SSA 200: Strategic Use of Data
Activity 2 – Interpreting Analysis Outputs

Objectives:

- Understand the use of AIC model selection to choose the best model out of a set of candidate models
- Interpret regression coefficients in terms of the ecological relationships they represent
- Use model outputs to make predictions

Background Information:

In the previous activity, you developed candidate model sets that represented competing ecological hypotheses for the drivers of Island Mouse occurrence, abundance, and breeding success. Here we will examine outputs from those models and use them to draw inference about the key stressors and needs for this species.

We will compare the relative support for competing models using a metric called Aikaike's Information Criterion, or **AIC**. We won't go into too much detail about AIC here, but know that it is a measure of how well the model fits the data while accounting for model complexity—the lower the value of AIC, the better the model.

For most analyses that use this method to rank models, you will see a table like this somewhere in the Results (where X, Y, and Z represent some ecological covariates of interest):

Model	AIC	ΔAIC	Np	w_i
Intercept + X	684	0	2	0.98
Intercept	693	9	1	0.01
Intercept + X + Y	698	14	3	0.01
Intercept + X + Y + Z	710	26	4	0

The actual AIC score for each model is not as important as the **ΔAIC ("delta AIC")**, which is the difference in AIC values between each model and the best model. This number tells us how much worse this model is than the best one. The general rule of thumb is that if ΔAIC is greater than 2, then it's not a very good model. If ΔAIC is less than 2, then we are uncertain about which model is better. If ΔAIC of the second-ranked model is ≥ 2, we would say there was a single best model and interpret the coefficient from that model. If ΔAIC of the next-best models are < 2, then we would use model averaging to averaging the coefficients from all models while accounting for model weight. Model averaging is not something that we will cover here. The third column in this table, Np, is the number of parameters in the model. The last column here, w_i, is the model weight. This corresponds to ΔAIC and is another way of seeing how "good" each model is relative to the others. In this example, the top model received 98% of the model weight, so we would be fairly confident that it is a better model than the others.

It is very important to note that **AIC is a relative measure of support only**. It only tells us how good each model is relative to the other ones in the model set. No matter how crappy the models you run, one of them will always have the lowest AIC score. This does not necessarily mean that the model with the lowest AIC score is a good fit for our data. There are a suite of **goodness-of-fit tests** that help us determine whether a given model fits the data, and can help us identify cases where our data do not meet the assumptions of the model we think we want to use. Frequently when AIC is used, we find the goodness-of-fit of the **global model**, which is the most complex model. We will not explore the world of goodness-of-fit testing in this course, but any time you see an AIC table, be sure to check that the authors used some test to ensure the models fit the data.

Part 1: AIC model selection

A study is conducted to measure breeding success in the Beach Bums, Dead Man's Dunes, and Misty Mountain populations. Over the course of five years, mouse nests are surveyed throughout breeding to estimate the number of offspring produced per female. Pitfall traps are also placed at each study population to estimate invertebrate abundance.

We used a Poisson generalized linear model (Poisson GLM) to estimate the number of offspring produced per female as a function of several potential covariates. We fit several different models and used AIC model selection to rank models. Goodness-of-fit testing of the global model indicated adequate model fit. The results of that process were:

Model	AIC	ΔAIC	Np	w_i
Int + Ecotype + Dune beetle + Avg temp.	830	0	4	0.575
Int + Ecotype + Dune beetle + Avg temp. + Min temp. coldest month	831.2	1.2	5	0.316
Int + Avg. temp + Min temp coldest month + Max wind speed	833.5	3.5	4	0.100
Int + Dune beetle + Percent rock/sand/clay	839.4	9.4	3	0.005
Int + Ecotype	840	10.0	2	0.004
Intercept only	844.2	14.2	1	0.000

1. **Why did we use a Poisson GLM? (Why not a normal linear regression?)**

2. **Did one model receive more support than all others? If so, which one? If not, explain your answer.**

3. **In a sentence or two, interpret the model weights for the top-ranked model(s).**

4. **What are the key ecological predictors of breeding success for Island Mice?**

Part 2: Regression coefficients

A graduate student developed a project to estimate Island mouse abundance and map the drivers of abundance across its range. His field crew conducted transect surveys at randomly-selected points across Darlost's island to estimate the abundance of Island mice while accounting for detection probability. He and his crew conducted vegetation surveys at each transect point and also recorded the presence or absence of Jack's sparrows and pirate rats each survey.

We used N-mixture models to estimate Island Mouse abundance at each site as a function of several ecological covariates. We used AIC model selection to rank models and the output is below.

Model	AIC	ΔAIC	Np	w_i
Int + Beachgrass + Noise + Avg. Temp	650	0	4	0.822
Int + Noise + Avg. Temp.	654.2	4.2	3	0.101
Int + Beachgrass + Noise + Distance to volcano	655.1	5.1	4	0.064
Int + Beachgrass + Noise + Avg. Temp + Distance to volcano + Jack's sparrow presence	658.6	8.6	6	0.011
Intercept only	662.9	12.9	1	0.001
Int + Distance to volcano + Jack's sparrow presence	665.8	15.8	3	0.000

1. **Why did we use N-mixture models?**

   a. **What type of sampling design do we have?**

   b. **What are the general assumptions of N-mixture models?**

2. **Which model received the most support? Support your answer using ΔAIC and model weight. What does that model say about the ecological drivers of abundance?**

This tells us that beach grass density, ambient noise level, and average air temperature are associated with abundance, but doesn't tell us the magnitude (weak/strong) or direction (positive/negative) of that relationship. For that, we need to look at the **coefficients** (also referred to as **β**, "beta") for those covariates in the model.

Covariate	β coefficient	SE	p-value
Intercept	-4.3	1.2	0.004
Beachgrass density	1.4	0.21	0.0021
Ambient noise level	-2.8	0.87	0.0001
Average air temperature	0.89	0.54	0.071

The table above describes the numerical relationships between each covariate and abundance of Island Mice. The β coefficient describes the magnitude (how large is the number?) and direction (is it positive or negative?) of the relationship. The standard error (SE) tells us how precise our estimate of this relationship is, which is often a function of how much data we have. This is a measure of our uncertainty in this estimate, and is used to calculate 95% confidence intervals. Finally, the p-value tells us whether this effect is statistically "significant", in other words whether or not the 95% confidence interval for the effect contains 0. If the p-value is < 0.05, then we typically say that it is a significant effect. The **intercept** (often denoted β_0) tells us about the expected condition if all covariates equaled zero. We usually don't draw inference from the value of the intercept alone.

3. **Describe the relationship between each covariate and abundance. Does it have a positive or negative effect? Is that effect statistically significant?**

Part 3: Using models to make predictions

The Island Mouse Recovery Team is interested in mapping the drivers of occurrence across Darlost's island in order to assess the suitability of other nearby islands for possible translocations. They have collected occurrence data from a variety of sources and want to use species distribution modeling to find the environmental covariates that best predict occurrence.

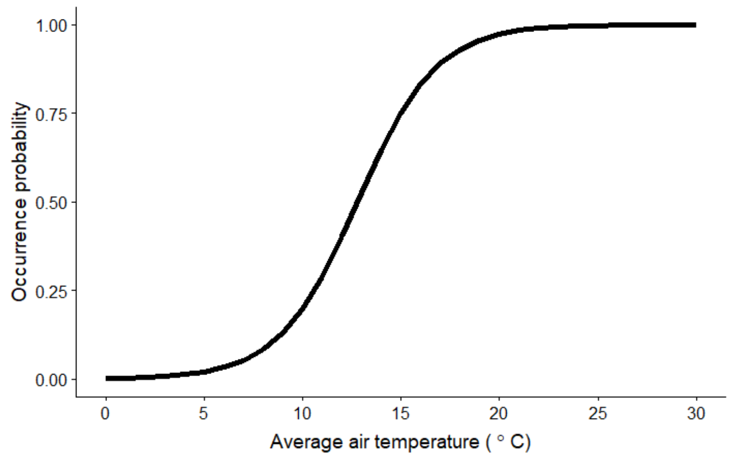
We fit a series of species distribution models and determined that the best model included average air temperature, percent cover of rock/sand/clay, and the temperature range as predictors of Island Mouse occurrence. Below are the model coefficents from the top model:

Covariate	β coefficient	SE	p-value
Intercept	-25.1	2.3	0.0001
Average air temperature	2.3	0.73	0.000026
Percent cover of rock/sand/clay	1.2	0.92	0.0032
Temperature range	-4.1	1.4	0.00085

1. **Describe the relationship between each covariate and occurrence. Does it have a positive or negative effect? Is that effect statistically significant?**

2. **Using the conceptual diagram from Activity 1, how would you interpret these results? Why are these three covariates good predictors of Island Mouse occurrence?**

From this we can see that average air temperature has a strong effect on mouse occurrence. We can visualize that relationship by plotting it (assuming all other covariates are held constant):



Use this relationship to estimate the probability of presence across Darlost's Island based on average air temperature alone. Below is a blank grid of 30x30 km squares across the island. The value in each grid is the average air temperature in °C. Use colored pencils to develop your own color scale from 0 to 1, and color in each square with corresponding probability of presence.

Probability of occurrence:

0	0.5	1

22	26	24	26	20
27	28	25	21	19
23	27	22	20	29
22	18	17	19	18
17	16	15	16	14

The Island Mouse Recovery Team is considering a few nearby islands for possible translocations of Island Mice if conditions on Darlost's Island continue to deteriorate. We can use our estimates of probability of occurrence as a suitability metric for these sites. We expect sites with high predicted probability of occurrence to be sites where Island Mice are likely to persist and thrive.

3. **Based on our analysis of Island Mouse occurrence, what should the team measure at each potential translocation site to determine if Island Mice will have a high probability of persistence there?**

Similarly to how you predicted the probability of presence across Darlost's Island above, we can use information about the new sites and the estimated relationships with occurrence to estimate the predicted probability of occurrence at each new site using the following equation:

$$p.occ = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3}}$$

Don't worry—you don't need to do these calculations by hand. Use this handy calculator (https://ssa200.shinyapps.io/logit-calculator) – just plug in the values for each covariate to get the probability of occurrence at that site.

For each of the sites below, calculate the predicted probability of occurrence from our model. Which one is the best option for possible translocations? Why?

Site A: Wallace Rock
Average air temperature = 23.5 °C
Percent rock/sand/clay cover = 30%
Temperature range = 15 °C

Probability of occurrence = ___________________________

Site B: Humboldt's Atoll
Average air temperature = 20.7 °C
Percent rock/sand/clay cover = 50.5%
Temperature range = 19.7 °C

Probability of occurrence = ___________________________

Site C: Attenborough Key
Average air temperature = 22 °C
Percent rock/sand/clay cover = 25%
Temperature range = 12 °C

Probability of occurrence = ___________________________

Site D: Isle Lyell
Average air temperature = 25 °C
Percent rock/sand/clay cover = 5%
Temperature range = 9 °C

Probability of occurrence = ___________________________