SEASONALITY IN LIVE FISH MOVEMENTS AND DISEASE SPREAD.

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1. INTRODUCTION

Scottish salmon industry is threatened by the invasion and spread of pathogens. Live fish movements between salmon farms risk spreading pathogens at a country-wide scale. Atlantic salmon are anadromous and have **freshwater (FW)** and **seawater phases (SW)**. In FW, salmon eggs are fertilized and hatched in a hatchery. Next, fry are transported to FW sites. Salmon movements between FW farms and movements from FW to SW for smolt supply show clear seasonality (figure 1). Seasonality could have a substantial impact on the course of disease.

Network models are often used to understand the **transmission** of pathogens between epidemiological units, e.g. animals or farms. These models can be based on live fish movements and are valuable as they can helps us to design and investigate the efficacy of **control strategies**.

2. AIM

In this study, we quantify the effects of seasonality of live fish movements on epidemic dynamics. Aquatic **networks** are rarely studied and seasonality is commonly not included. We used a **dynamic** network model populated with **live fish movements** between Scottish fish farms of 2002 to 2004. In addition, local transmission was included each farm could infect two other farms (Werkman et al., 2011) and different local transmission rates were compared.

A **stochastic SIR model** was developed and two types of networks were studied: A) the **real-life situation** in which timing and pair-wise movements between farms were as observed as in the data; B) as network A, but with a **random reordering** of all movements between FW farms and movements from FW to SW farms. In each network **seasonality** was included and excluded to investigate the effects of seasonality of live fish movements on the course of an epidemic.

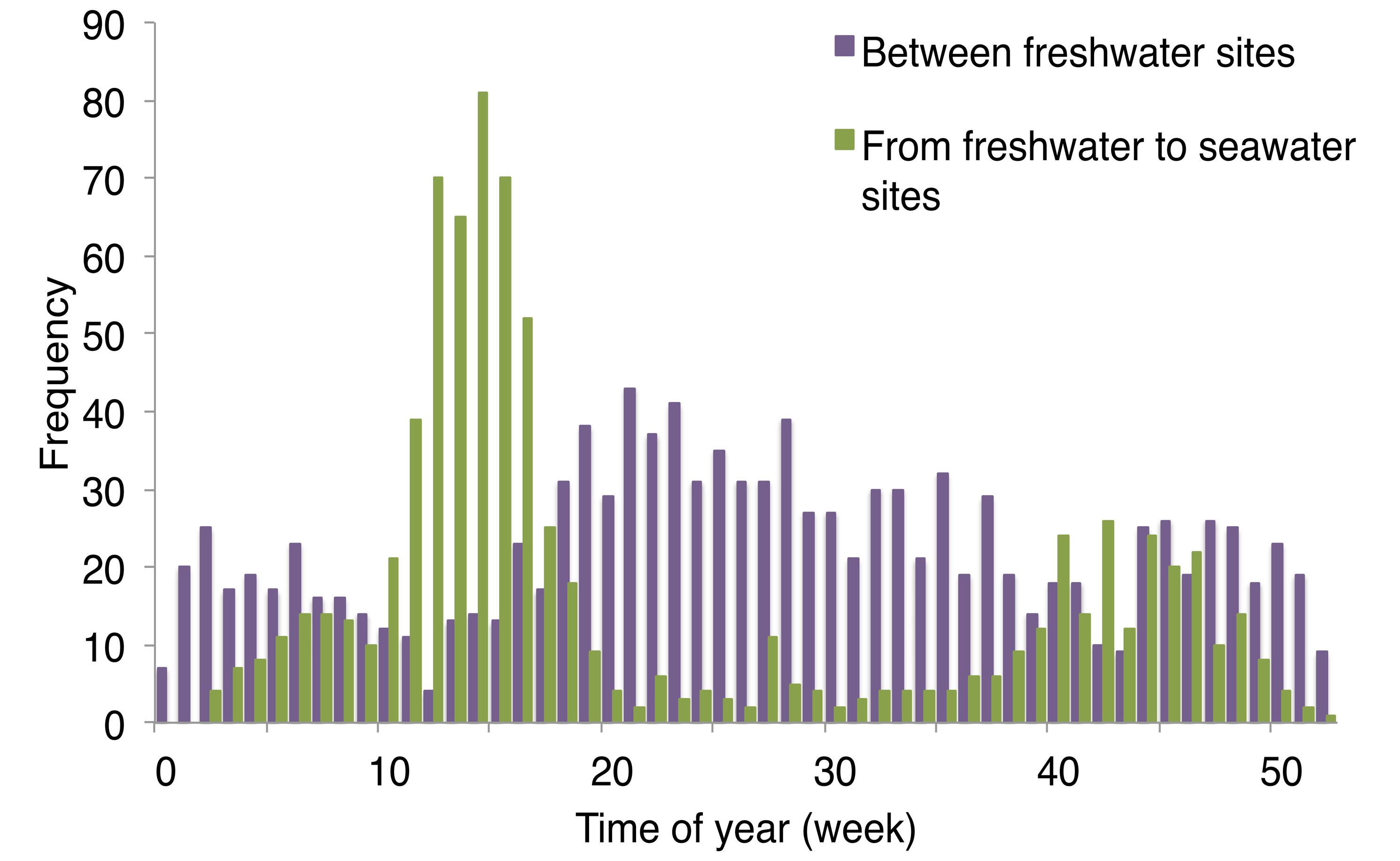
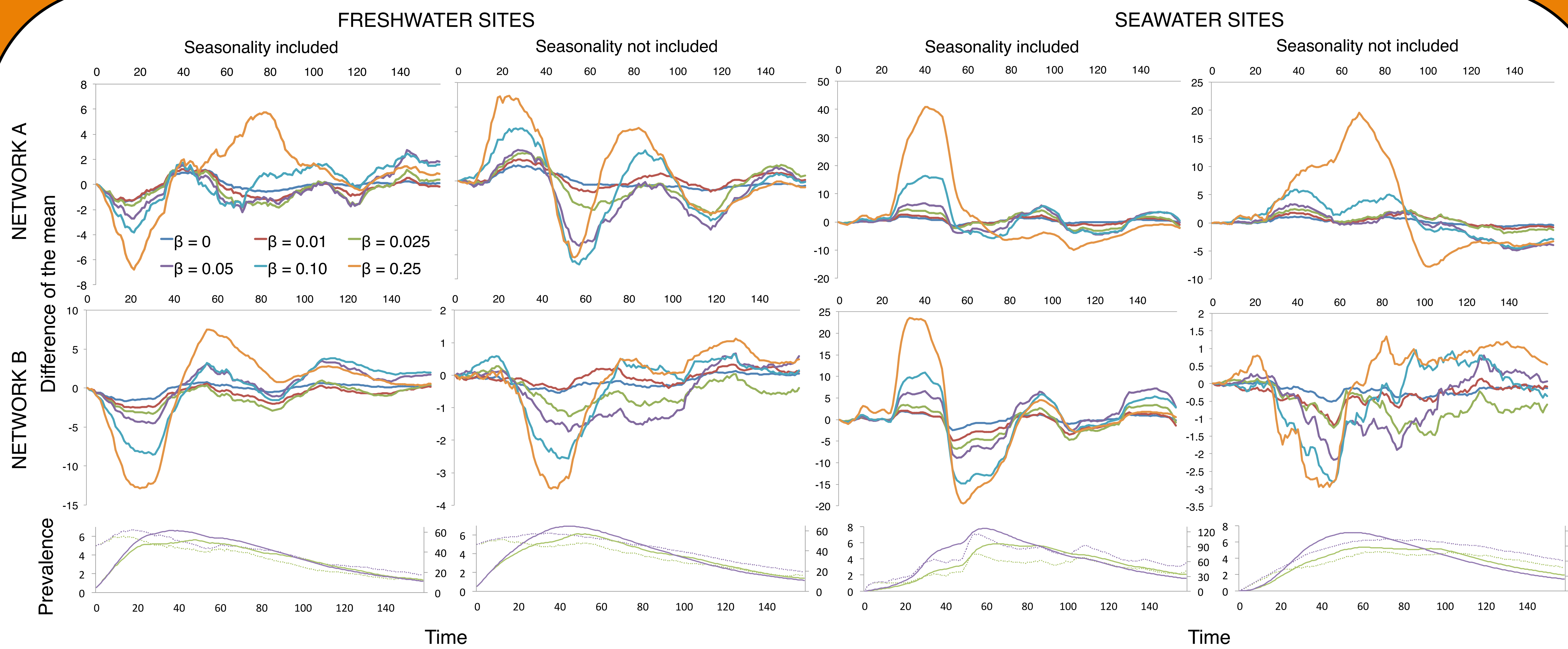


Figure 1. The timing of salmon movements during the study period (2002 to 2004). All other movement types did not show a clear seasonal pattern

3. DATA ANALYSIS

Scottish farms are required to keep records regarding the live fish movements onto and off their farms. We collected **salmon movement records** from 1 January 2002 until 31 December 2004. Only confirmed movements, i.e. movements recorded by both source and destination site, were used. Epidemics were initiated just before and after the movement peak in FW movements (wk 17 & 41), the difference of the mean prevalence of these timings is shown in figure 2.



These graphs show the difference in mean prevalence of freshwater farms and seawater sites when an epidemic was initiated in week 17 or 41 with a removal rate 0.025 and six local transmission rates. Two types of networks, A) the real-life situation in which timing of movements were as observed B) movements were randomly reordered.

The bottom graphs show the prevalence of β=0 (dotted lines, left y-axis) and β=0.25 (solid lines, right y-axis) for network A (—) and network B ( ).

4. CONCLUSION

- **Early identification** of infected farms is important, especially in periods when many movements occur between sites.
- Seasonality mainly has an effect when local transmission is high
- **Surveillance** should be targeted to periods with a high movement activity.
- Network properties are very important to the course of an epidemic and control strategies should consider **clustering**, **sequence** and **direction** of movements.

"TAKE-HOME MESSAGE"
Salmon live fish movements show a clear seasonal pattern and this could have a substantial effect on the course of epidemics. The timing of these movements differ between production phases. Disease control measures should take this into account.

ACKNOWLEDGEMENTS
Funding and data access provided by Marine Scotland Science

REFERENCES
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