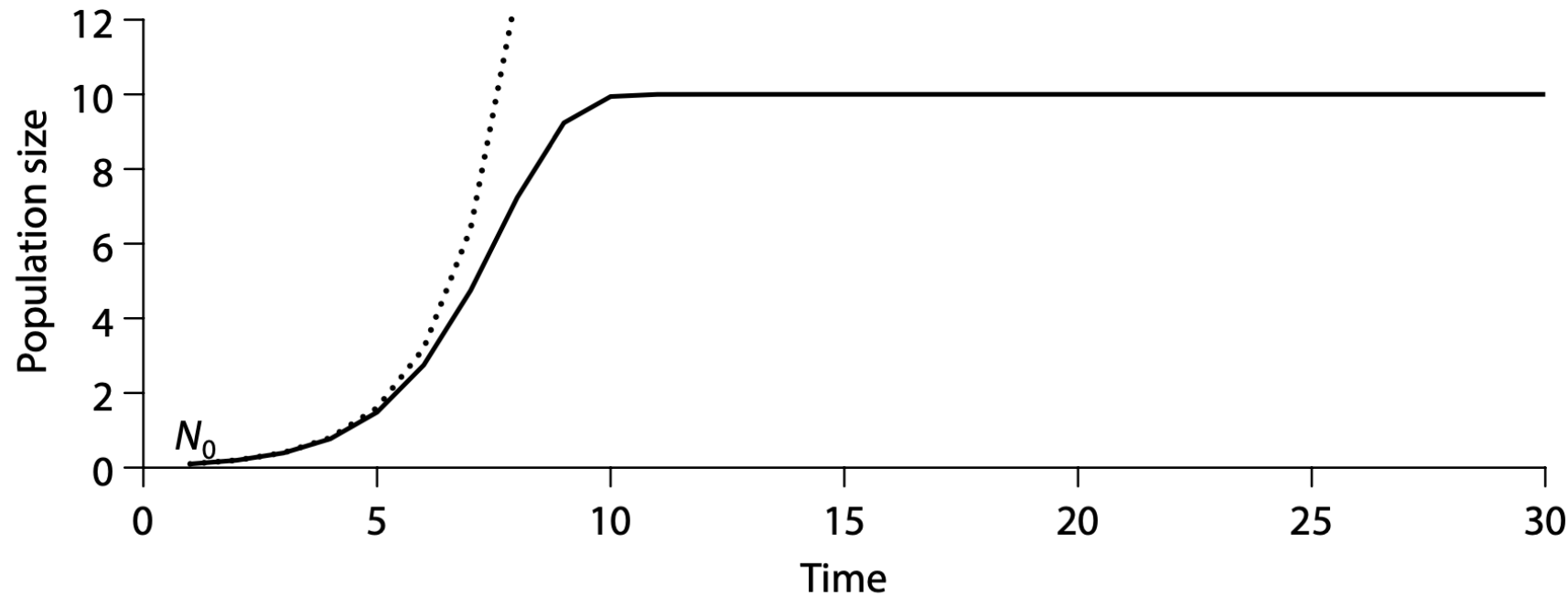


# **Why “ecological forecasting”?**

Amy Hurford  
Memorial University

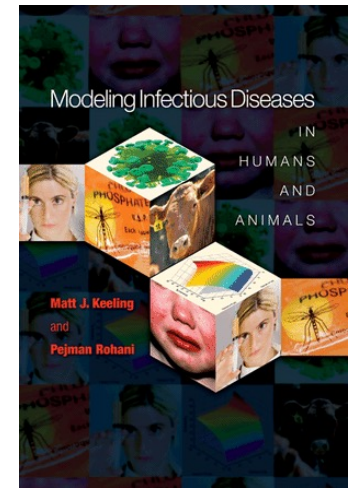
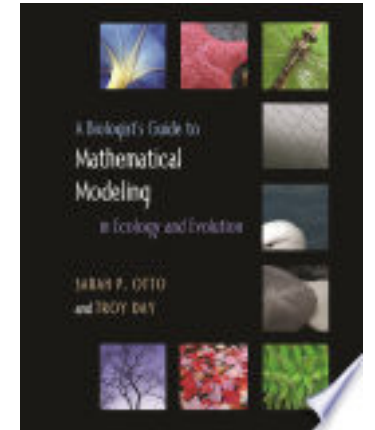
# Population biology, deterministic dynamical systems, mechanistic models



Dietz 2017. Ecological forecasting. Ch 2.

$$\frac{dN(t)}{dt} = rN(t) \left(1 - \frac{N(t)}{K}\right)$$

$$N_{t+1} = N_t + rN_t \left(1 - \frac{N_t}{K}\right)$$



# Simple parameterization approach

$$N_{t+1} = N_t + r N_t \left(1 - \frac{N_t}{K}\right)$$

- $r = b - d$
- $b$ : births per individual per time step
- $d$ : fraction of the population that dies per time step

$$\frac{dN(t)}{dt} = r N(t) \left(1 - \frac{N(t)}{K}\right)$$

# Simple parameterization approach

The information below is taken from the following source:

Newcomb, HR. 1940. [Ring-necked pheasant studies on Protection Island in the Strait of Juan de Fuca, Washington](#). MS thesis. Oregon State University.

- a. Pheasant chicks are born during the summer.
- b. In May 1937, 10 pheasants were introduced to the island. Before the next breeding season there were 35.
- c. November 10, 1938 a census estimated 110 pheasants.
- d. October 13, 1939 a census estimated 400 pheasants.
- e. Between the 1938 and 1939 censuses, Newcomb observed that 17 adult birds died.
- f. During the 1938 nesting season: 5.86 eggs/nest. 83.57% of eggs hatched.
- g. During the 1939 nesting season: 8.73 eggs/nest. 64.58% hatched.
- h. During the 1939 nesting season: Average number of chicks per clutch was 6.93.<sup>1</sup>
- i. You can assume the sex ratio is 50:50 male to female. Pheasants are a sexually reproducing species.

# Simple parameterization approach

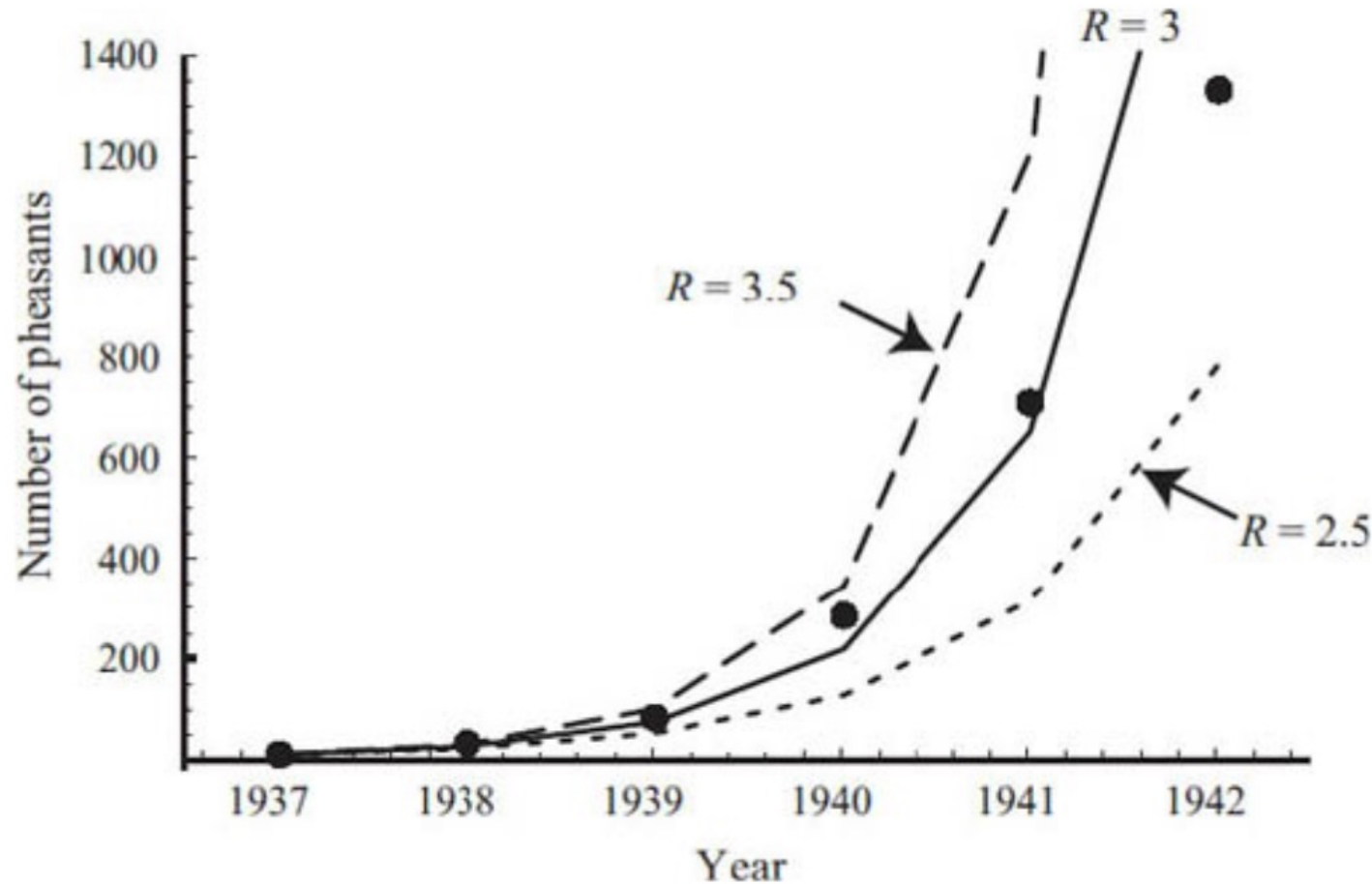
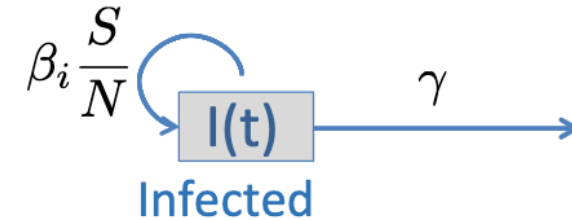


Figure 3.2: Example of exponential population growth in pheasants. The dots are based on spring census data (Lack 1954). The

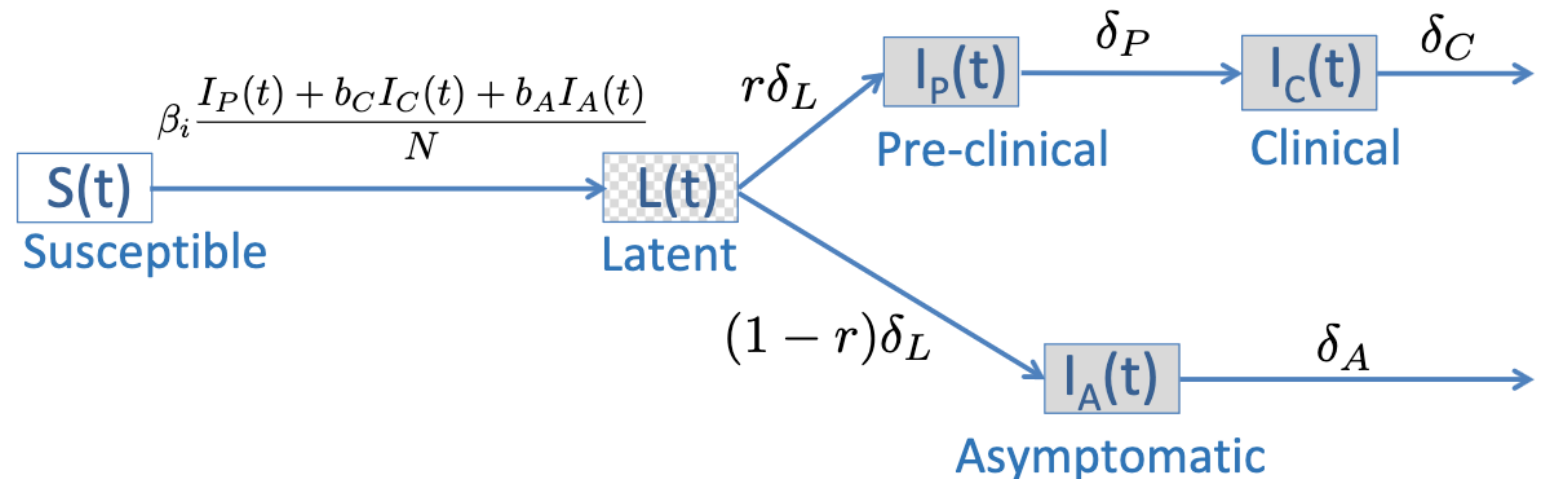
# Simple parameterization approach

$$\frac{dI(t)}{dt} = ac_i S \frac{I(t)}{N} - \gamma I(t) + m_i$$
$$\frac{dC(t)}{dt} = ac_i S \frac{I(t)}{N},$$

## Linear SIR model



## COVID-19 model

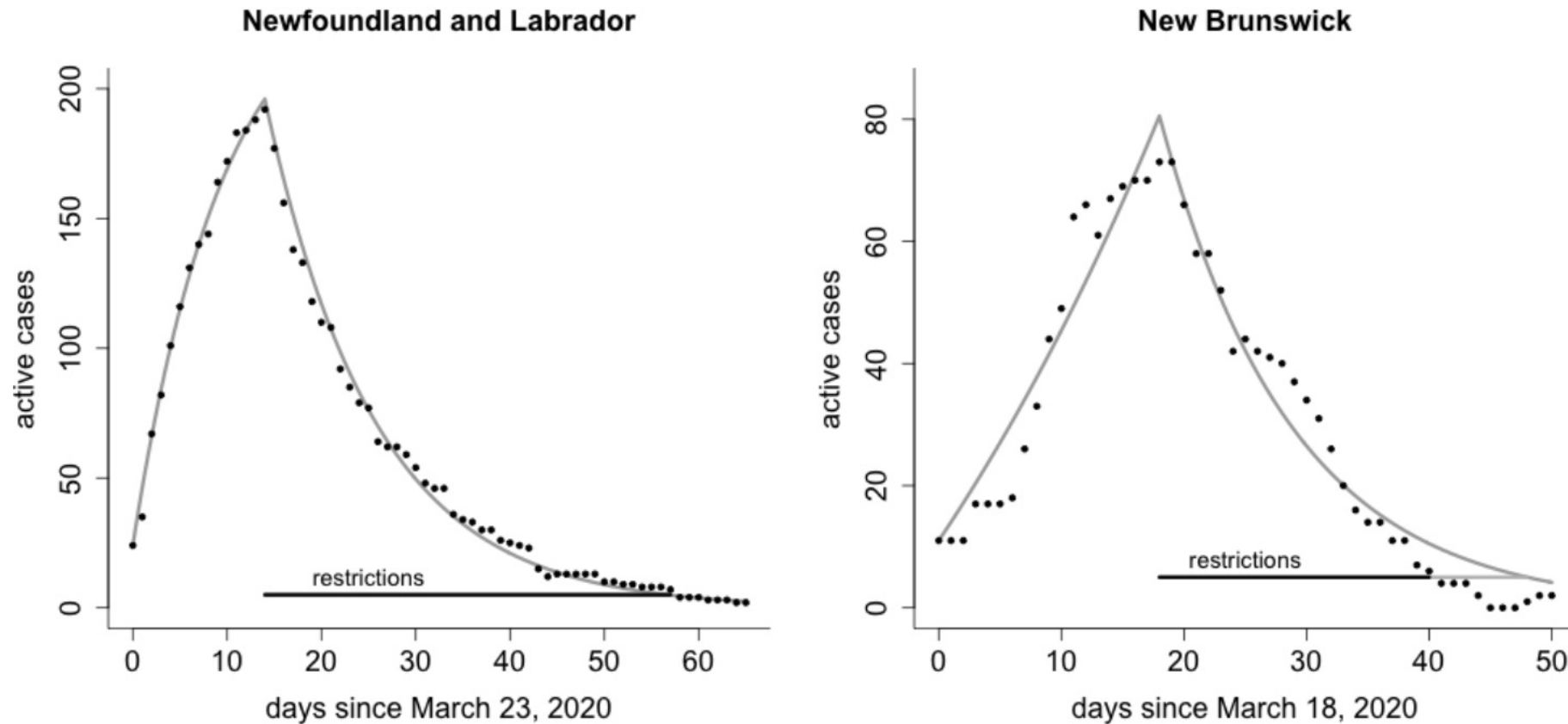


# Simple parameterization approach

		Newfoundland and Labrador		New Brunswick	
	units	Fixed parameters			
Date corresponding to $t = 0$	date	March 23, 2020		March 18, 2020	
Recovery rate, $\gamma$	individuals per day	1/14		1/14	
Active cases when restrictions lifted, $I_2$	individuals	5		5	
Initial number of infected individuals, $I(0)$	individuals	10		10	
Day restrictions are enacted, $t_1$	day	14		18	
End time, $t_2$	day	65		50	
		Fitted parameters			
Exponential coefficient prior to restrictions, $\lambda_1$	per day	-0.104		0.027	
Exponential coefficient after restrictions, $\lambda_2$	per day	-0.086		-0.093	
Importation rate, $m_1$	individuals per day	25.9		2.70	
		Data	Predicted	Data	Predicted
Active infected individuals at peak, $I_1$	individuals	192	197	73	81
Duration of restrictions, $\tau$	days	43	43	22	30
Total number of cases, $C(t_2)$	individuals	260	293	120	117

Hurford & Watmough. 2021. Don't wait; re-escalate: delayed action results in longer duration of COVID-19 restrictions.

# Simple parameterization approach



**Fig. 1** The linear SIR model fitted to data describing the active number of COVID-19 cases in Newfoundland and Labrador and New Brunswick from March-May, 2020. Equation 1a,

Hurford & Watmough. 2021. Don't wait; re-escalate: delayed action results in longer duration of COVID-19 restrictions.

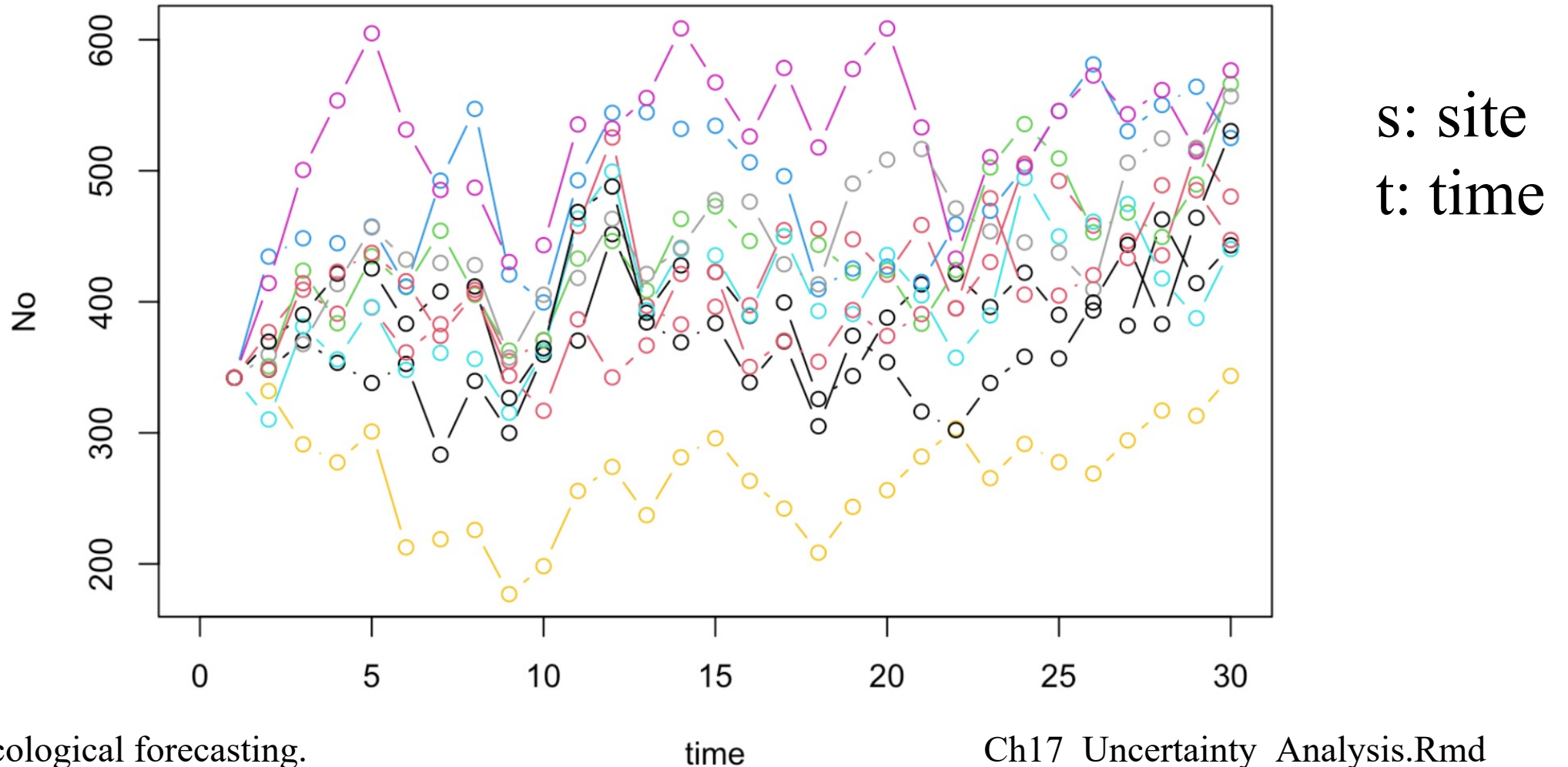


# Simple parameterization approach

- Search the literature for 1 value or average
  - Not rigorous
- No or limited treatment of uncertainty in forecasts
  - Some error sources overlooked, falsely confident predictions
- Does not fit data
- Disconnected from statistics

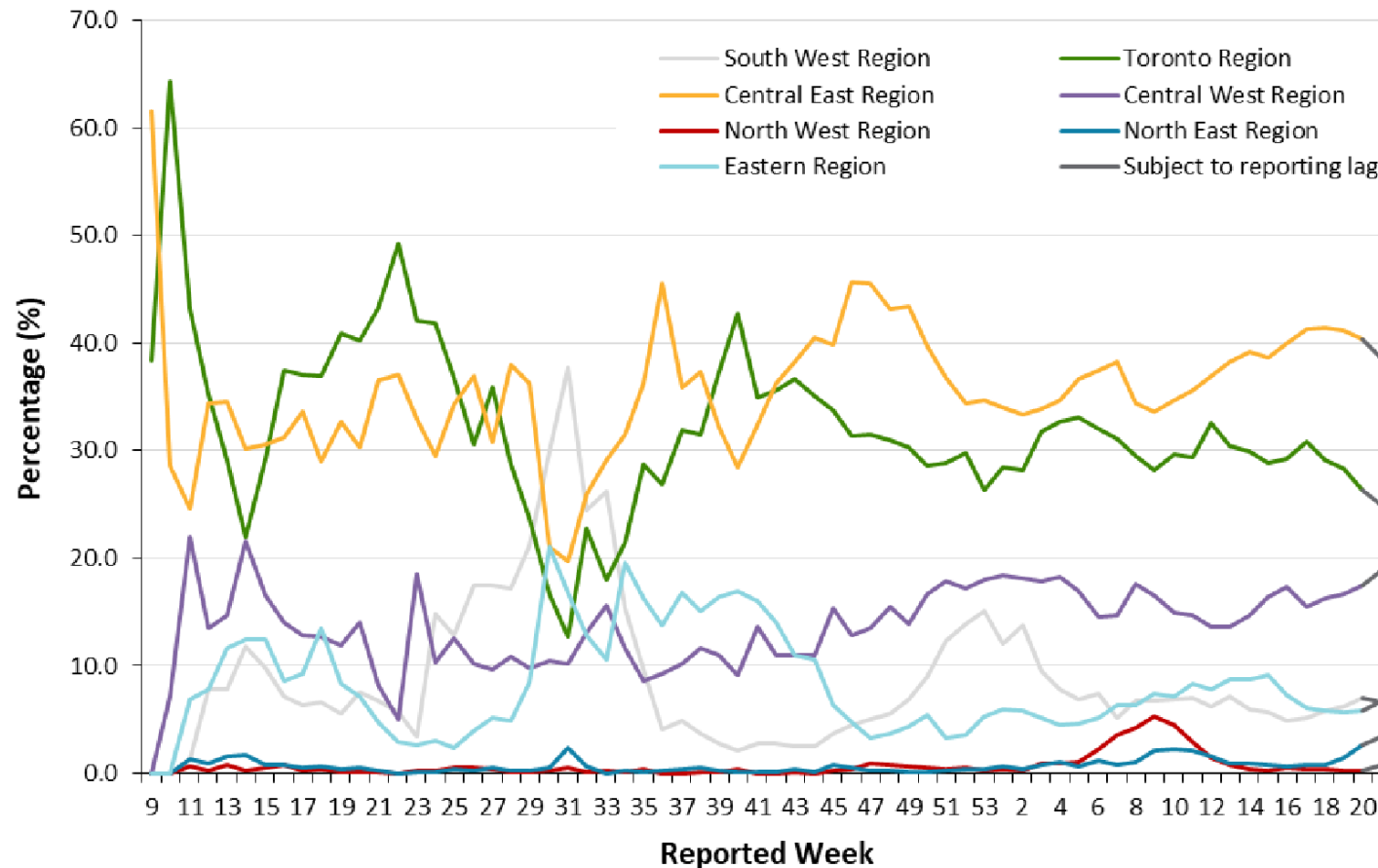
# Ecological forecasting

Observed population size,  $No[s,t]$



# COVID-19 cases by geographic region

Figure 8. Percentage of COVID-19 cases by geographic region and public health unit reported week: Ontario

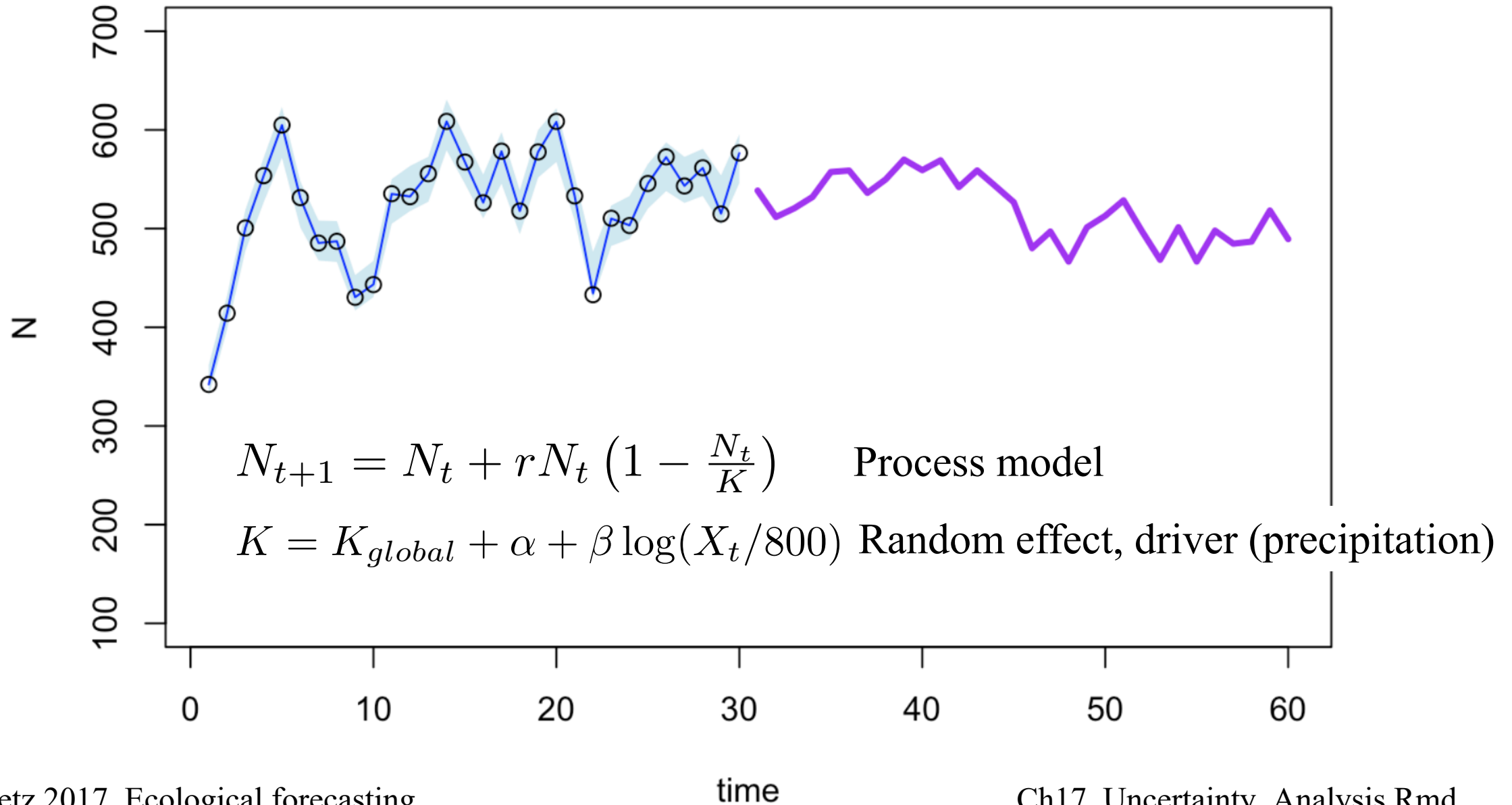


**Note:** Only weeks with more than 10 cases by public health unit reporting date are included (starting in week-9). Include cases with reported dates ranging from week-9 (February 23 and 29, 2020) to week 21 (May 23 and 29, 2021). [Table 2A](#) in Appendix A has a listing of public health units by region.

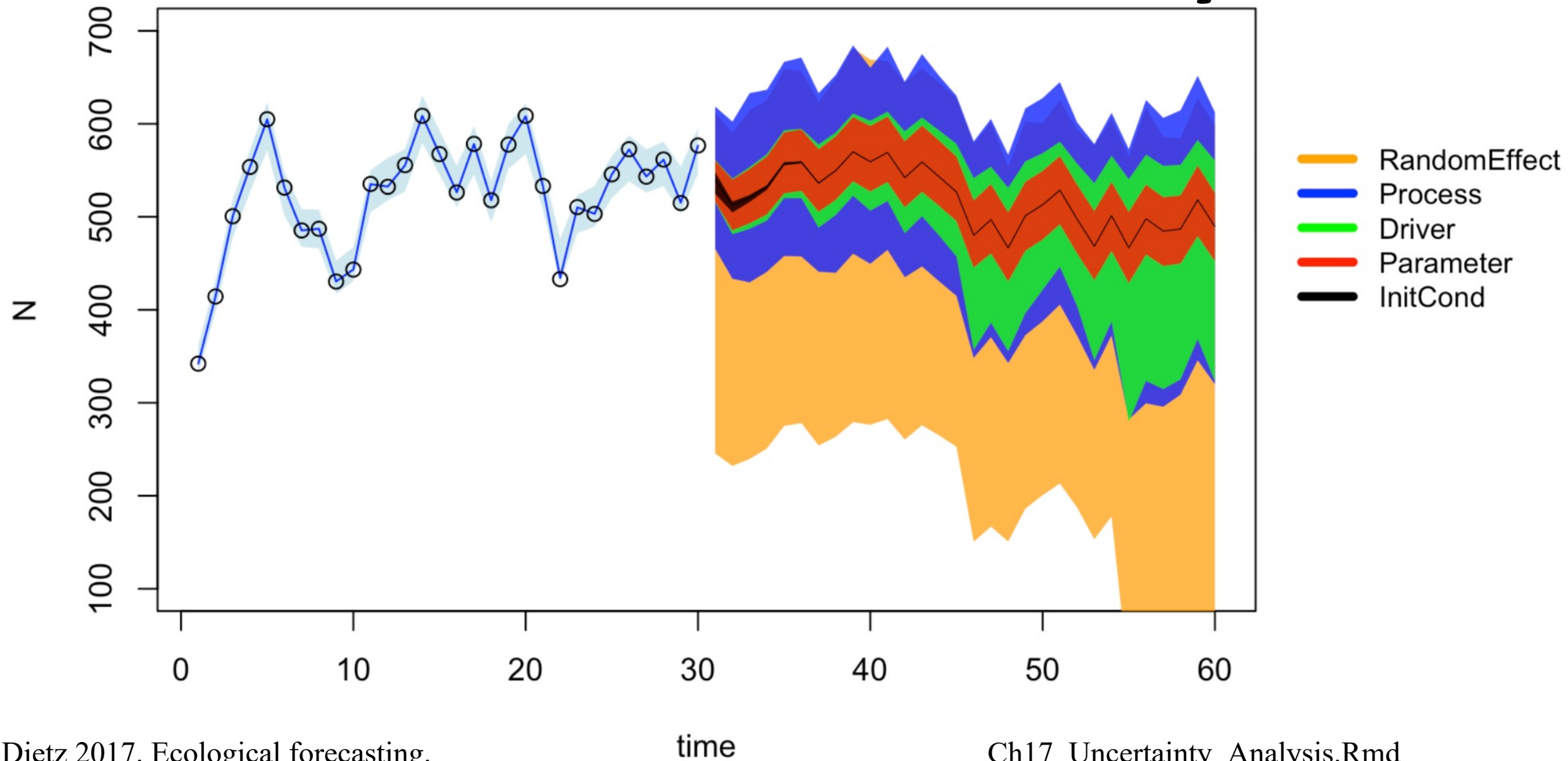
**Data Source:** CCM

Weekly epidemiological summary.  
COVID-19 in Ontario: Focus on May 23, 2021 to May 29, 2021. Public Health Ontario. [link](#)

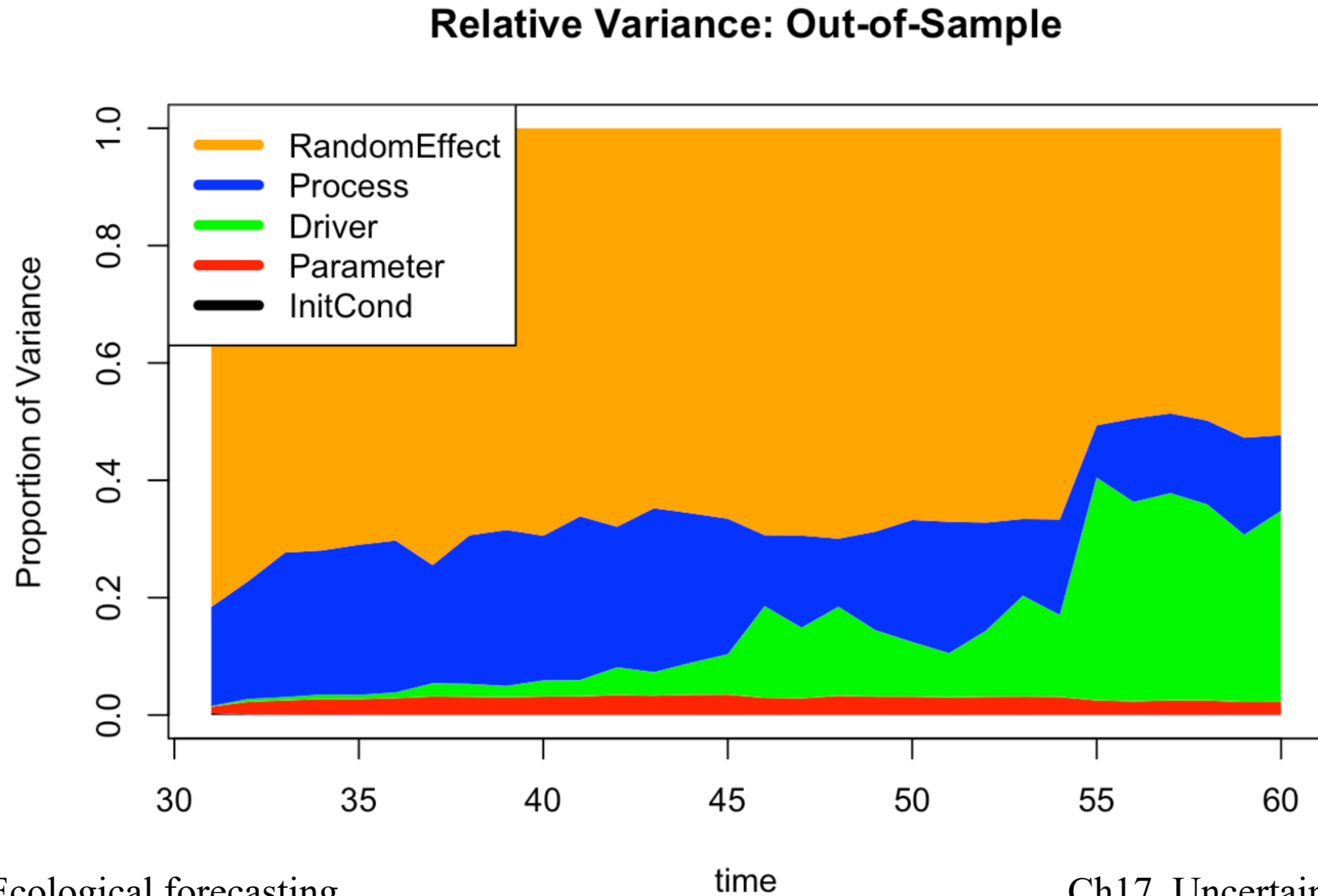
# Deterministic forecast for site, s=6



# Sources of uncertainty



# Sources of uncertainty



# Schedule

- Chapter 6: Characterizing uncertainty (Tuesday PM)
- Chapter 8: Latent and state-space models (Wednesday PM)
- Chapter 9: Fusing data sources (Wednesday PM)
- Chapter 11: Propagating uncertainty (Thursday PM)