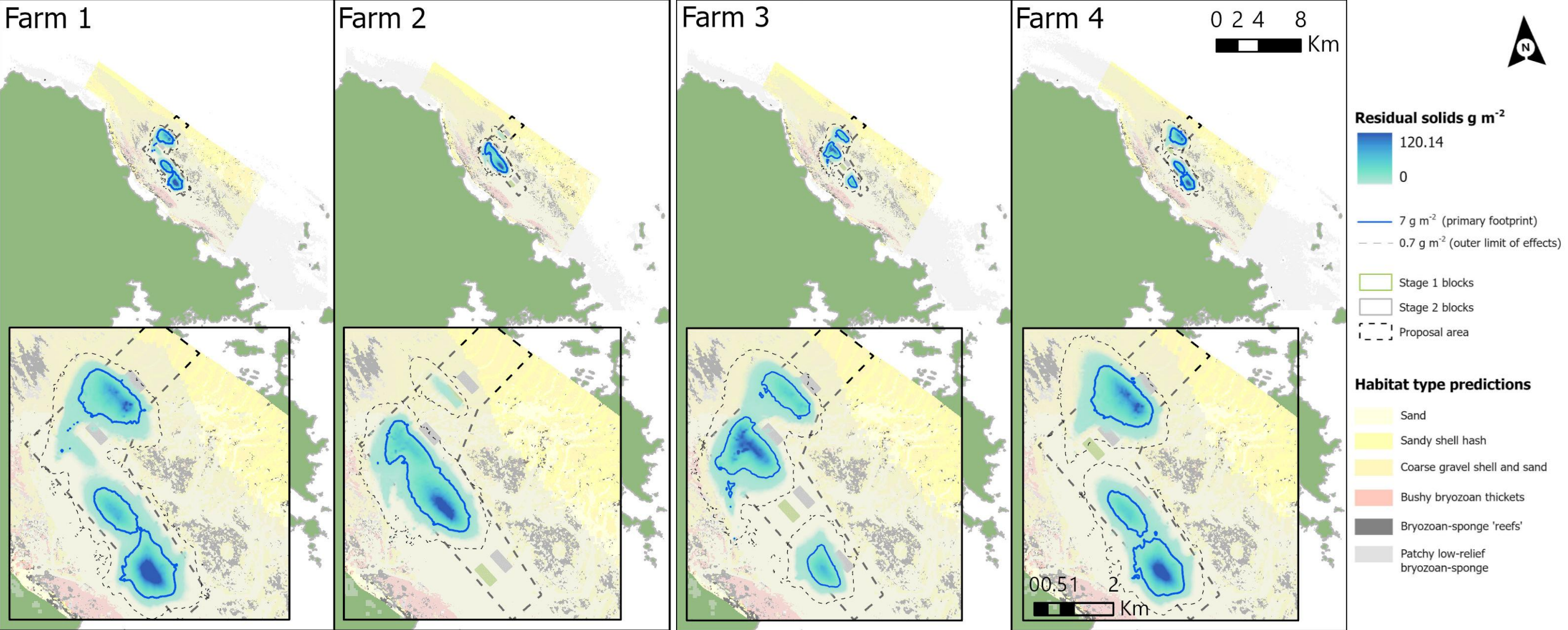
# Stage 2: Solids flux (no resuspension)

Daily mass flux (g/m<sup>2</sup>) on 01-Jun-2018

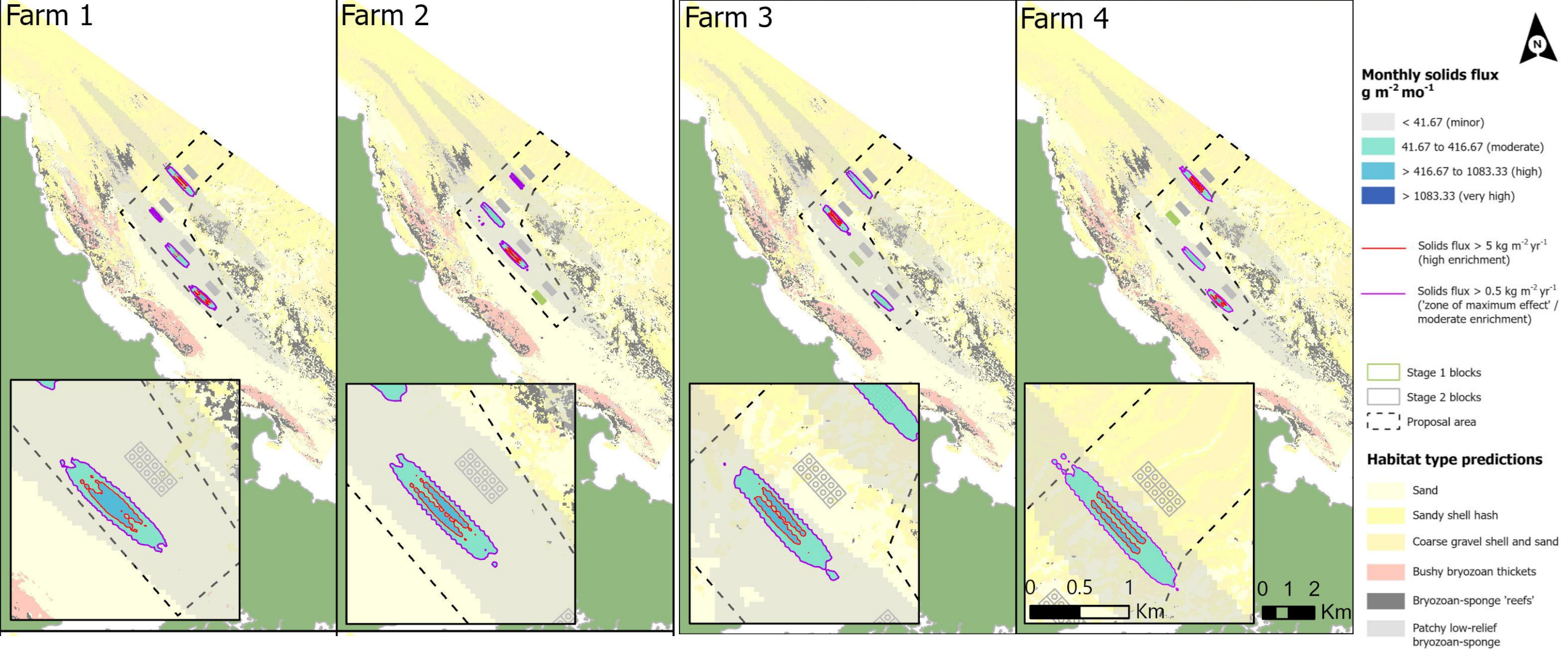


Zoomed area (g/m<sup>2</sup>)





## Residual solids (resuspension) – stage 1 peaks

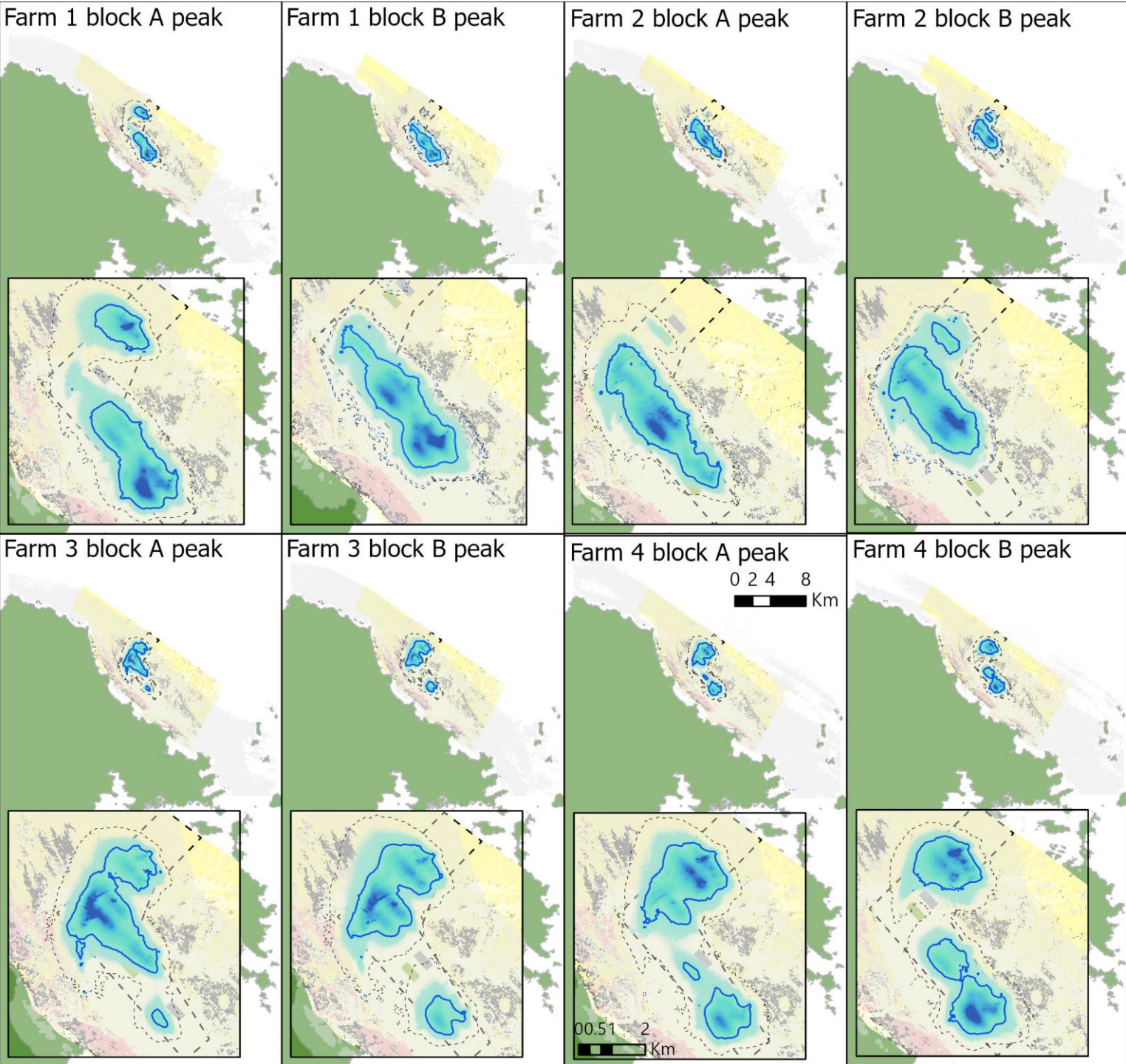


**Solids flux (no resuspension) – stage 1 peaks**

# Stage 2 – 25,000 TPA

2 full production cycles at stage 1 required at each farm + need to demonstrate:

- environmental effects are consistent with, or less than, those predicted for Stage 1 and that the progression to Stage 2 is not likely to result in unacceptable adverse effects.
- model validation may also be undertaken.



**Residual solids  $\text{g m}^{-2}$**



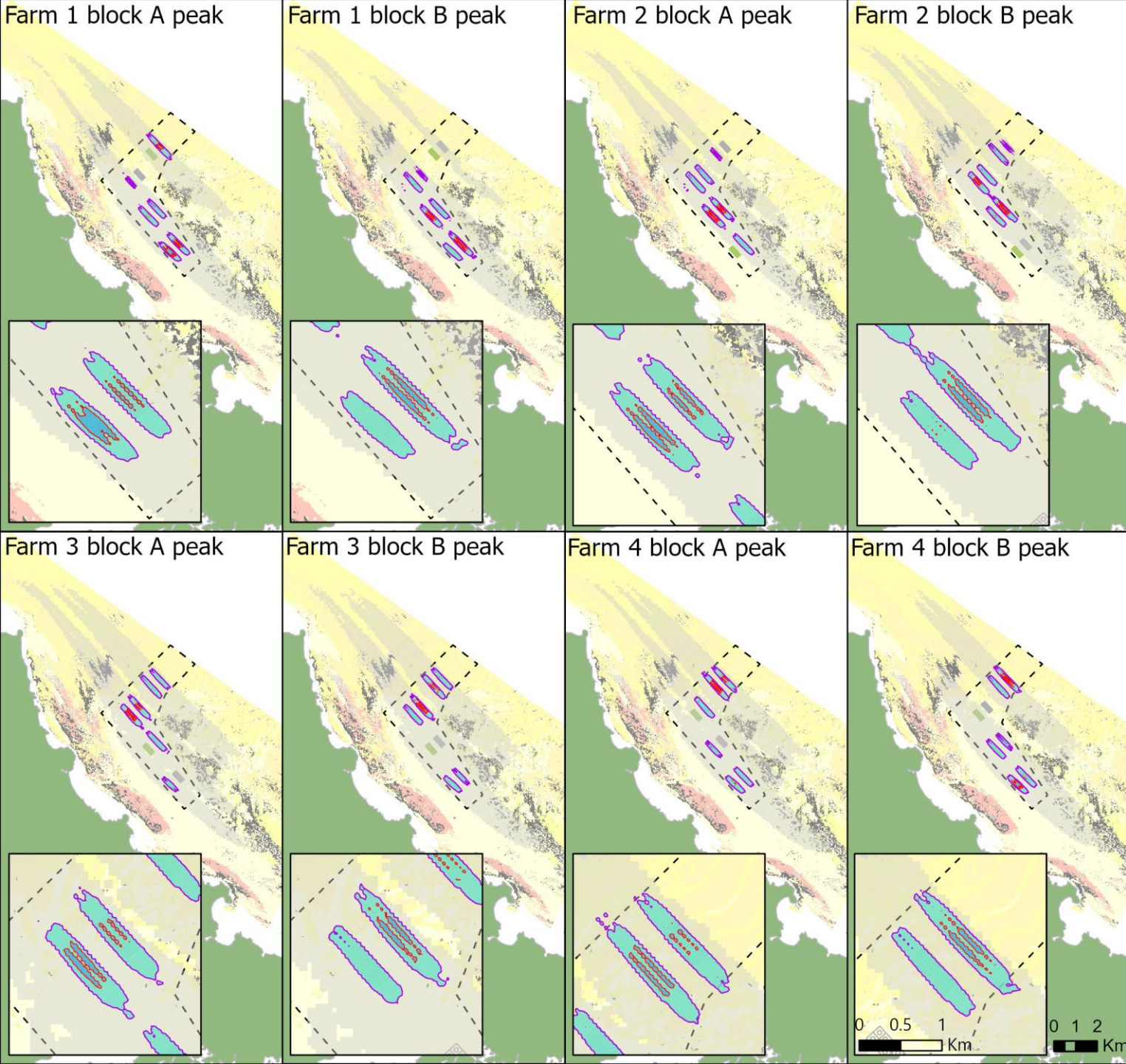
- $7 \text{ g m}^{-2}$   
(primary footprint)
- $0.7 \text{ g m}^{-2}$   
(outer limit of effects)

- Stage 1 blocks
- Stage 2 blocks
- Proposal area

**Habitat type predictions**

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# Residual solids (resuspension) – stage 2 peak



**Monthly solids flux**  
 $\text{g m}^{-2} \text{mo}^{-1}$

- < 41.67 (minor)
- 41.67 to 416.67 (moderate)
- > 416.67 to 1083.33 (high)
- > 1083.33 (very high)

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- Stage 1 blocks
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- Proposal area
- Solids flux > 5  $\text{kg m}^{-2} \text{yr}^{-1}$  (high enrichment)
- Solids flux > 0.5  $\text{kg m}^{-2} \text{yr}^{-1}$  ('zone of maximum effect' / moderate enrichment)

**Solids flux  
 (no resuspension) –  
 stage 2 peak**



# Addressing earlier concerns

1. **Previous concerns:** *uncertainty in depositional modelling, uncertainty around sensitivity of biogenic habitats / thresholds for biogenic habitat and whether monitoring and adaptive management were sufficient.*

## 2. Where we are now

**Advanced and more conservative modelling = More reliable estimates of solids flux and residual deposition than previous application**

- *Long-duration hydrodynamics*
- *Variable feed loading reflecting real operations*
- *Explicit particle-size and sinking-rate treatment*
- *Seabed substrate included to represent resuspension*
- *Additional conservatism: decay assumptions + slightly elevated feed inputs*

**Refined habitat mapping & farm siting**

- *Clearer boundaries and improved confidence in extent of biogenic habitats*
- *Farm sites repositioned to increase separation from sensitive habitats*

**Predicted deposition reaching biogenic habitat at Stage 1 an order of magnitude lower than Tory Channel levels (no observed effects)**

- *Much lower than levels predicted to reach these habitats in the previous application*

**Precautionary staging & strengthened monitoring**

- *Staged development, staggered stocking, fallowing*
- *Intensive monitoring with predefined triggers*
- *Adaptive management to respond early to any departures from predictions*

**Favourable site characteristics**

- *Highly dispersive environment*
- *Predominantly sandy seabed in primary deposition zones*
- *Naturally reduces risk of deposition on sensitive epibiota*

## 3. Key takeaway

While some uncertainty remains at very low deposition levels, the combination of advanced modelling, refined habitat mapping, staging, and intensive monitoring provides confidence that adverse effects on biogenic habitats can be avoided.