

Parallel slopes linear regression

INTERMEDIATE REGRESSION IN R



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The previous course

This course assumes knowledge from [Introduction to Regression in R](#).

From simple regression to multiple regression

Multiple regression is a regression model with more than one explanatory variable.

More explanatory variables can give **more insight** and **better predictions**.

The course contents

Chapter 1

- "Parallel slopes" regression

Chapter 3

- More explanatory variables
- How linear regression works

Chapter 2

- Interactions
- Simpson's Paradox

Chapter 4

- Multiple logistic regression
- The logistic distribution
- How logistic regression works

The fish dataset

mass_g	length_cm	species
242.0	23.2	Bream
5.9	7.5	Perch
200.0	30.0	Pike
40.0	12.9	Roach

- Each row represents a fish
- `mass_g` is the response variable
- 1 numeric, 1 categorical explanatory variable

One explanatory variable at a time

```
mdl_mass_vs_length <- lm(mass_g ~ length_cm, data = fish)
```

```
Call:
lm(formula = mass_g ~ length_cm, data = fish)

Coefficients:
(Intercept)    length_cm
      -536.2         34.9
```

- 1 intercept coefficient
- 1 slope coefficient

```
mdl_mass_vs_species <- lm(mass_g ~ species + 0, data = fish)
```

```
Call:
lm(formula = mass_g ~ species + 0, data = fish)

Coefficients:
speciesBream  speciesPerch  speciesPike  speciesRoach
       617.8         382.2         718.7         152.0
```

- 1 intercept coefficient for each category

Both variables at same time

```
mdl_mass_vs_both <- lm(mass_g ~ length_cm + species + 0, data = fish)
```

Call:

```
lm(formula = mass_g ~ length_cm + species + 0, data = fish)
```

Coefficients:

length_cm	speciesBream	speciesPerch	speciesPike	speciesRoach
42.57	-672.24	-713.29	-1089.46	-726.78

- 1 slope coefficient
- 1 intercept coefficient for each category

Comparing coefficients

```
coefficients mdl_mass_vs_length
```

(Intercept)	length_cm
-536.2	34.9

```
coefficients mdl_mass_vs_species
```

speciesBream	speciesPerch	speciesPike	speciesRoach
617.8	382.2	718.7	152.0

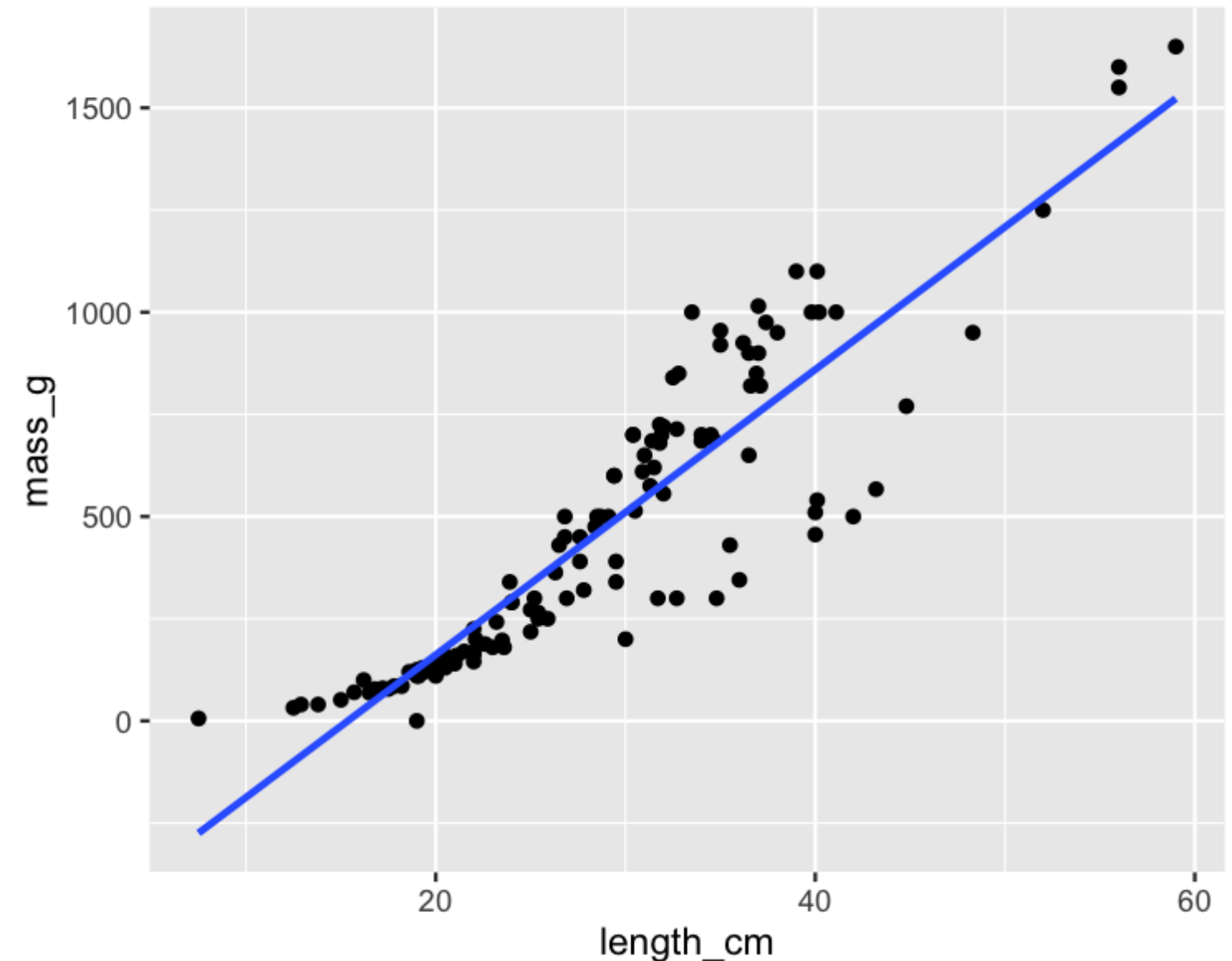
```
coefficients mdl_mass_vs_both
```

length_cm	speciesBream	speciesPerch	speciesPike	speciesRoach
42.57	-672.24	-713.29	-1089.46	-726.78

Visualization: 1 numeric explanatory var

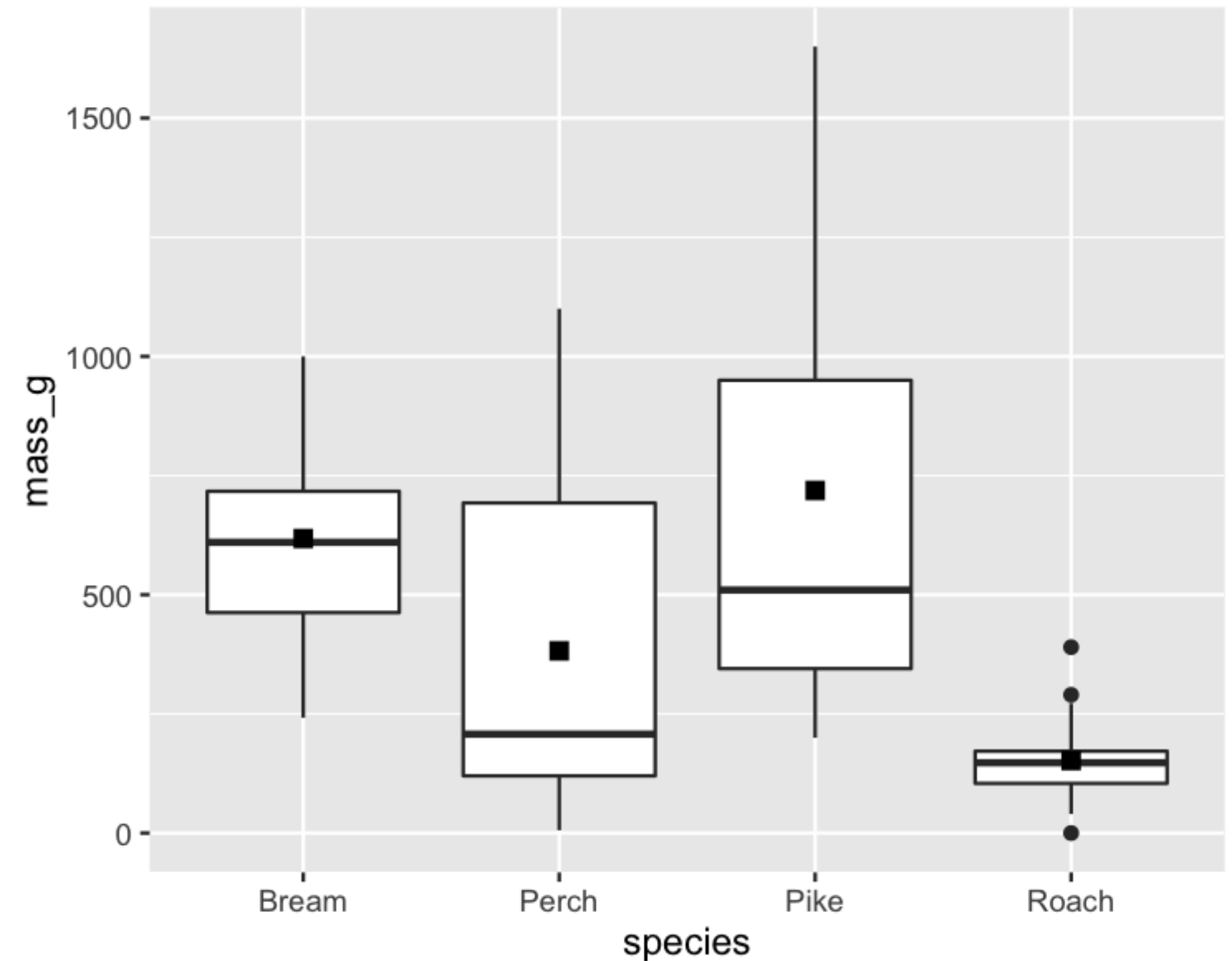
```
library(ggplot2)
```

```
ggplot(fish, aes(length_cm, mass_g)) +  
  geom_point() +  
  geom_smooth(method = "lm", se = FALSE)
```



Visualization: 1 categorical explanatory var

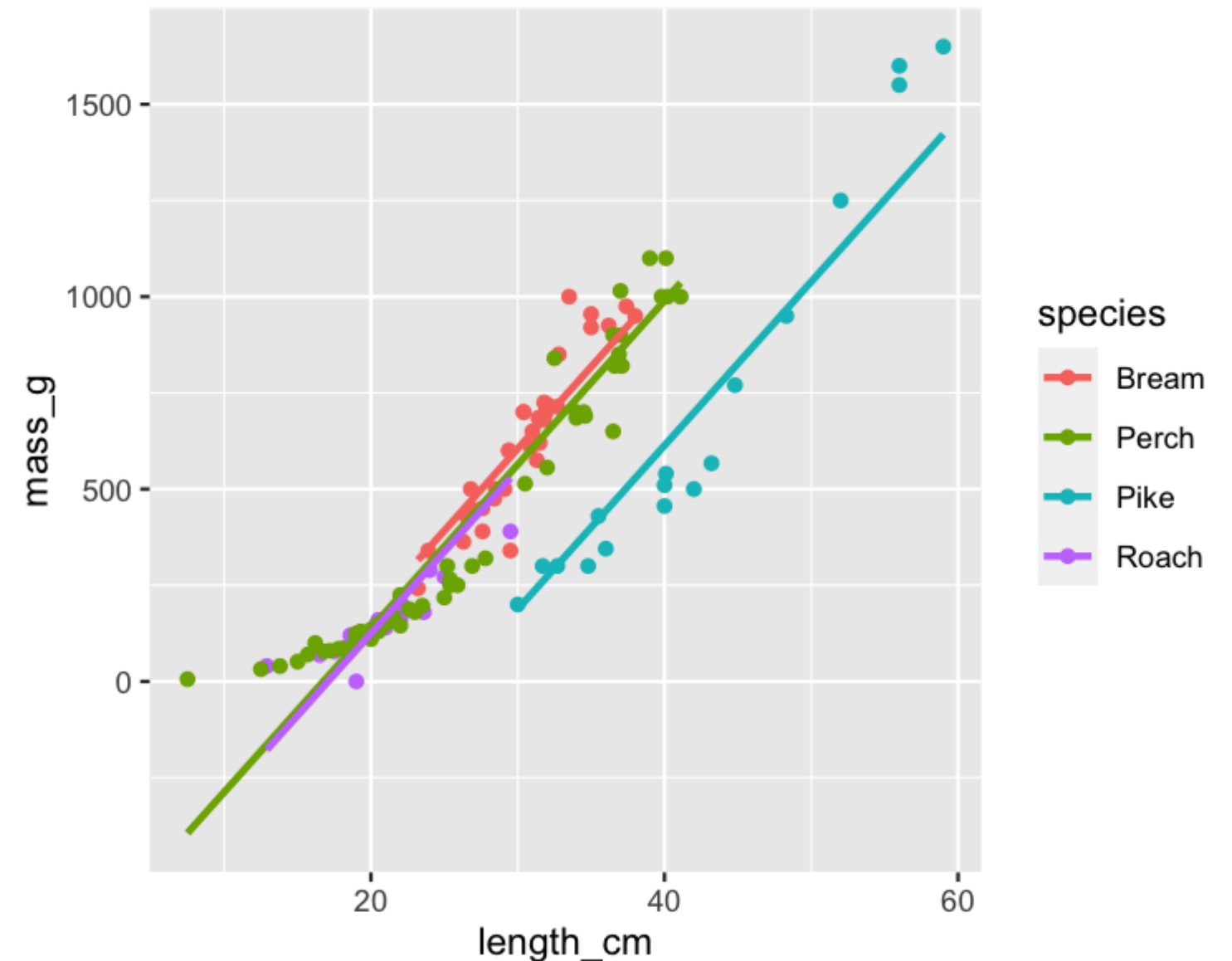
```
ggplot(fish, aes(species, mass_g)) +  
  geom_boxplot() +  
  stat_summary(fun.y = mean, shape = 15)
```



Visualization: both explanatory vars

```
library(moderndive)
```

```
ggplot(fish, aes(length_cm, mass_g, color = species)) +  
  geom_point() +  
  geom_parallel_slopes(se = FALSE)
```



Let's practice!

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Predicting parallel slopes

INTERMEDIATE REGRESSION IN R



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The prediction workflow 1

```
library(dplyr)
```

```
explanatory_data <- tibble(  
  length_cm = seq(5, 60, 5)  
)
```

```
glimpse(explanatory_data)
```

```
Rows: 12  
Columns: 1  
$ length_cm <dbl> 5, 10, 15, 20, 25, 30, 35, 40...
```

```
library(dplyr)
```

```
library(tidyr)
```

```
explanatory_data <- expand_grid(  
  length_cm = seq(5, 60, 5),  
  species = unique(fish$species)  
)
```

```
glimpse(explanatory_data)
```

```
Rows: 48  
Columns: 2  
$ length_cm <dbl> 5, 5, 5, 5, 10, 10, 10, 10, 1...  
$ species    <chr> "Bream", "Roach", "Perch", "P..."
```

The prediction workflow 2

```
library(dplyr)
```

```
explanatory_data <- tibble(  
  length_cm = seq(5, 60, 5)  
)
```

```
prediction_data <- explanatory_data %>%  
  mutate(  
    mass_g = predict(  
      mdl_mass_vs_length, explanatory_data  
    )  
  )
```

```
library(dplyr)
```

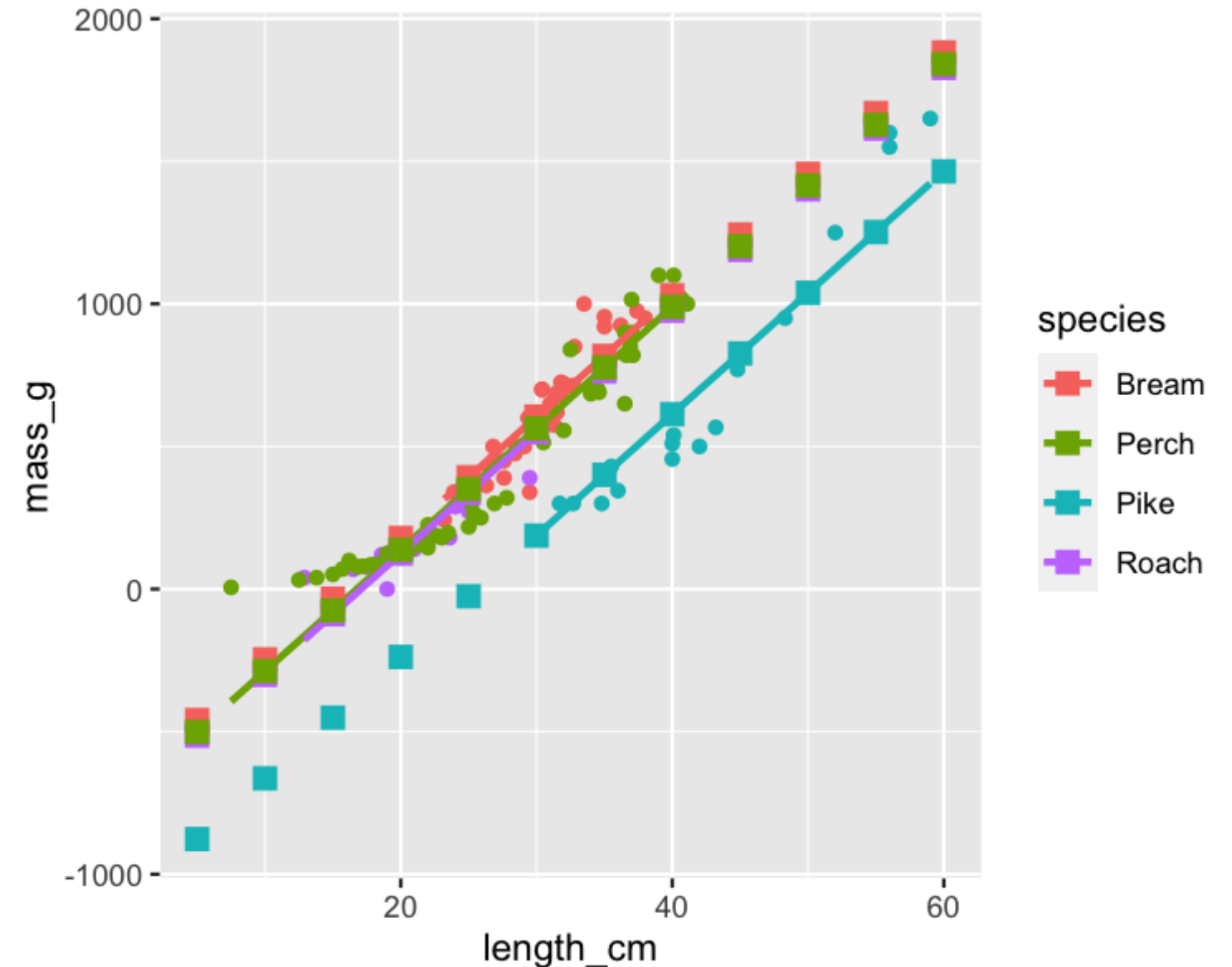
```
library(tidyr)
```

```
explanatory_data <- expand_grid(  
  length_cm = seq(5, 60, 5),  
  species = unique(fish$species)  
)
```

```
prediction_data <- explanatory_data %>%  
  mutate(  
    mass_g = predict(  
      mdl_mass_vs_both, explanatory_data  
    )  
  )
```

Visualizing the predictions

```
library(ggplot2)
library(moderndive)
ggplot(fish, aes(length_cm, mass_g, color = species)) +
  geom_point() +
  geom_parallel_slopes(se = FALSE) +
  geom_point(
    data = prediction_data,
    size = 3, shape = 15
  )
```



Manually calculating predictions

```
coeffs <- coefficients mdl_price_vs_length
```

```
(Intercept)  length_cm  
    -536.2         34.9
```

```
intercept <- coeffs[1]  
slope <- coeffs[2]
```

```
explanatory_data %>%  
  mutate(  
    mass_g = intercept + slope * length_cm  
  )
```

length_cm	mass_g
5	-361.73
10	-187.23
15	-12.74
20	161.76
25	336.26
30	510.75

Coefficients for parallel slopes

```
coefficients mdl_mass_vs_both)
```

```
length_cm speciesBream speciesPerch speciesPike speciesRoach
      42.57      -672.24      -713.29     -1089.46      -726.78
```

```
slope <- coeffs[1]
intercept_bream <- coeffs[2]
intercept_perch <- coeffs[3]
intercept_pike <- coeffs[4]
intercept_roach <- coeffs[5]
```

Choosing an intercept with ifelse()

```
explanatory_data %>%  
  mutate(  
    intercept = ifelse(  
      species == "Bream",  
      intercept_bream,  
      ifelse(  
        species == "Perch",  
        intercept_perch,  
        ifelse(  
          species == "Pike",  
          intercept_pike,  
          intercept_roach  
        )  
      )  
    )  
  )  
)
```

case_when()

```
dataframe %>%  
  mutate(  
    case_when(  
      condition_1 ~ value_1,  
      condition_2 ~ value_2,  
      # ...  
      condition_n ~ value_n  
    )  
  )
```

Choosing an intercept with case_when()

```
explanatory_data %>%  
  mutate(  
    intercept = case_when(  
      species == "Bream" ~ intercept_bream,  
      species == "Perch" ~ intercept_perch,  
      species == "Pike" ~ intercept_pike,  
      species == "Roach" ~ intercept_roach  
    )  
  )
```

The final prediction step

```
explanatory_data %>%
  mutate(
    intercept = case_when(
      species == "Bream" ~ intercept_bream,
      species == "Perch" ~ intercept_perch,
      species == "Pike" ~ intercept_pike,
      species == "Roach" ~ intercept_roach
    ),
    mass_g = intercept + slope * length_cm
  )
```

```
# A tibble: 48 x 4
  length_cm species intercept mass_g
    <dbl> <chr>      <dbl> <dbl>
1         5 Bream    -672. -459.
2         5 Roach    -727. -514.
3         5 Perch    -713. -500.
4         5 Pike    -1089. -877.
5        10 Bream    -672. -247.
6        10 Roach    -727. -301.
7        10 Perch    -713. -288.
8        10 Pike    -1089. -664.
9        15 Bream    -672.  -33.7
10       15 Roach    -727.  -88.2
# ... with 38 more rows
```

Compare to predict()

```
predict(mdl_mass_vs_both, explanatory_data)
```

```
      1      2      3      4  
-459.39910 -513.93503 -500.45009 -876.61328  
      5      6      7      8  
-246.55633 -301.09226 -287.60732 -663.77051  
# ...
```

```
# A tibble: 48 x 4  
  length_cm species intercept mass_g  
    <dbl> <chr>      <dbl>   <dbl>  
1         5 Bream    -672.  -459.  
2         5 Roach    -727.  -514.  
3         5 Perch    -713.  -500.  
4         5 Pike   -1089.  -877.  
5        10 Bream    -672.  -247.  
6        10 Roach    -727.  -301.  
7        10 Perch    -713.  -288.  
8        10 Pike   -1089.  -664.  
9        15 Bream    -672.   -33.7  
10       15 Roach    -727.  -88.2  
# ... with 38 more rows
```

Let's practice!

INTERMEDIATE REGRESSION IN R

Assessing model performance

INTERMEDIATE REGRESSION IN R



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Model performance metrics

- *Coefficient of determination (R-squared)*: how well the linear regression line fits the observed values.
 - Larger is better.
- *Residual standard error (RSE)*: the typical size of the residuals.
 - Smaller is better.

Getting the coefficient of determination

```
library(dplyr)
library(broom)
```

```
mdl_mass_vs_length %>%
  glance() %>%
  pull(r.squared)
```

0.8226

```
mdl_mass_vs_species %>%
  glance() %>%
  pull(r.squared)
```

0.7163

```
mdl_mass_vs_both %>%
  glance() %>%
  pull(r.squared)
```

0.9694

Adjusted coefficient of determination

- More explanatory variables increases R^2 .
- Too many explanatory variables causes overfitting.
- *Adjusted coefficient of determination* penalizes more explanatory variables.
- $\bar{R}^2 = 1 - (1 - R^2) \frac{n_{obs} - 1}{n_{obs} - n_{var} - 1}$
- Penalty is noticeable when R^2 is small, or n_{var} is large fraction of n_{obs} .
- In `glance()`, it's the `adj.r.squared` element.

Getting the adjusted coefficient of determination

```
library(dplyr)
library(broom)
```

```
mdl_mass_vs_length %>%
  glance() %>%
  select(r.squared, adj.r.squared)
```

	r.squared	adj.r.squared
	<dbl>	<dbl>
1	0.8226	0.8212

```
mdl_mass_vs_species %>%
  glance() %>%
  select(r.squared, adj.r.squared)
```

	r.squared	adj.r.squared
	<dbl>	<dbl>
1	0.7163	0.7072

```
mdl_mass_vs_both %>%
  glance() %>%
  select(r.squared, adj.r.squared)
```

	r.squared	adj.r.squared
	<dbl>	<dbl>
1	0.9694	0.9682

Getting the residual standard error

```
library(dplyr)
library(broom)
```

```
mdl_mass_vs_length %>%
  glance() %>%
  pull(sigma)
```

152.1

```
mdl_mass_vs_species %>%
  glance() %>%
  pull(sigma)
```

313.6

```
mdl_mass_vs_both %>%
  glance() %>%
  pull(sigma)
```

103.4

Let's practice!

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