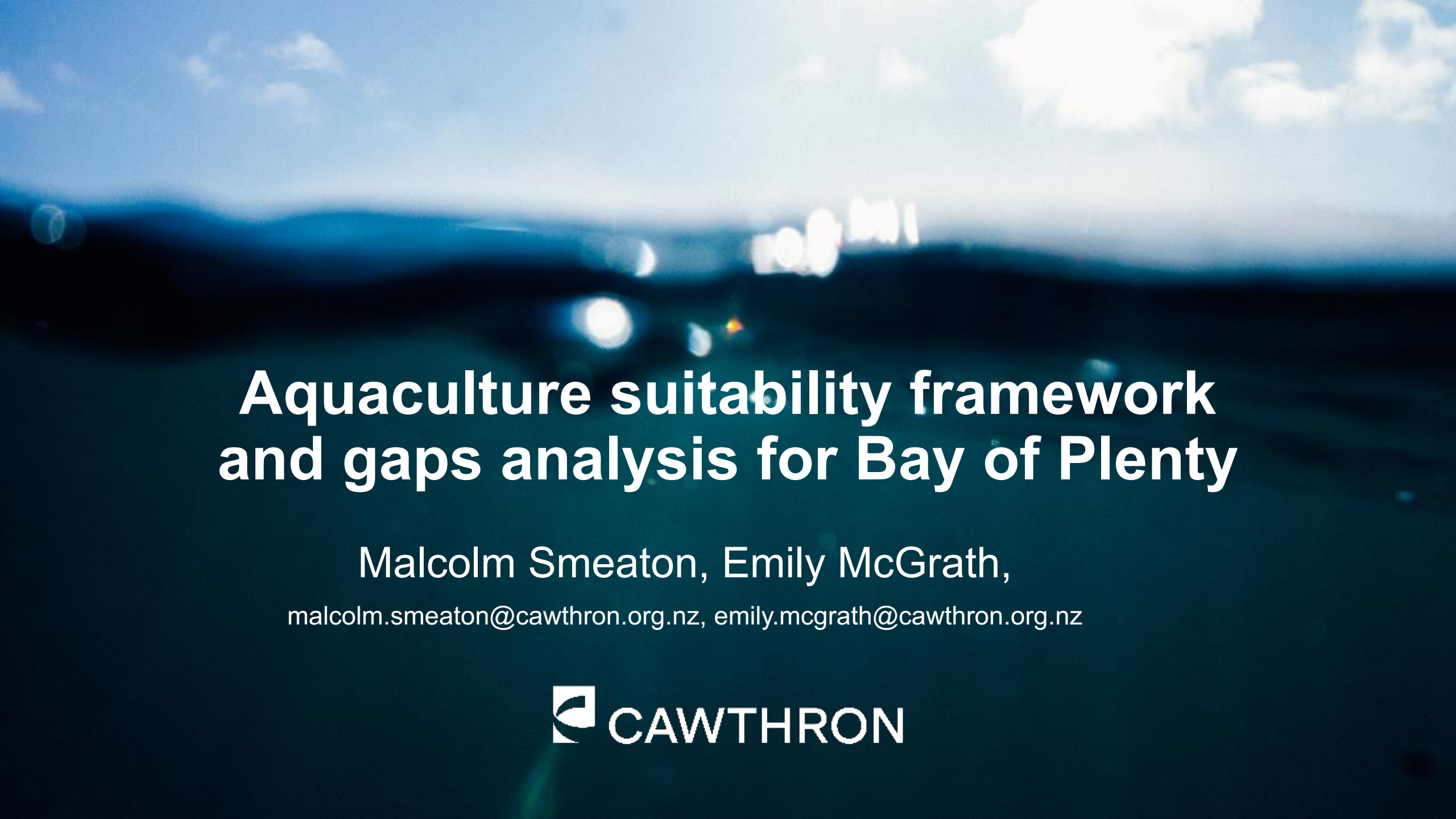

Aquaculture suitability framework and gaps analysis for Bay of Plenty

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CAWTHRON

Introduction

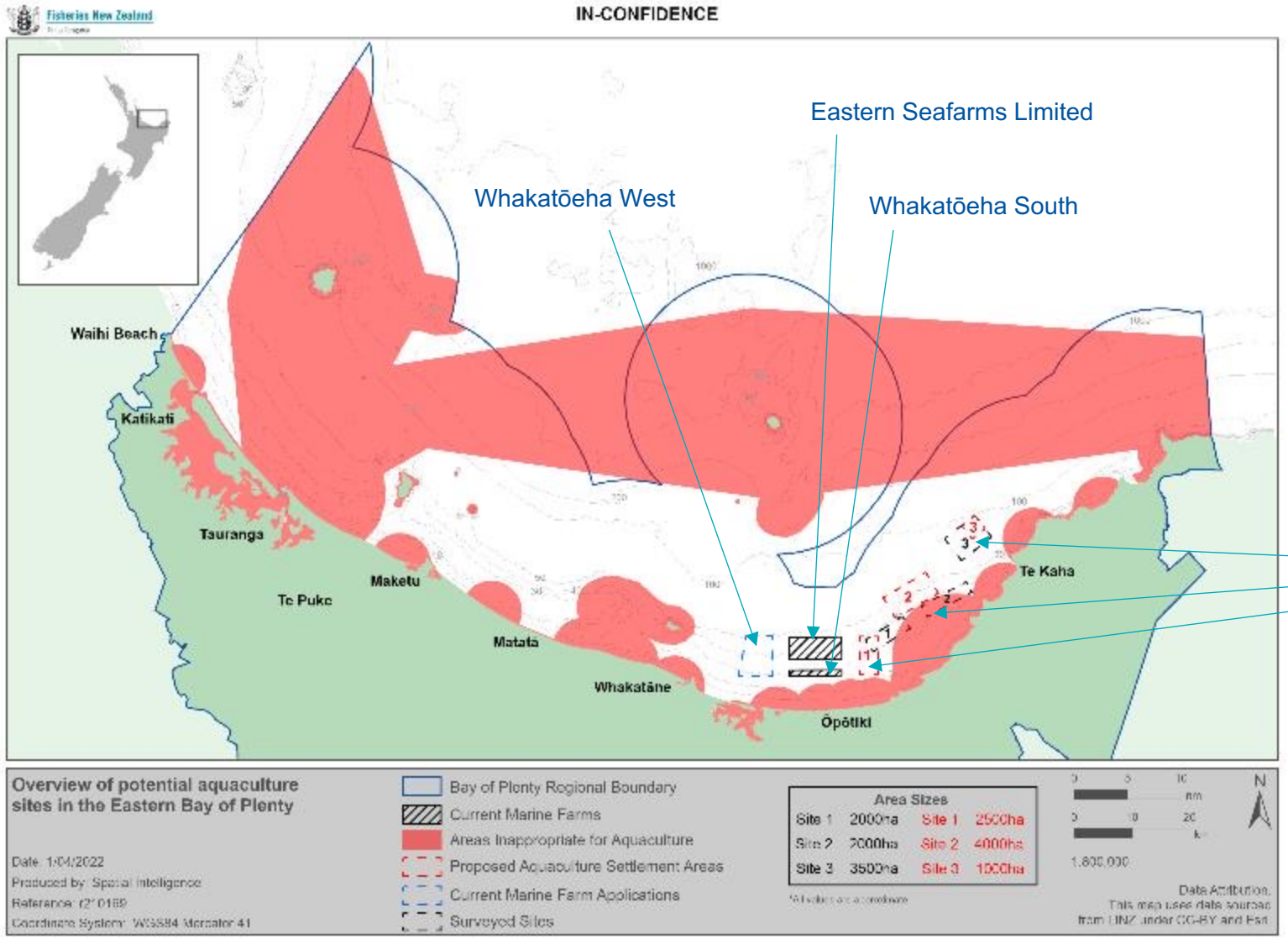
- Malcolm Smeaton
  - PhD (Otago) in oceanography: Modelling tidal turbines to optimize farm layout.
  - Aquaculture suitability, environmental modelling, engineering modelling, open ocean aquaculture, waves and currents

- Emily McGrath
  - PhD (Victoria) in marine biology: Impacts of habitat degradation on sponges in Indo-Pacific
  - Aquaculture suitability, benthic ecology, benthic surveying, environmental effects monitoring

Overview

- Introduction, background, scope
- Frameworks for GSM, Kingfish, Ecklonia
  - Physiological
  - Environmental
  - Other considerations
- Review of existing data
- Gaps
  - BOP Wide
  - Revised areas in Eastern BOP

Area of interest



Red shaded area inappropriate for new aquaculture according BOP Coastal Environmental Plan

Black sites 1, 2, 3: Areas assessed for suitability by McGrath et al. (2021) and McGrath (2021)

Red sites 1, 2, 3: Revised areas

Suitability depends on scale of operation

- Small and low intensity aquaculture has different requirements than large and high intensity aquaculture
  - E.g. not enough plankton to feed that many mussels
  - Not enough oxygen for that many fish
  - Environment can’t process that much organic matter
- Define some scale so we can talk about suitability
  - GSM aquaculture of 000s of ha at low intensity
  - Kingfish farm with 4kt yr^{-1} feed
  - Ecklonia farm of 00s of ha

Where in the food chain?

- Environmental impact of aquaculture related to where farmed species fits in food chain.
- All about energy (feed, organic matter) and an environment that processes that energy.

- Seaweeds – take up nutrients (existing energy)
- GSM – eat phytoplankton and zooplankton (existing energy)
- Kingfish – eat fish or fish feed (bringing energy into system)

Don’t change things too much…

- Aquaculture can have positive and negative effects on the environment e.g.
  - Good: Mussels, seaweed can remove nutrients from farm run-off
  - Bad: Faeces from mussels might accumulate on the seabed.

- Don’t change trophic state by adding/removing too much of anything.
- Staged approach. Monitoring. Adaptive management

Basics of farming seaweed/algae

- Little to no uptake in NZ, kicking off elsewhere (Aus)
- Food, trace elements (pharmaceutical), nutrients (fertiliser)
- Needs light and nutrients. Probably suspended?
- Large-scale farming might compete with plankton for nutrients
- Few unknowns regarding impact of large-scale farming

Basics of farming GSM

- Lots around NZ
- Food, trace elements (pharmaceutical, nutraceutical)
- Takes phytoplankton from the water, excretes faeces and pseudofaeces.
- Sensitive habitats to be avoided.

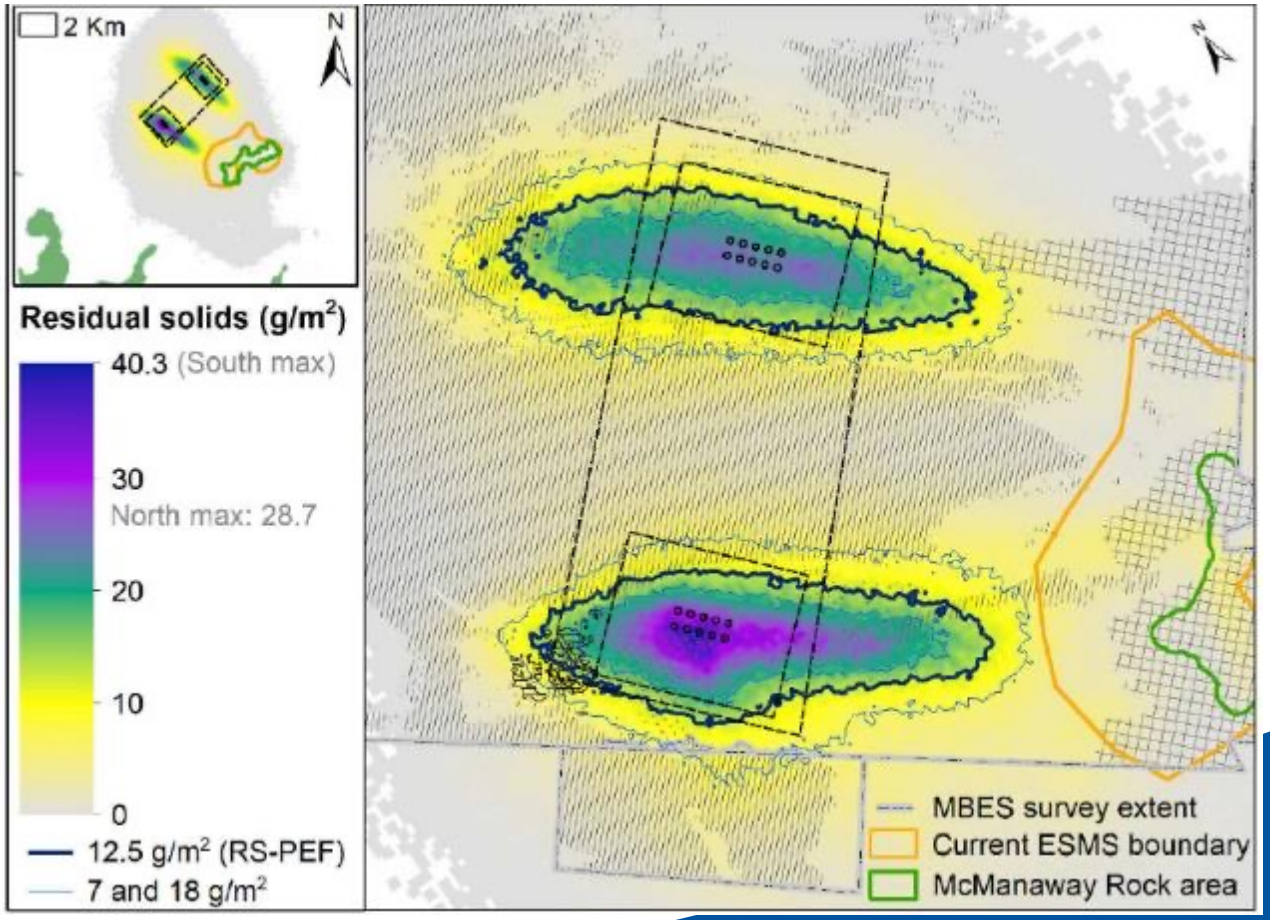
Basics of farming kingfish/finfish

- Similar methods as for salmon farming (pens)
- Fish need feeding and a good oxygenated environment
- Currents/flow required to dilute and disperse waste and keep oxygenated water flowing through pens.
- Sensitive habitats to be avoided.

A need for mathematical modelling

- Can’t measure everywhere, or in the future
  - Modelling can fill in gaps
- Many environmental effects must be predicted using models
  - Measurements add robustness to model results
  - Monitoring and staging reduces risk against model predictions

Example below shows predicted waste on seabed from a proposed salmon farm in outer Marlborough Sounds (Smeaton 2021)



Information required to assess site suitability

"What data is required to make a site suitability assessment?"

- **Suitability of site for physiology**
- **Suitability of site at hosting aquaculture**
  e.g. environmental effects
- **Other considerations**
  e.g. biosecurity, mammals, seabirds

Key physiological factors

Current speeds: >15 cm·s^{-1} * **
replenish oxygen in pens **
disperse effluent **
waste deposits **

Temperature: 18 to 26.5°C *

Deeper water preferred *

Current speeds: >5 cm·s^{-1} *
food supply **

Temperature: 5.3 to 27°C *
New research: < 24°C

Chlorophyll-*a*: 1-2 µg·L^{-1} * **

Salinity: 30 to 35 PSU

Turbidity: Ideally low

Dissolved oxygen: >80% saturation

Tolerant up to high current speeds *

Does best in medium wave exposure *
morphological plasticity?

Up to 24°C *

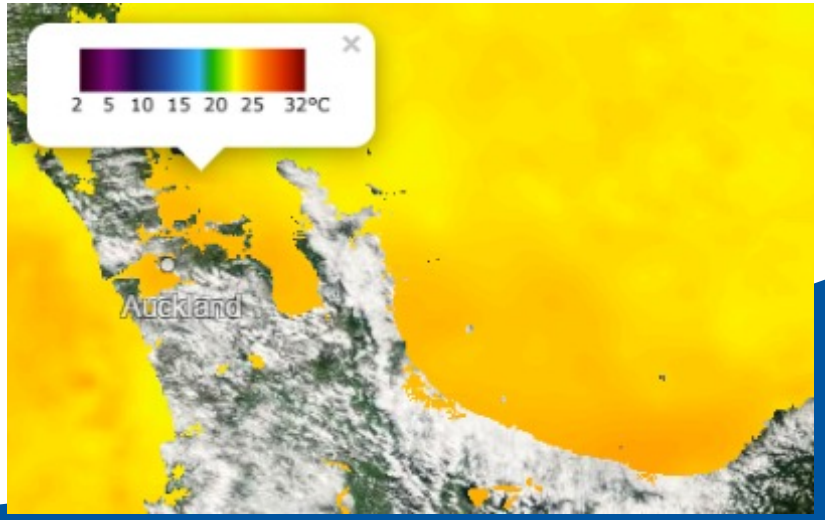
Depth: 8-30 m (light limited*)

Predation by urchins

* Requires field measurements
** Requires modelling exercise

Physiologically speaking…

- No major issues with any species
  - Natural populations in BOP
- Watch out for:
  - Chl-*a* (GSM)
  - Nutrients (Ecklonia)
  - Temps can get high: MHW Summer (2018)
    - GSM mortality around 24°C
    - Ecklonia optimal temp up to 24°C
    - Stratification



Key environmental factors

Faecal waste deposited to seabed * **
Can seabed ecology deal with it?

Nutrient emission, algal bloom risk? * **

Biosecurity: HMOs via infrastructure, vessels and cultured fish

Wild fish and disease

Mammals and seabirds

Phytoplankton depletion * **

Faecal waste deposited to seabed * **?
Can seabed ecology deal with it?

Mammals, seabirds HABs

Biosecurity: vessels, spat, infrastructure may be vectors for HMOs

Could compete with phytoplankton for nutrients **?

Shading effects on seabed communities

Mammals & seabirds

Biosecurity?

* Requires field measurements
** Requires modelling exercise

GSM

- Currents & waves
  - Measured waves and currents near farm location
  - Modelled currents and waves
- Benthic survey – check for sensitive habitat
  - Seabed variability (side scan or multibeam sonar)
  - Sediment data
  - Drop cams
- Water data (ideally across multiple seasons)
  - Conductivity, temperature, salinity, oxygen, turbidity, depth
  - Plankton water samples
  - Nutrients: TAN, POM, TSS, PN, TP, TN
- Satellite data: long-term surface chl-*a*, temperature
- Depositional waste modelling for large farms
  - Requires currents model, stocking density information
- Plankton depletion modelling or carrying capacity model?
  - Requires currents model, stocking density information, chl-a data

Plus:

Baseline monitoring and management plans for:

- HABs
- Mammals
- Seabirds
- HMOs

Kingfish

- Currents & waves
  - Measured waves and currents at multiple locations
  - Currents and waves models – may need refining
- Benthic survey – check for sensitive habitat
- Water quality data (ideally across multiple seasons)
  - Conductivity, temperature, salinity, oxygen, turbidity, depth
  - Plankton water samples
  - Nutrient water samples: TN TAN NO3, DRSi, TP, DRP
- Satellite data: long-term temperature

- Depositional waste modelling for large farms
  - Requires currents model, feed inputs, pen locations, kingfish specific data
- Oxygen depletion modelling and nutrient waste modelling
  - Requires currents model*, stocking density, pen locations

Plus:

Baseline monitoring and management plans for:

- HABs
- Mammals
- Seabirds
- Wildfish
- HMOs

Ecklonia Radiata

- Currents & waves
  - Measured currents near farm site
  - Currents model desirable
  - Wave model
- Benthic survey
- Water data (ideally across multiple seasons)
  - Conductivity, temperature, salinity, oxygen, turbidity, depth
  - Nutrient water samles: Dissolved inorganic nitrogen
  - Chlorphyll-a water samples??
- Satellite data: surface chl-a, temperature
- Carrying capacity model?
  - Requires currents model, stocking density, chl-a data

Photography by William Boyle

Plus:

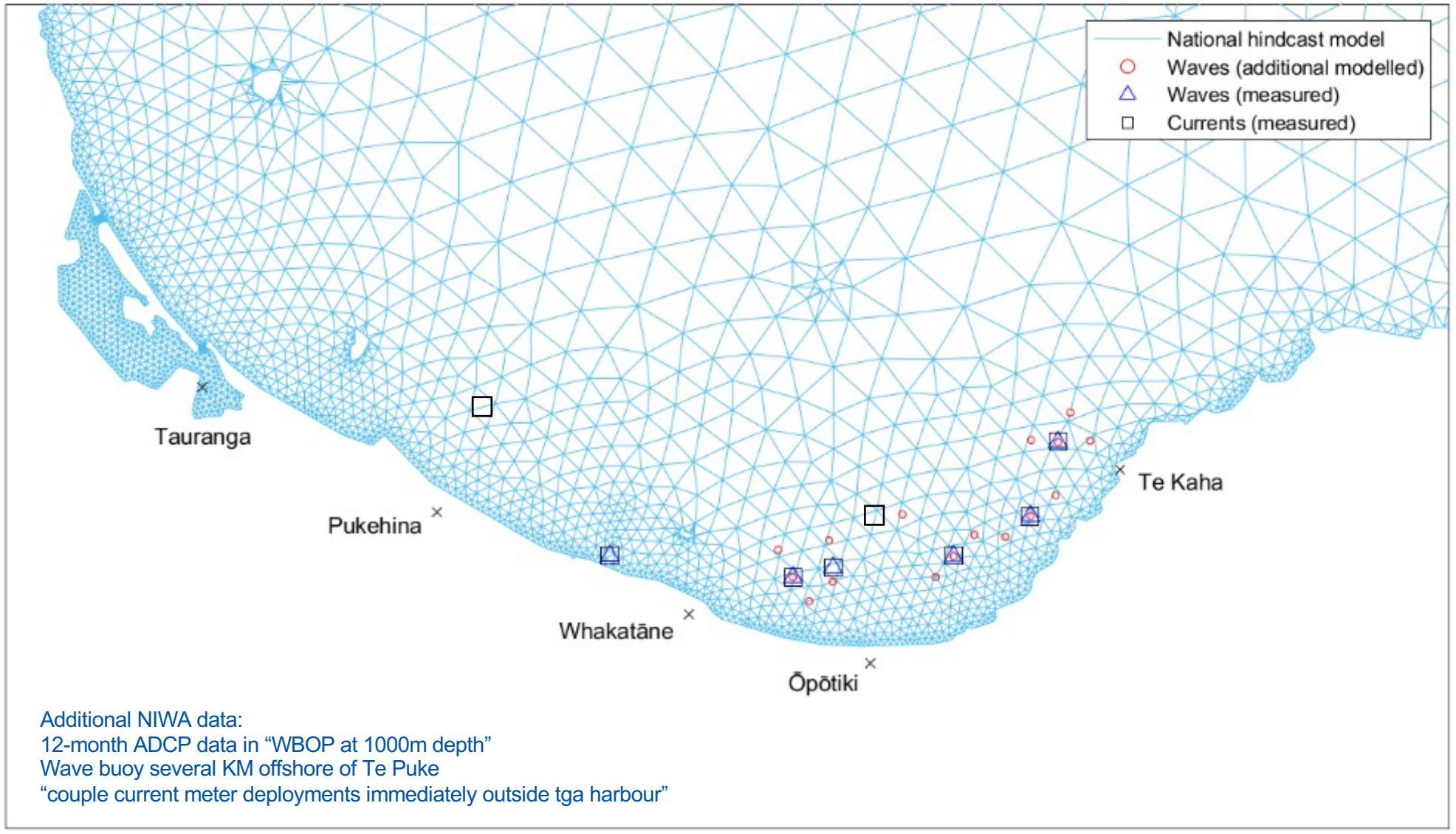
Baseline monitoring and management plans for:

- HABs
- Mammals
- Seabirds
- HMOs

Data

What's out there?

Hydrodynamic coverage (waves + currents)



Additional NIWA data:
12-month ADCP data in “WBOP at 1000m depth”
Wave buoy several KM offshore of Te Puke
“couple current meter deployments immediately outside tga harbour”

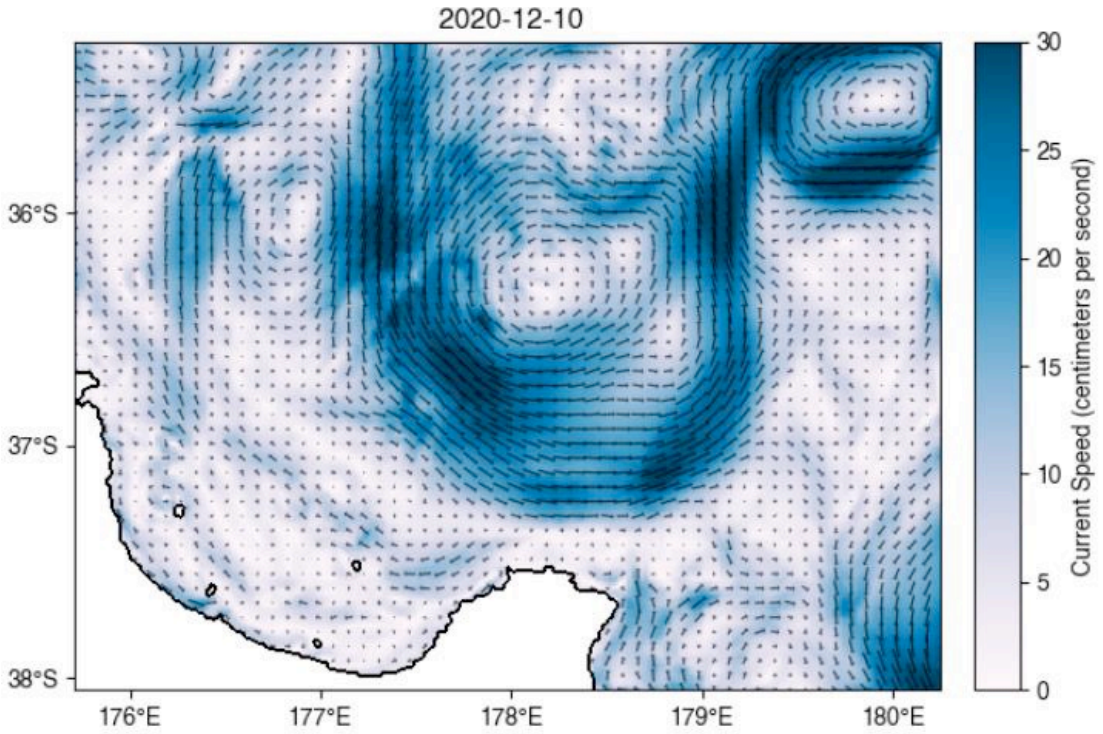
Hindcast model is 10 years of data at every intersection for waves, wind, currents (3D)

Currents measured by ADCP: c. 28 days

Waves measured by wave buoy (inertia sensor) or ADCP (sound wave reflection)

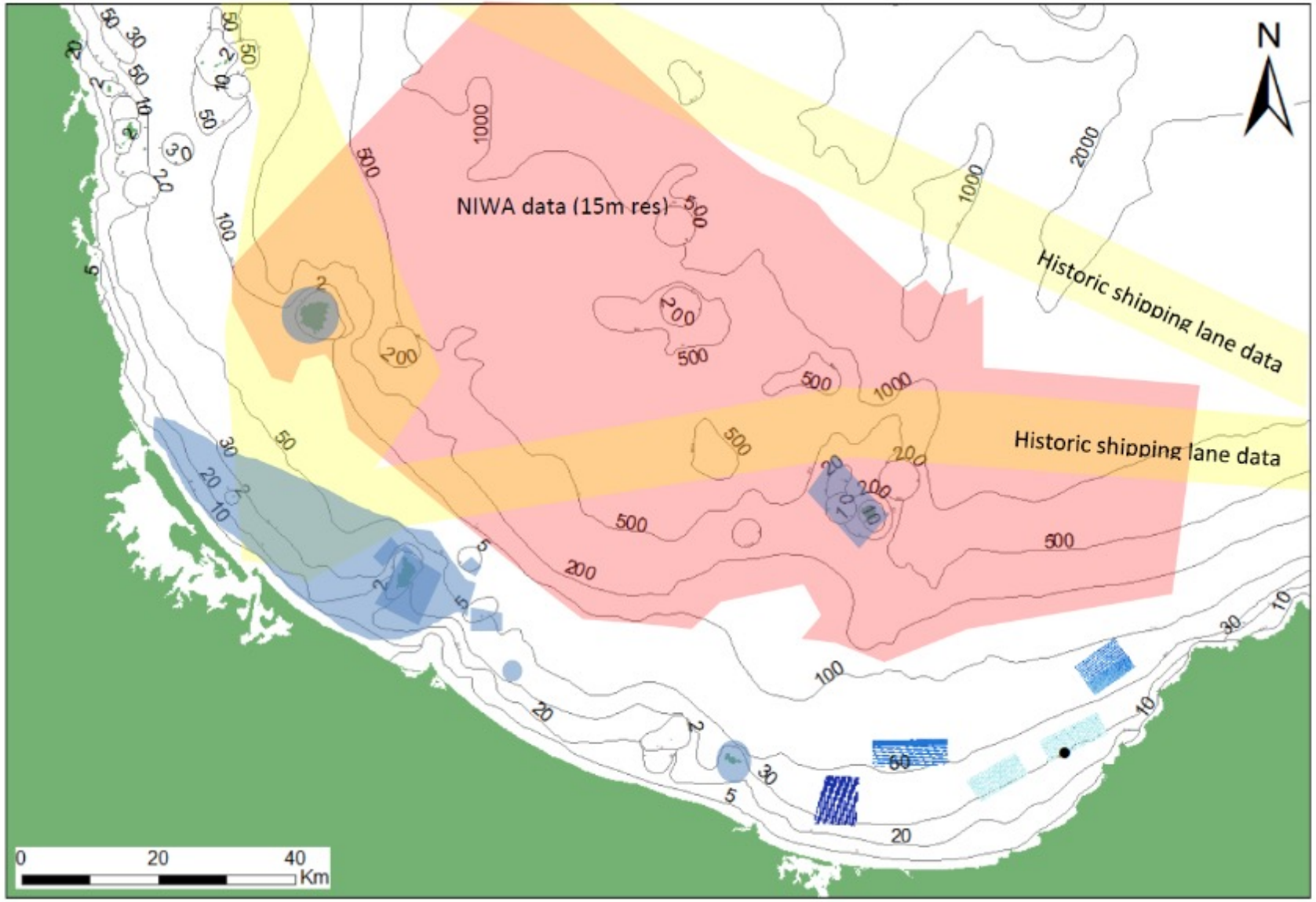
Two particularly good models

- **Oceanum model (national hindcast)**
  - 10 year hindcast, 500m nearshore res
  - No field validation
  - Would need extending to 2020 to validate in eBOP against measured currents
  - Freely available for research and commercial purposes
- **Moana project BOP/East Cape Model**
  - 28 year hindcast, 1km res
  - Validated against field data in Longdill's thesis
  - Already includes 2020 so could be validated against eBOP measured currents.
  - Freely available for research purposes, commercial use assessed on case by case basis



Spatial extent of the Moana project model

Benthic habitat mapping
Knowledge about what's on the seabed

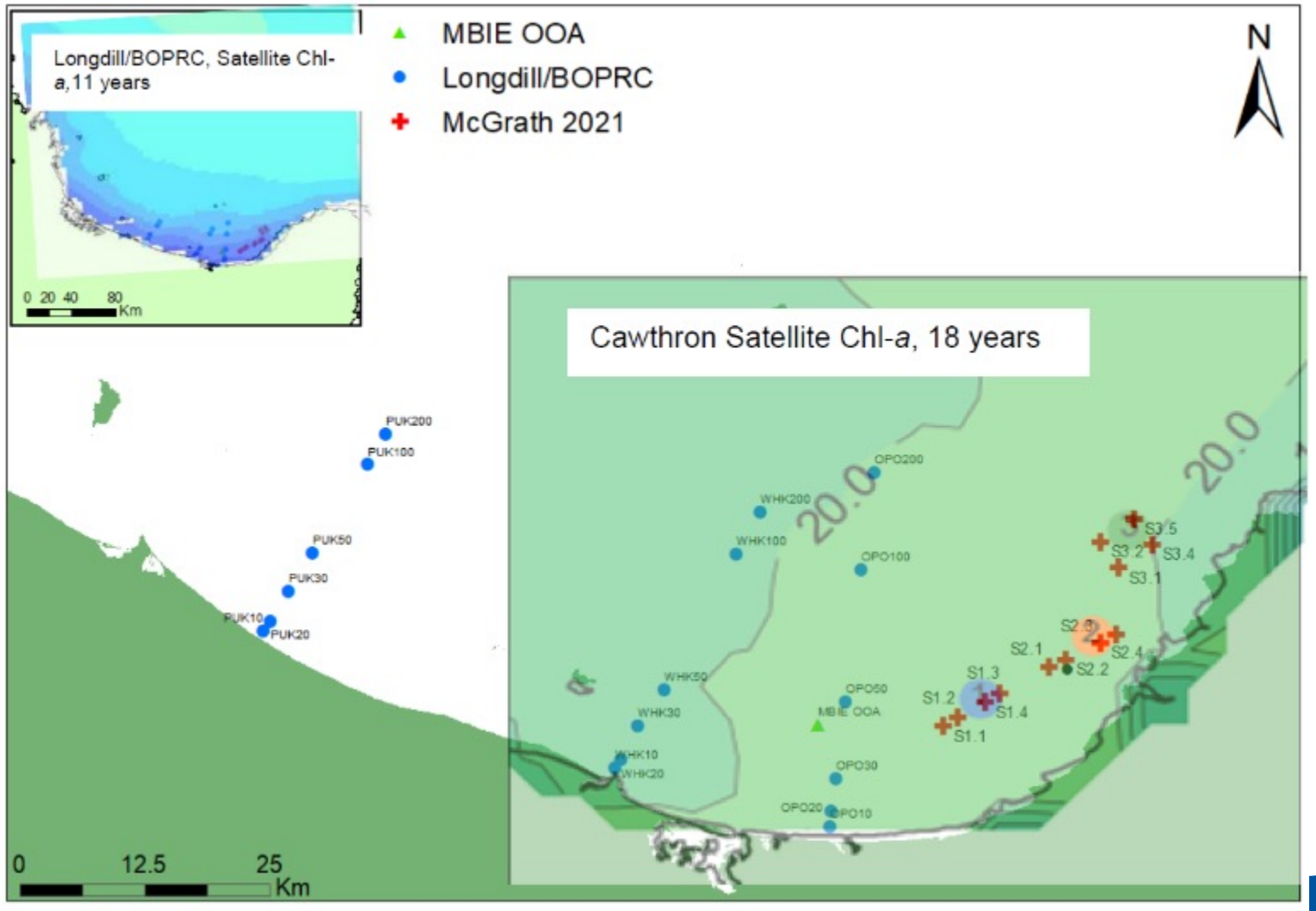


Anything blue is probably high enough resolution to identify habitat

NIWA hold large data in red

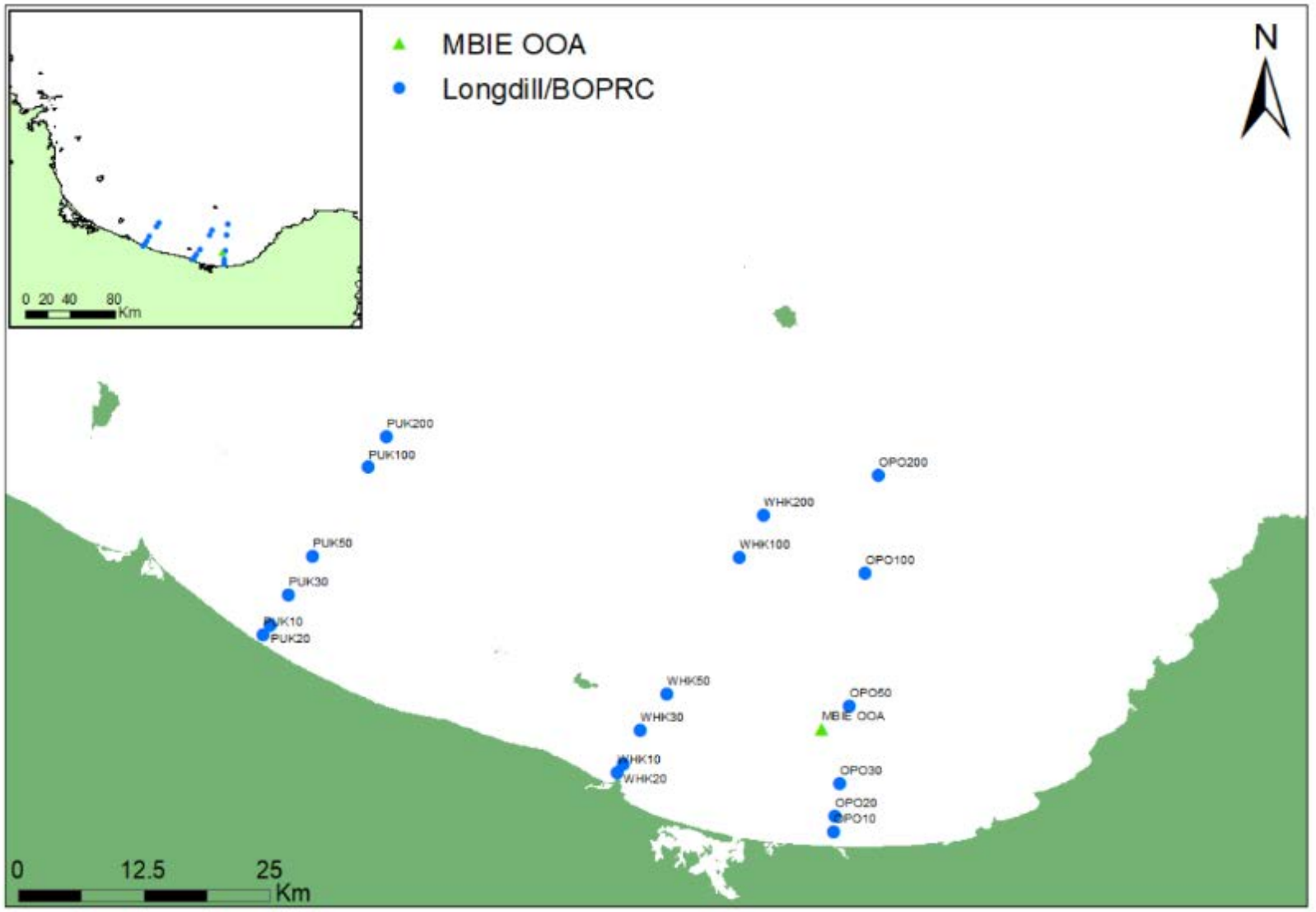
Despite reasonably homogenous seabed, additional benthic surveying will be required on site-specific basis

Chl-*a* (phytoplankton) Knowledge about food



- Transects off Whakātane, Pukehina, Ōpōtiki
- Existing ESL site, Whakatōhea W, MPI sites
- Satellite data of surface Chl-*a*
- Depletion modelling exercises (tbd later)
- Lacking inter-seasonality

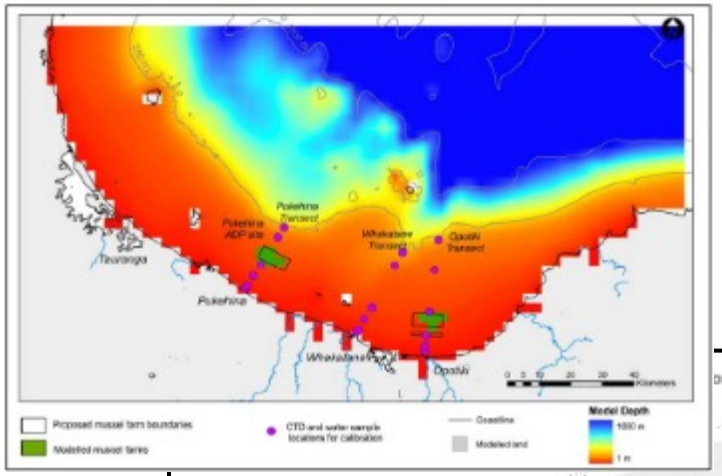
Nutrients – Knowledge about food



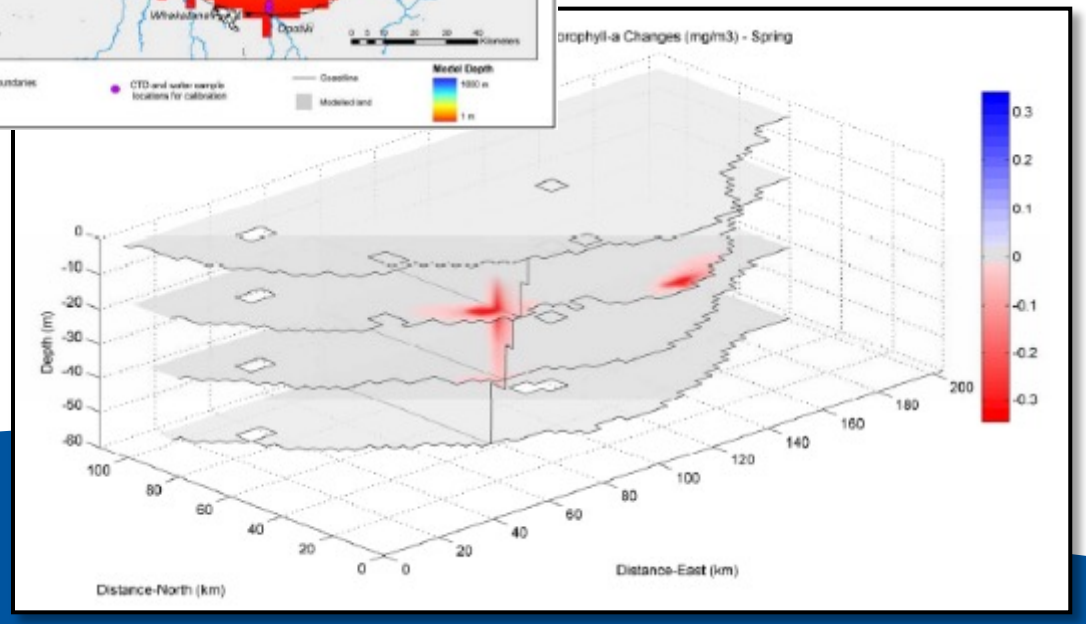
- Lack of data
  - Longdill/ASR
- OOA site collecting now sporadically (COVID19)
- Some biogeochemical + ecology models
  - EBOP

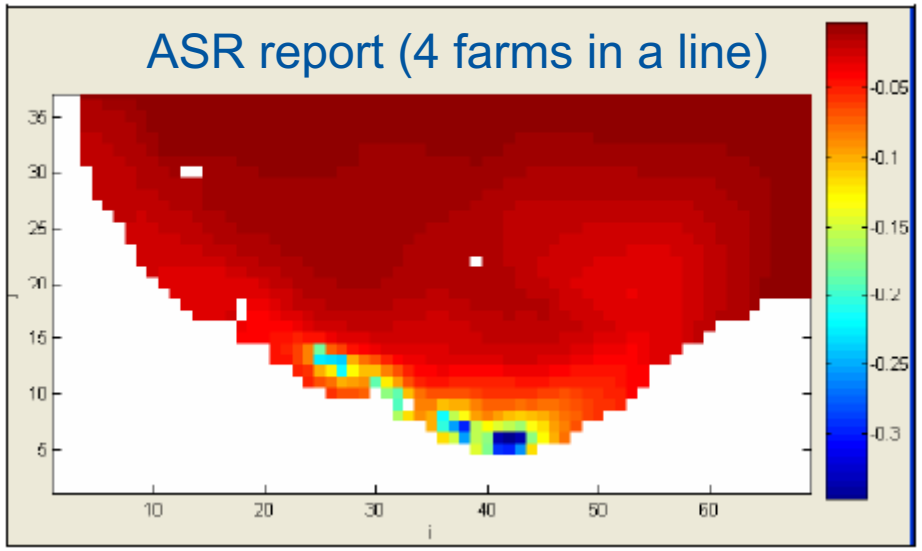
Depletion/Carrying capacity

Enough food/nutrients in the bay to support aquaculture? Let's check.



Longdill thesis (2 farms)





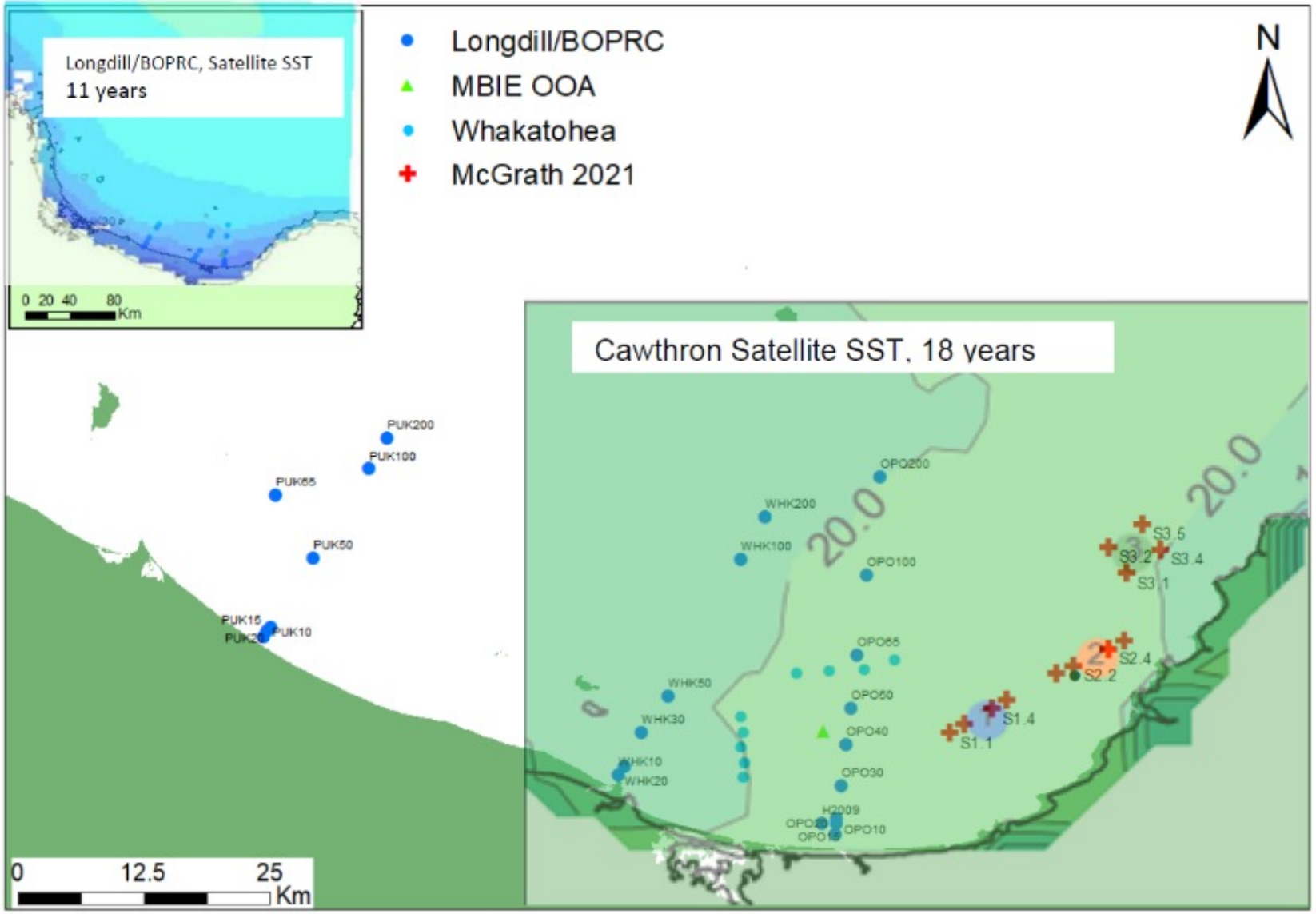
Use hydrodynamic model and chlorophyll-a information to look at phytoplankton dynamics

Is there enough plankton to sustain more GSM?

Will farms this close together impact each other?

Existing model no longer relevant (Longdill, 2008)

Temperature, Salinity, DO Knowledge about ocean structure



Measurements limited to EBOP

- Longdill/ASR work
- Cawthron Assessments
  - Numerous Whakatoeha
  - McGrath et al. 2021

Satellite Data (Temp)

- BOPRC/Longdill
- Cawthron Assessments
- More data easy to get*

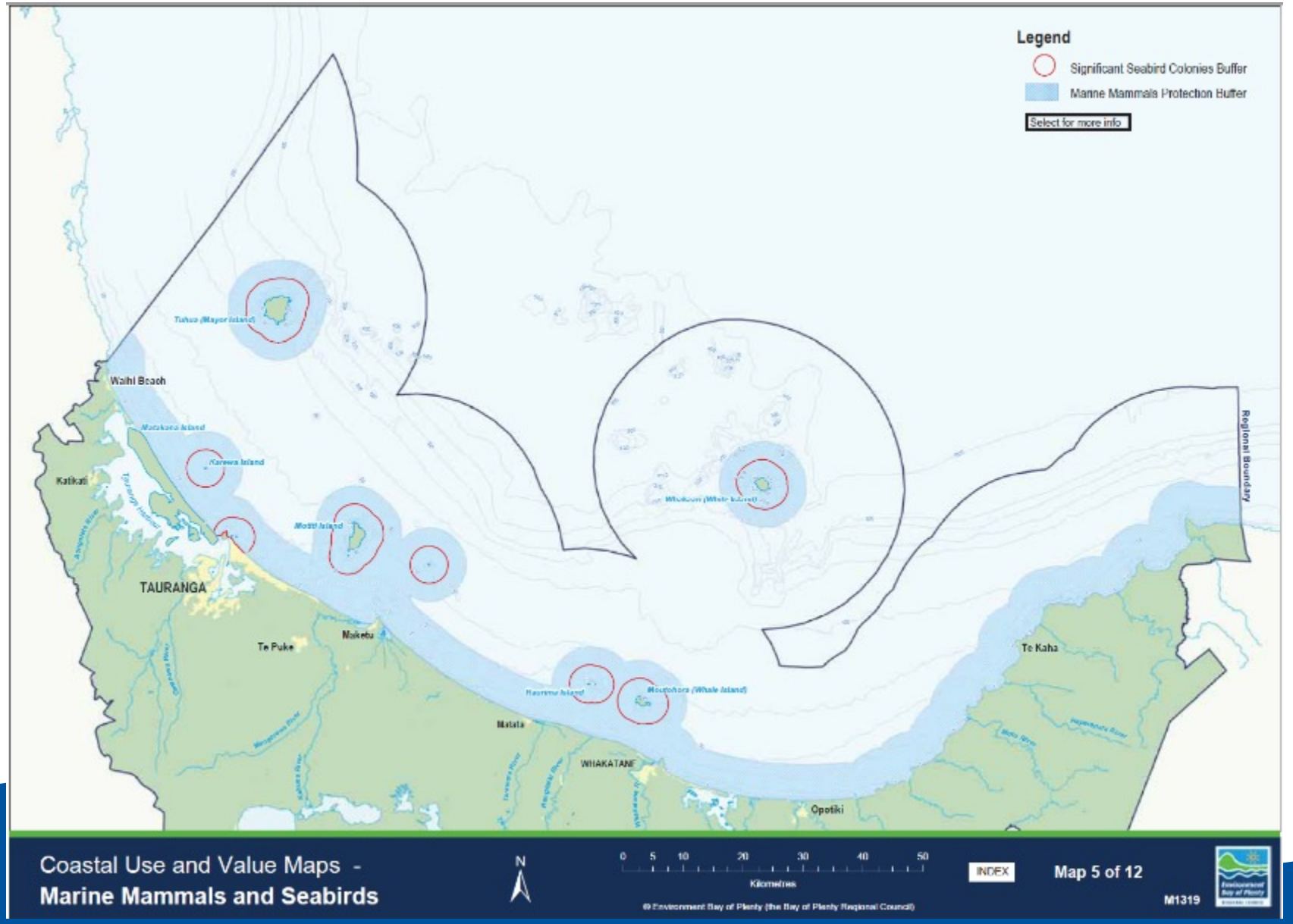
Also, model data for:

- Temp
- Salinity

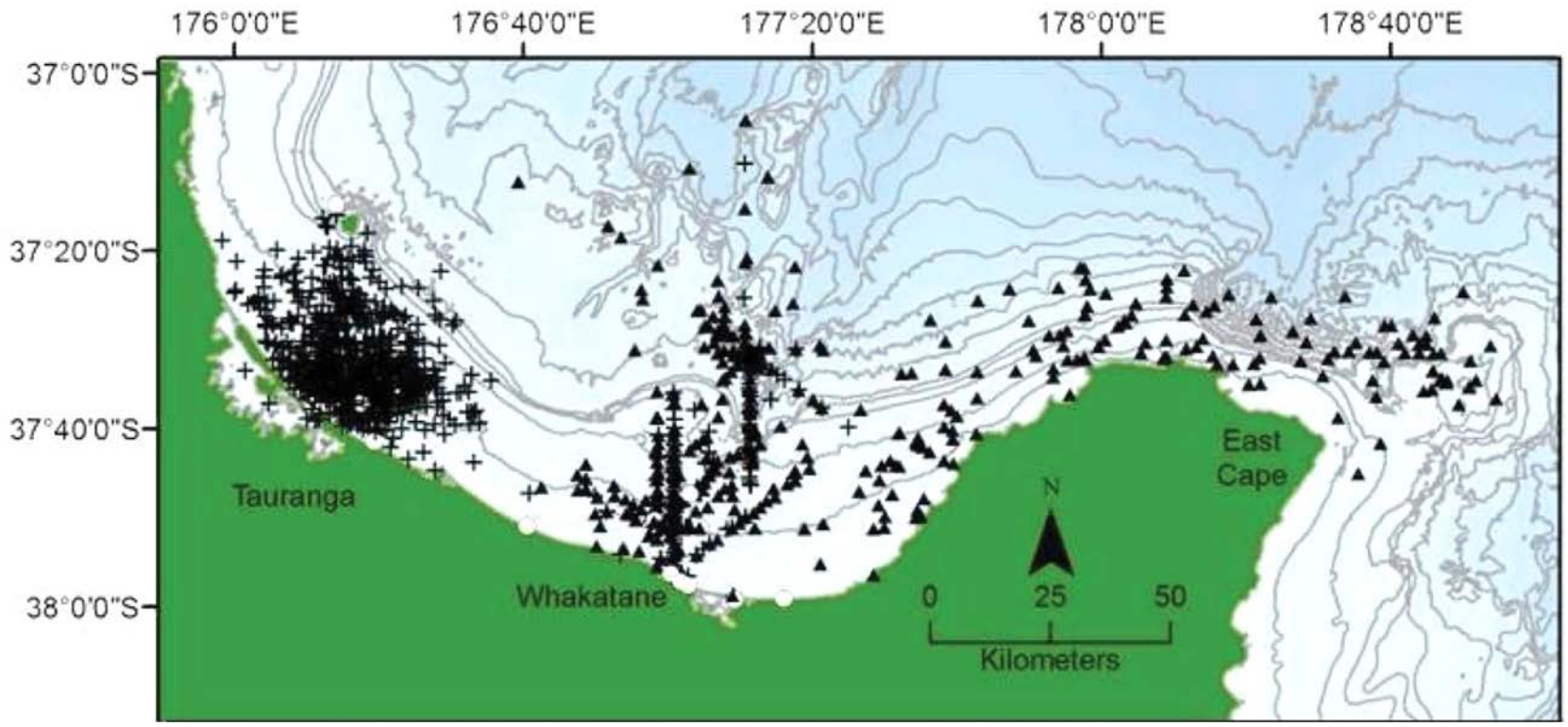
Moana project has fishing vessel SST data.

*touch wood

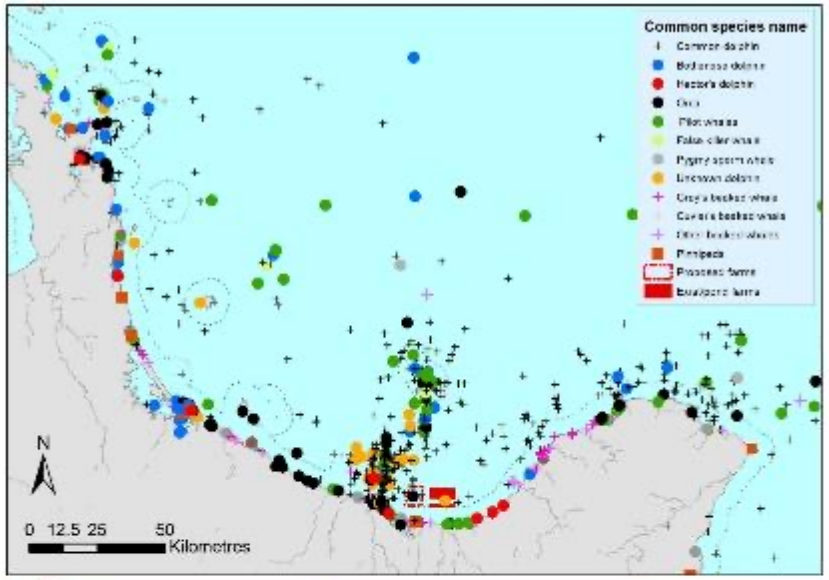
Mammals and seabirds

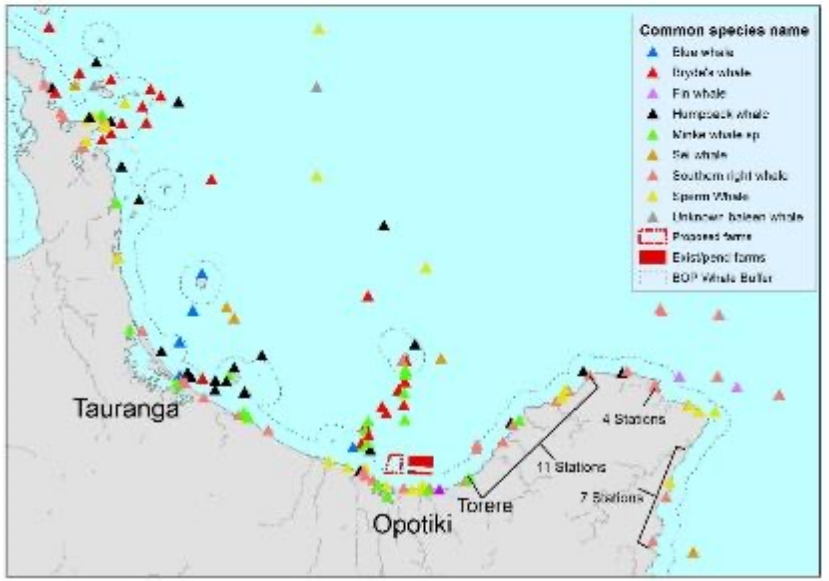


- BOPRC has outlined significant seabird and marine mammal buffer zones to be avoided
- Lack of data in general (NZ wide)
- Clement's (2020) assessment for Whakatoeha West re-useable for other GSM farms in BOP.
- New assessments needed for kingfish or Ecklonia (likely based off same data as Clement 2020)
- Seaweed risk largely unknown. Full details of methods needed.



Opportunistic mammal sightings between 2000 and 2010 (Meissner 2015)



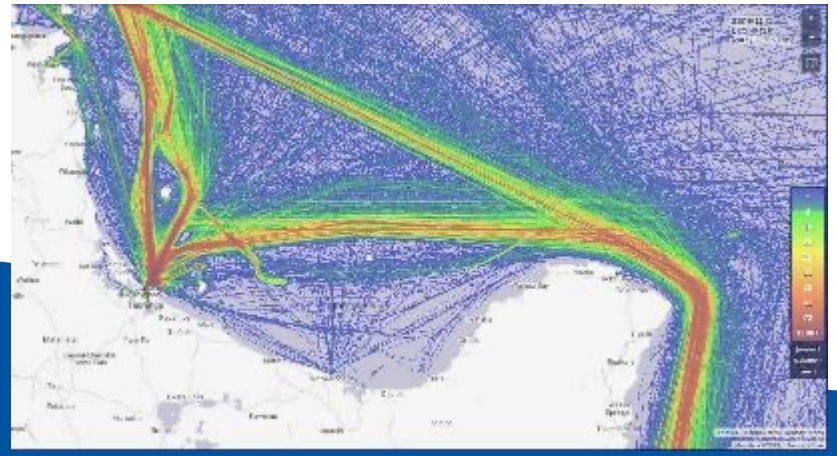


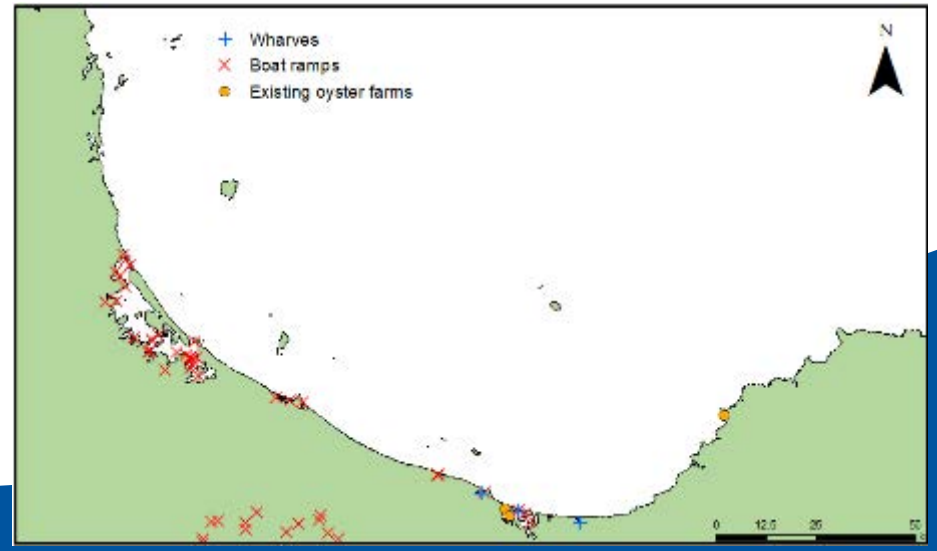
DOC reported strandings (1912-2015) and sightings (199 – 2018).

Some overlap between datasets

Biosecurity: HMOs

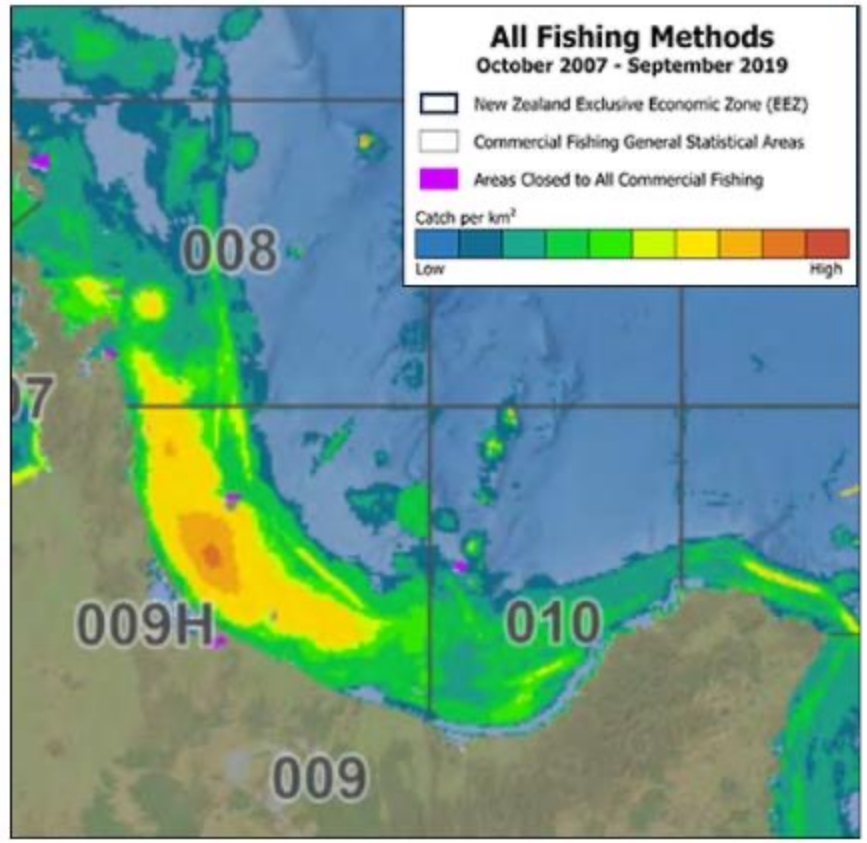
- Whakatohea W assessment (Fletcher 2020)
  - New assessments can use same information
  - Farm-specific operational details needed on case-by-case basis
- Other data:
  - Ports data and other HMO detections (NIWA)
  - Biofouling data from ESL farm (Cawthron)





Wild fish and disease

- Wild kingfish may congregate around pens
  - Vector for parasite and disease exchange between wild and farmed populations
- NIWA has trawl survey data back to 80s
- Commercial catch data



Gaps

In general

- Hydrodynamic coverage of the bay is good
  - Measurements lacking in West (in general)
  - Model checks/validation needed
    - Both need validation against measured currents in Sites 1-3
- Benthic habitat coverage needed on site specific basis
- Nutrient and chl-*a* measurements near prospective sites needed including seasonal variability
- Carrying capacity model recommended
- Can use existing data to complete new mammals, seabirds, HAB assessments for future sites

Gaps by species

GSM

- Benthic survey
- Model data may suffice in Eastern Bay, otherwise ADCP deployment needed
- Hydrodynamic model check
- Inter-seasonal nutrient and plankton samples
- Desktop assessments and baseline data: wild fish, mammals, seabirds, biosecurity
- Modelling exercises
  - Depositional
  - Depletion
  - Carrying capacity

Kingfish

- Benthic survey
- Multiple ADCPs to ground truth hydrodynamic model and measure waves
- Hydrodynamic model refinement
- Inter-seasonal nutrient samples
- Desktop assessments and baseline data: wild fish, Mammals, Seabirds, Biosecurity, HABs
- Modelling exercises
  - Depositional
  - Nutrients
  - Oxygen depletion

Ecklonia

- Benthic survey
- Model data may suffice in Eastern Bay, otherwise ADCP deployment needed
- Hydrodynamic model check
- Inter-seasonal nutrient samples
- Desktop assessments and baseline surveys of mammals and seabirds
- Modelling exercises
  - Nutrient/Carrying capacity?

Prioritised gaps by species

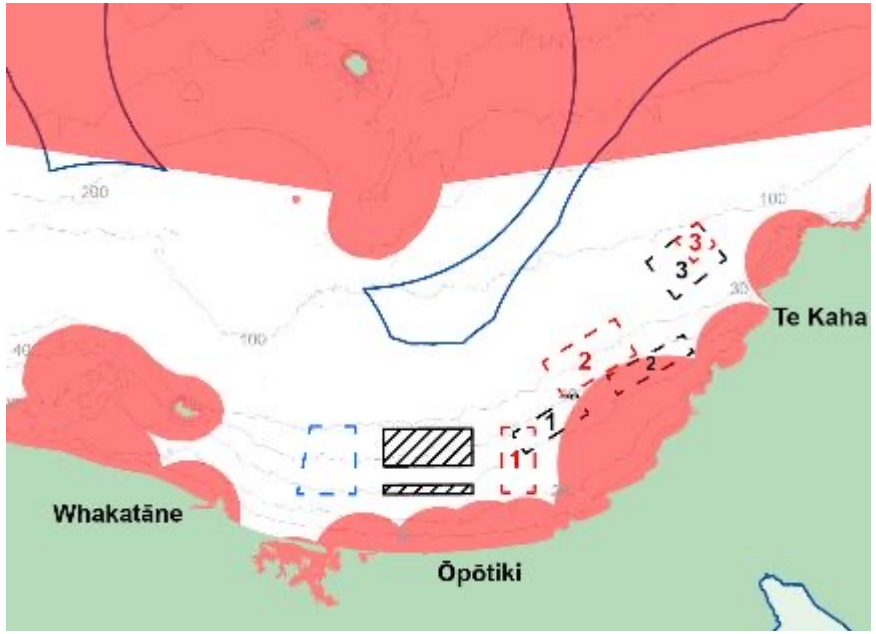
	GSM	Kingfish	Ecklonia
1	Phytoplankton and chl-a sampling. Do nutrient and CTD at same time.	Benthic survey	Nutrient samples. Do CTD at same time.
2	Scoping of mammal and seabed effects for any likely issues	Scoping of mammal and seabed effects for likely issues	Scoping of mammal and seabed effects for likely issues
3	Benthic survey	Hydrodynamics: ADCPs and hydrodynamic model refinement.	Benthic survey
4	Hydrodynamics. Model check.	Depositional modelling	Hydrodynamics Model check
5	Carrying capacity model	Oxygen depletion modelling	Mammals assessment
6	Depletion model (could be done with above)	Nutrient samples and modelling. (Take phytoplankton samples at same time).	Complete remaining seabird desktop assessments and other remaining desktop assessments
7	Depositional model for large farm	Complete mammal and seabird desktop assessments and other remaining desktop assessments	
8	Complete mammal and seabird desktop assessments and other remaining desktop assessments		

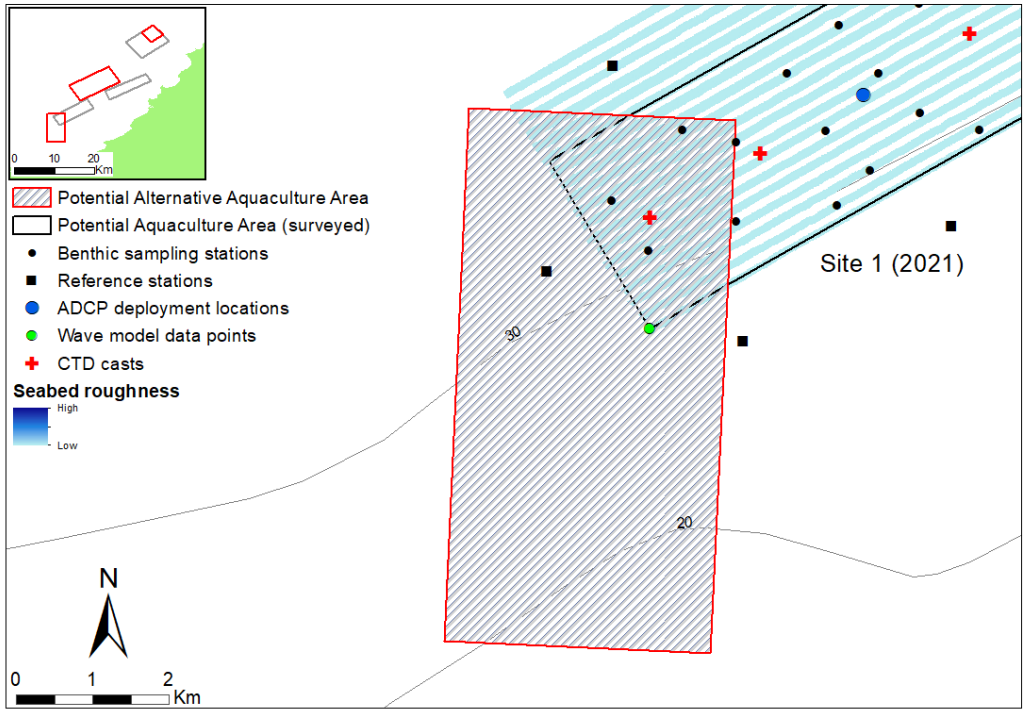
Revised Sites 1-3

Application of previous suitability assessment data to revised site locations

Old sites in black

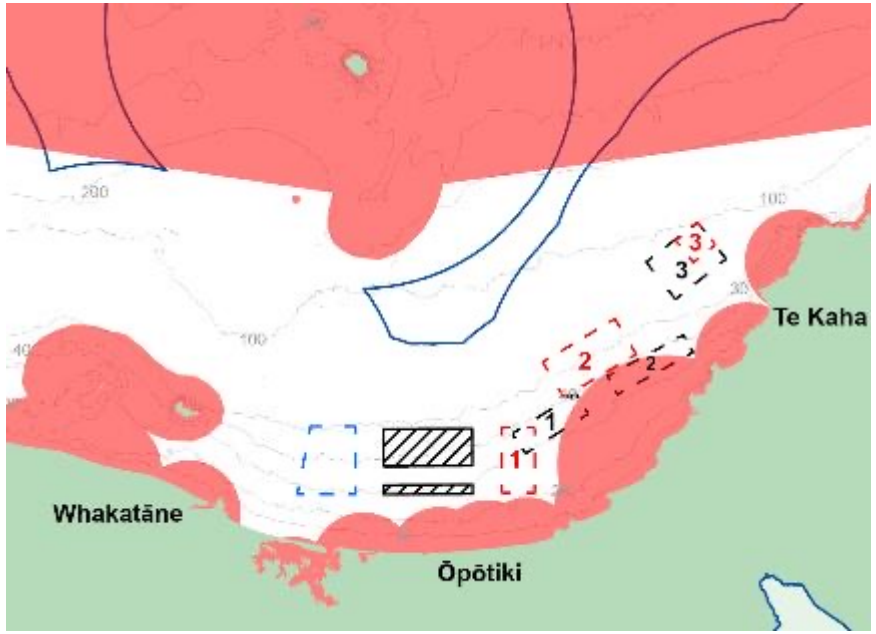
New sites in red

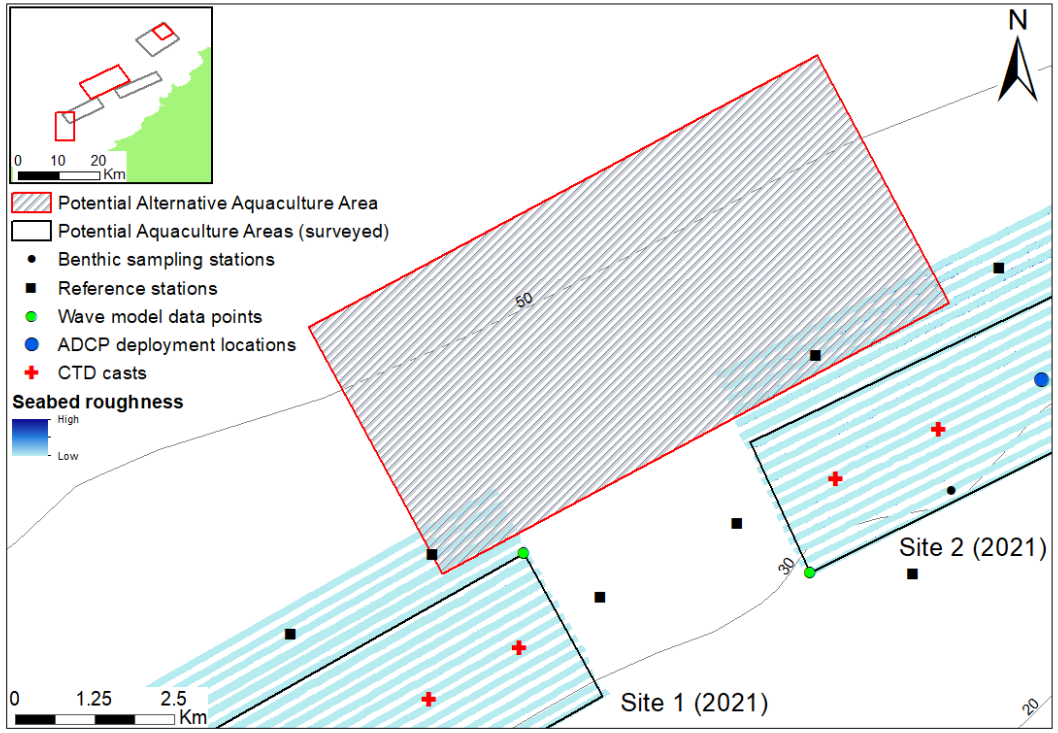




Site 1

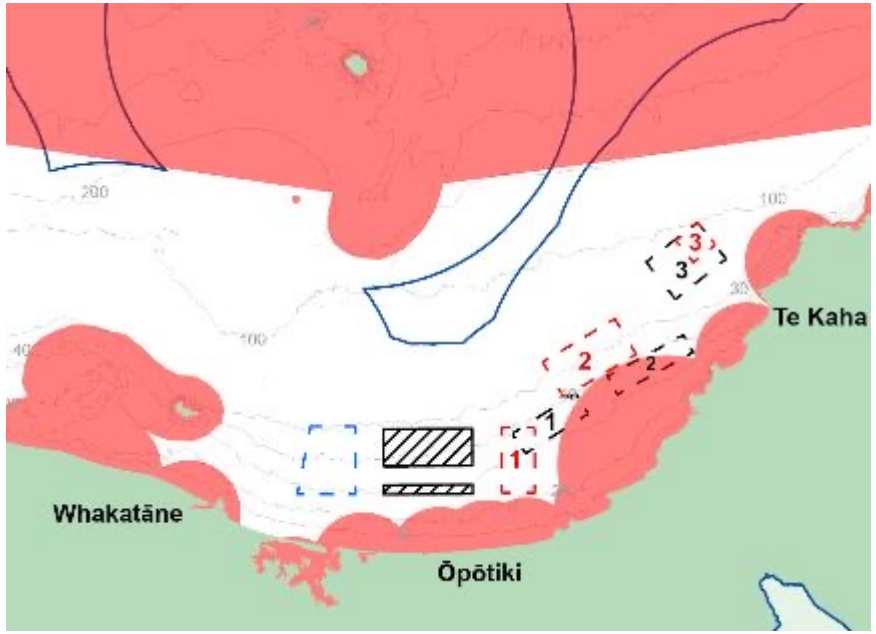
- Target GSM and *Ecklonia* aquaculture, not suitable for kingfish aquaculture
- Increase benthic survey coverage to include new area
- Check hydrodynamic model performance for suitability in new area
- Extend temporal coverage of chl-*a* and nutrient sampling
- GSM-specific modelling exercises
  - Depletion model or carrying capacity model
  - Depositional model
- *Ecklonia*-specific modelling exercises
  - Carrying capacity model or basic calculation of impact
- Relevant desktop assessments (e.g. mammals, seabirds, HMOs).

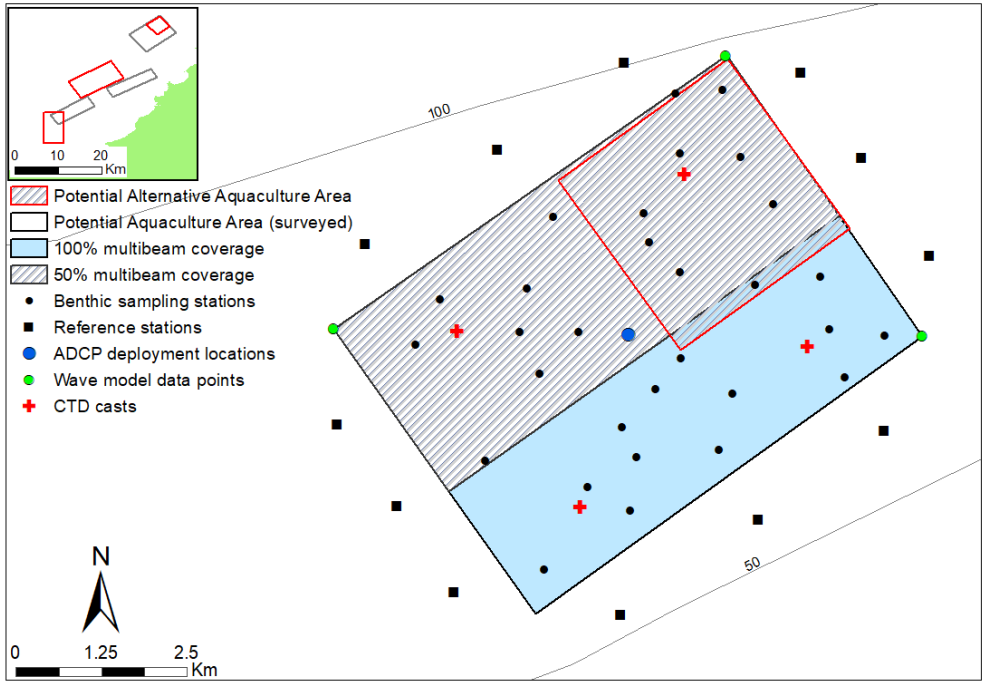




Site 2

- Target GSM and *Ecklonia* aquaculture
- Likely unsuitable for kingfish aquaculture
- Increase benthic survey coverage to include new area
- Extend temporal coverage of chl-*a* and nutrient sampling
- Check hydrodynamic model performance for suitability in new area
- GSM-specific modelling exercises
  - Depletion model or carrying capacity model
  - Depositional model
- *Ecklonia*-specific modelling exercises
  - Carrying capacity model or basic calculation of impact
- Relevant desktop assessments (e.g. mammals, seabirds, HMOs).





Site 3

- Target GSM and *Ecklonia* aquaculture
- Possibly suitable for finfish aquaculture (review hydrodynamic model)
- Extend temporal coverage of chl-*a* and nutrient sampling
- GSM-specific modelling exercises
  - Depletion model or carrying capacity model
  - Depositional model
- *Ecklonia*-specific modelling exercises
  - Carrying capacity model or basic calculation of impact
- Finfish-specific modelling exercises
  - Hydrodynamic model refinement
  - Depositional model
  - Oxygen-depletion model
  - Nutrient model
- Relevant desktop assessments (e.g. mammals, seabirds, HMOs).

Summary of gaps at revised sites

- Benthic surveys at Sites 1, 2
- Inter-seasonal nutrients, plankton at all sites
- Hydrodynamic model check against ADCPs to validate its use for GSM or Ecklonia farms at Sites 1, 2, 3.
- Hydrodynamic model refinement for Kingfish farming
- Additional modelling exercises will predict effects and further determine suitability

Kia ora
Thank you

CAWTHRON