Spatial Externalities in Salmon Aquaculture: Salmon Lice Management in Norway

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The Single Biggest Challenge of the Industry

Sea lice as a density-dependent constraint to salmonid farming (Jasen et al., 2012)

Sea lice have developed resistance to chemical treatments

- Surging treatment costs: x5 since 2011
- Industry-wide costs: 5bn NOK[1] (575 million USD)
- Treatments (about 20% of production costs, 5 NOK/kg):
  - Biological: wrasse (cleaner fish)
  - Medecine: in-feed pellet (oral)
  - Chemical: bath delousing (hydrogen peroxide)
- Innovation: fully-enclosed pens, "snorkel" barrier, tarpaulin shielding skirt, open-ocean facility, laser, land-based facilities...

[1] Nofima (2015): These costs excludes reduced growth, higher feed conversion ratio, mortality, decrease in quality of product...

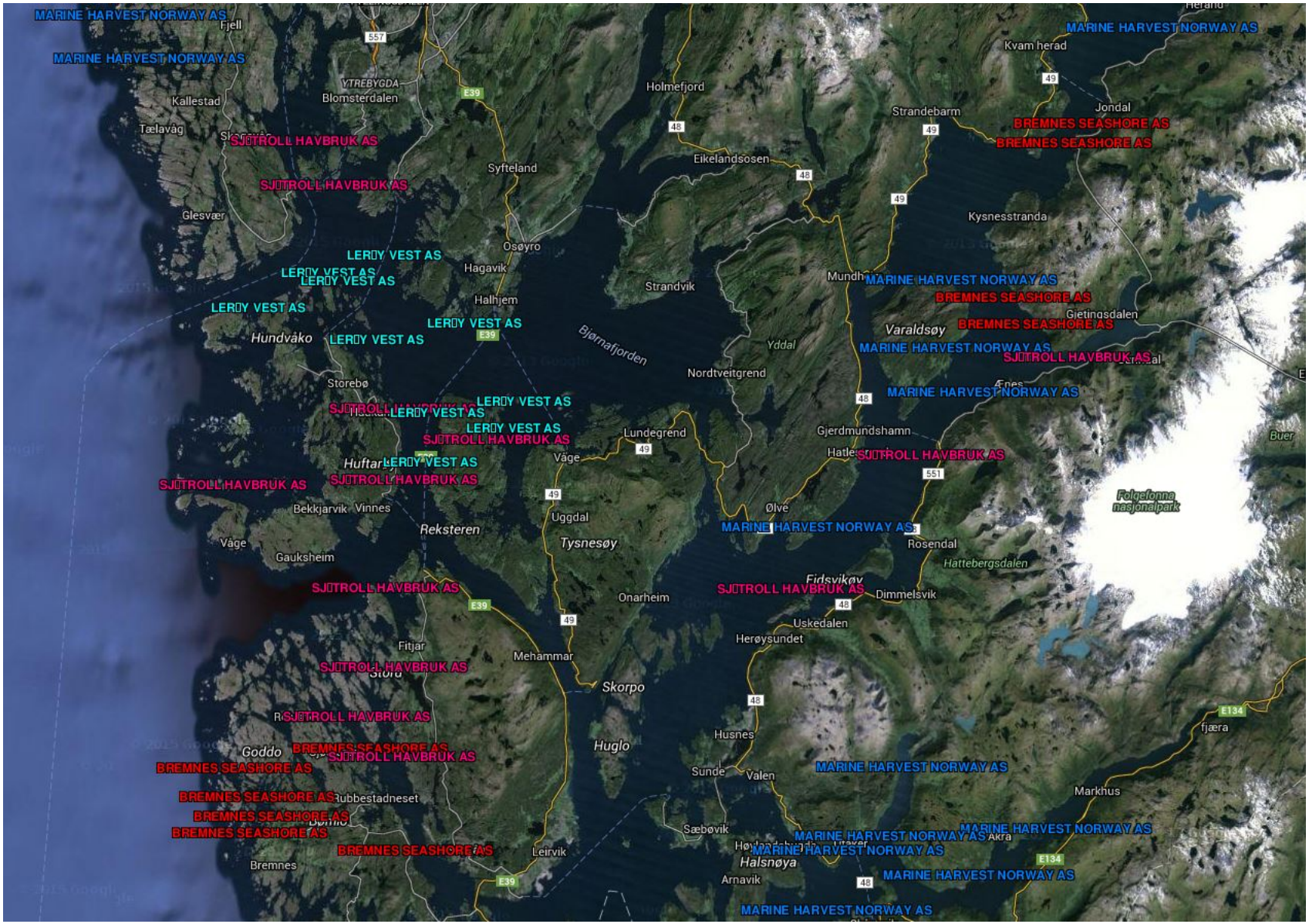

Figure: Large Salmon Farming Firms Located in Hardangerfjord

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- Existing literature focuses on impact on other activities (Ex: wild salmon, Krkosek, Lewis, & Volpe, 2005)
- Not focused on intra-industry interactions: except knowledge spillovers (Tveteras, 2002)

What can be learned from other resources/industries?

- Method: literature review of 100 papers
- Scope: agriculture, forestry, fishery/aquaculture, epidemiology
- Focus: "edge effect" externalities under fragmented ownership
- Related topics: spatial interaction/interdependence, connectivity, neighbor-to-neighbor spillovers, contamination, invasive species, pest management, adjacent (multi-use) stands.
- Contribution: Identify key lessons for salmon aquaculture

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Spatial Externalities and Edge Effects

*"**Spatial externalities** arise whenever economic activity in one location influences returns in another location."* (Costello & Polasky, 2008)

Edge effects: *"spatial externalities whose marginal impacts decrease as distance from the border generating the negative impact increases."* (Parker & Munroe, 2006)

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Agriculture 1

Pest Control and Invasive Species Management

Citrus Trees damaged by insect pest Asian citrus psyllid (ACP)

The Control of Invasive Species on Private Property with Neighbor-to-Neighbor Spillovers (Fenichel, Richards, Shanafelt, 2013)

- Focus: Incentives to property managers
- High connectivity attenuates property rights and values
- High value owners have stronger incentives for pest-control
- Strategic complement of cooperating with the weakest link, preferably with a Coasian system of exchange

➔ Role of government or trade associations in detection schemes, reporting, and information sharing

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Agriculture 2

Genetically Modified Crops

Spatial Efficiency of Genetically Modified and Organic Crops (Ambec, Langinier, Marcoul, 2013)

- Results:
  - Regional clubs, buffer zones
  - Number producers required to cooperate depends on the distance of pollination[2]
- Even in absence of regulation, coordination can restore efficiency

➔ Create regional management clubs

[2] Sea lice spreads estimated 20 km-seaway distance (Krkosek, 2005; Patanasatienkul, 2015)

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Forestry 1

Managing an Unobservable Invasive Species

Forest management when invasion and damages of invading species are unobservable (Ollikainen, working paper)

- Risk preferences affect treatment levels
- Policy recommendations:
  - Improve information on invasion probabilities
  - Education of landowners

➔ Research and education

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Forestry 2

Fire Prevention

Adjacency Externalities and Forest Fire Prevention (Crowley, Malik, Amacher, Haight, 2009)

- Decisions variables: density of planting + timing of fuel treatment
- Results:
  - Informed landowner might reduce treatment and free-ride
  - Larger consequences if multiple adjacent lands
  - "Active" manager has incentive to buy from passive ones
- Policy recommendations:
  - Inform about own-stand benefits

➔ Engage producers

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Key Lessons for Aquaculture

- Information (mandatory reporting and sharing):
- Cooperation and coordination :
- Research:
- Regional management clubs and buffer zones:

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- Information (mandatory reporting and sharing):
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  - Fallow period by areas
  - Synchronize treatments (in spring)
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- Research:
  - The Sea Lice Research Centre (www.slrc.no)
  - "Green licences" : to develop new technologies tackling sea lice and escapes
- Regional management clubs and buffer zones:

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- Regional management clubs and buffer zones:
  - Institute of Marine Research (IMR) proposes 11-13 management zones with buffers (Ådlandsvik, 2015)

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A New Geography for Salmon Farms

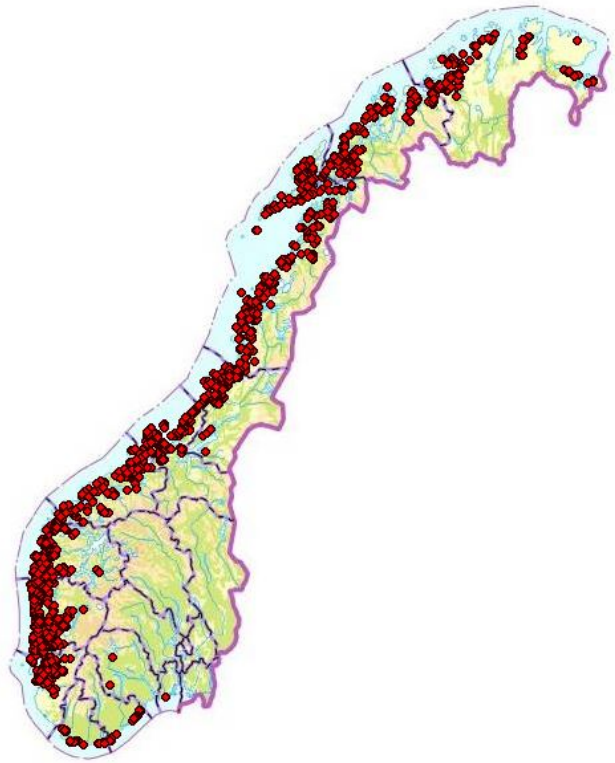

Figure: All marine aquaculture locations (Source: Directorate of Fisheries)

Conclusion

- Cross-contamination between adjacent locations is a common challenge in many industries such as agriculture and forestry
- These industries can guide and inspire the design of a spatial policy response in aquaculture
- Implication:
  - Future regulations will focus more on farm locations
  - Policies will discourage production at poor locations ("Traffic lights")
- Further research:
  - Spatial interactions
  - Innovation incentives
  - Industry consolidation

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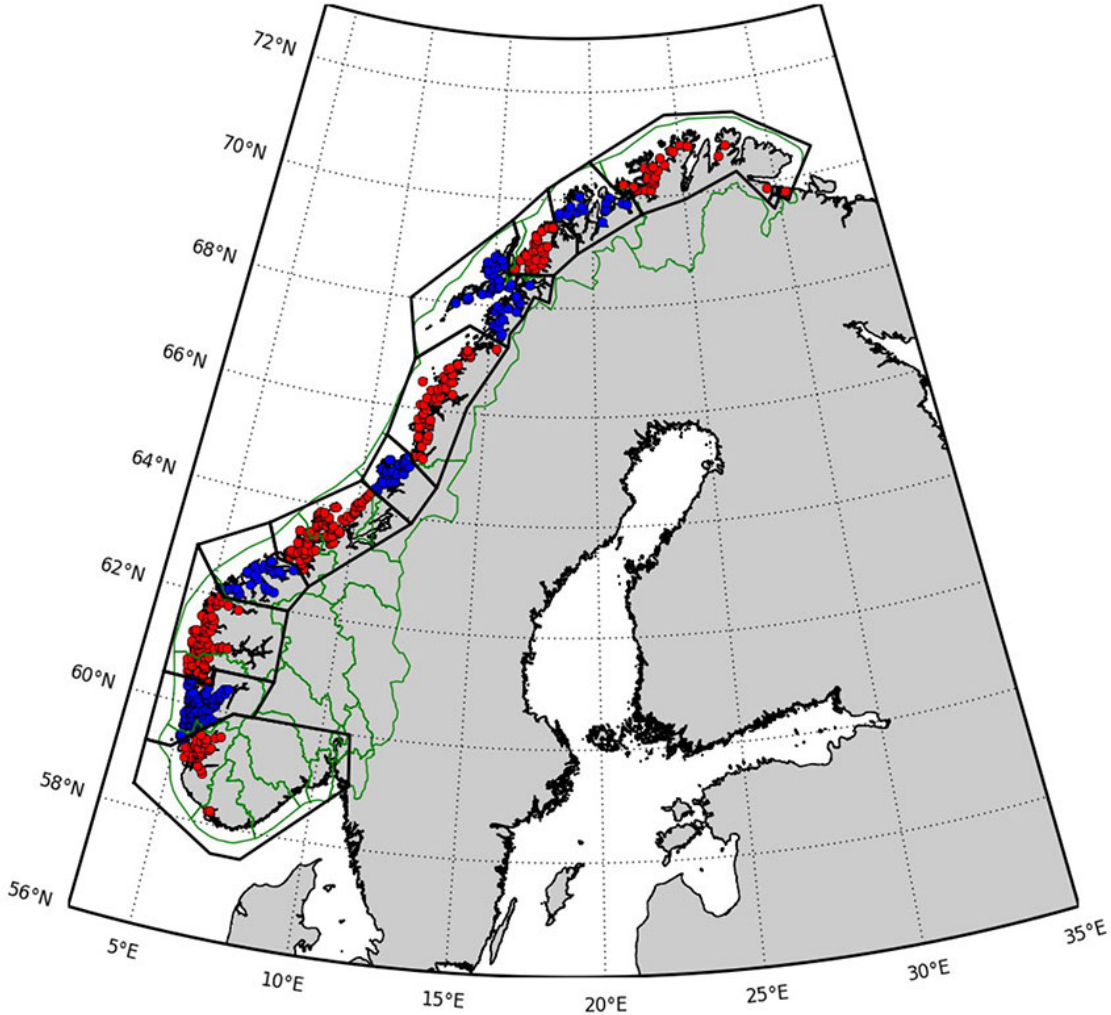

Figure: Proposed Management Regions by IMR (Ådlandsvik, 2015)

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