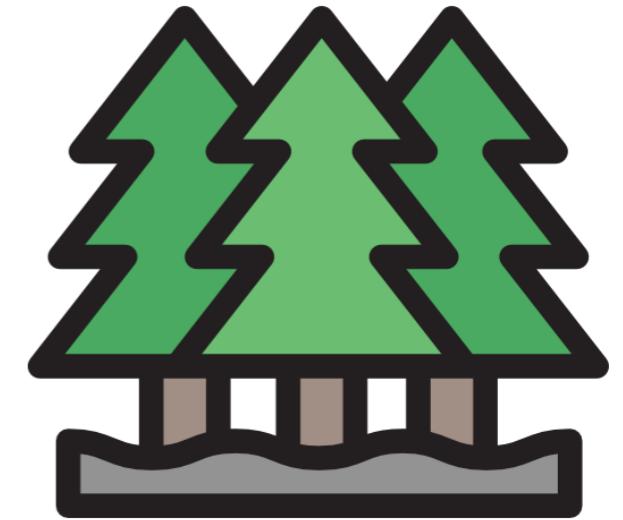


Self-Driving Cars & Forest Ecology: Modeling for Machine Learning

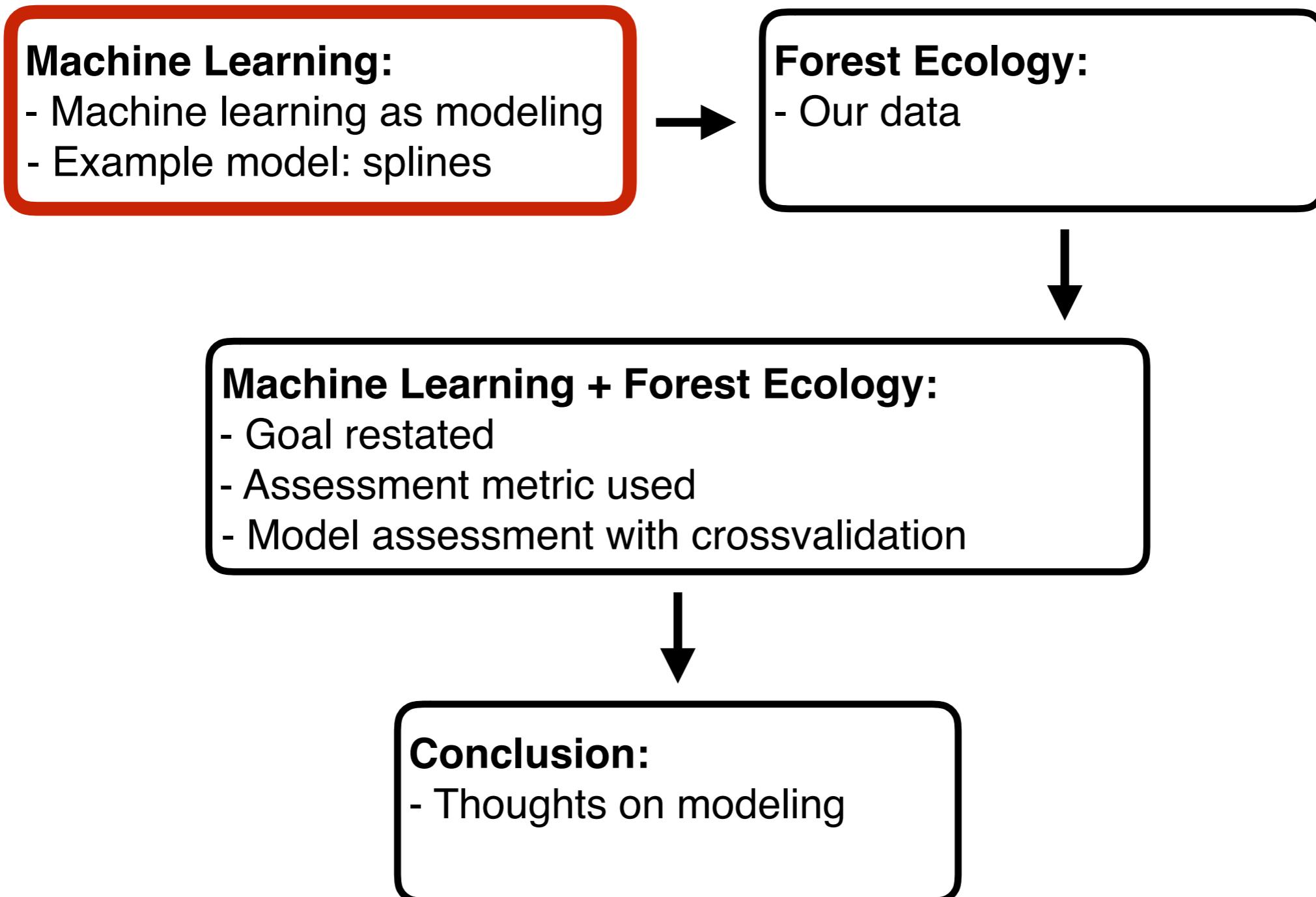


Albert Y. Kim
Assistant Professor
[Statistical & Data Sciences](#), Smith College
Thursday Lunch Talks, Mathematics & Statistics
Thursday 2019/3/21

What variables are being collected?



Road Map



Machine Learning



WAYMO

NFT

AI

Prediction!

ATCH FIX



Machine Learning as Modeling

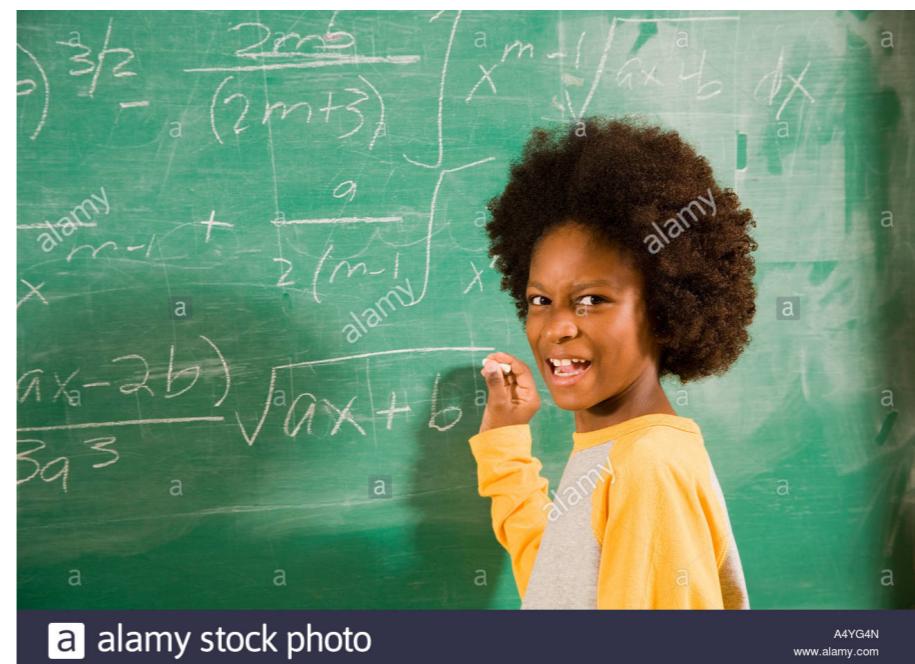
True (Unknown) Model:

$$y = f(\vec{x}) + \epsilon$$

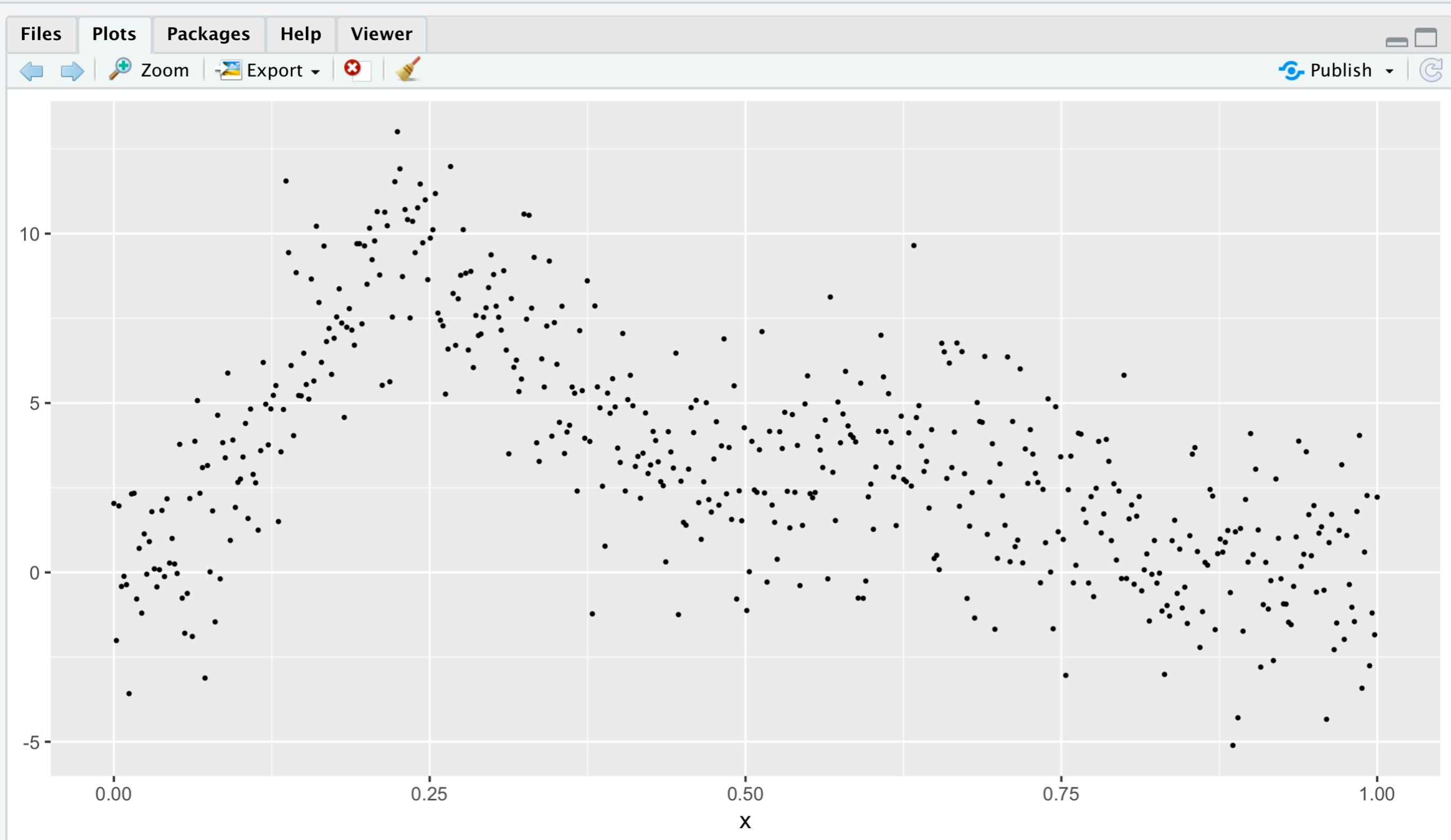
Approximated Model:

$$\hat{y} = \hat{f}(\vec{x})$$

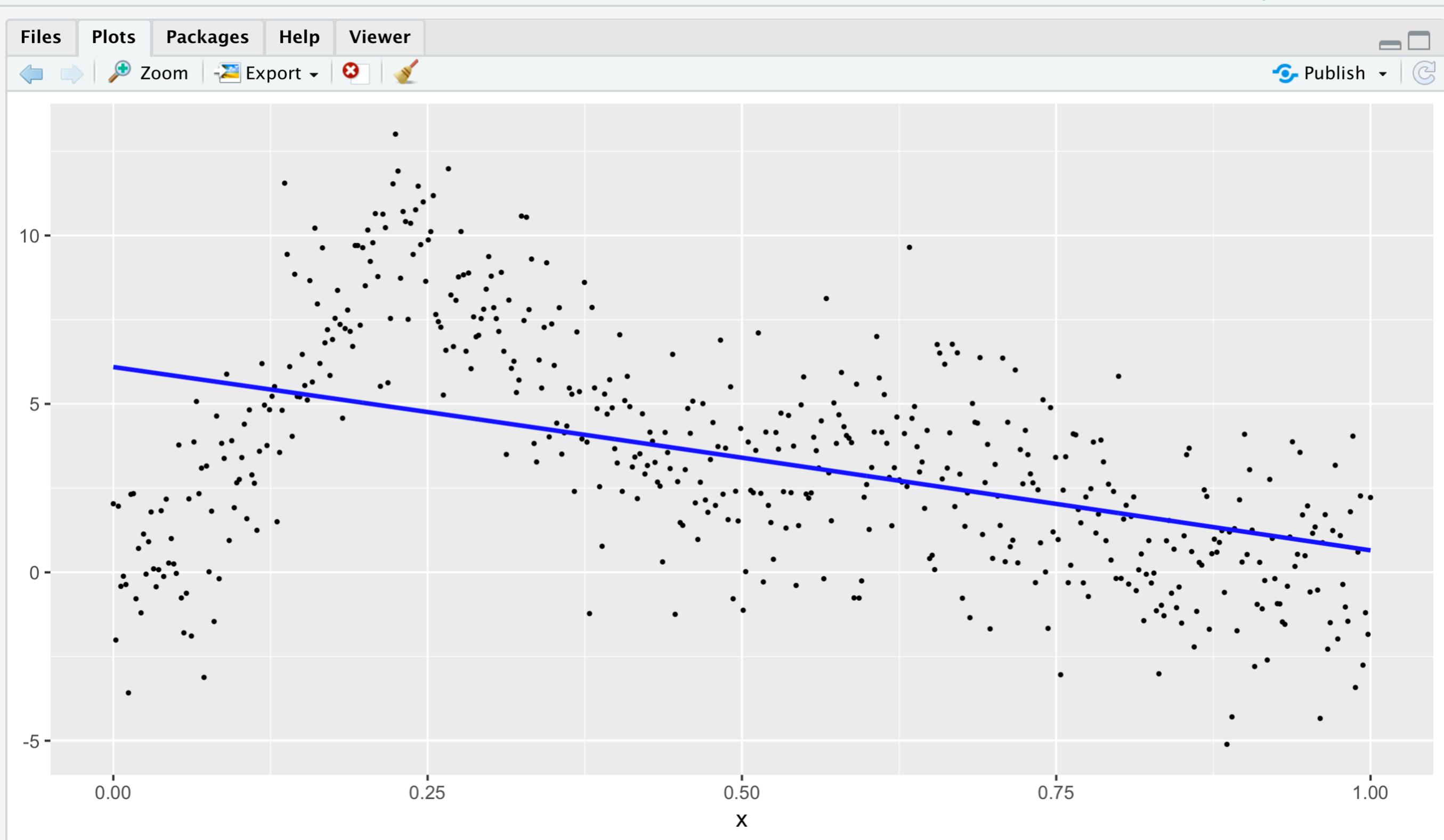
Now to the blackboard for
Chalk Talk #1...



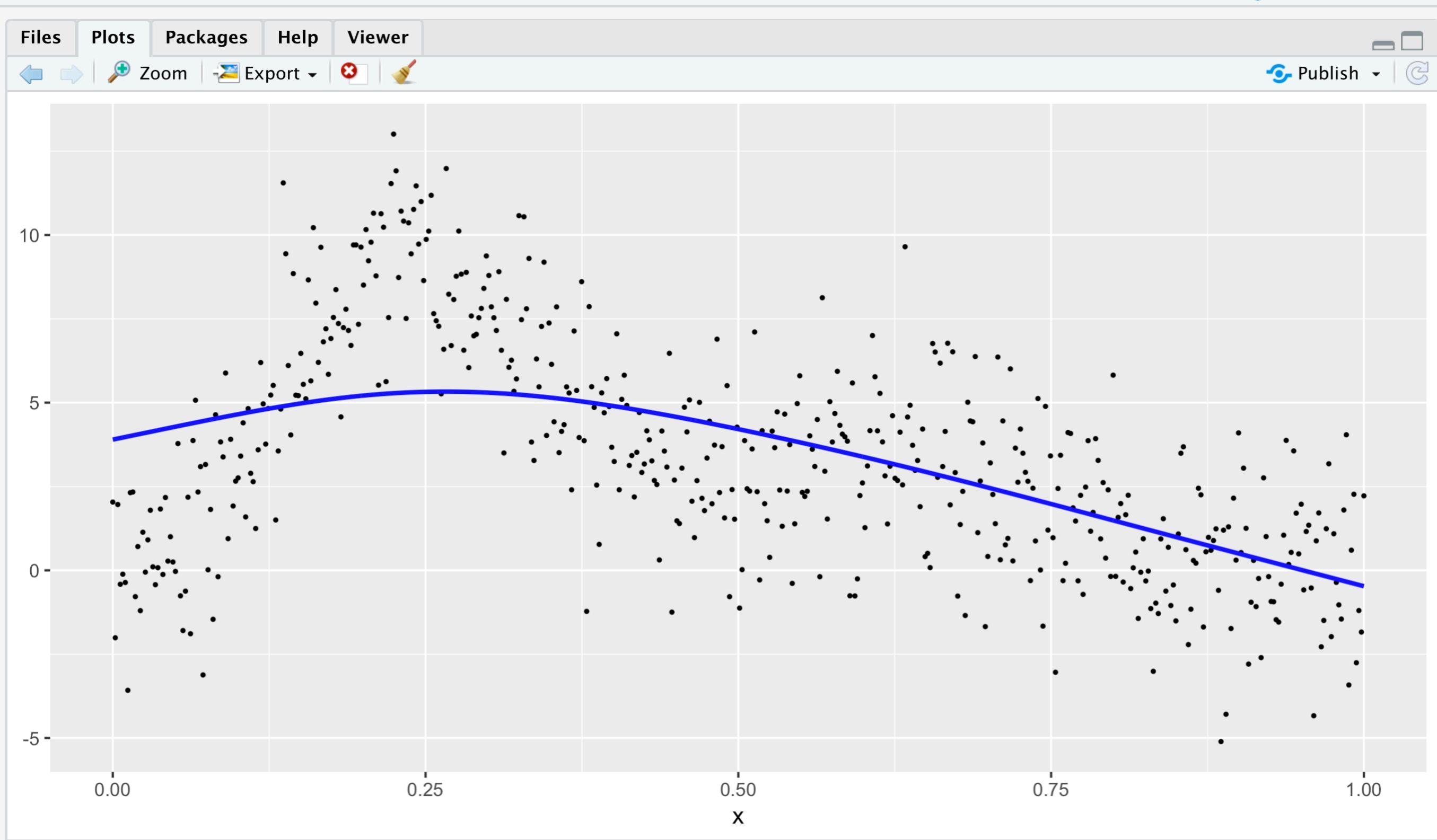
Given Data (x, y) from “unknown” $f(x)$



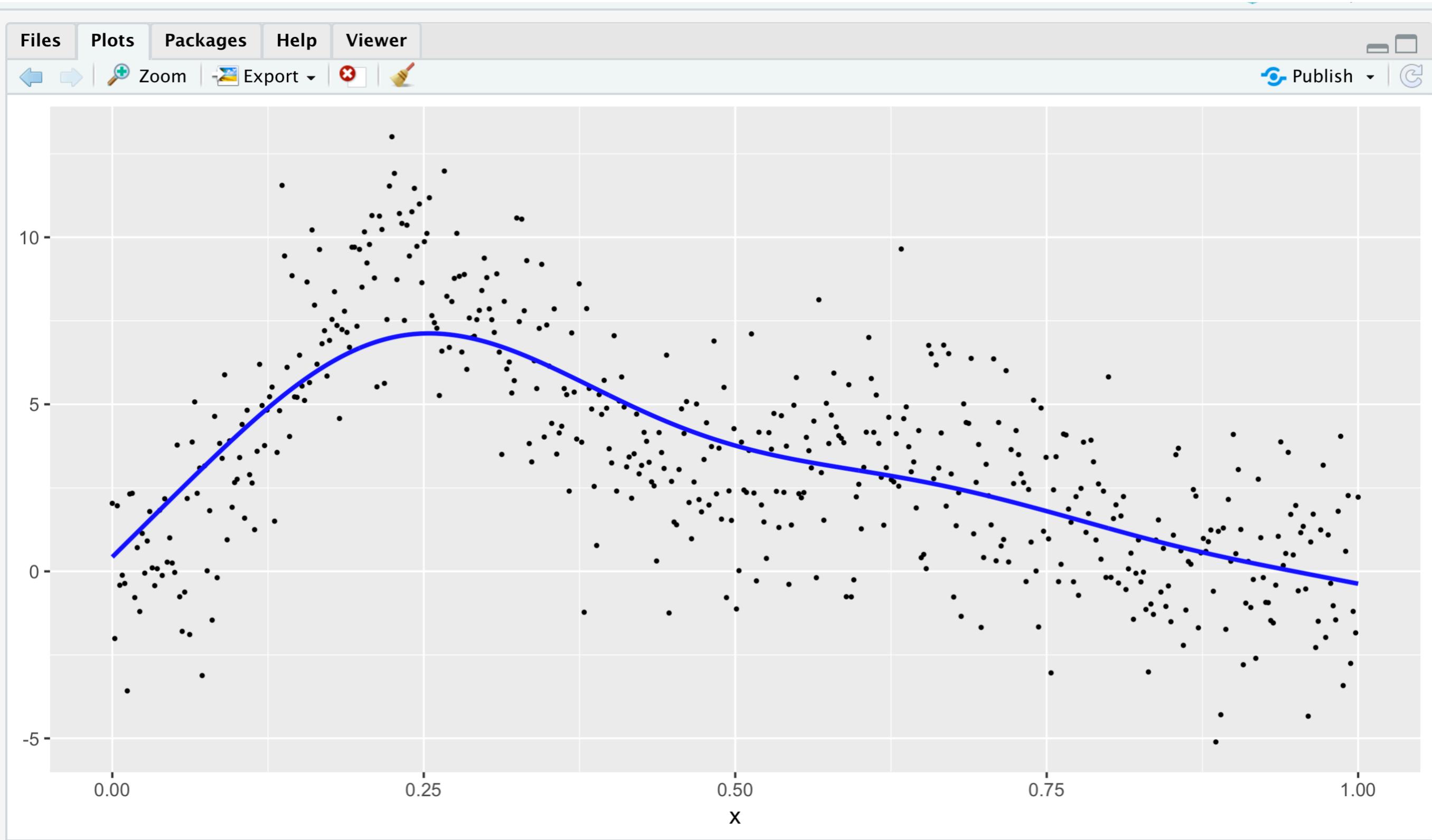
Approximate (i.e. “fit”) a Model $\hat{f}(x)$



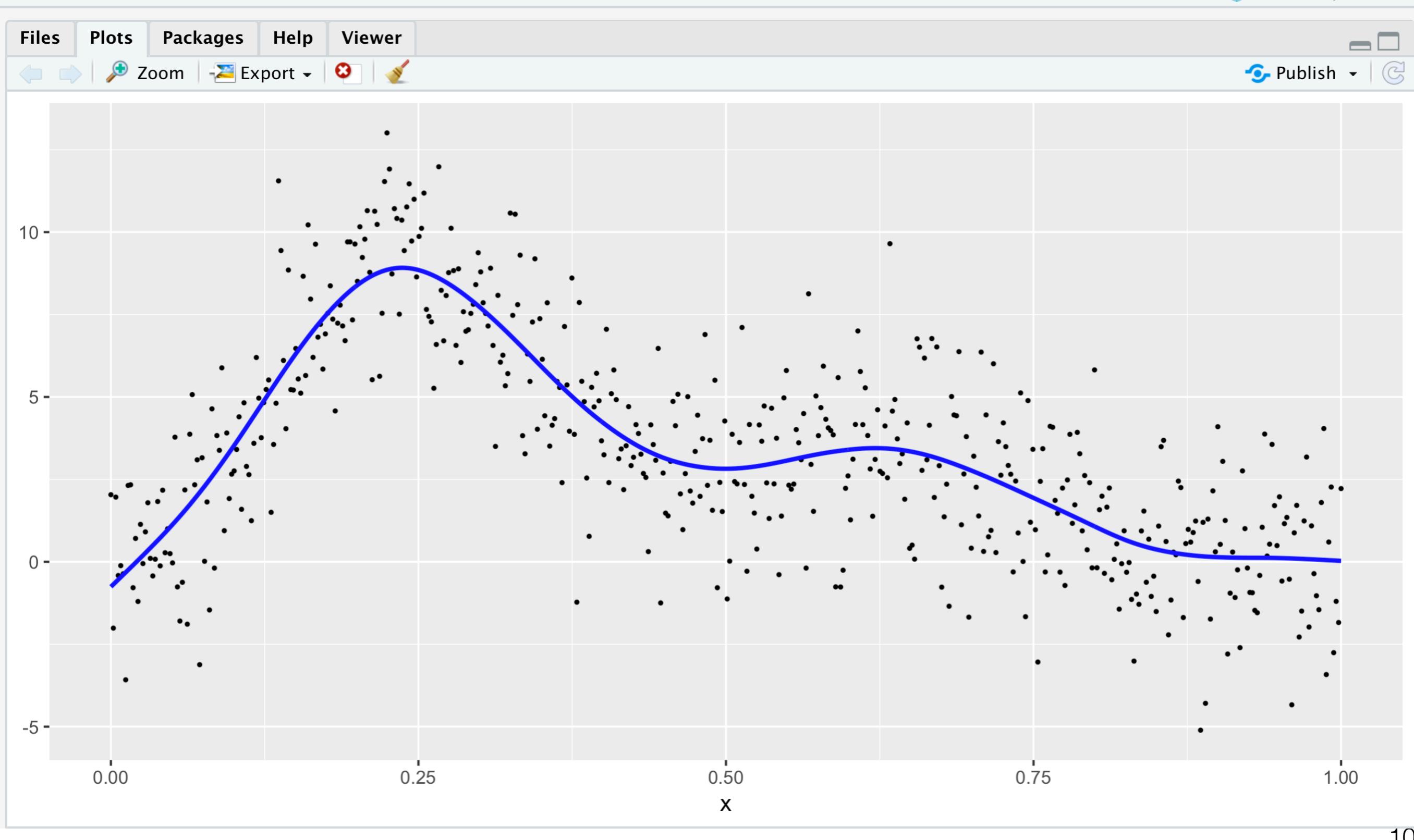
How about this $\hat{y} = \hat{f}(x)$?



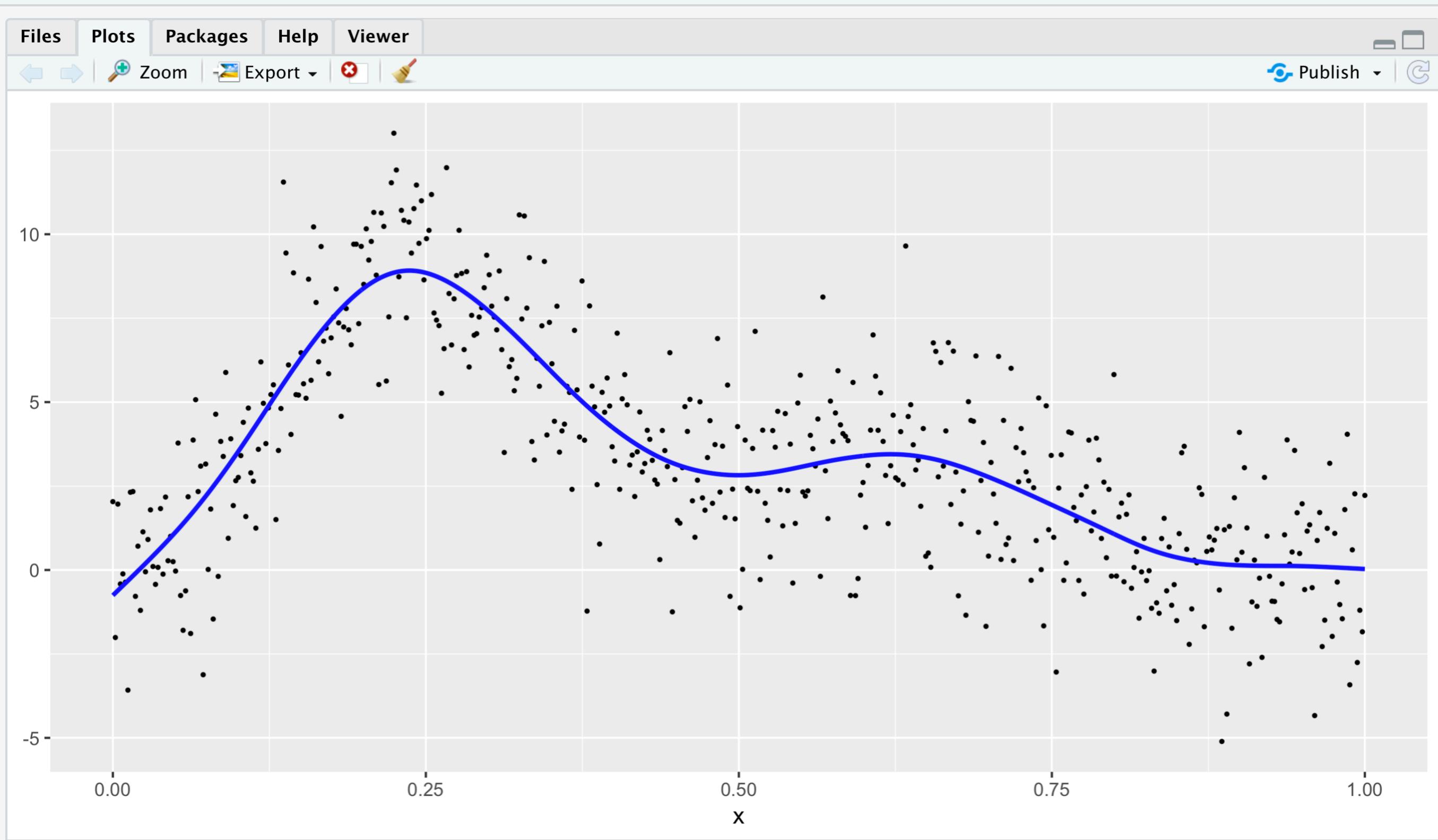
How about this $\hat{f}(x)$?



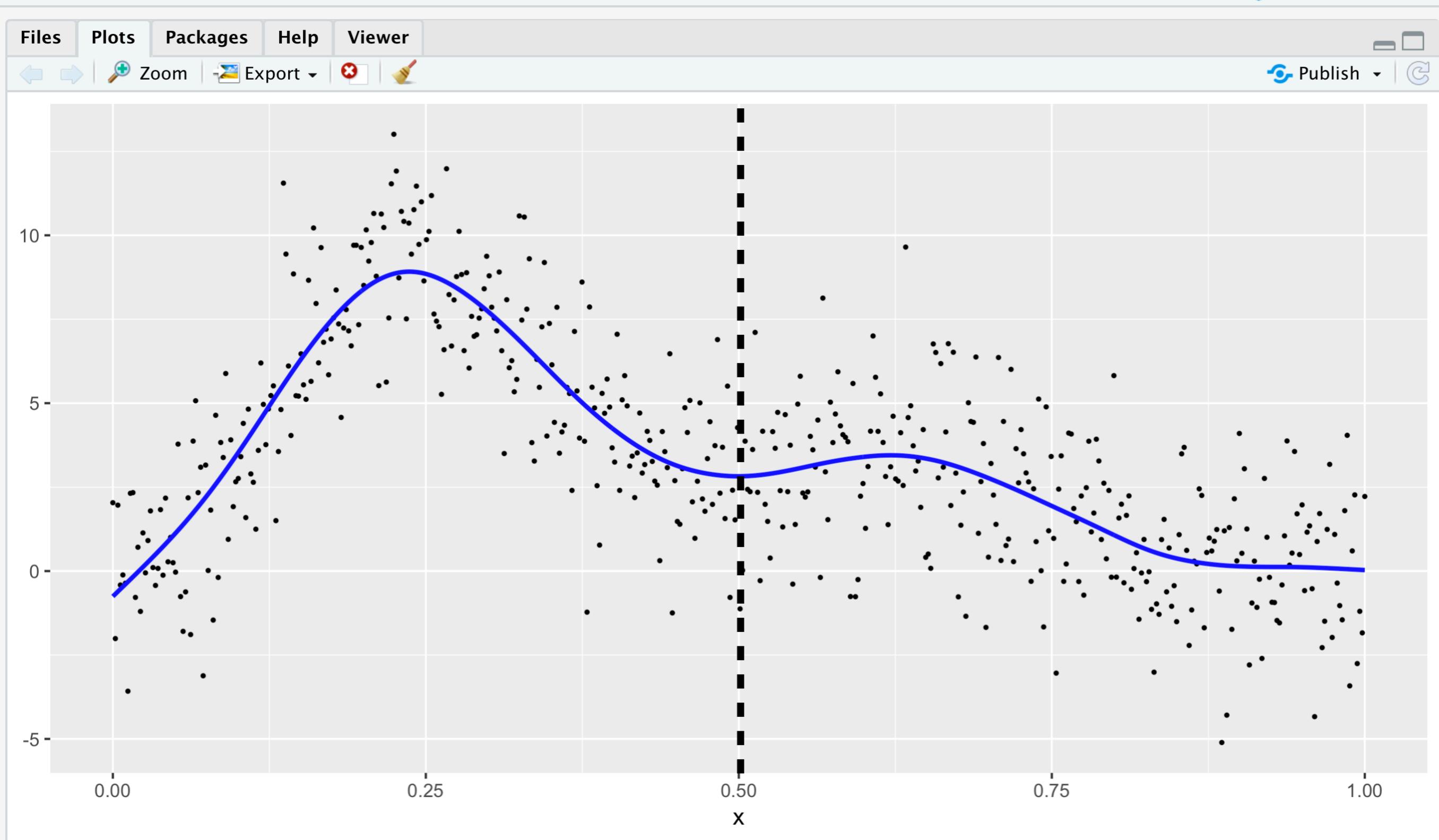
How about this $\hat{f}(x)$?



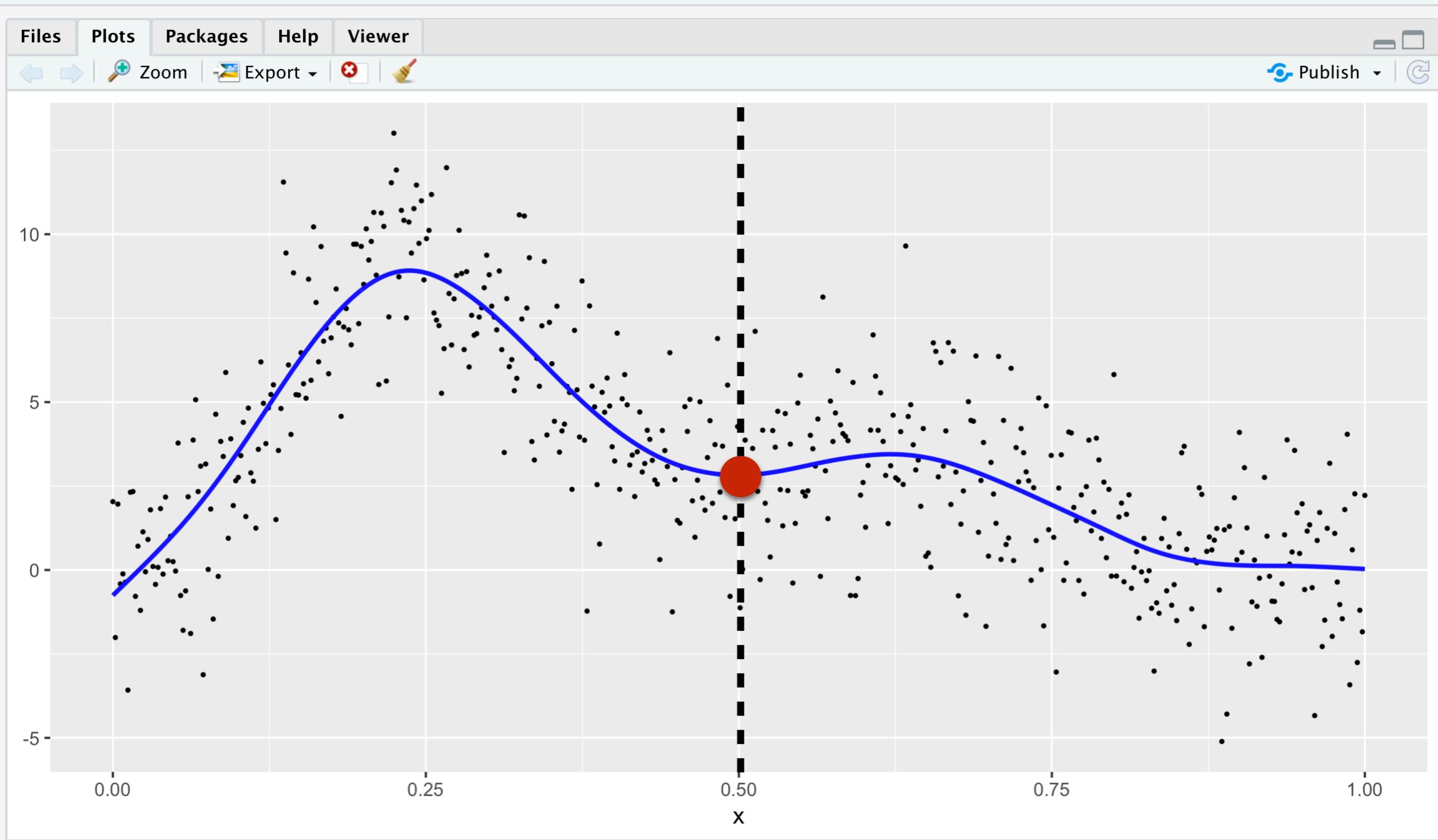
What does this $\hat{f}(x)$ predict for $x = 0.5$?



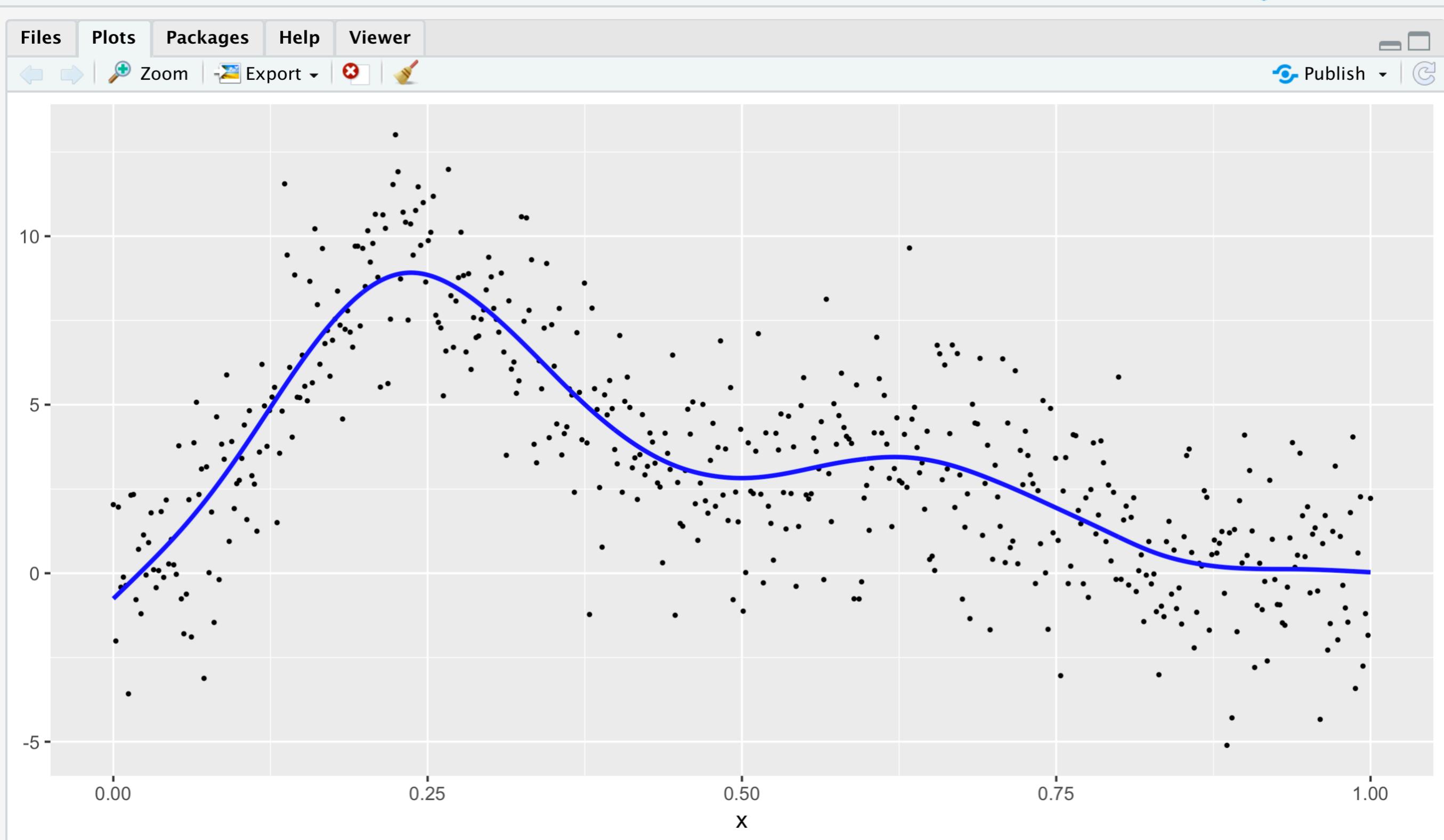
What does this $\hat{f}(x)$ predict for $x = 0.5$?



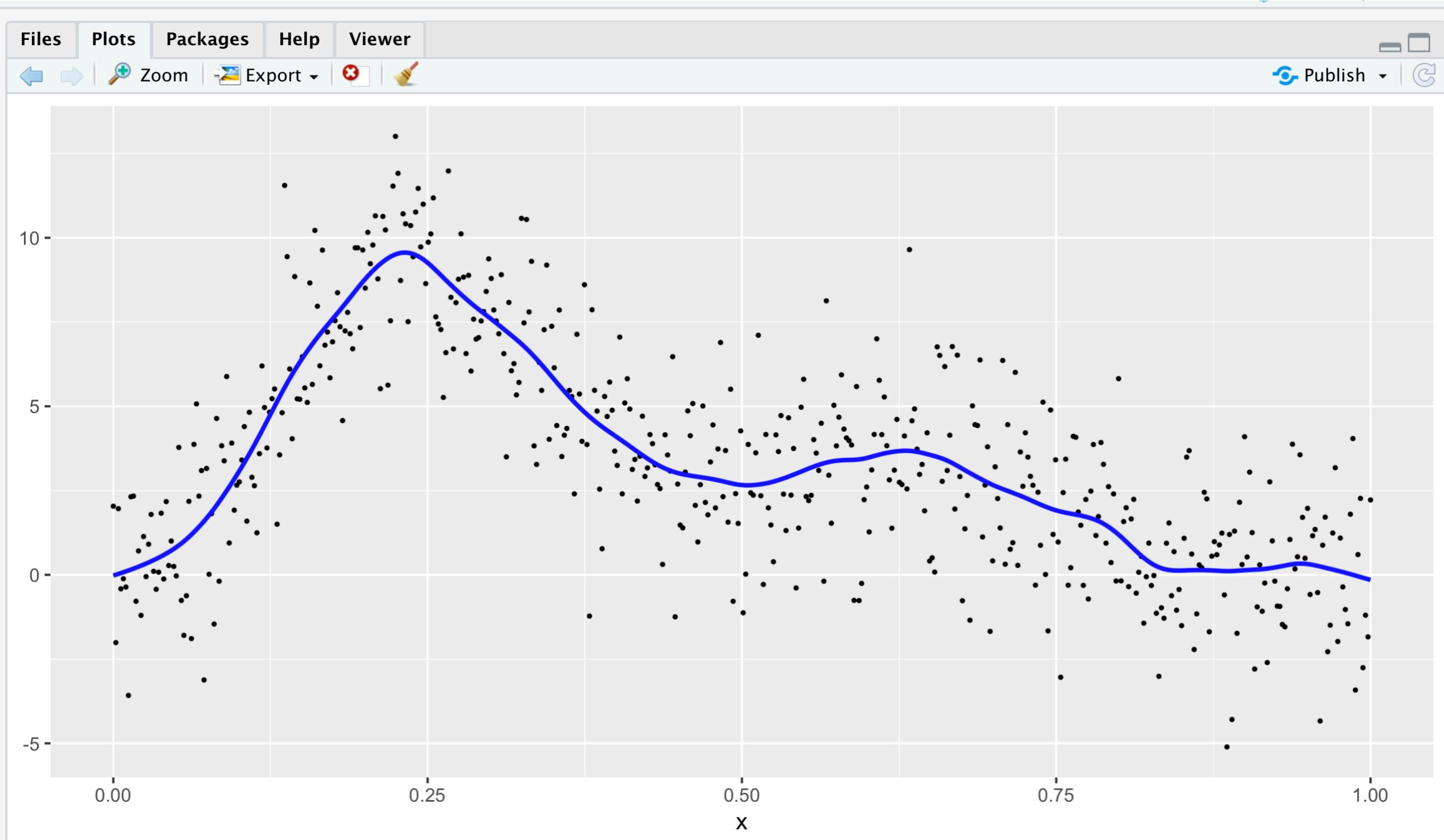
What does this $\hat{f}(x)$ predict for $x = 0.5$?



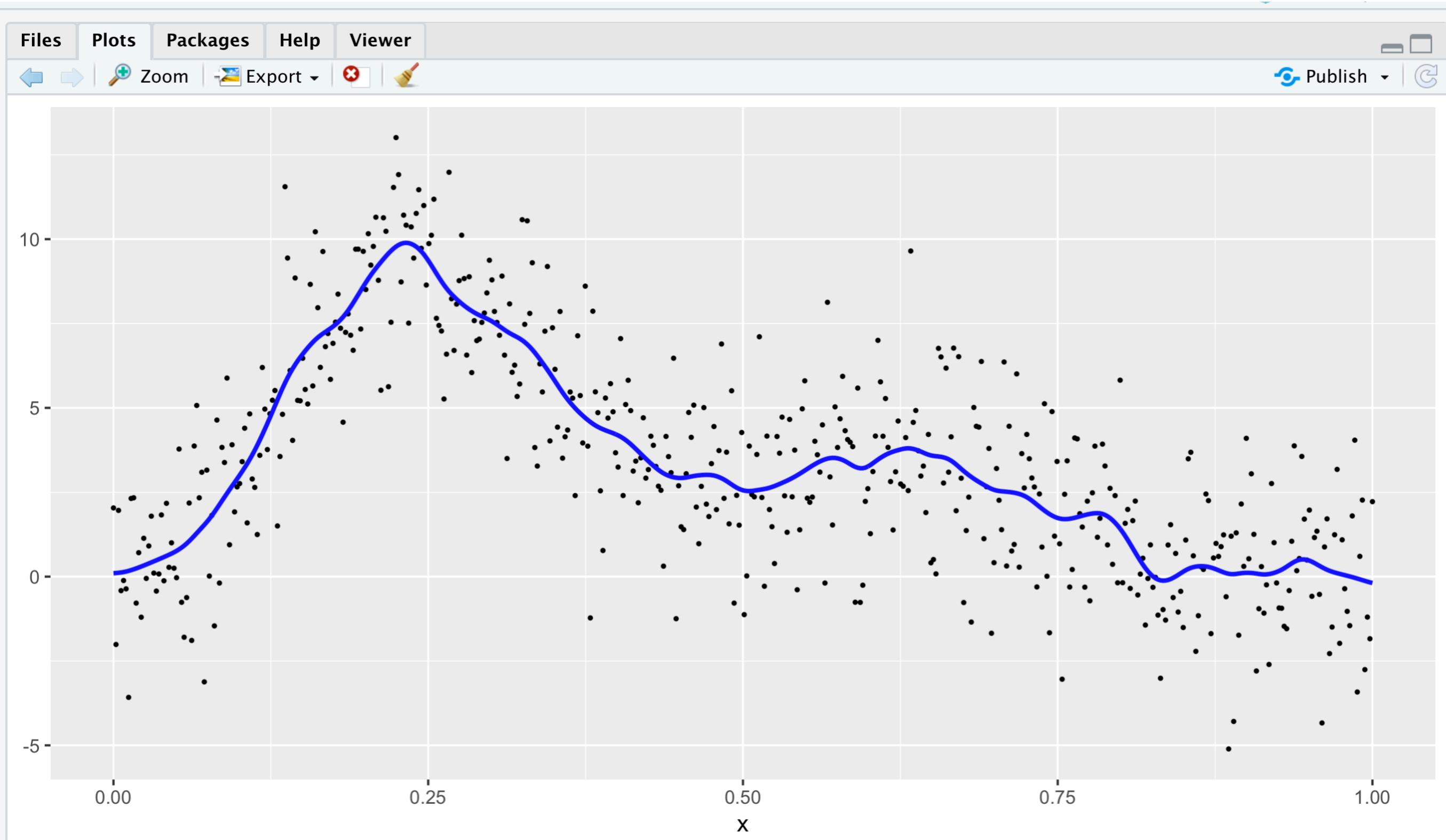
Ok, great. But instead of this $\hat{f}(x)$...



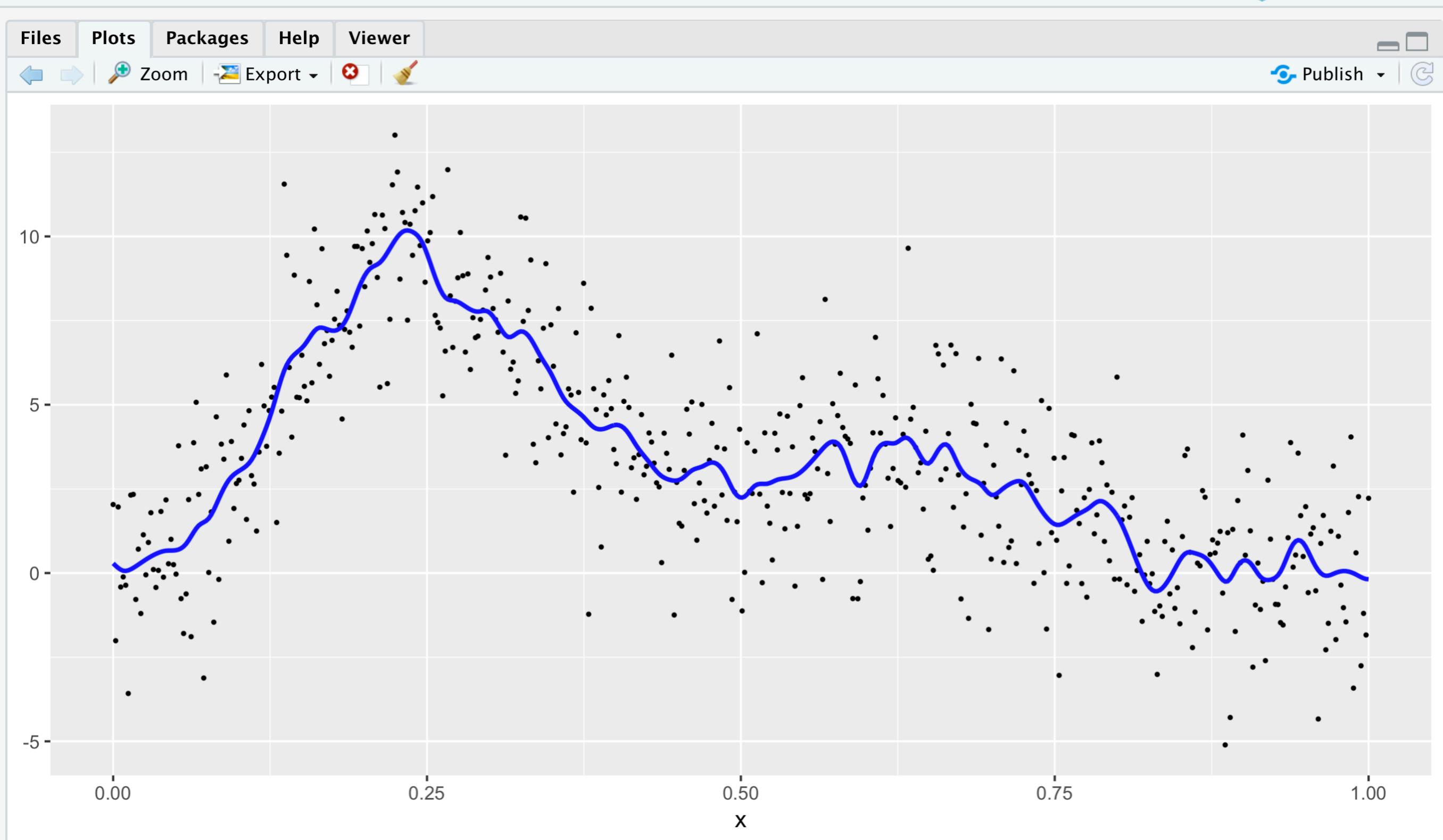
How about this $\hat{f}(x)$?



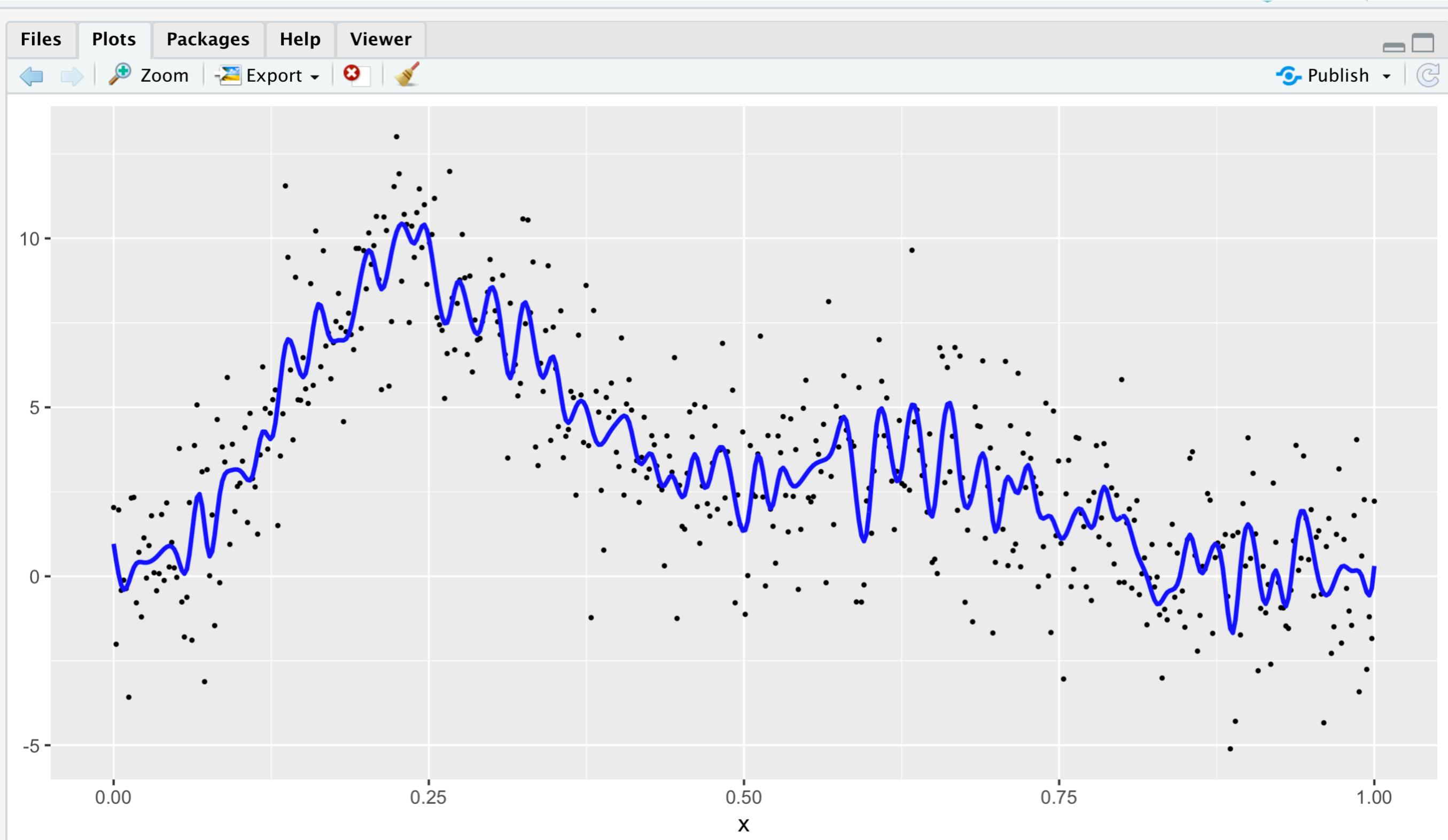
How about this $\hat{f}(x)$?



How about this $\hat{f}(x)$?



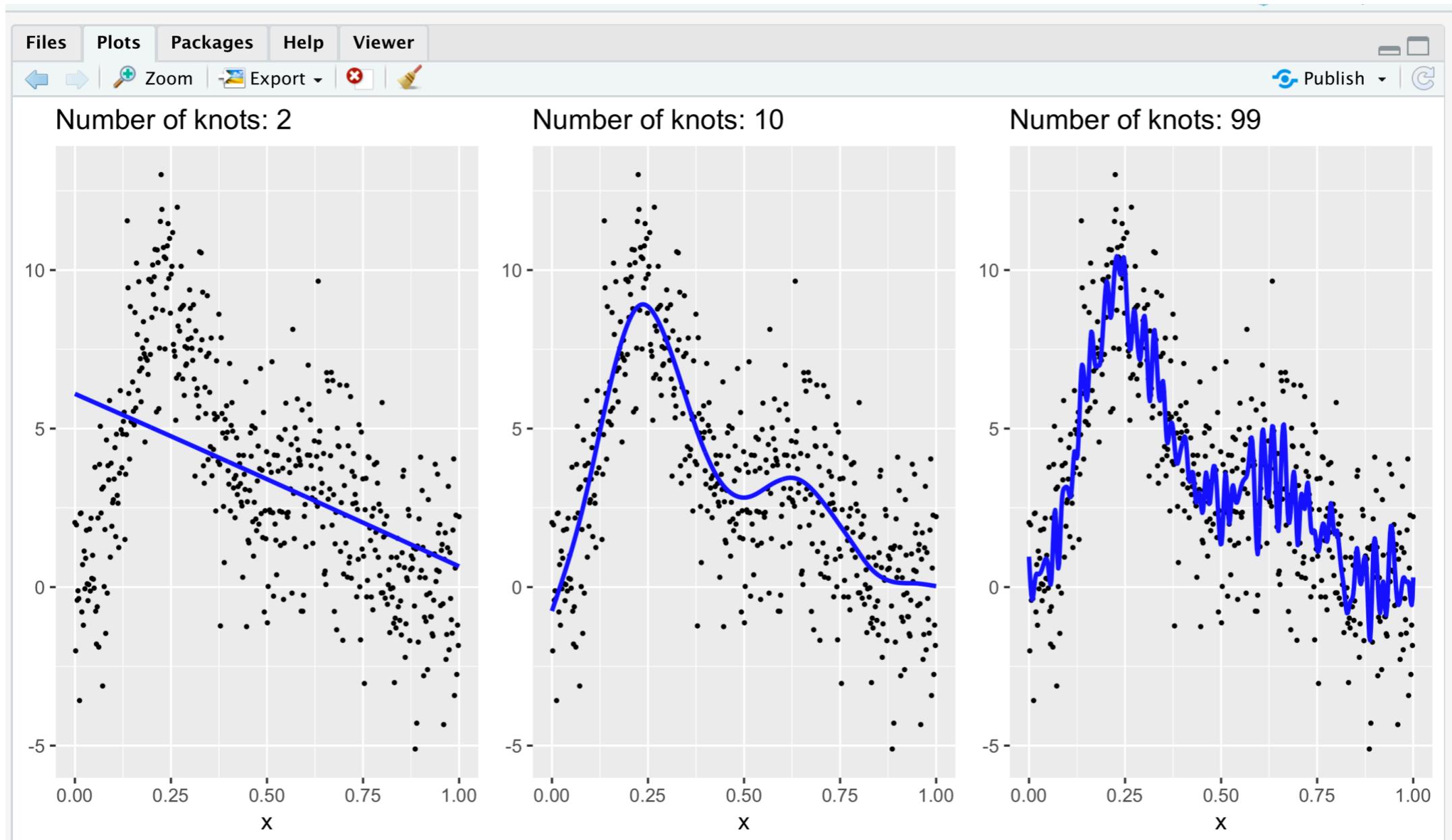
How about this $\hat{f}(x)$?



Model Fitting Method: (Cubic) Splines

- Splines fit the blue curve $\hat{f}(x)$ that **minimizes** the (squared) vertical distances between all:
 - predicted points $\hat{y} = \hat{f}(x)$ and
 - observed points y
- Amount of “wiggle” is the **complexity of the model**
- Occam’s Razor

Three Different $\hat{f}(x)$

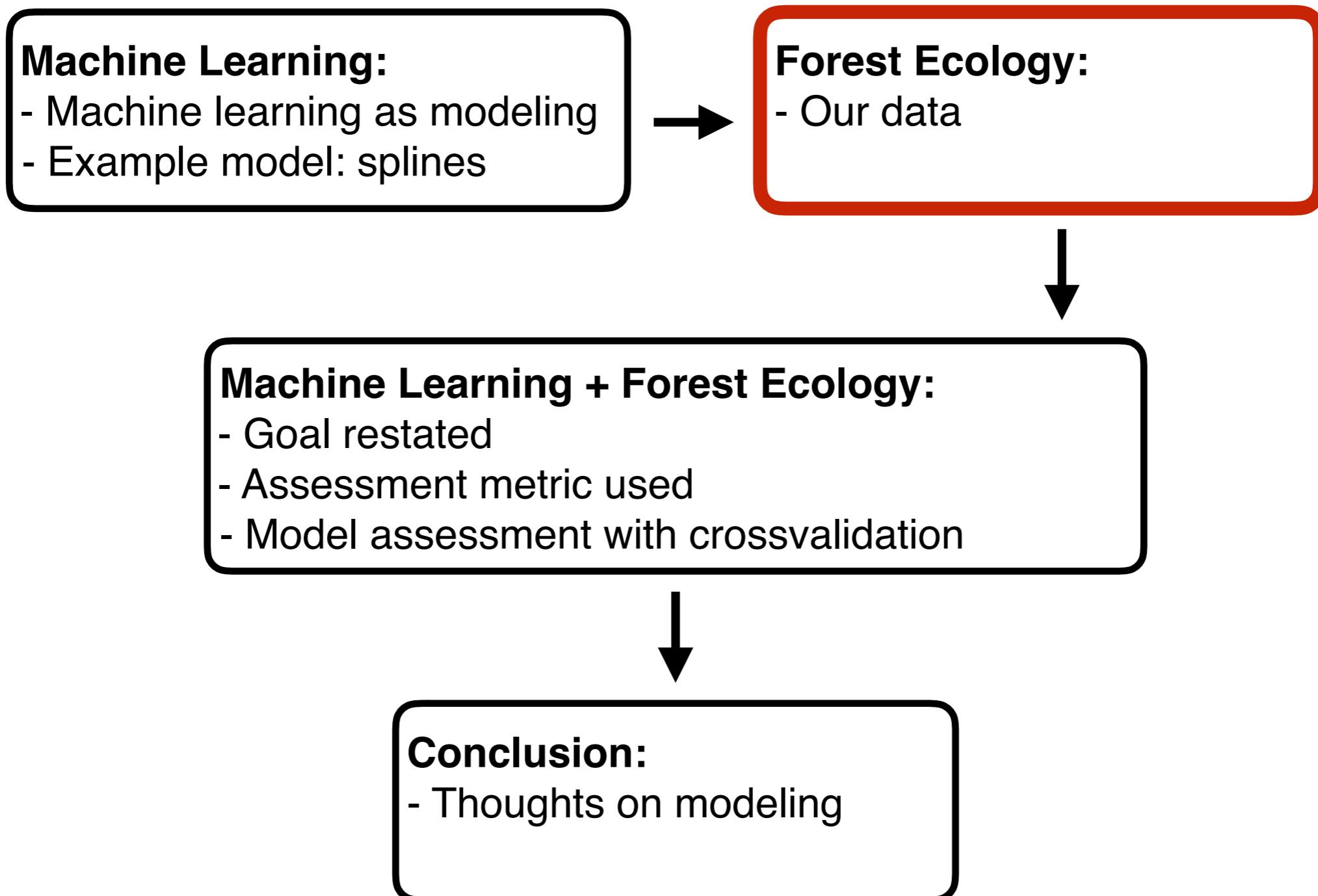


Underfit!

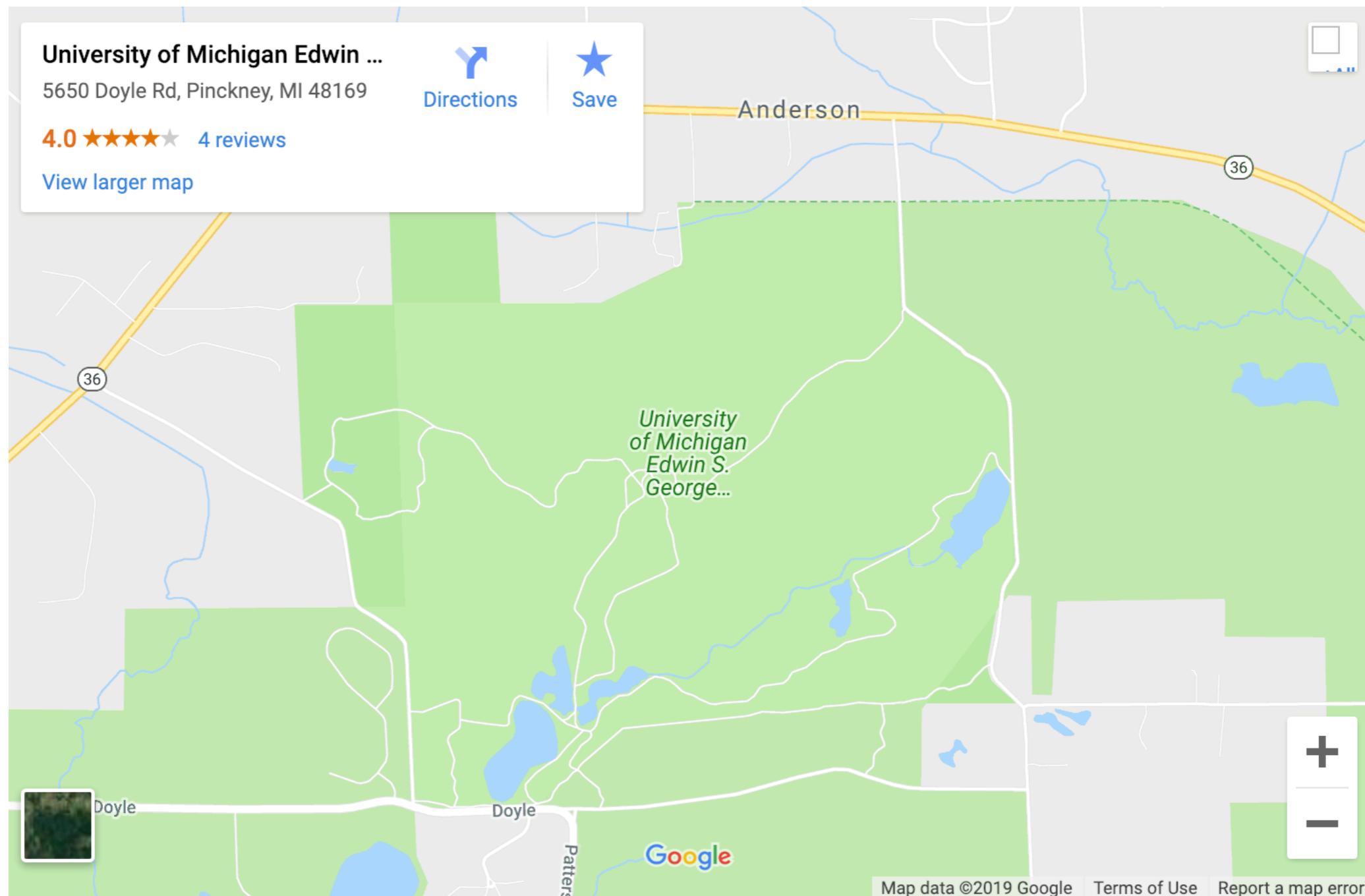
“Just right!”

Overfit!

Road Map

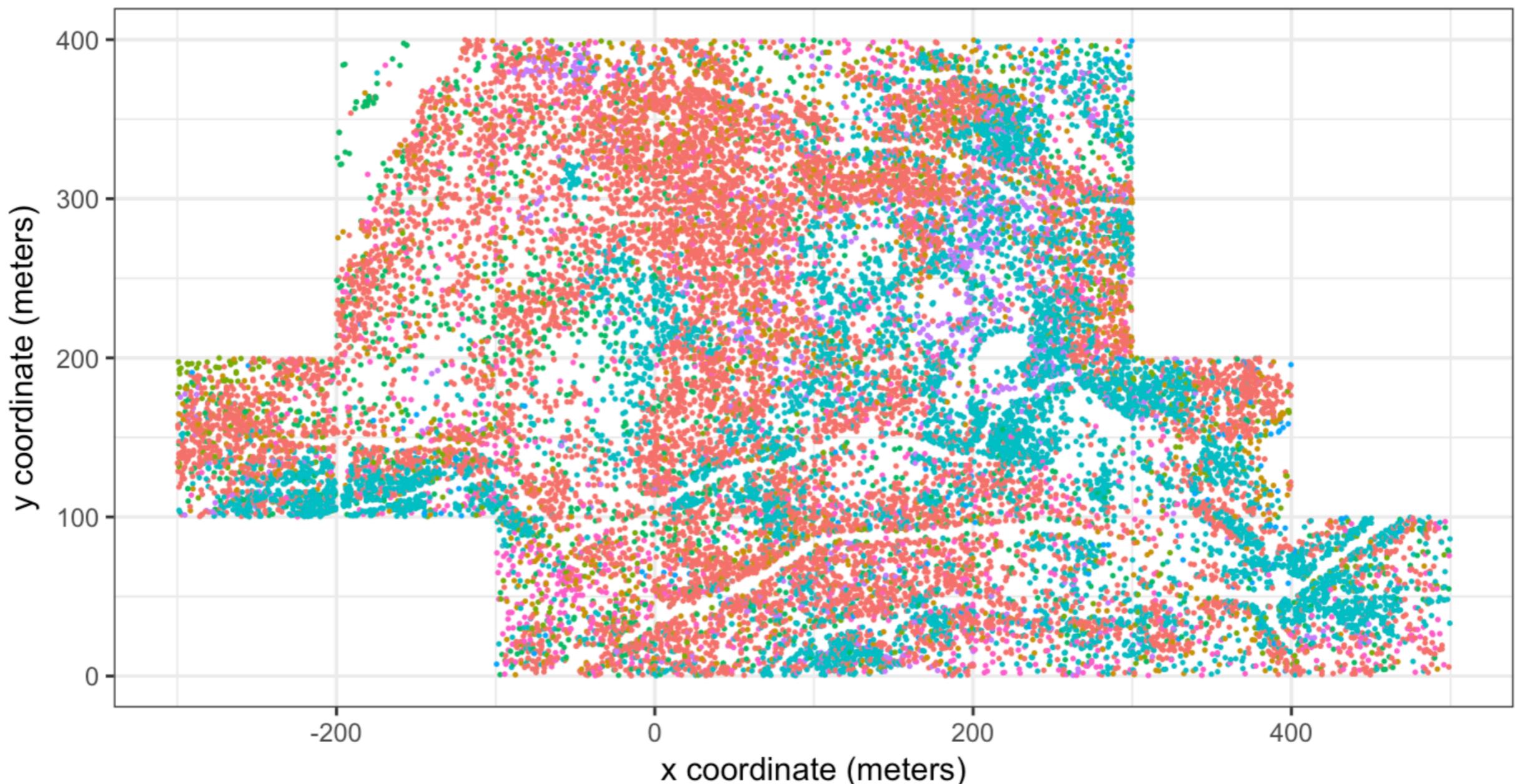


Data: 2008 & 2014 Censuses of Trees



Data: 2008 Snapshot

Spatial distribution of top 8 species

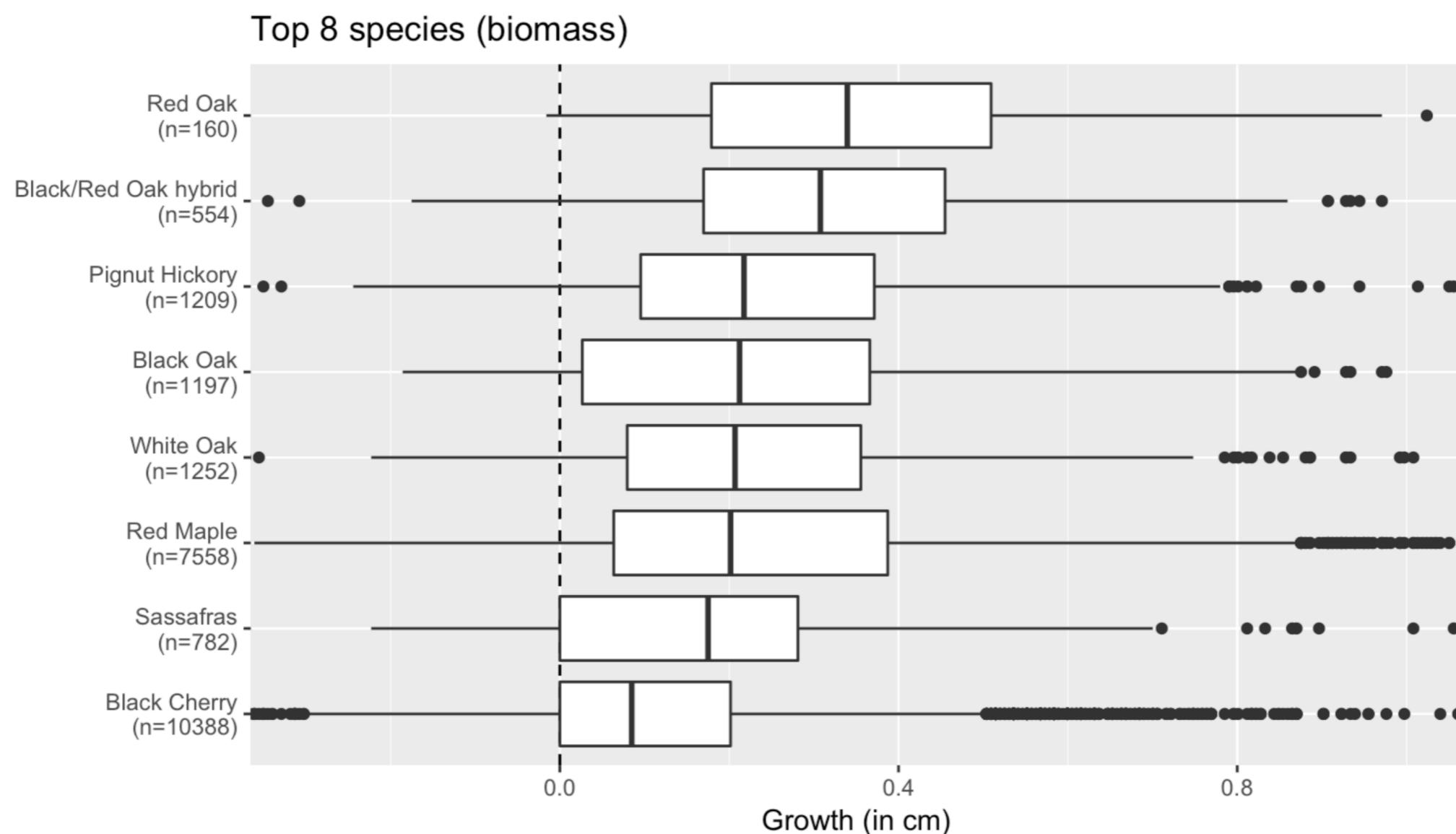


Recall our Variables!



y : Outcome Variable = Avg Annual Growth

Observed average annual growth of trees 2008-2014



Predictor Variables \vec{x}

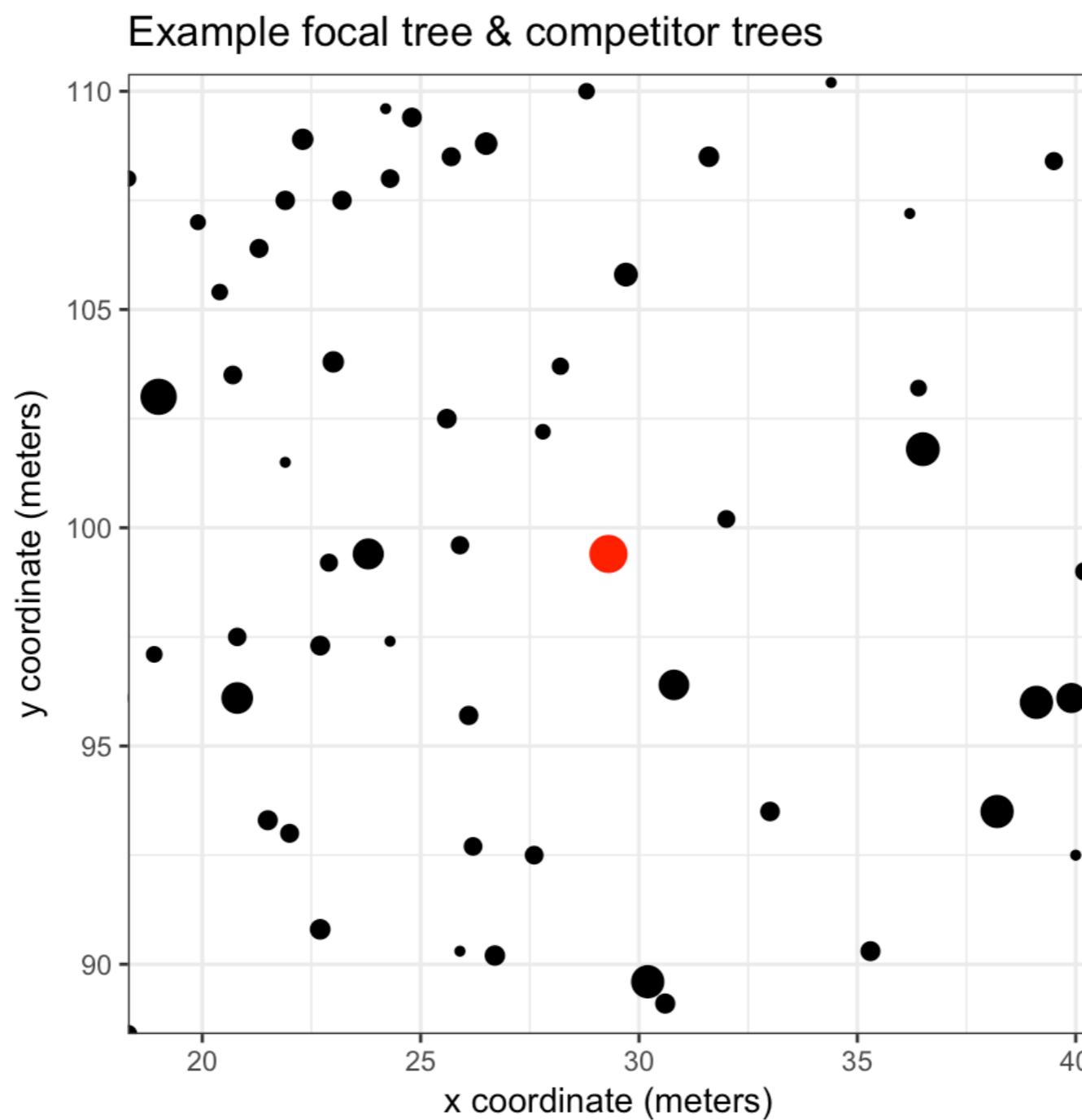
x_1 : Species of tree

x_2 : Size of tree (diameter at breast height)



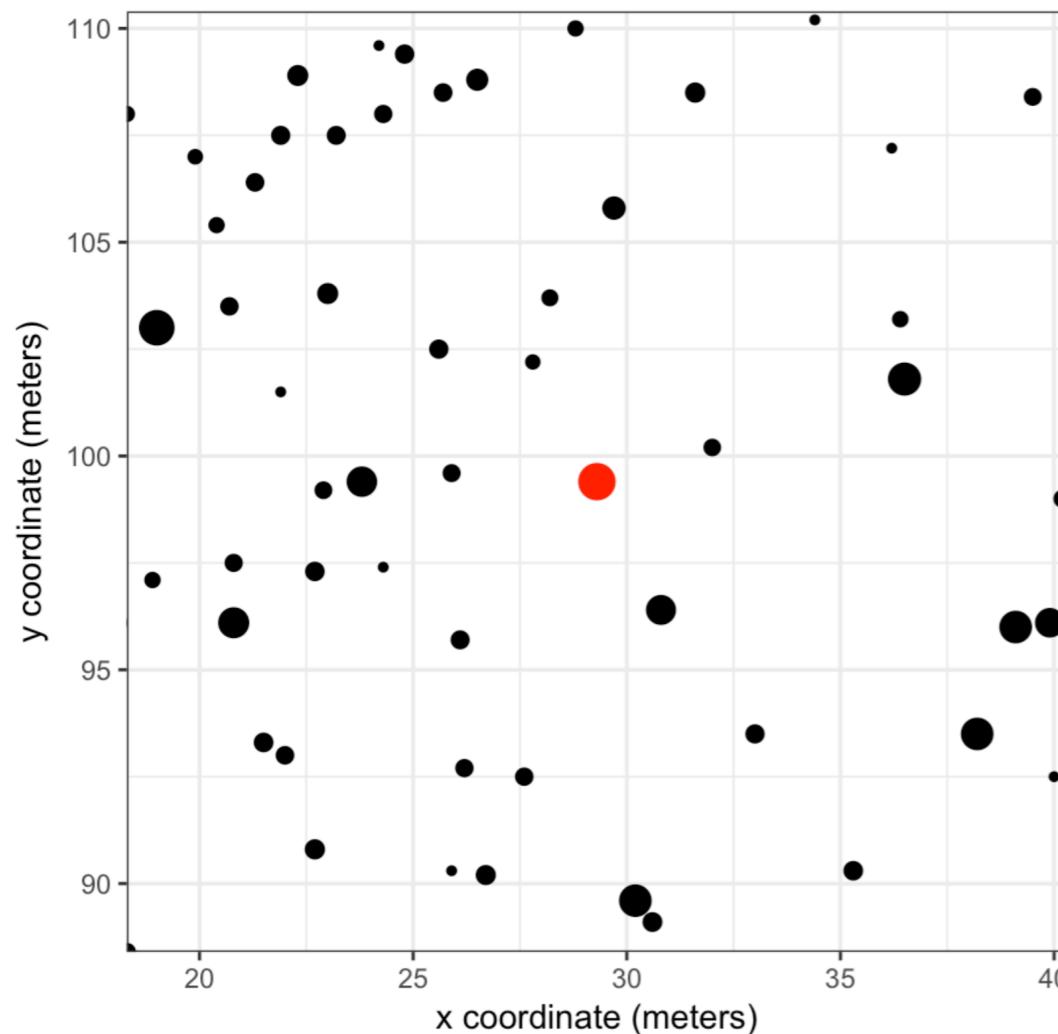
Predictor Variables

x_3 : Number and size of competitor trees (biomass)

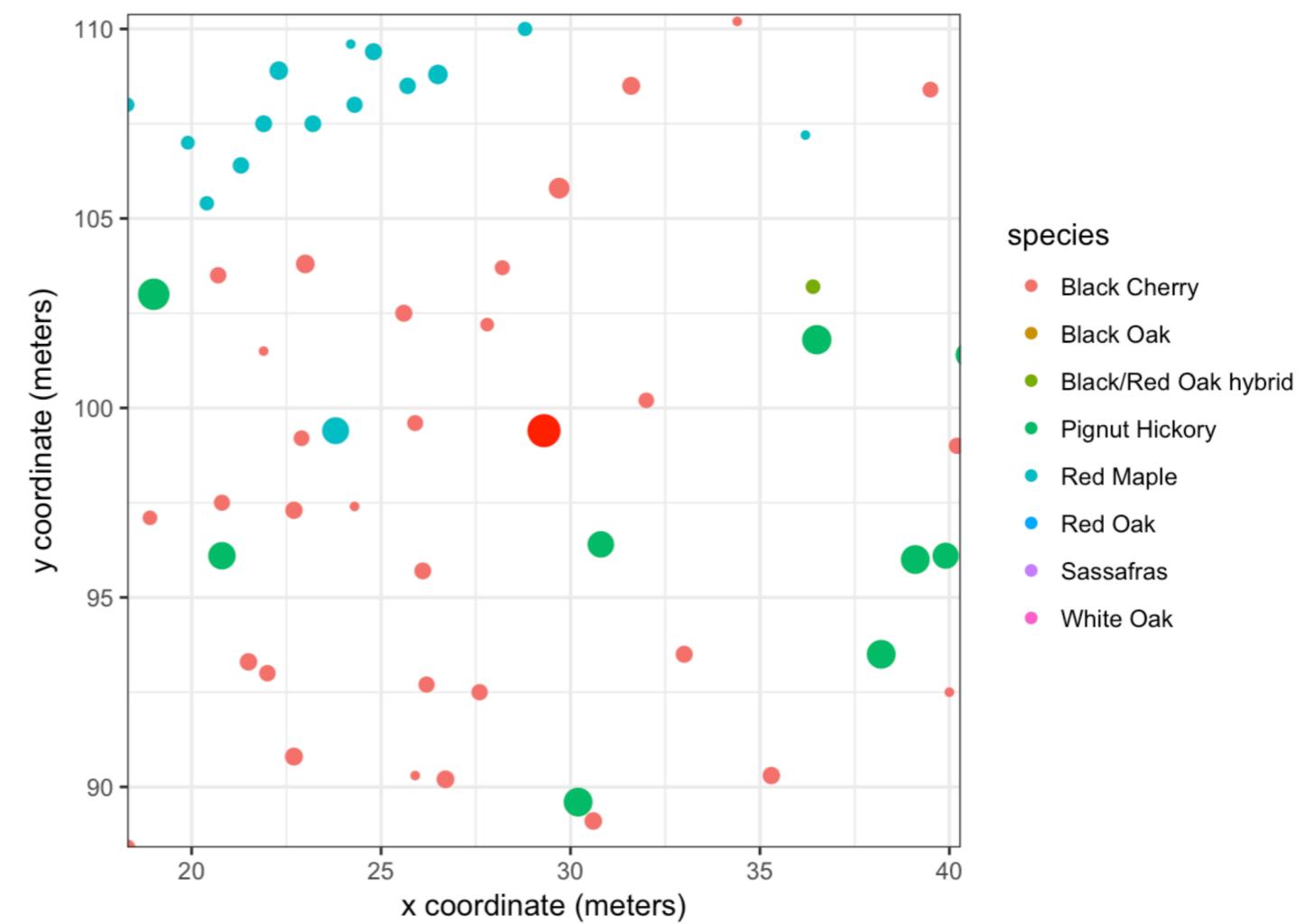


Two Models of Competition

Example focal tree & competitor trees



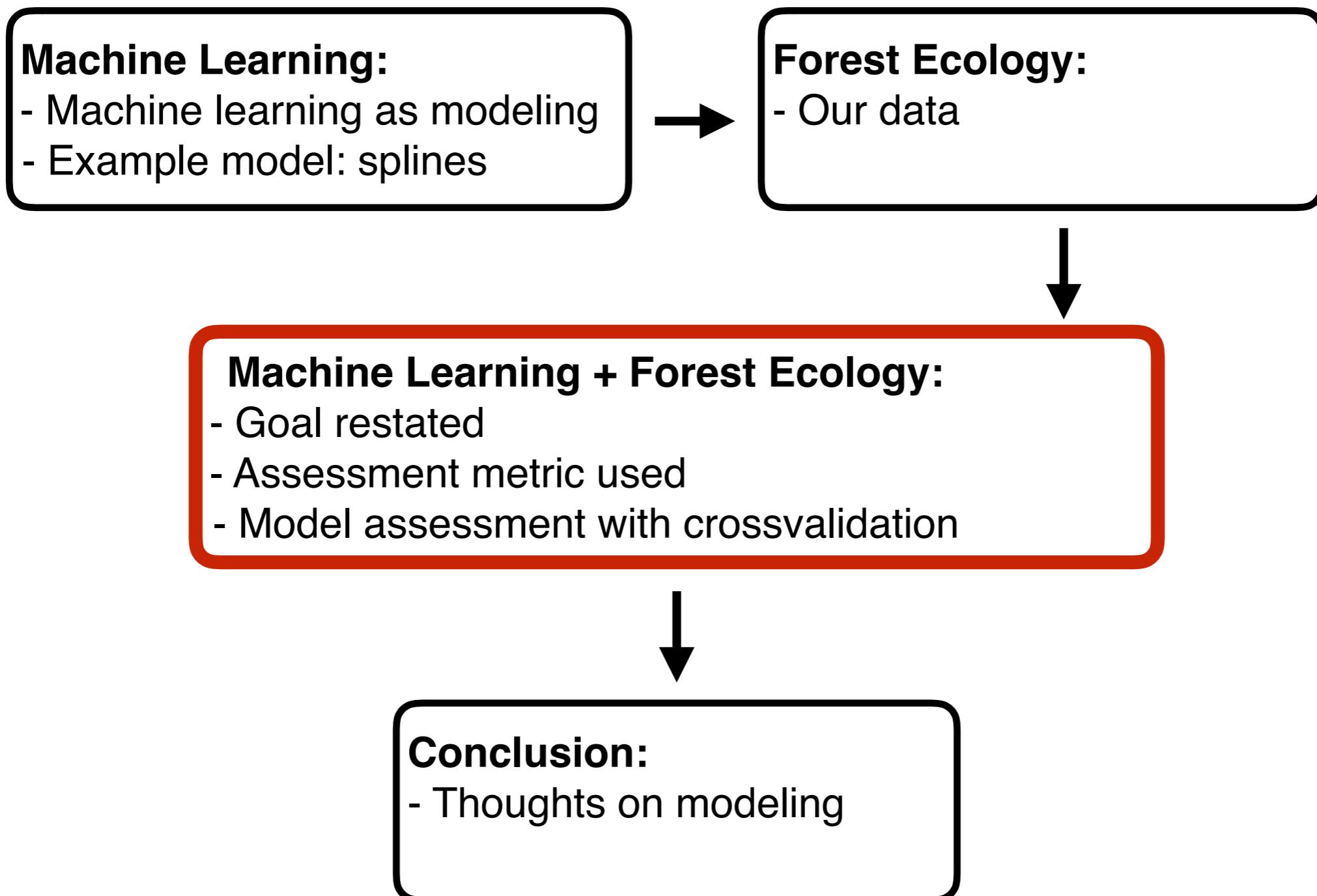
Example focal tree & competitor trees



Which model is better?

Yea or nay on distinguishing competitor species?

Road Map



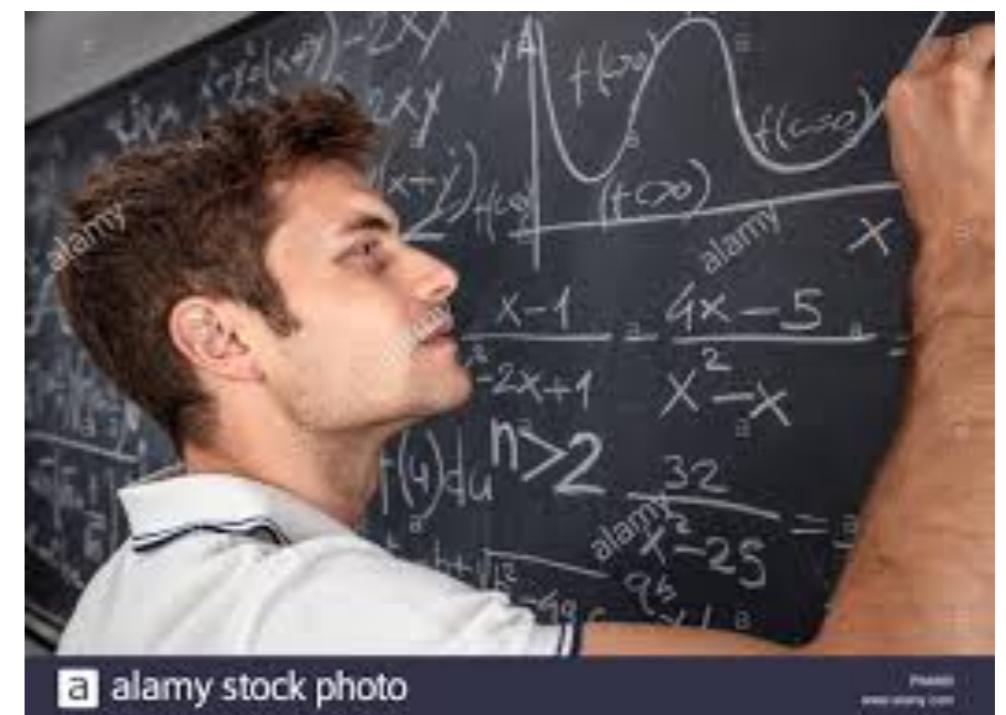
Machine Learning & Forest Ecology

- **Goal of Modeling:** Fit models $\hat{f}(x)$ that best approximate the true (unknown) model $f(x)$
- **Goal of Machine Learning:** Fit models that best “predict” the outcome variable
- **My goal:** Fit models that best predict the growth of trees
- **Tools:** The same machine learning tools and framework as self-driving cars

Model Assessment Metric

- Question: “How good is our model?”
- Answer: “This is answered using the **Mean Square(d) Error** metric!”

Back to the blackboard
for Chalk Talk #2...



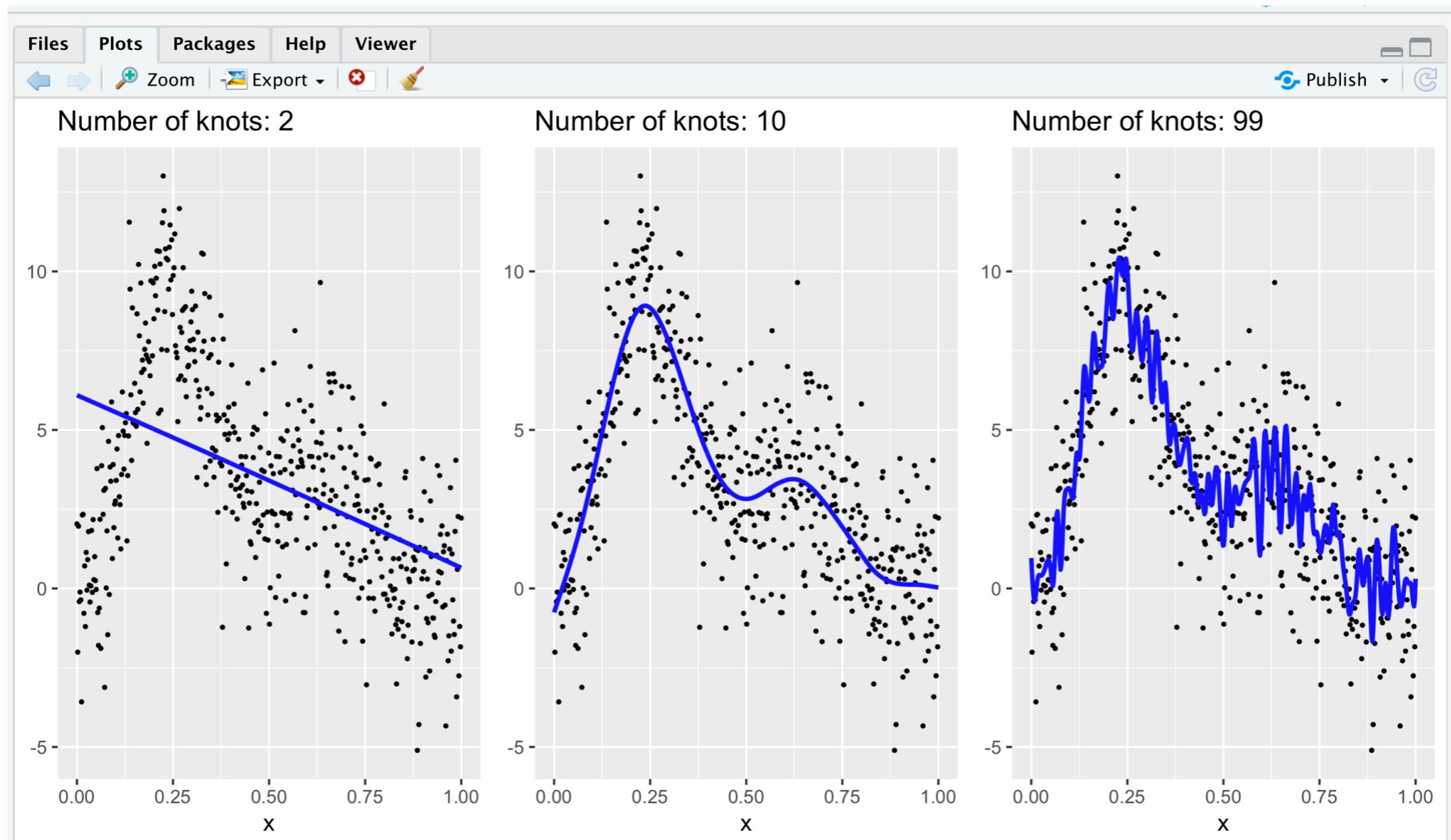
Mean Squared Error

On Machine Learning predictive modeling competition site [Kaggle](#):

The screenshot shows the Kaggle Leaderboard for the "Google Analytics Customer Revenue Prediction" competition. The competition is described as a "Featured Prediction Competition" with a prize of \$45,000. It is an RStudio competition with 1,104 teams and has one month left. The current leader is Marwen Sallem with a score of 0.0000, achieved using the "Root Mean Squared Error" metric. Other top performers include Paulo Pinto and Its Me, both with scores of 0.0000.

#	△1w	Team Name	Kernel	Team Members	Score	Entries	Last
1	—	Marwen Sallem			Root Mean Squared Error 0.0000	2	2mo
2	—	Paulo Pinto	</> 1line Perfect Score		0.0000	13	1mo
3	—	Its Me			0.0000	6	2mo

Issue of underfitting vs overfitting?



Underfit!

“Just right!”

Overfit!

Validation Set Approach

1 2 3

n

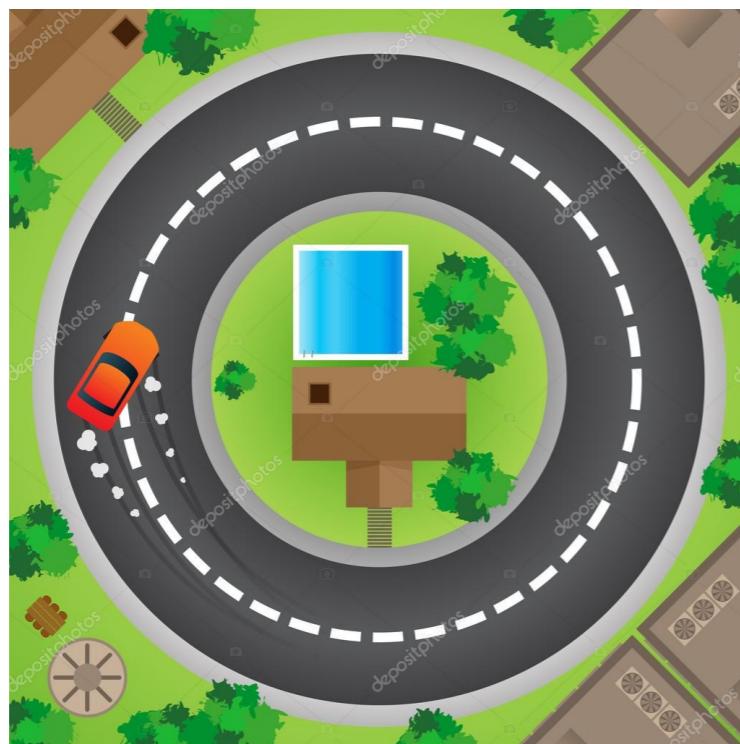
Split your data into:

7 22 13

91



Fit/train model on
training data



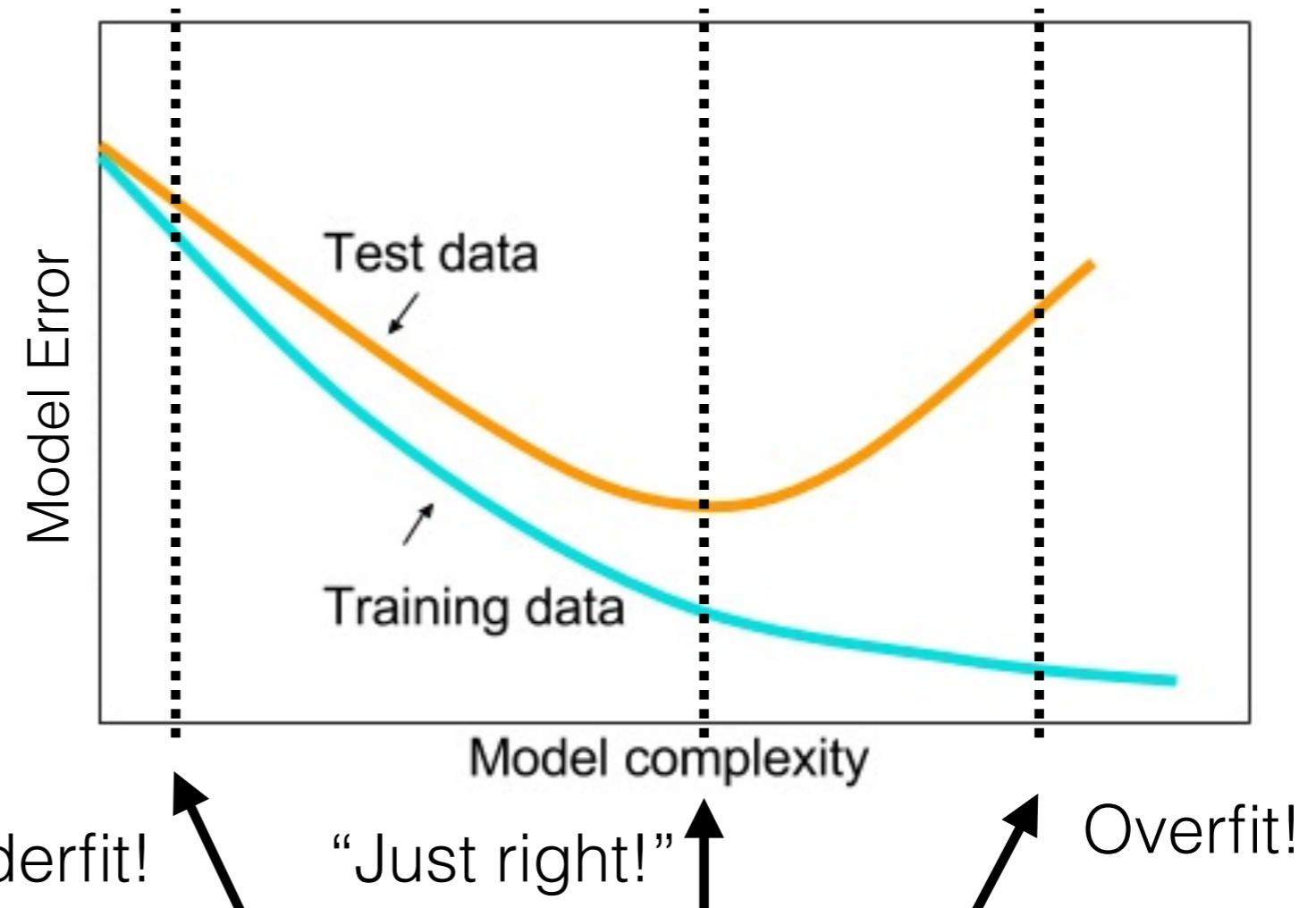
Assess model on
independent ***test*** data



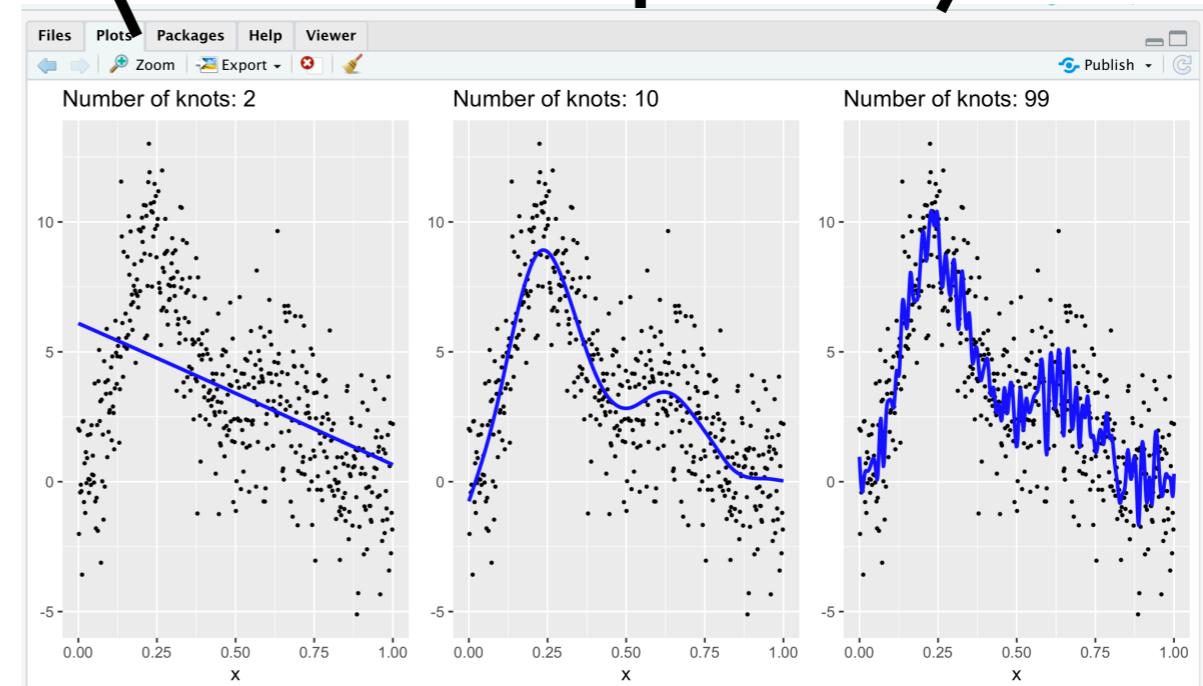
Typical Model Performance

Fit/train model on
the ***training*** data

Assess your
model's "error" on
independent ***test***
data

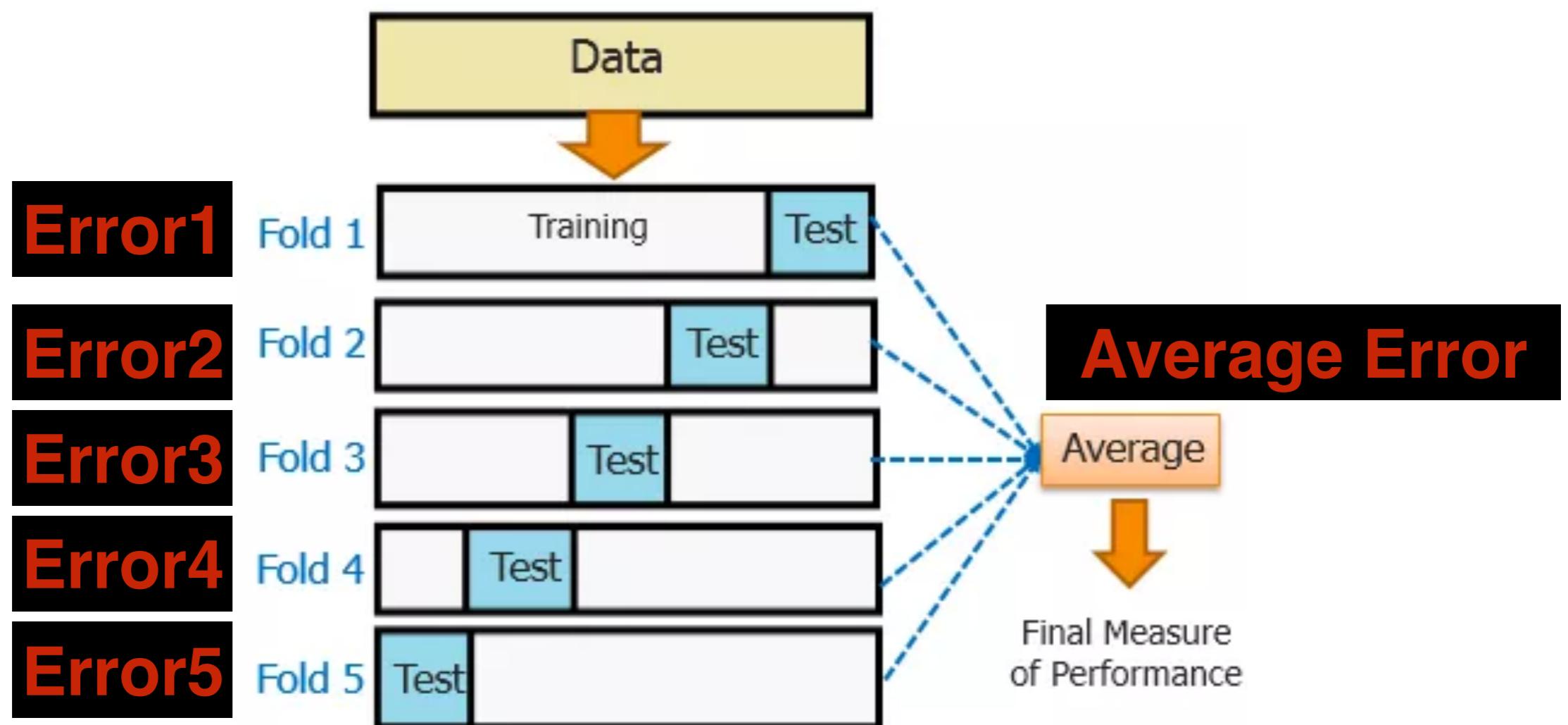


Recall for splines,
the # of knots controls
the **model complexity**

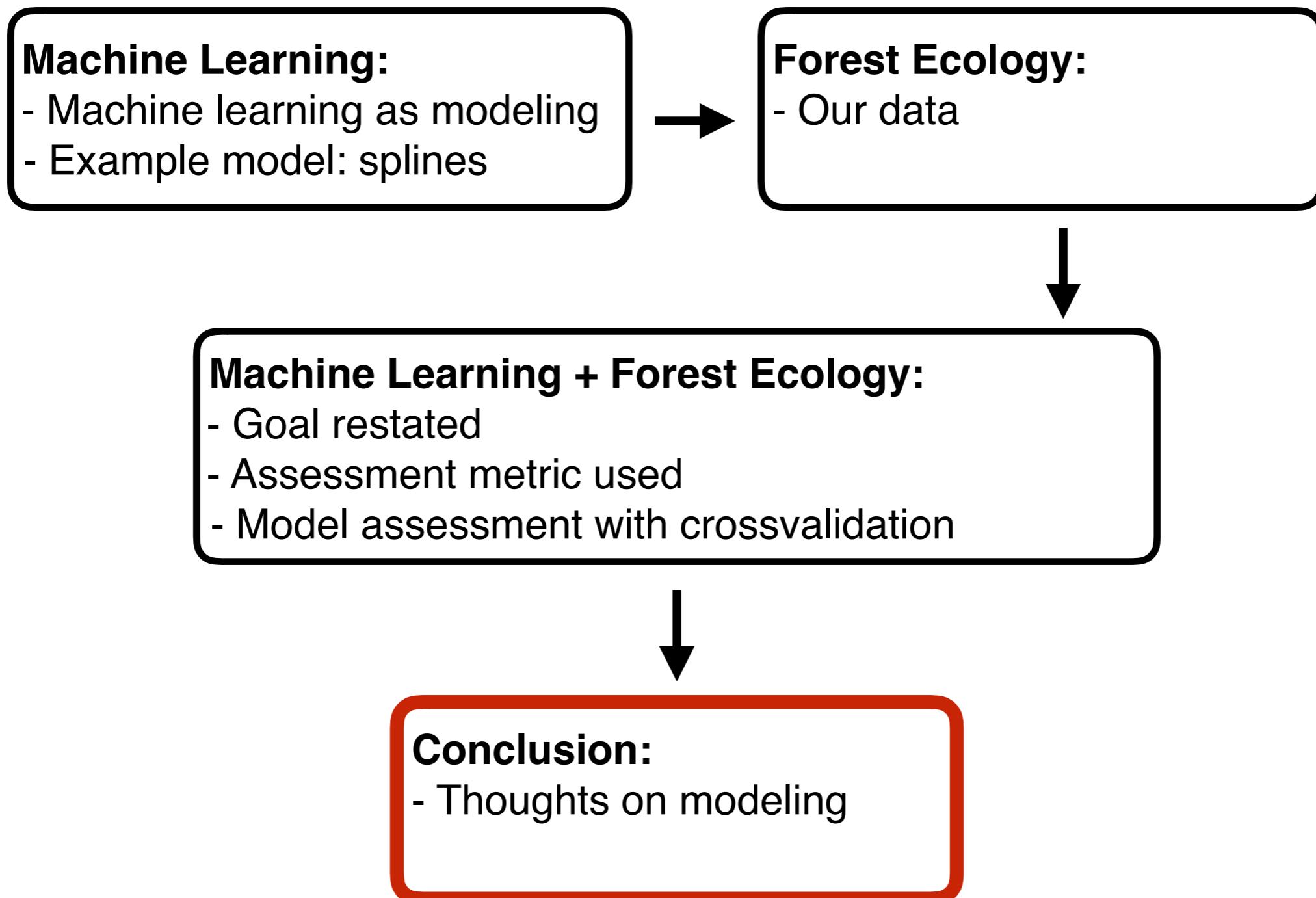


Generalization: 5-Fold Crossvalidation

Repeat validation training/test set split 5 times:



Road Map



$\hat{f}(x)$ Model Fitting



Daniela Witten
@daniela_witten

Follow



Perfect gym for a statistician



Modeling is not as objective as you think

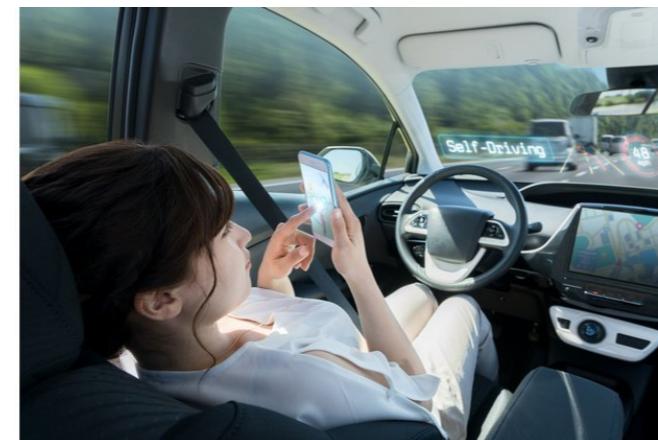
Scenario:



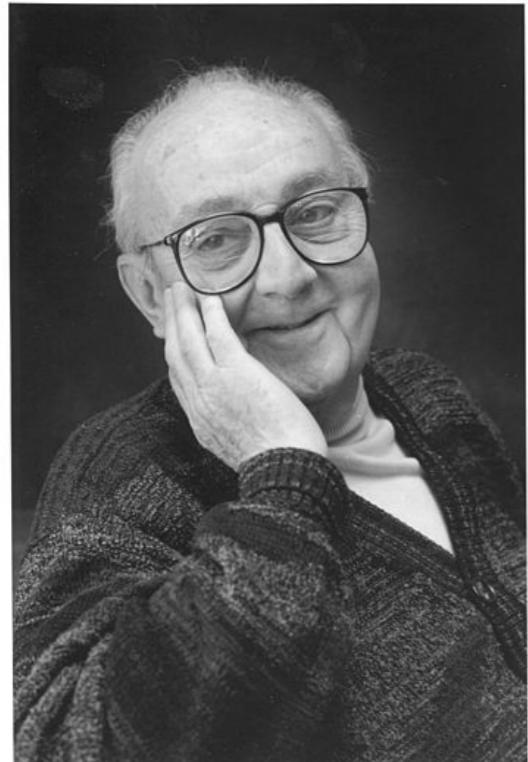
What they think is an
“appropriate” model...



... might not be the
same for these folks:



To Close: Two Quotes on Modeling



“All models are wrong,
but some are useful.”
George Box



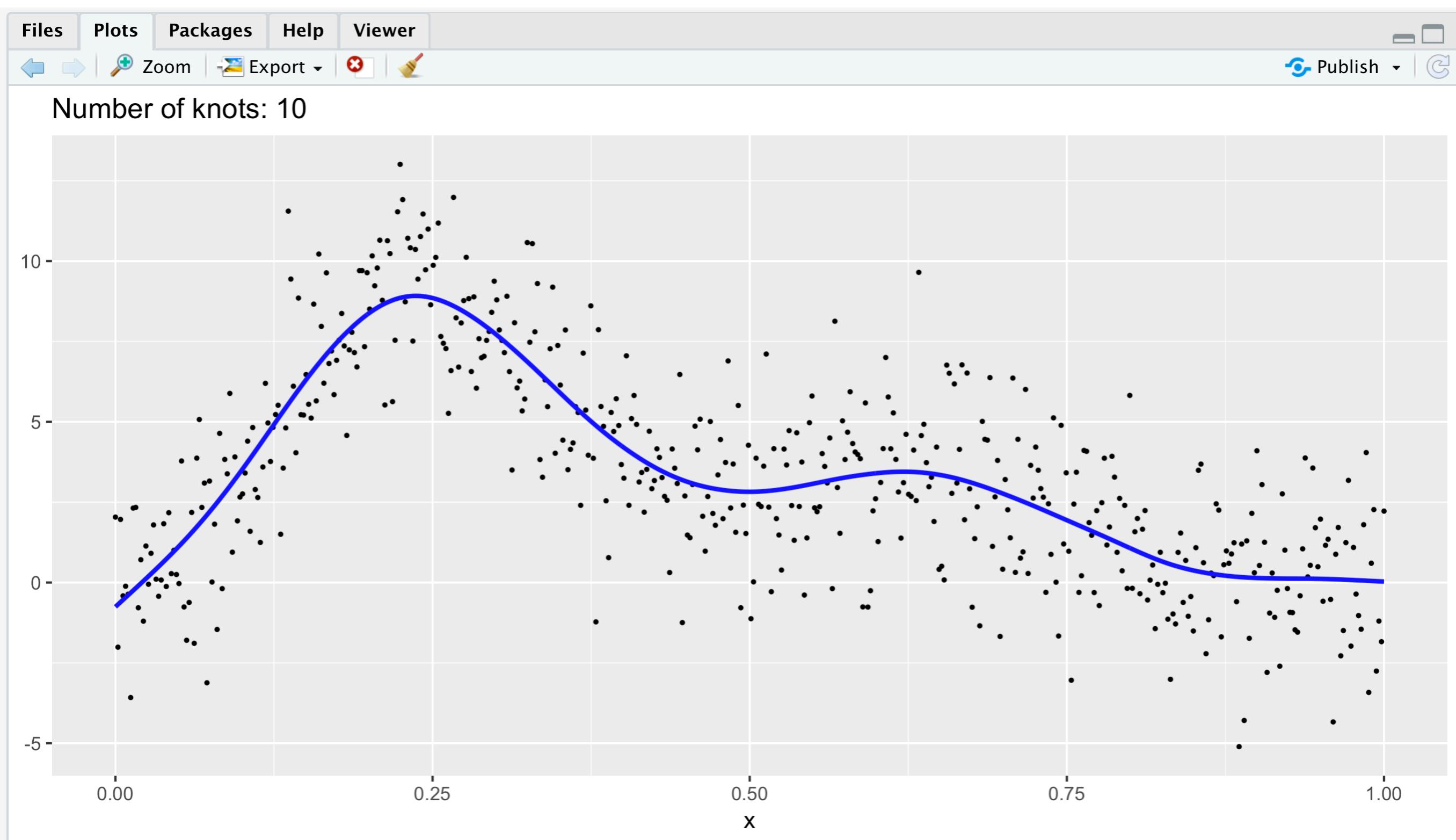
“WTF is up with your
 $\hat{f}(x)$?” @rudeboybert

Thanks!

Before I go: A “Wizard of Oz” Reveal...

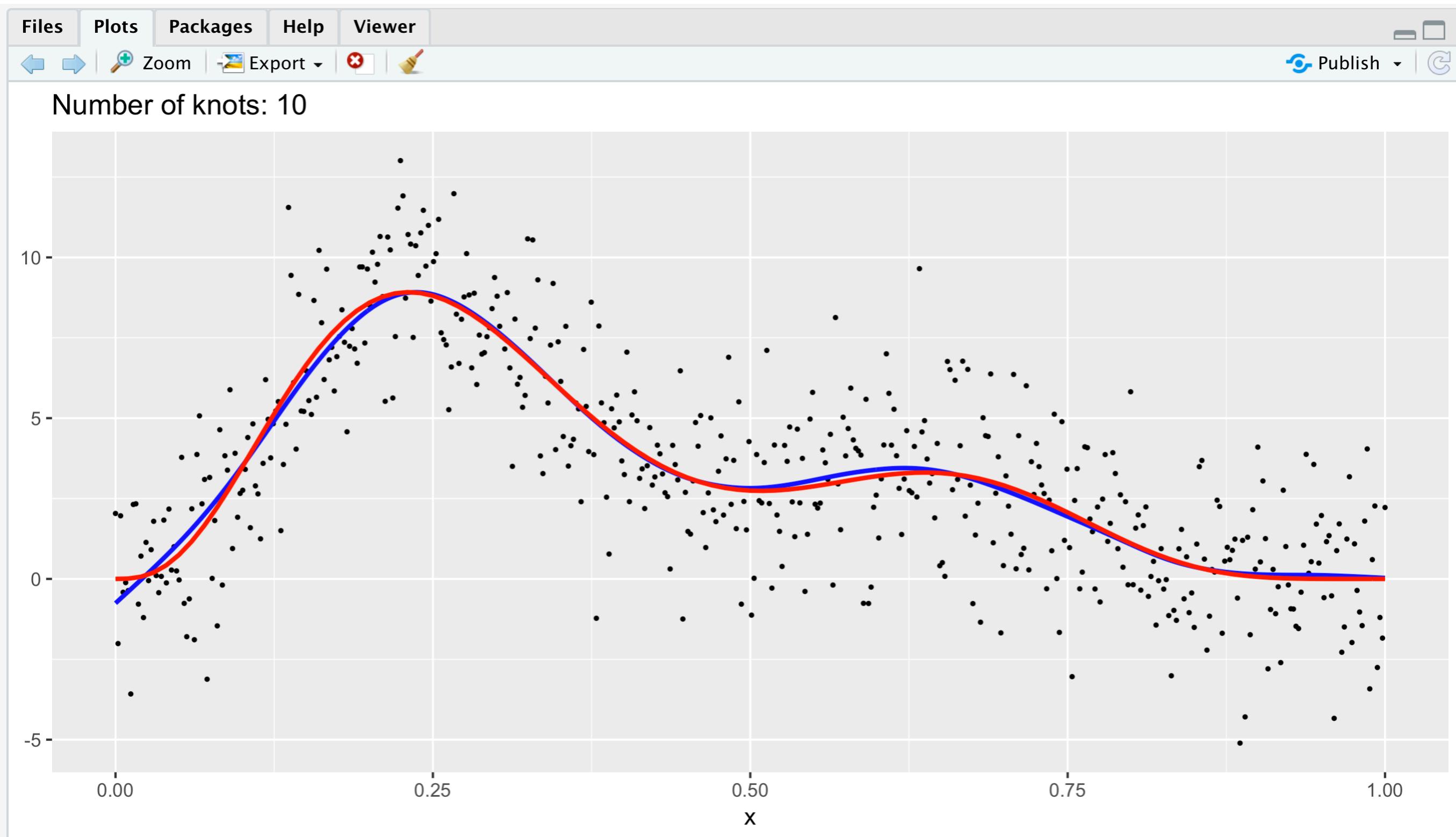


Our approximated $\hat{f}(x)$...



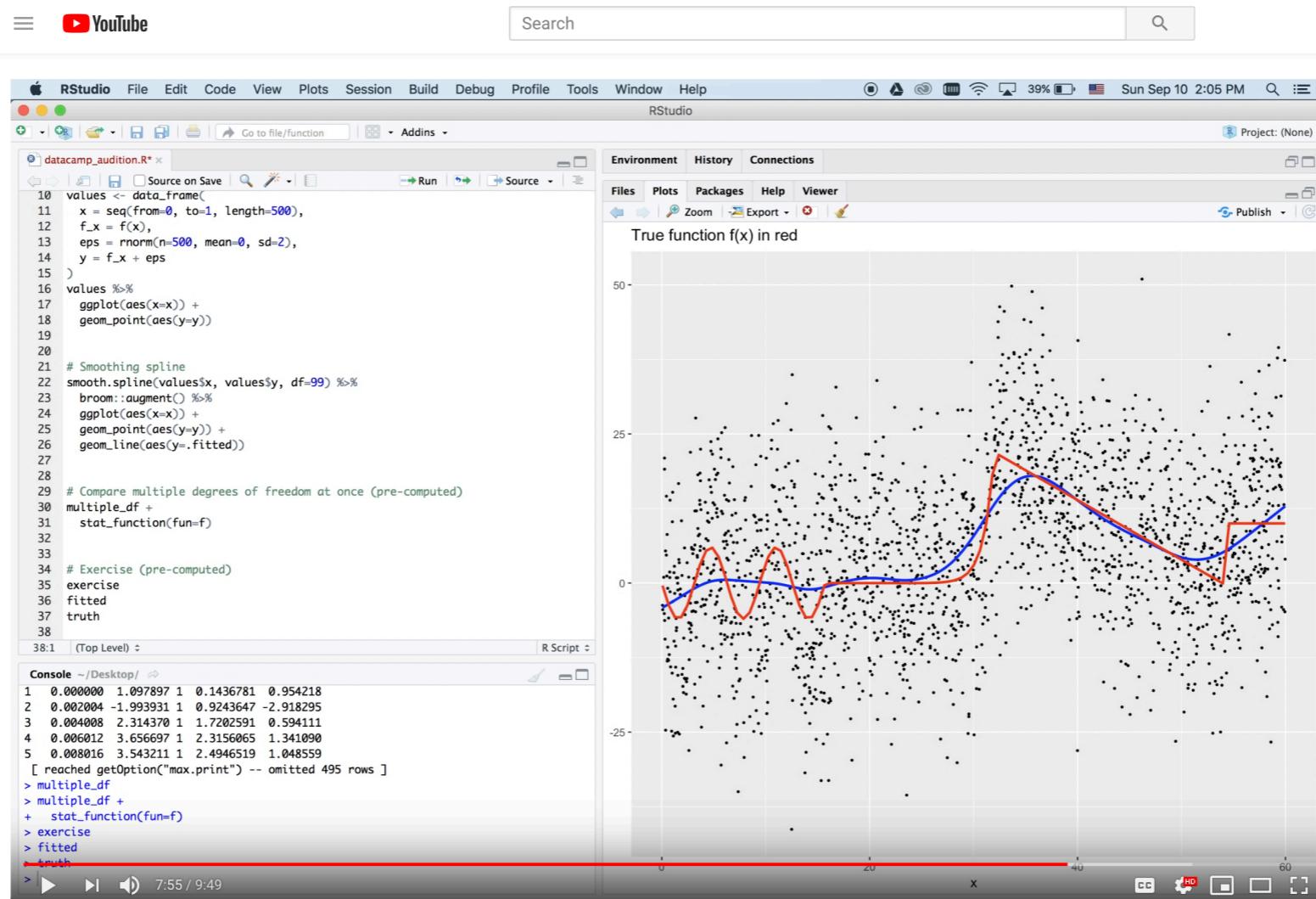
... was pretty close
to the *true* model:

$$f(x) = 0.2x^{11}(10(1 - x))^6 + 10(10x)^3(1 - x)^{10}$$



Resource 1: Intro to Splines Video

IMO splines are among the gentlest intro models to learning ML with!

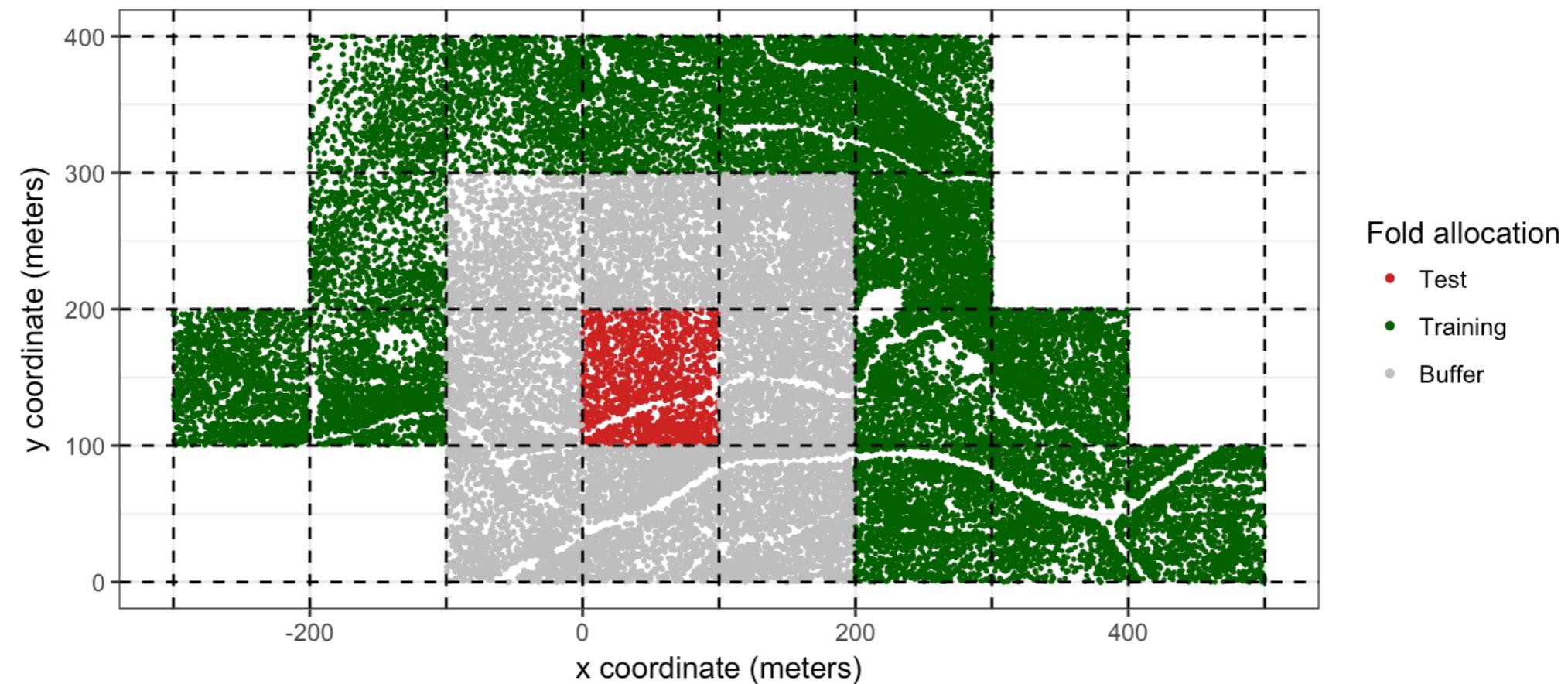


Corresponding R code at bit.ly/rudeboybert_splines

Resource 2: DataCamp Pathway

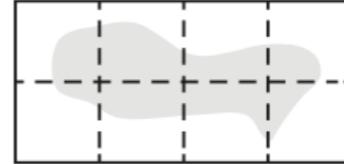
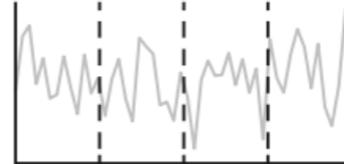
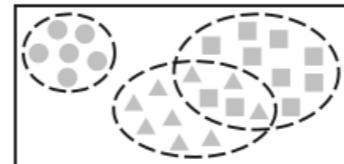
1. Build your tidyverse data science toolbox with [Introduction to the Tidyverse](#).
In particular data viz and data wrangling.
2. Just enough modeling theory & exercises with [Modeling with Data in the Tidyverse](#).
In particular Ch4 “Validation Set Prediction framework”, the bridge between modeling and...
3. Machine learning methods with [Machine Learning in the Tidyverse](#)

Our Data is Spatial: Spatial Crossvalidation



Resource 3: Paper

“Cross-validation strategies for data with temporal, spatial, hierarchical, or phylogenetic structure” [Roberts \(2017\)](#)

Dependence structure	Parametric solution	Blocking	Illustration
Spatial	Spatial models (e.g.CAR, INLA, GWR)	Spatial	
Temporal	Time-series models (e.g.ARIMA)	Temporal	
Grouping	Mixed effect models (e.g. GLMM)	Group	
Hierarchical / Phylogenetic	Phylogenetic models (e.g. PGLS)	Hierarchical	