# C11a: North East Atlantic Salmon Aquaculture

Simulation case

**2020 International Forum on the Effects of Climate Change on Fisheries & Aquaculture**

**25-26 February 2020, Rome**

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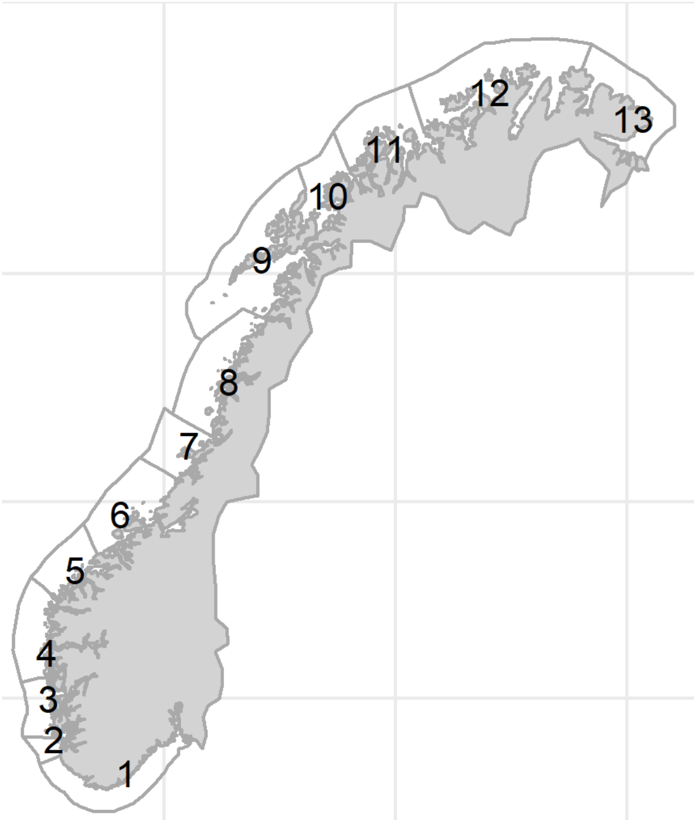
This project has received funding from the European Union´s Horizon 2020 research and innovation action under grant agreement no. 677039

# Case study description

- Atlantic Salmon
  - On-grown in sea cages
- Norway, and Scotland
  - Main salmon producers
  - 1.3MT produced in Norway
  - 72.5 billion NOK (7.2 billion Euros)
- Main stakeholders
  - producer companies
  - regulators
  - feed manufacturers

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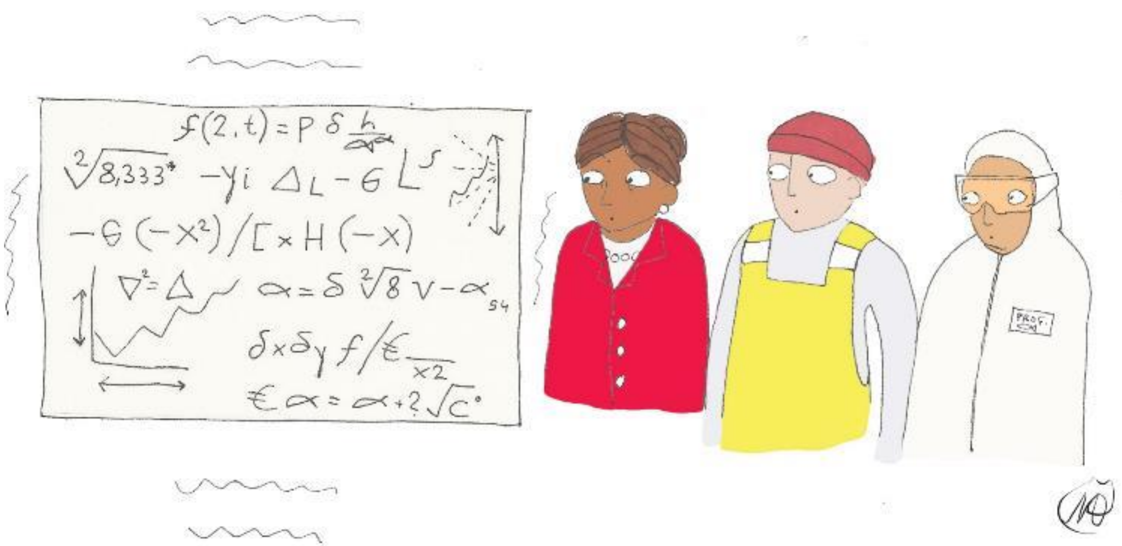
# Biological Forecasting (WP3)



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# Biological forecasting

- Climate projection
  - RCP4.5 from NorESM-ROMS regional model
- Direct effects of projected temperature on fish growth
- Variation by site and stocking strategy
- Also: more extreme temperatures and events such as feed withdrawal
- Responses: growth; impact on biomass that can be grown over a period for given stock; and time to harvest particular weight of fish.



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# Modelling Challenges

- Discrete sites with specific hydrodynamic conditions
  - Global and regional climate models do not capture site specific details
- Variation in stocking strategies
  - that have different physiology
  - exposed to different seasonal effects.
  - Extreme events (temperature, disease…) have additional impacts on production.
- Extremes
  - management and fish respond to temperature thresholds – not all changes are gradual, and limited quantitative data on effects of extremes

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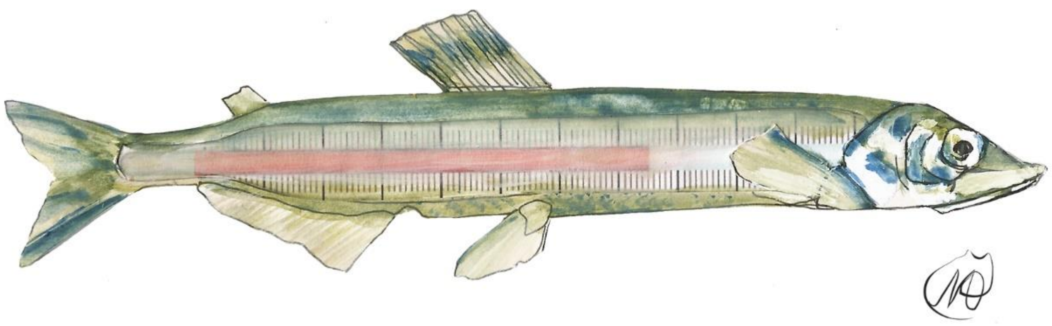
# Calibrating temperature projections



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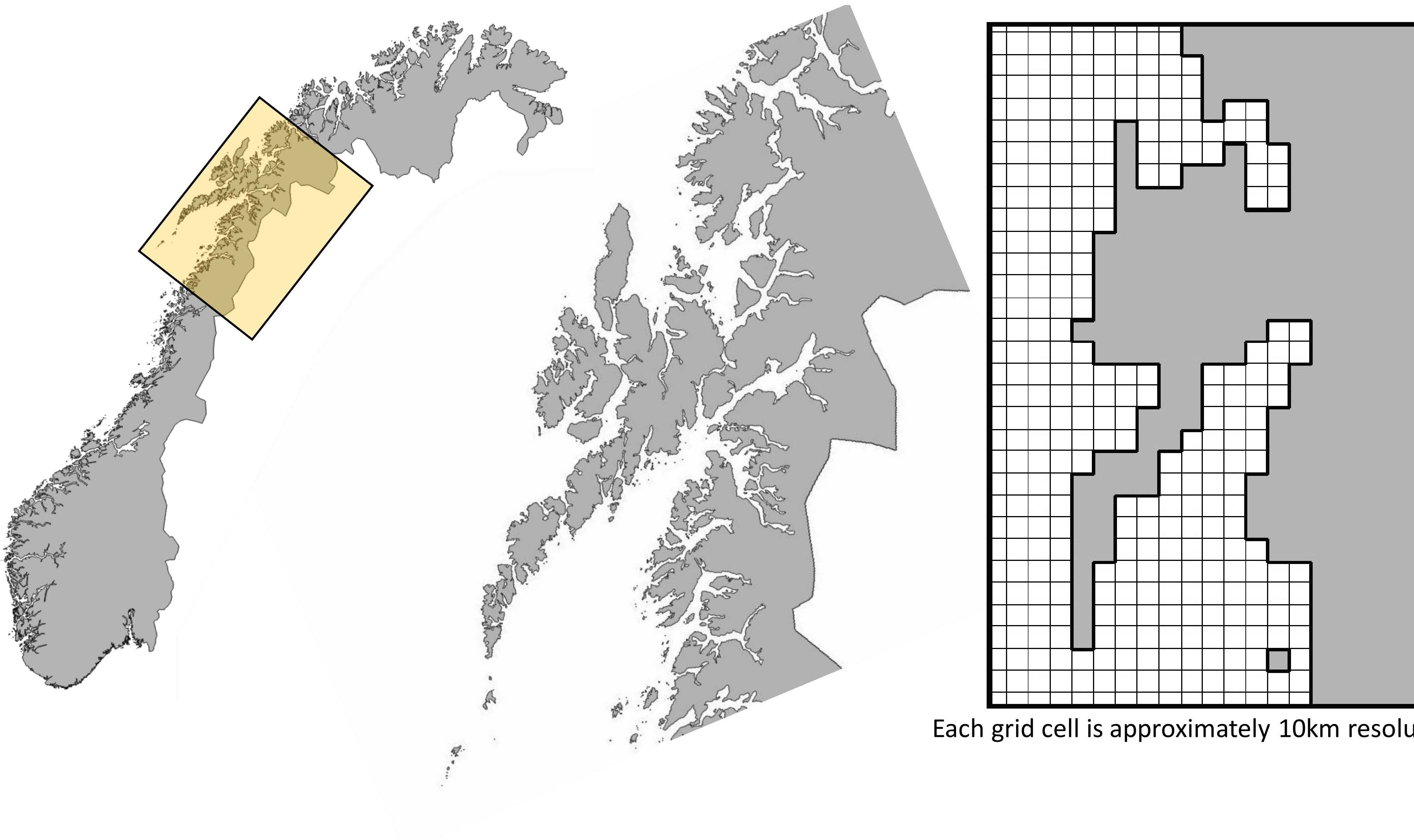

Each grid cell is approximately 10km resolution

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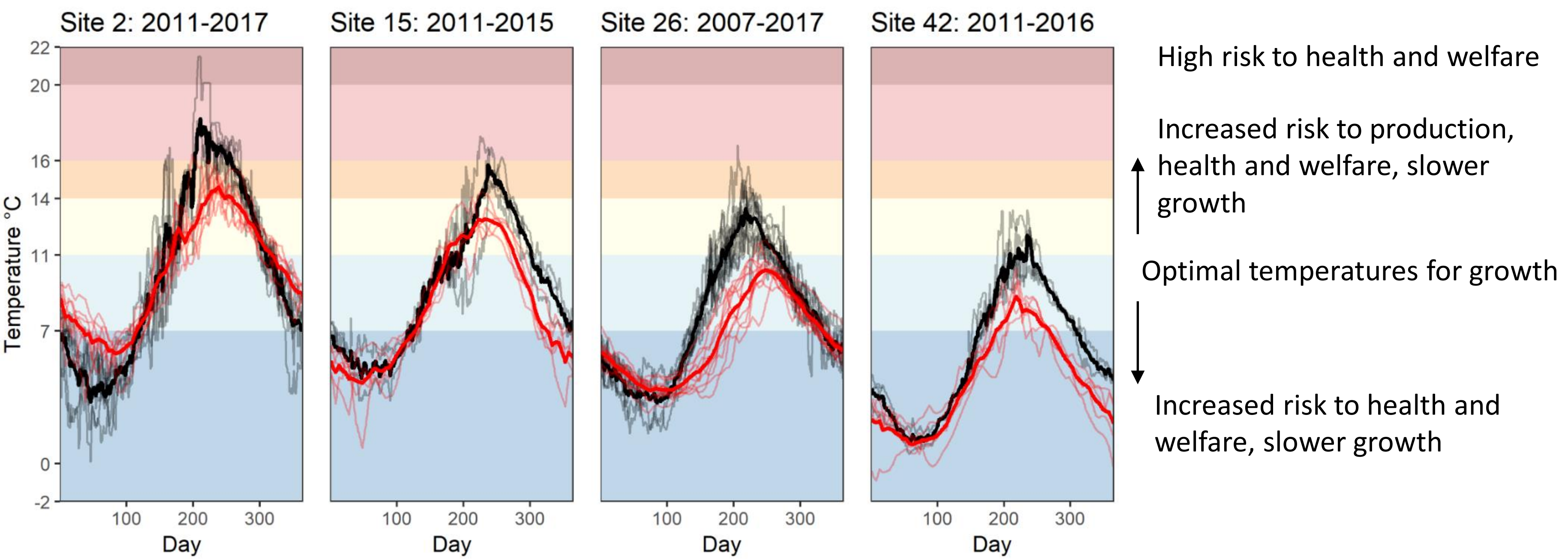
# Comparing farm measurements and model outputs




Black line = Farm measurements

Red line = Modelled temperatures

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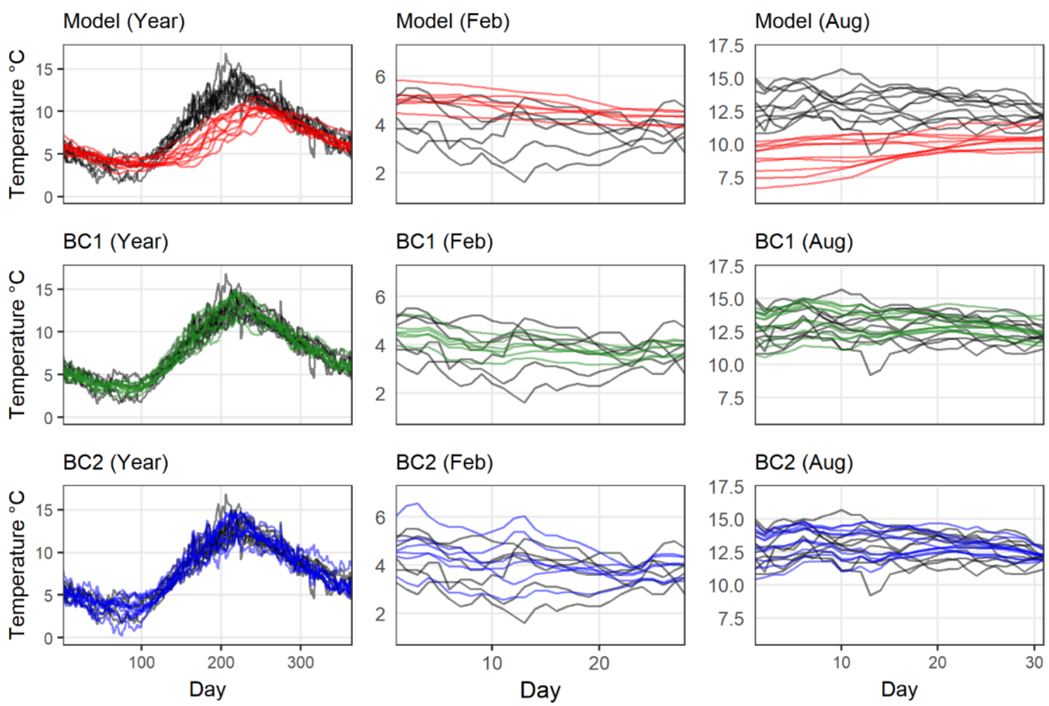
# Bias correction

$$T_{BC1}(t) = M_{FUT}(t) + (\overline{O_{REF}} - \overline{M_{REF}})$$




BC1

- Does not capture extremes
- generally good approximation of average conditions

BC2

- introduces more variation compared to BC1
- values are exaggerated.

Falconer et al (2020) *The importance of calibrating climate change projections to local conditions at aquaculture sites*, Aquaculture, Volume 514, https://doi.org/10.1016/j.aquaculture.2019.734487

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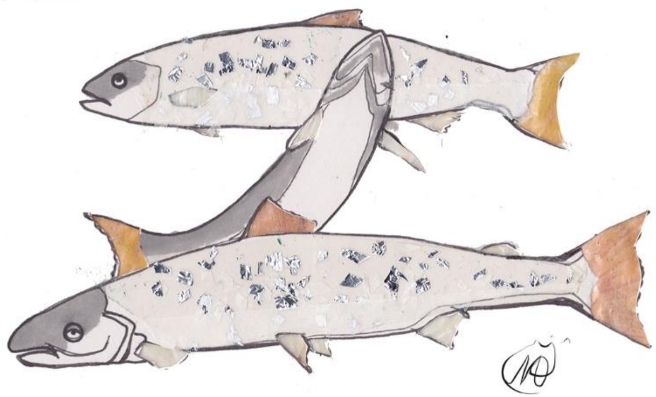
# Modelling Growth



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# Management variation

- Stocking size
  - Approx 100g to 500g or more, with a trend to bigger fish
- Stocking season
  - fish deployed in Autumn with no winters in freshwater (S0); or Spring with one winter in freshwater (S1)
  - These fish have life-long differences in growth
- Feeding intensity varies between farms
  - Some monitoring and management practices allow for greater feed quantities and faster growth
- Fish feeding rate varies with daylight (hence latitude) and temperature

- A commercial model for feed planning was used to model these variations



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# Extreme events

- Basic models do not capture range of issues that affect fish and farms at extreme temperatures (e.g. >16 degrees)
- Discussion with farmers showed
  - Feeding halted at low (freezing) and high (>16 degree) temperatures
- These extremes occur for many short periods in projections.
- Existing models did not capture effect on fish
  - Added simulation of this intervention to biological model
  - Also: Feed withdrawal due to increased disease frequency
  - Also: More extreme temperatures than RCP4.5
- Issue: lack of high resolution data at extremes to properly calibrate models



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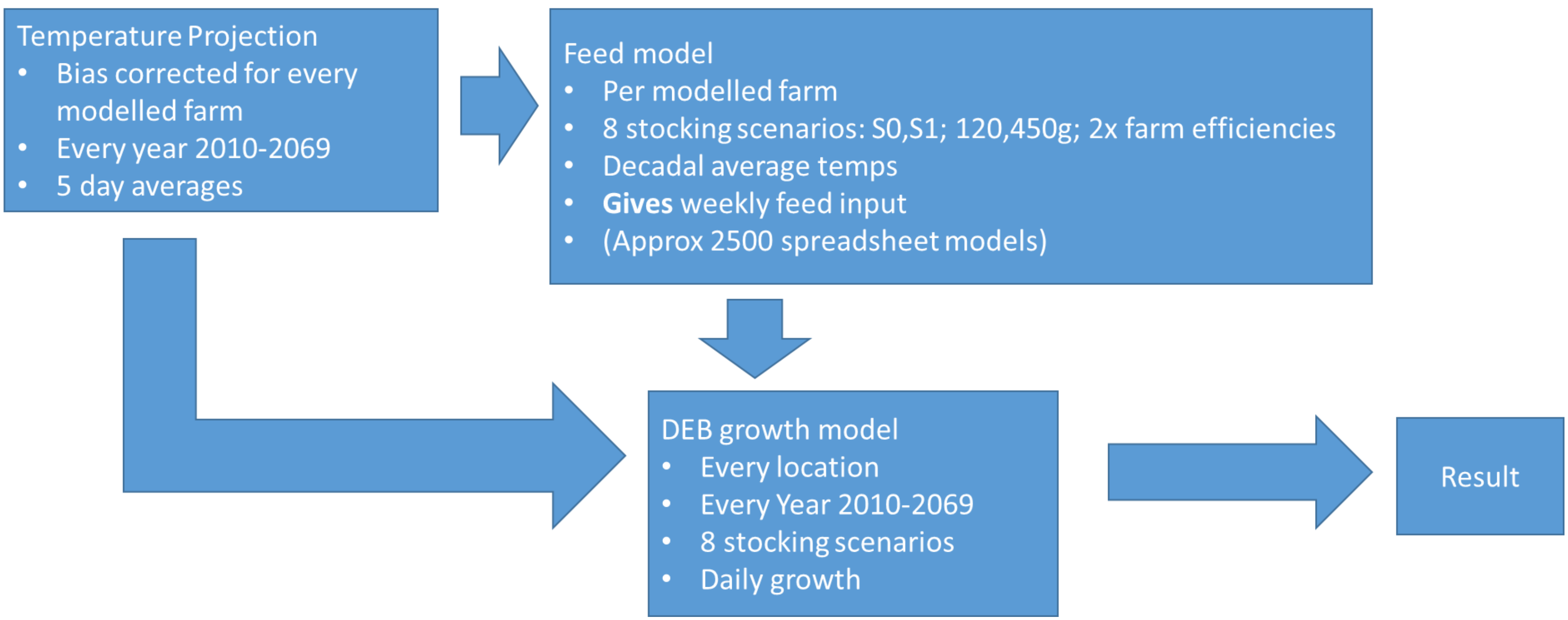
# Biological Model Structure

- ‘Dynamic Energy Budget’ (DEB) model
  - Growth of a salmon day-by-day smolt to harvest
  - Growth depends of temperature and feed
  - Apply to every year, location, multiple stocking scenarios

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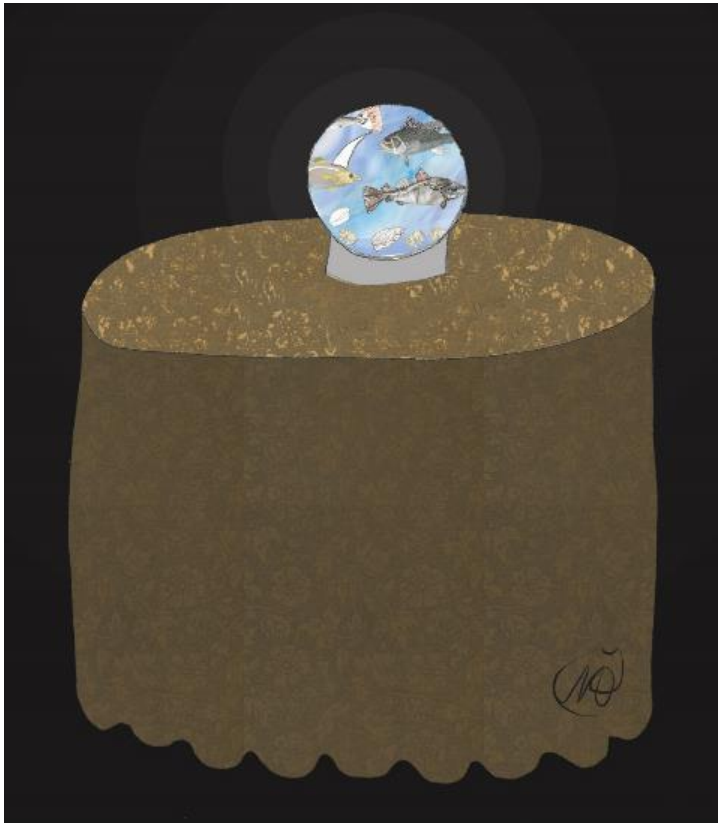
# Biological Forecasting Results



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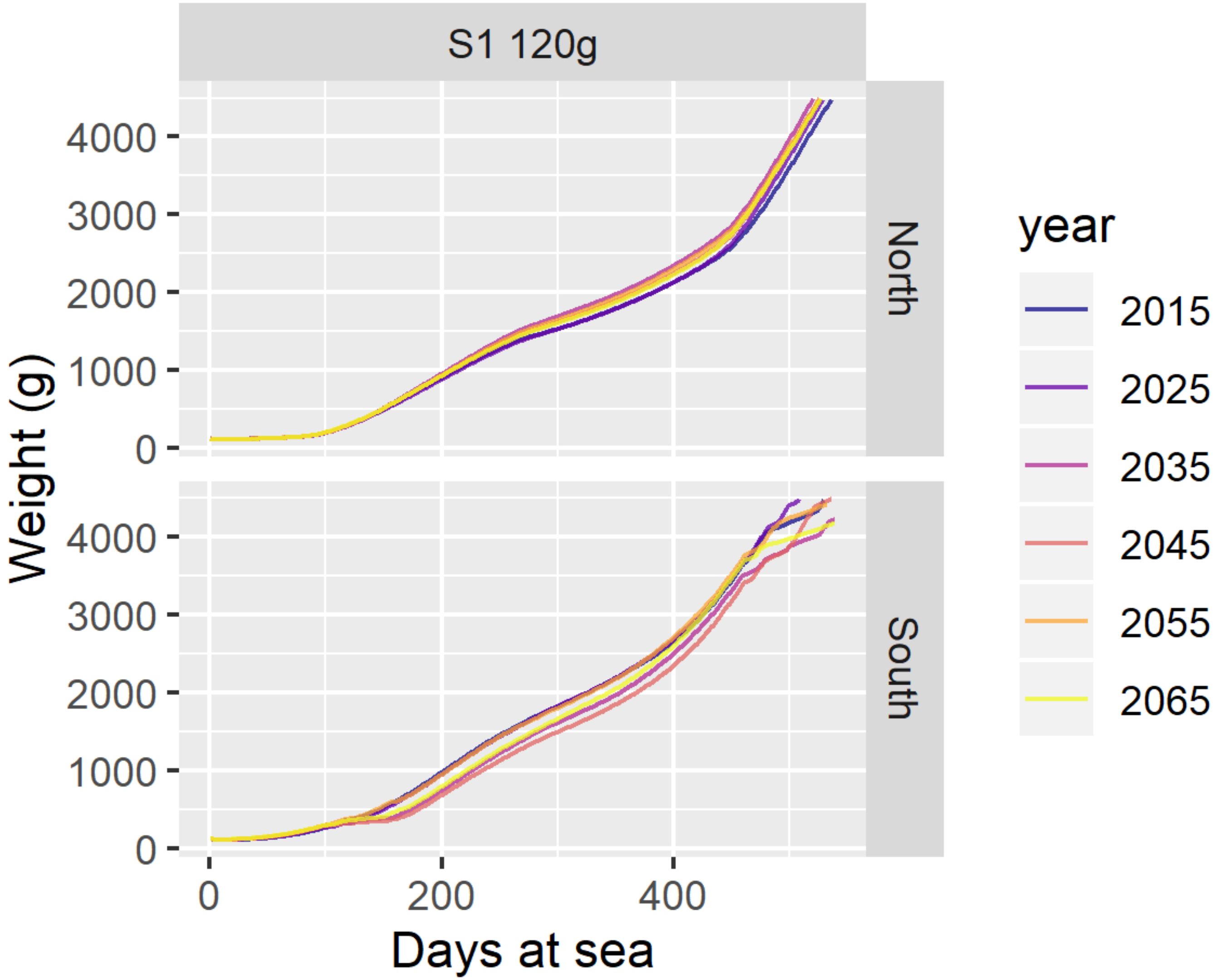
# Example Growth Curves – RCP4.5

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# Risks and Opportunities Adaption Measures

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# Key Lessons

- Outcomes are site specific
  - And temperature projections must be calibrated to sites
- Variation is driven by extremes
  - Presence of heatwaves matter more than changes in average
- Adaption depends on understanding management
- Existing management practices give scope for adaption
- We need to understand how multiple stressors interact as climate changes
  - Disease, treatments, nutrient demands, breeding…
  - Monitoring is critical


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# References


- Falconer et al (2020) *The importance of calibrating climate change projections to local conditions at aquaculture sites*, Aquaculture, Volume 514, https://doi.org/10.1016/j.aquaculture.2019.734487
- Climefish deliverable D3.3 (Case study C11A)


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