Using ocean modelling to structure salmonid farming in Norway

Bjørn Ådlandsvik & Anne Sandvik

Institute of Marine Research
Bergen, Norway

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

JONSMOD 2016, Oslo, 2016-05-12

Background

- Salmon farming is a **multibillion** industry in Norway
  - Export 2015; mass: 1 Tg (=mt), value: 48 GNOK
- Government wants a **sustainable growth** in the industry
- IMR is working on **environmental consequences** of salmon farming
- Presently growth is limited by harmful effects of **salmon louce** on wild salmon and sea trout

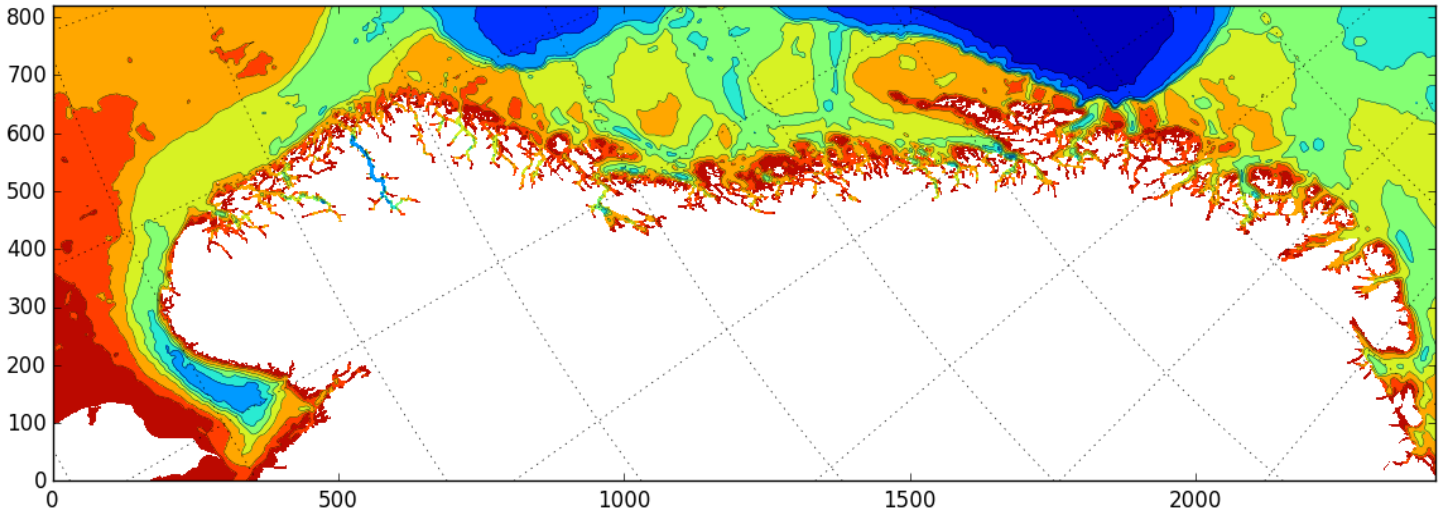
Salmon louce, *Lepeophtheirus salmonis*

- **Copepod**
- Parasite on salmonid fish
- **Planktonic** phase
  - Nauplii (non-infective)
  - Copepodite (infective)
- Total duration 150 degree-days
- Eggs developes in egg-strings
- Fish farming multiplies the number of hosts by 1000

Photo: Wikipedia

Modelling spreading of salmon lice

- Regional circulation model
  - ROMS, Norkyst800 or NorFjords
    - Albretsen et al. 2011
- Particle tracking
  - LADIM
    - Ådlandsvik & Sundby, 1994 ....
  - Individual based behaviour
    - Incorporating what we know about salmon lice
    - Asplin et al., 2011; Johnsen et al., 2014



Norkyst800
bathymetry

Operational Monitoring at IMR

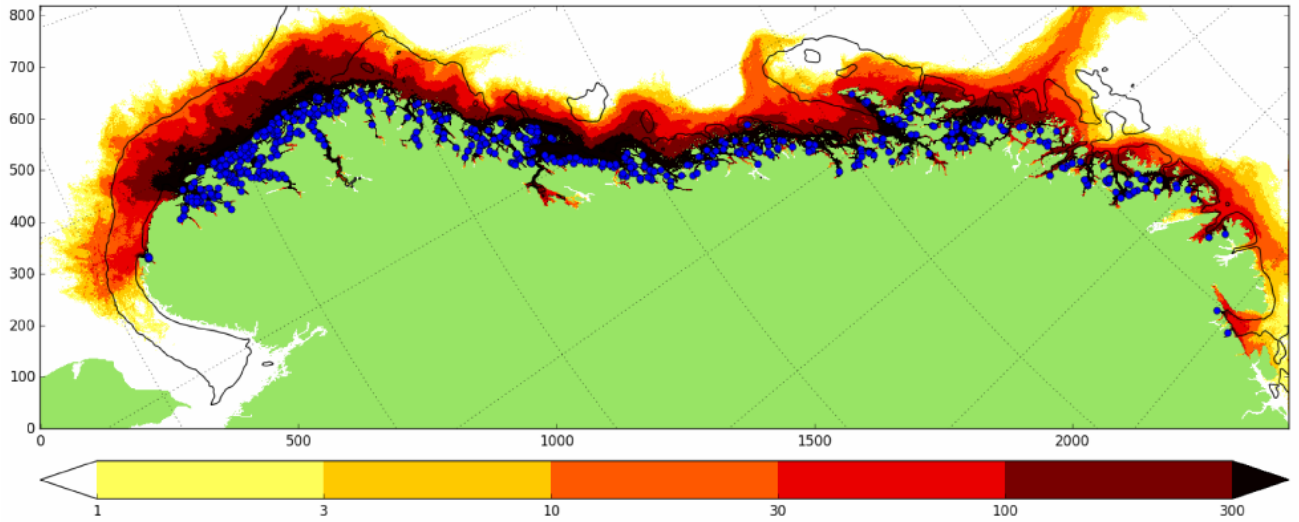
- Weekly simulations during spring and summer
- Counting of mature female lice by fish farmers
- NorKyst800 operational runs by MET
- Result is salmon lice **copepodite density**
  - Low density, in practise not observable
- Indirect field verification
  - Sentinel cages, fishing by traps and nets
  - Areas selected by high values in model

Production areas

- Proposed management units for regulating production volume
- Large enough to minimize cross infection of salmon lice
- Small enough to be connected with regard to infestation of salmon lice
- Problem:
  - How to define such areas in an **objective** way?

Dispersion modelling

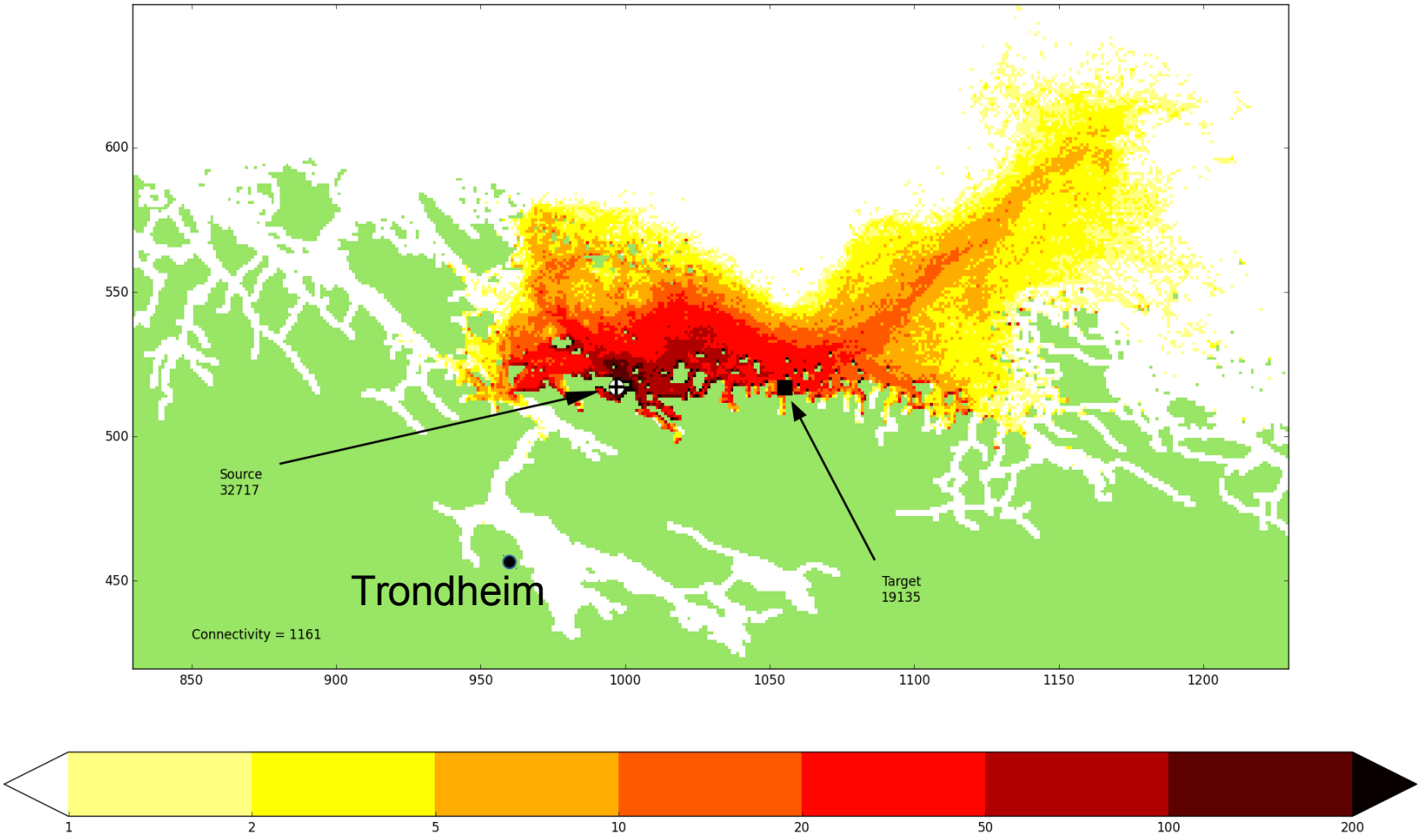
- Use the model tools available, in particular NorKyst800
- Continuous release of particles from all farms (active in 2014)
    - Fixed release rate, characterize **pathways**
- Behaviour and mortality as planktonic salmon lice
- Simulation period, 120 days, April-July 2013
    - Computing the aggregate distribution – probabiltity of finding copepods



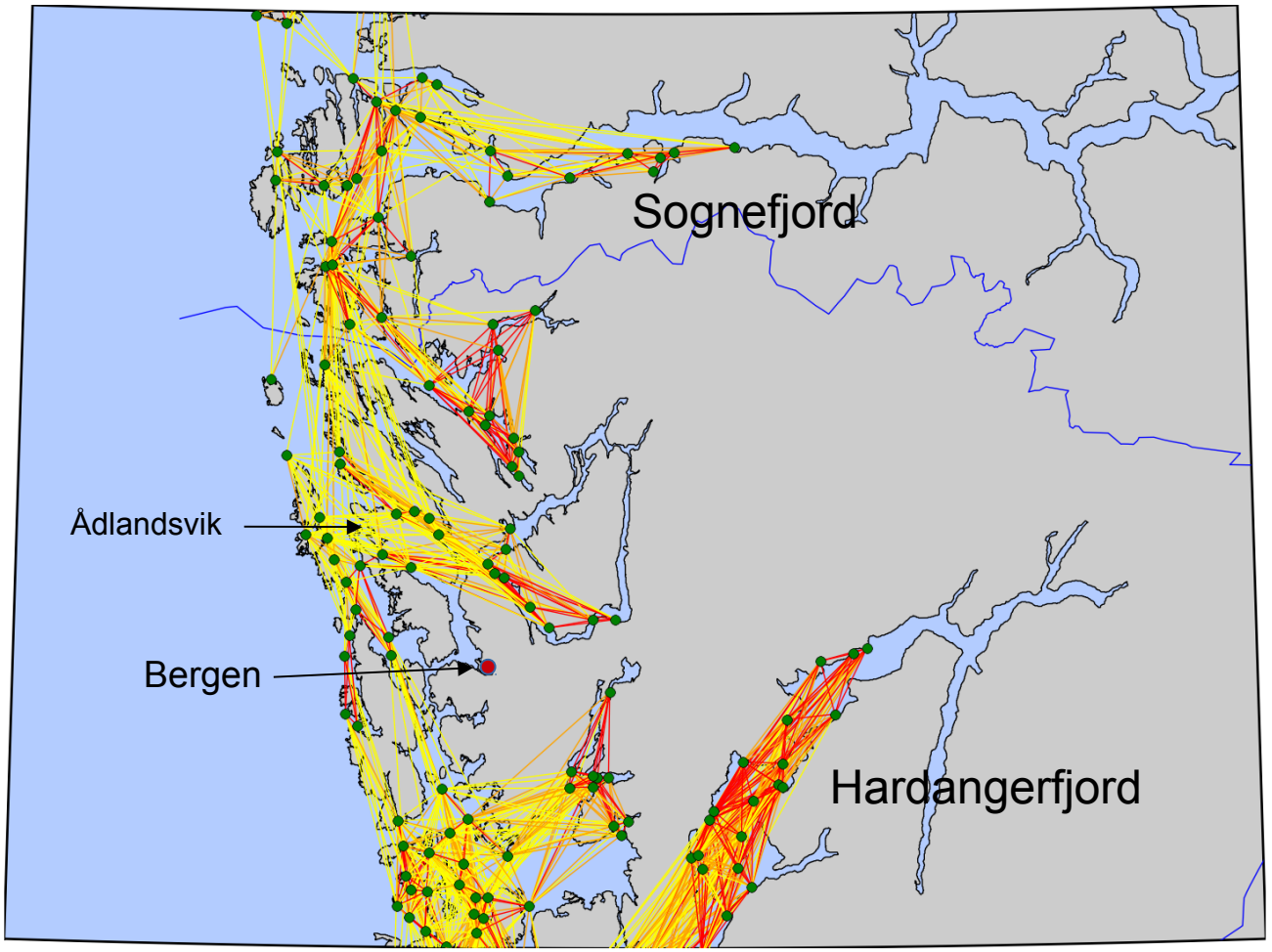
- 591 farms
- Infectious copepodites
- Logarithmic colour scale

Example from Trøndelag

Dispersion from Tranøy in Bjugn
Influence on Sandøy i Roan



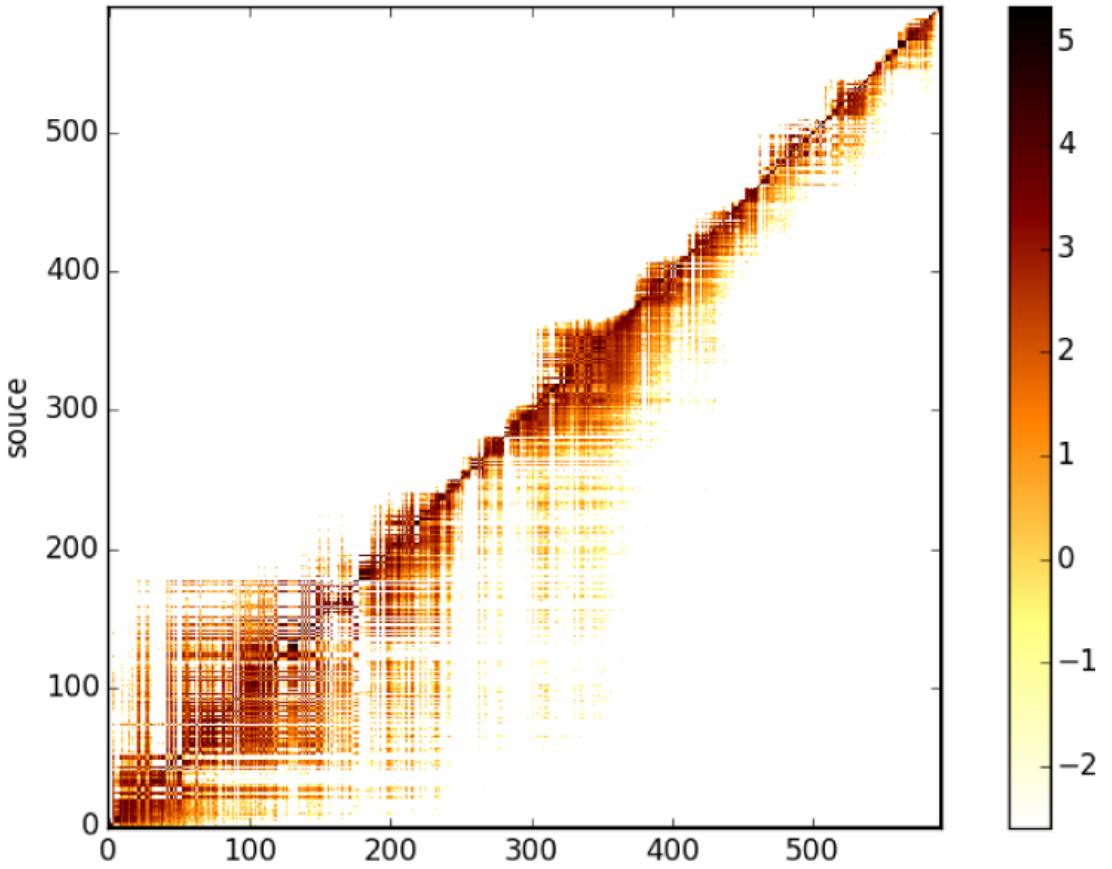
Network plot



Northern Hordaland is more connected to Sogn than Hardanger

Influence matrix

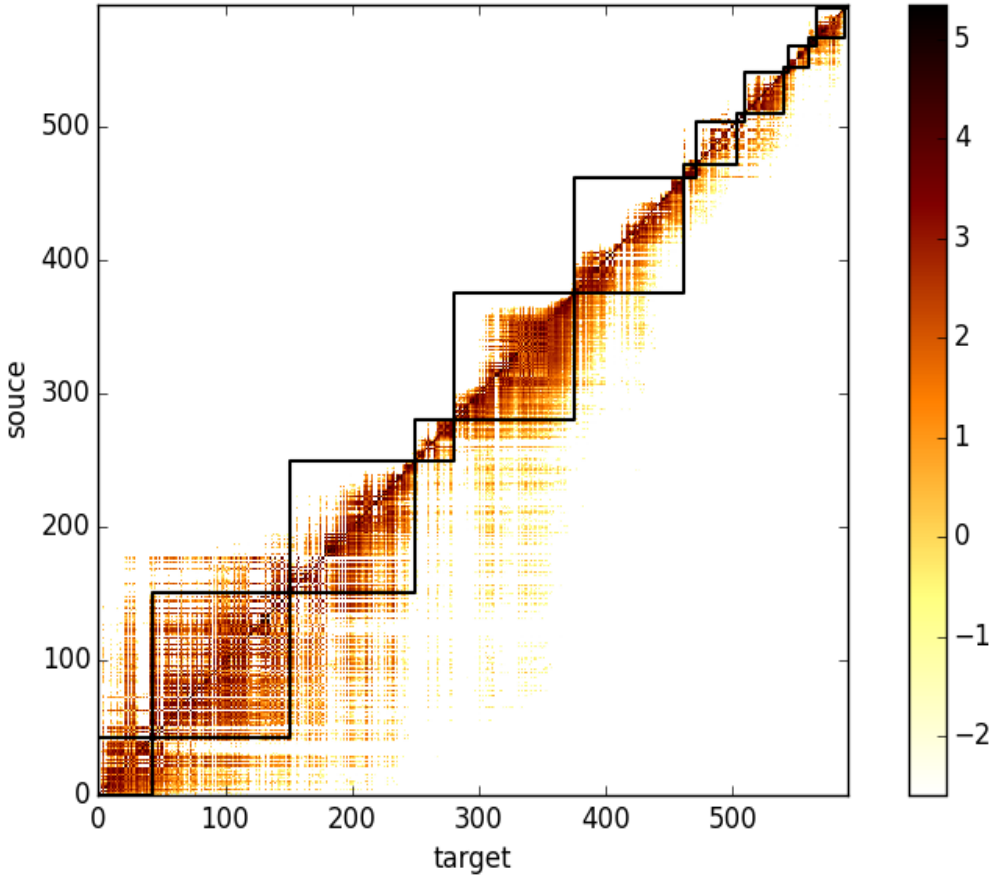
- Sort locations from south to north.
- Pixel row *i* and column *j* is influence from location *i* on *j*
- Logarithtnic colour scale

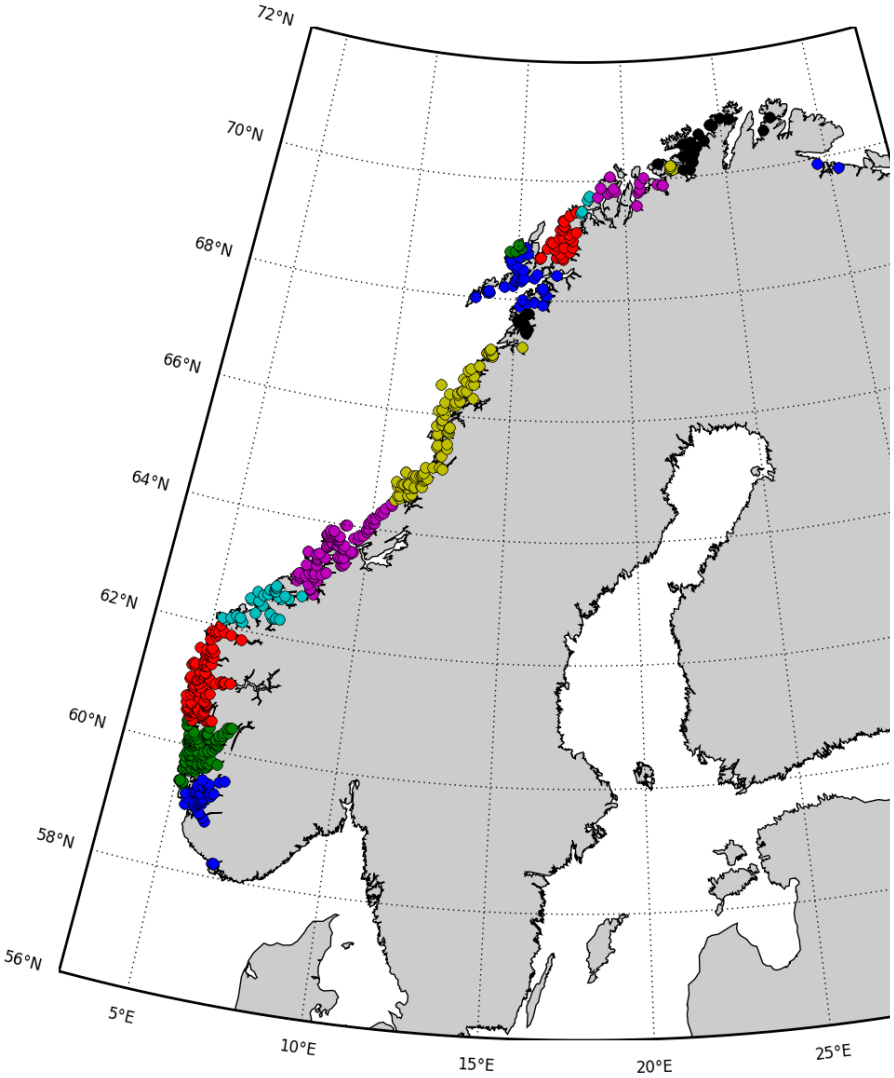


Cluster Analysis

- Many algorithms available
- Need a method based on a connectivity measure (affinity) rather than spatial distance
    - Affinity = symmetrized influence
- Spectral clustering (Ng et al., 2001) as implemented in python package scikit-learn

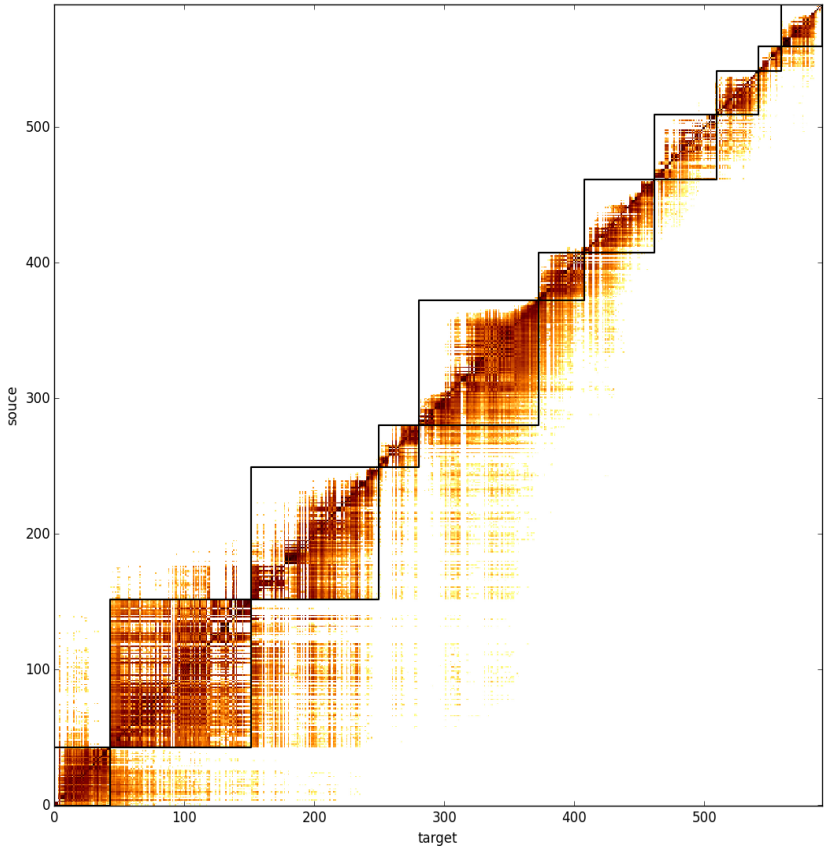
Cluster analysis, 15 clusters

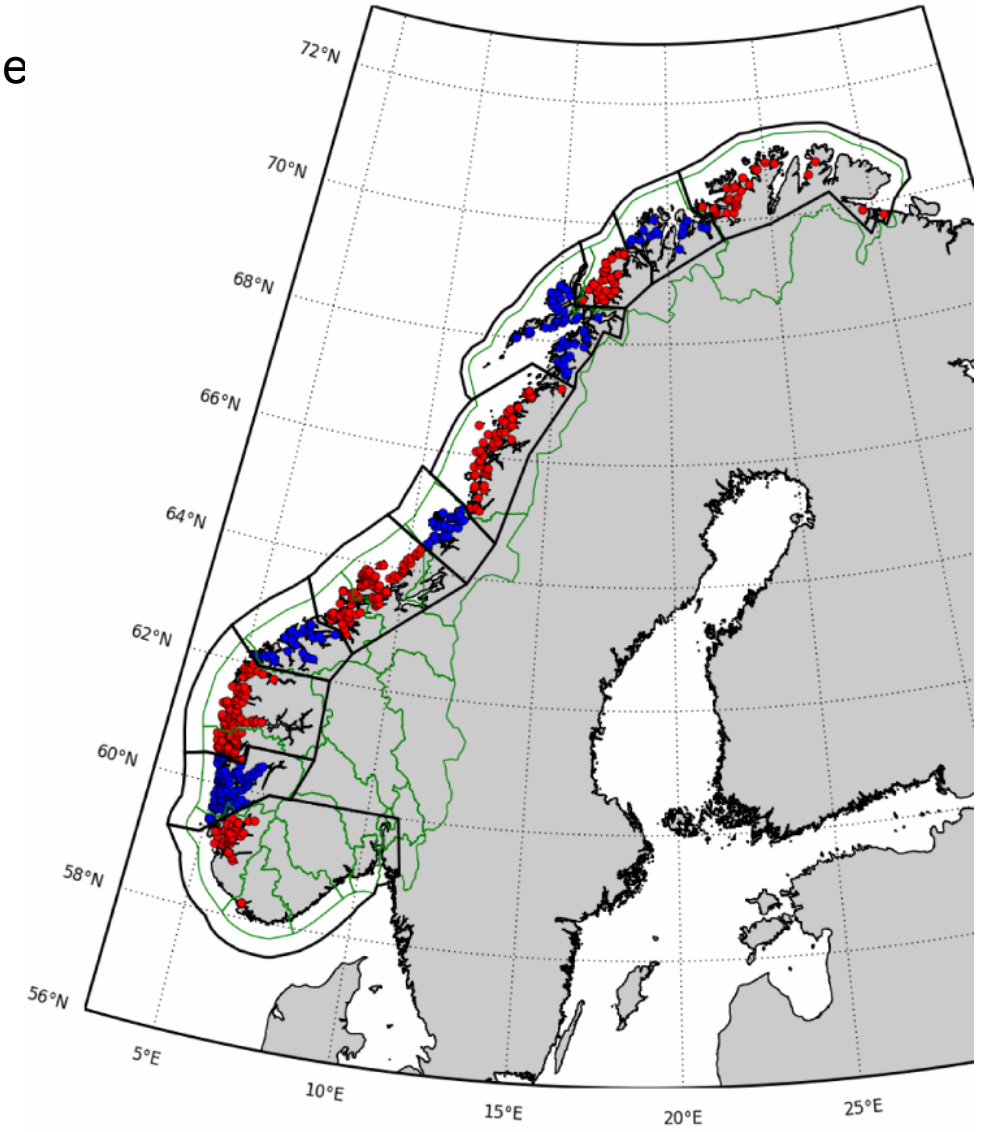




Suggestion for area decomposition

- Subjectively
  - Incorporate some small clusters into the neighbours
  - Make boundary polygons
  - 11 production areas





Export/import statistics

Nummer	Område	Antall anlegg	Absolutt import	Absolutt eksport	Relativ import %	Relativ eksport %
1	Svenskegrensen → Karmøy	43	5	56	0,1	1,6
2	Karmøy → Sotra	109	144	302	1,1	2,2
3	Nordhordland → Stad	98	297	94	3,3	1,0
4	Stad → Hustadvika	31	3	33	0,3	2,8
5	Nordmøre + Sør-Trøndelag	92	36	76	0,5	1,1
6	Nord-Trøndelag	35	79	43	3,8	2,1
7	Helgeland + Salten	54	44	9	2,2	0,4
8	Vestfjorden + Vesterålen	48	6	11	0,2	0,5
9	Andøya → Senja	32	11	7	0,6	0,4
10	Kvaløya → Loppa	18	7	5	0,9	0,7
11	Finnmark	31	5	0	0,2	0,0
Total		591	636	636	1,4	1,4

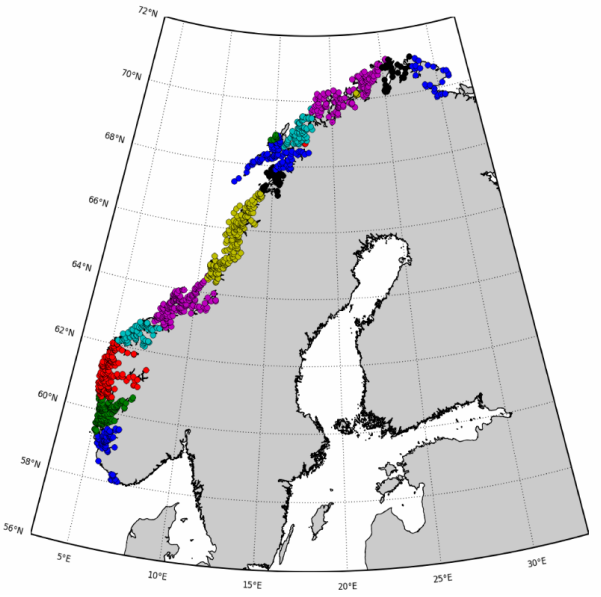
Sensitivity analysis

- «Arbitrary» choices
  - 591 locations (active in 2014)
  - Existing geographical structure of farms
  - Model currents from 2013
  - Mortality 17% per day
  - Target area, 3x3 grid cells

Source locations

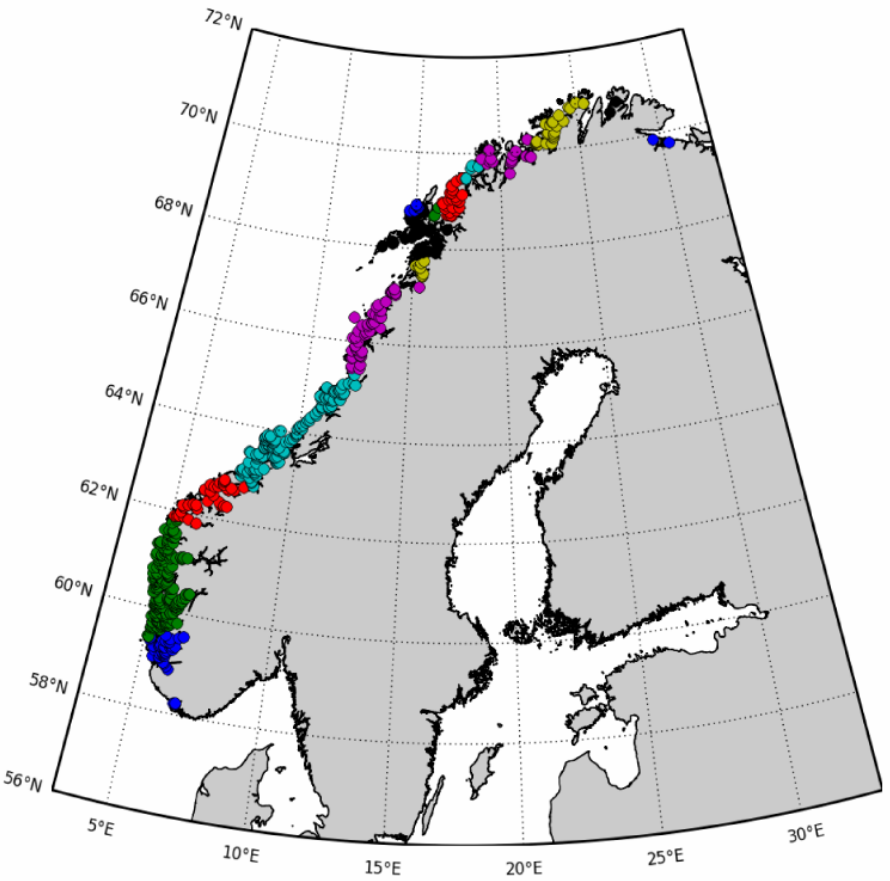
- 921 existing locations
  - Similar results
- 645 arbitrary locations
  - Some clear differences
- 591 standard + 594 arbitrary new locations
  - New locations not closer than 16 km from area boundaries
  - Similar results to standard

591+594



Same locations, currents from 2014

- Slightly weaker currents
- Some differences in cluster analysis
- Standard area decomposition work well (better than 2013)



Mortality

- Standard value 17% per day
  - 1% per hour
  - Lab. studies by Stien et al., 2005
- Runs with no mortality and 25% per day
  - Same spatial patterns, but
  - higher mortality limits spreading time and thereby distance

Summary

- ✓ Using the usual combo of a regional ocean model and particle tracking we have produced a connectivity matrix for Norwegian fish farms
- ✓ Cluster analysis has been used to propose a structure of 11 production areas
- ✓ The analysis is not too sensitive to choice of modelling parameters
- ✓ Have methods for analysing alternative suggestions