Assessing the utility of fisheries-dependent data to support mixed fisheries management: a spatiotemporal simulation framework

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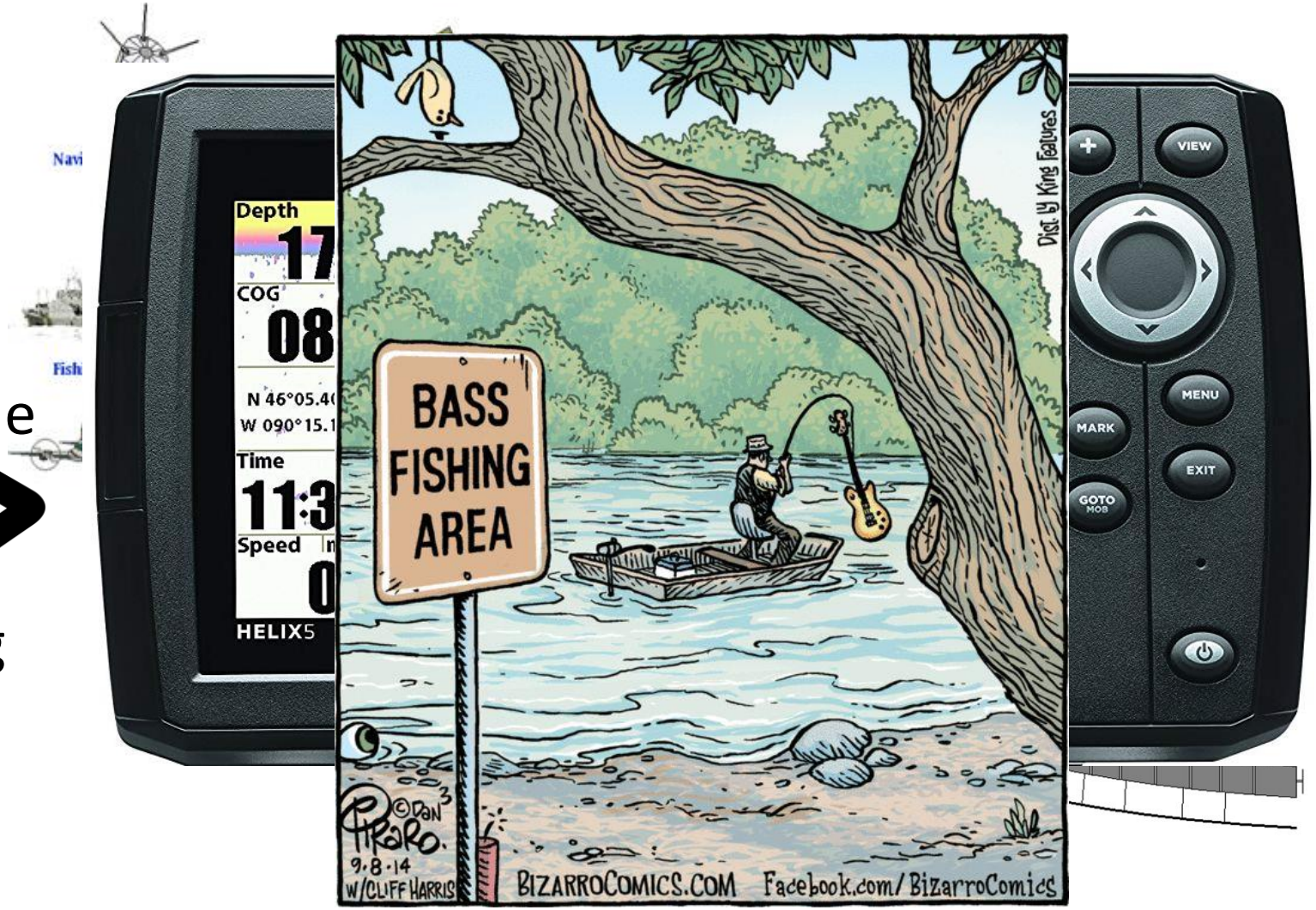
Cefas

Fishing is an inherently spatiotemporal process

- Fisheries catch multiple heterogeneously distributed fish stocks
- Uncertainty about distribution in space-time
- Provides lots of dat

…but a biased sa g process: spatial (a gear-based) target

Created by Andrew Doane
from Noun Project



Increasing use of fisheries-dependent data to understand mixed fishery dynamics

Dunn et al 2016.

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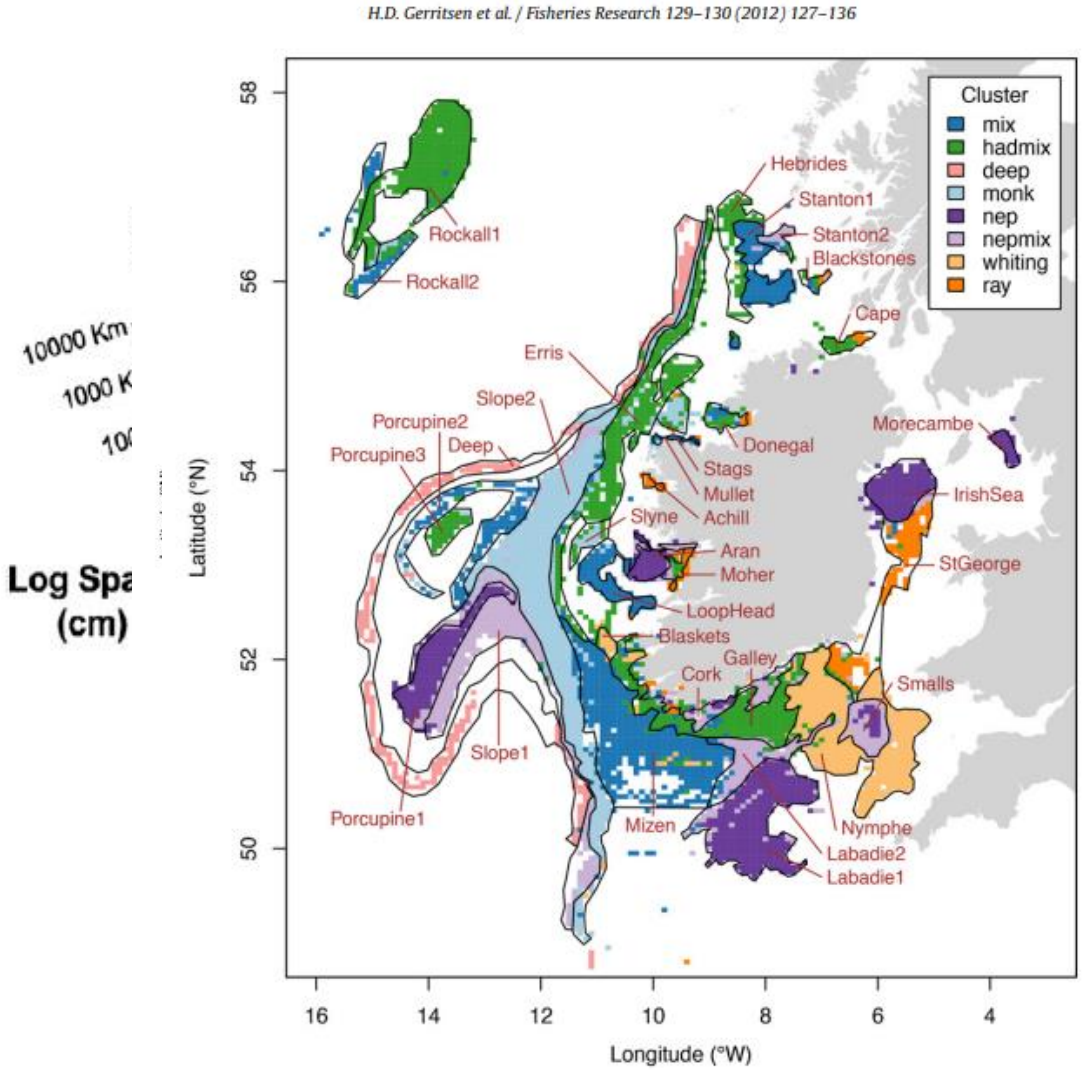
- Increasing interest in spatiotemporal management in mixed fisheries
- Spatial and temporal resolution of fisheries-independent survey data sparse
- Use of fisheries-dependent data, but fishing biased sampling process
- True distribution of populations unknown



What Qs do we want to answer?

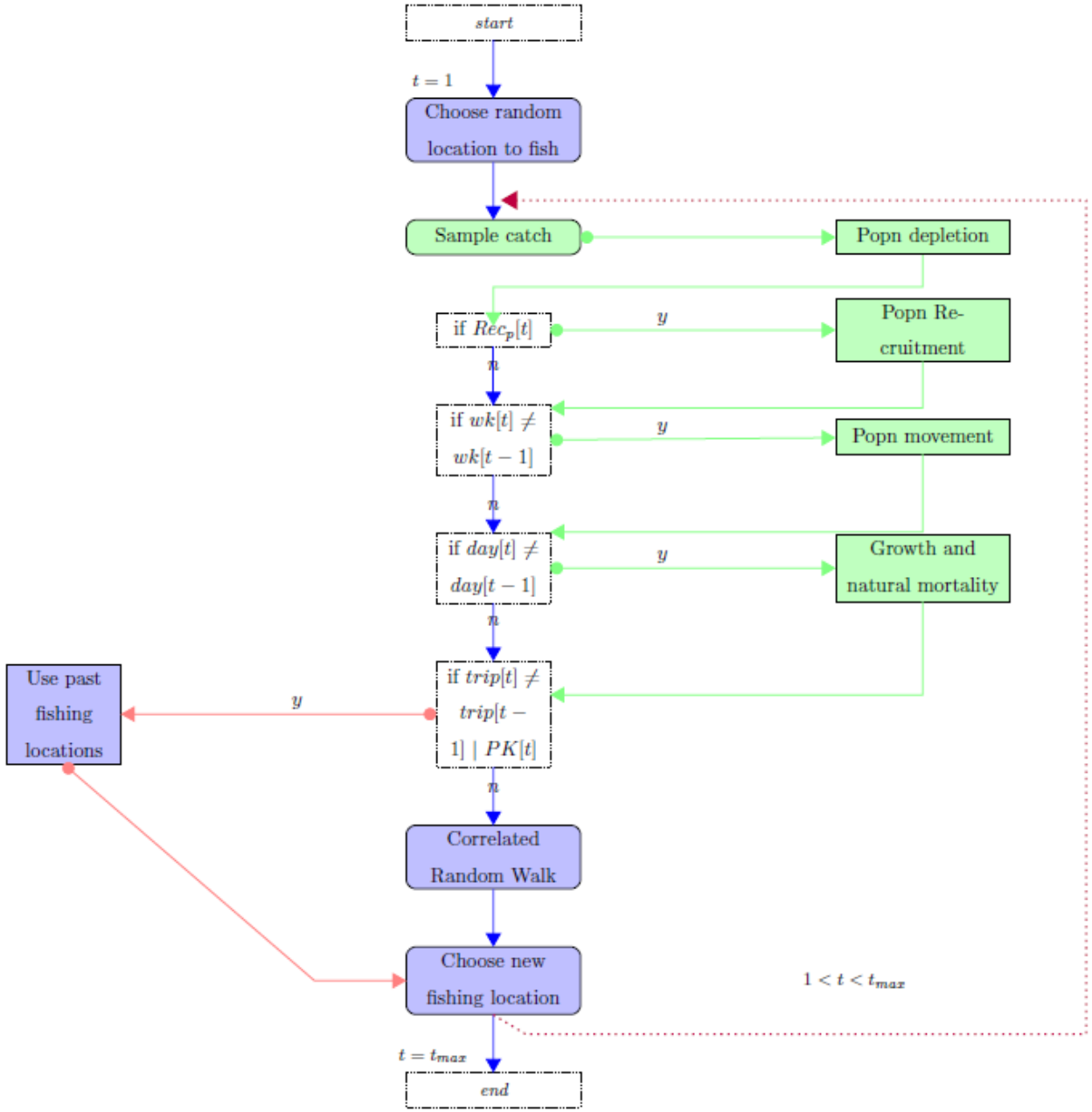
- Q1. Do catches observed from the fishery reflect the underlying population structure?

- Q2. At what spatial and temporal scales of aggregation are appropriate for management (does the “true” population signal degrade)?

- Q3. How “useful” is commercial data for implementing spatial fisheries management measures within a mixed fishery?

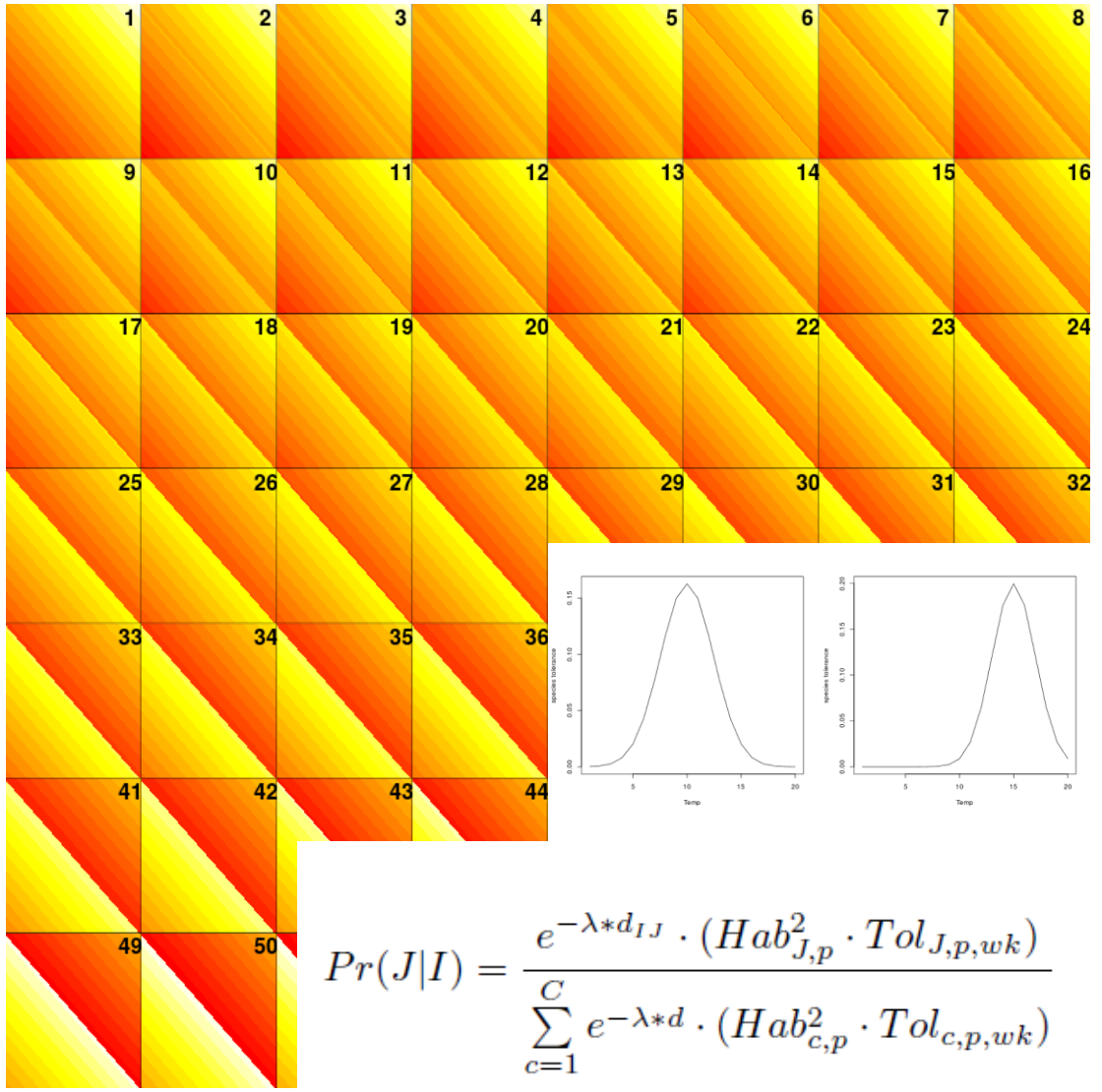
Introducing MixFishSim

- Modular, event-based:
  - Spatial population dynamics
  - Vessel-level (agent-based) fishing dynamics
- Highly resolved
  - Temporally
  - spatially
- True population structure known at each time-step



Gaussian Random Fields define habitat suitability

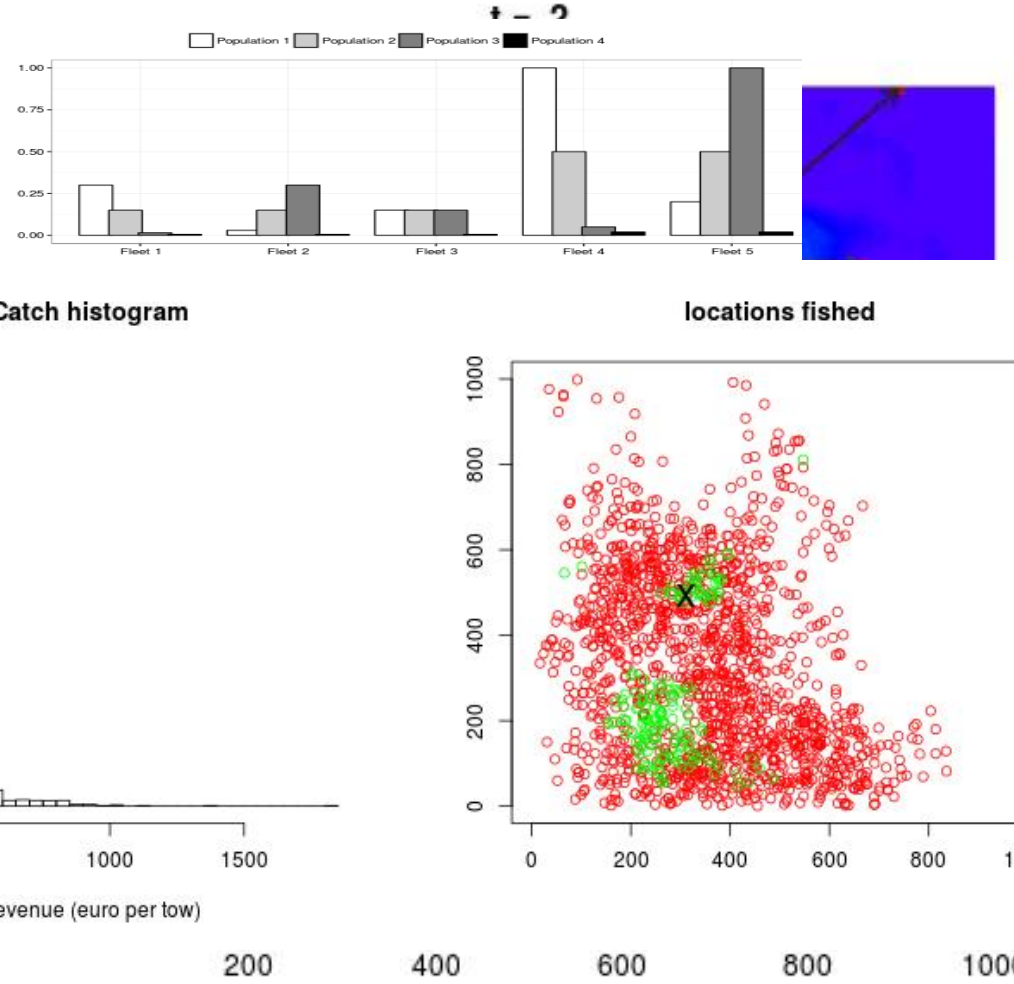
- Define a GRF process per population for habitat suitability
- Define spawning grounds per population >> increased affinity to spawning grounds during certain weeks
- Define a temperature field per week, and individual population tolerances
- Populations move between cells according to maximum distance, habitat suitability and temp tolerance



$$Pr(J|I) = \frac{e^{-\lambda * d_{IJ}} \cdot (Hab^2_{J,p} \cdot Tol_{J,p,wk})}{\sum_{c=1}^{C} e^{-\lambda * d} \cdot (Hab^2_{c,p} \cdot Tol_{c,p,wk})}$$

Individual vessel-based fishery dynamics

- Transition from exploratory to established fishery
- Exploratory:
  - Correlated Random Walk
- Transition:
  - Mix
- Established:
  - (mostly) past experience *of individual*



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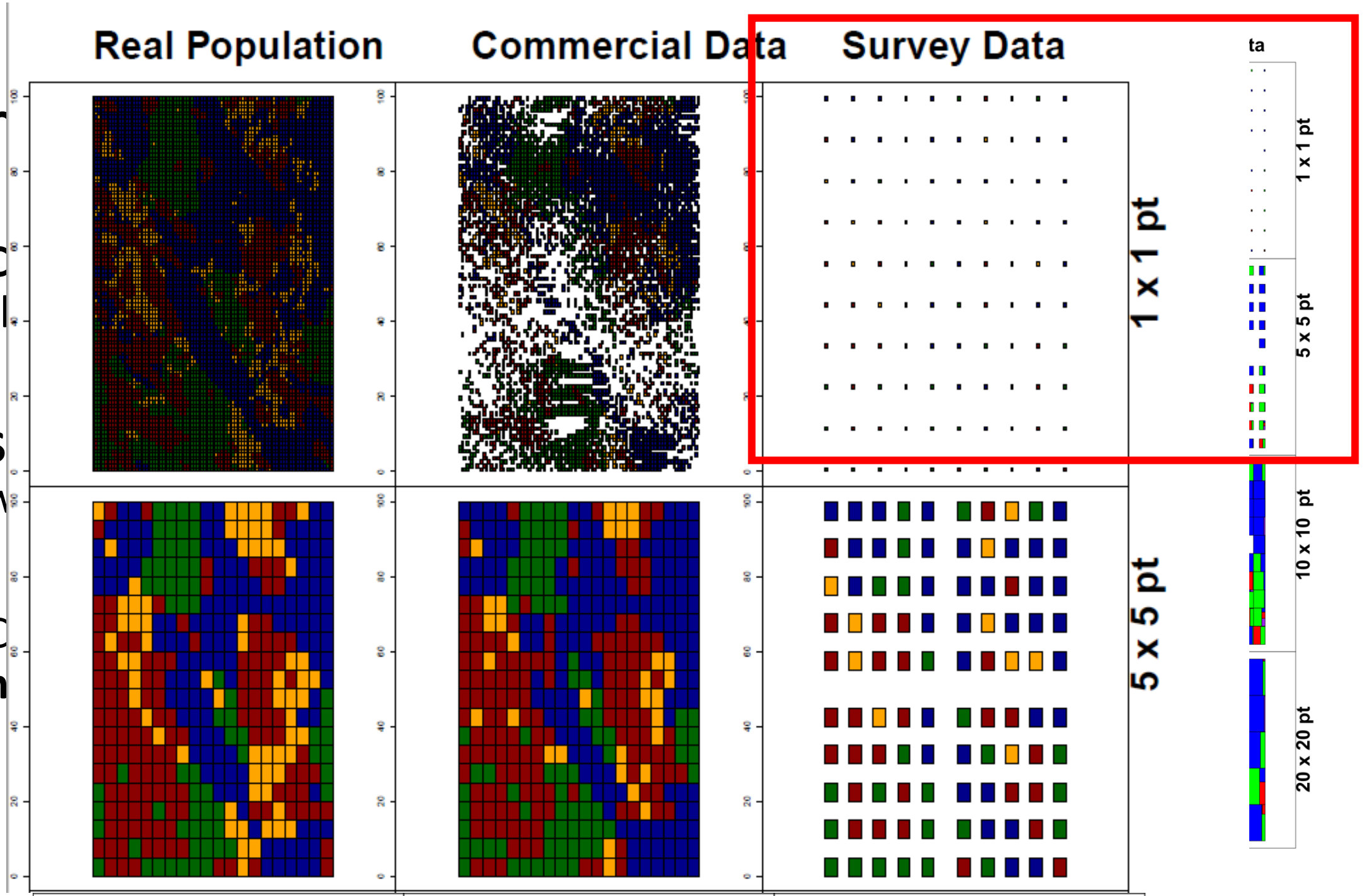
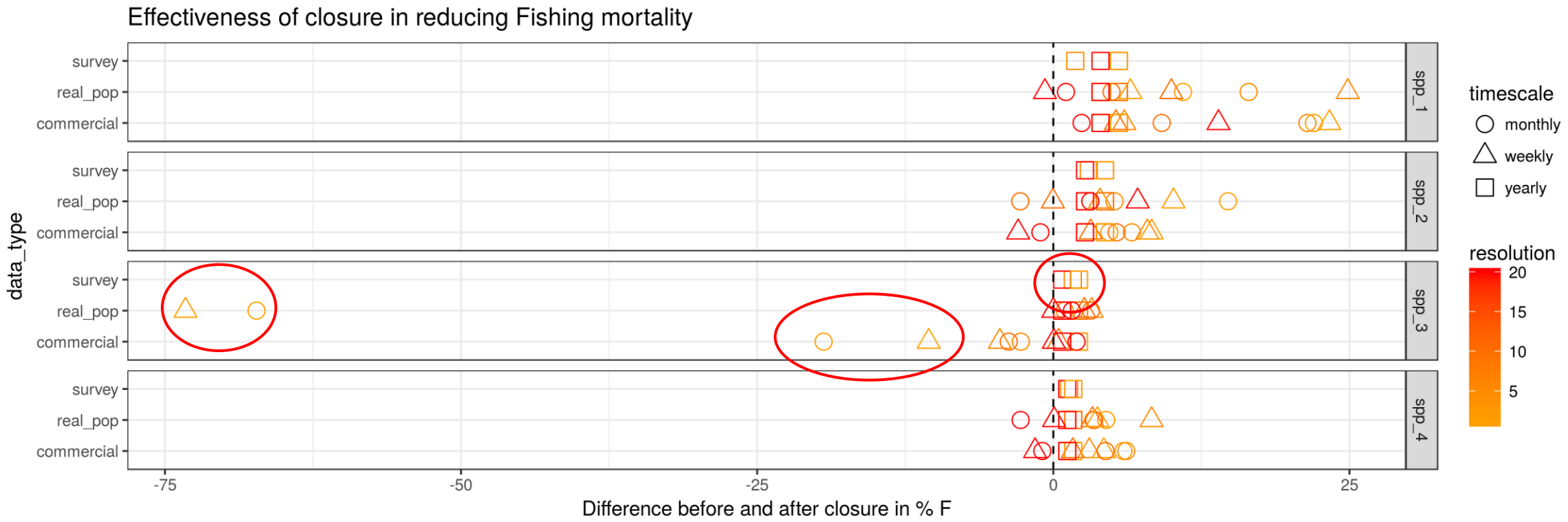

Real Population
Commercial Data
Survey Data
1 x 1 pt
5 x 5 pt
ta
1 x 1 pt
5 x 5 pt
10 x 10 pt
20 x 20 pt

Simulation experiment: spatial closures

- 4 populations
- 5 fleets of 20 vessels each
- 40 year simulation
  - 20 years to establish
    - 10 year “data”
    - 10 year closure to protect a population

- 3 **data** sources:
  - “real” population
  - Inferred from fishery
  - Inferred from “survey”
- 3 **temporal resolutions**:
  - Weekly
  - Monthly
  - Yearly
- 4 **spatial resolutions**
  - 1 x 1
  - 5 x 5
  - 10 x 10
  - 20 x 20

Simulated closure “experiment”



- Scenarios based on “real population” most effective, though **not for annual closures** (no single location effective).
- Scenarios based on survey ineffective (as above).
- Scenario based on commercial data were effective in some cases**, best was 1 x 1 grid aggregated to a monthly level** (sufficiently captures temporal dynamics, more spatial data due to increased samples).

Summary: what can we say about our Qs?

- Q1. Do available representations of simulated population underlying population dynamics?
- **Reasonable representation of the simulated population at finer spatial and temporal resolutions, but then lack sufficient data**

- Q2. At what spatial and temporal scales is aggregation appropriate, given data availability and population movement?
- **Monthly fine spatial scale seems reasonable for our experimental system: good compromise between data availability and population movement rates (elsewhere, population move-on rules have been 2-3 weeks)**

- Q3. How "useful" is commercial data for implementing spatial closure management?
- **Commercial data potentially useful and more representative than once-a-year survey, though effectiveness of closure potentially moderated by biases in data (lack of full picture)**

Thank you for listening!

Questions?

Contact: paul.dolder@gmit.ie

Acknowledgements:

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Cefas Seedcorn

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Extra material

Spatially resolved population dynamics

- 2-stage biomass delay difference model

$$
\begin{aligned}
B_{c,d+1} = & \\
& (1+\rho)B_{c,d} \cdot e^{-Z_{c,d}} - \rho \cdot e^{-Z_{c,d}} && \times \\
& (B_{c,d-1} \cdot e^{-Z_{c,d-1}} + Wt_{R-1} \cdot \alpha_{d-1} \cdot R_{\tilde{y}(c,y,d-1)}) && + \\
& Wt_R \cdot \alpha_d \cdot R_{\tilde{y}(c,y,d)}
\end{aligned}
$$

- Recruitment function

$$\bar{R}_{c,d} = \frac{(\alpha * B_{c,d})}{(\beta + B_{c,d})}$$

$$R_{c,d} \sim \log N[(\log(\bar{R}_{c,d}), \log(\sigma^2))]$$

- Catch and spatial depletion of population per day

$$C_{c,d} = \frac{F_{c,d}}{F_{c,d} + M_{c,d}} * (1 - e^{-(F_{c,d}+M_{c,d})}) * B_{c,d}$$