Ecology in Action: Suggested approaches and answers to Thinking Ecologically exercises, Synthesis and Application questions, and Analyze the Data questions.

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Chapter 1

Thinking Ecologically exercises

Thinking Ecologically 1.1. What types of problems might a researcher encounter when conducting aerial surveys? How might a researcher deal with these problems?

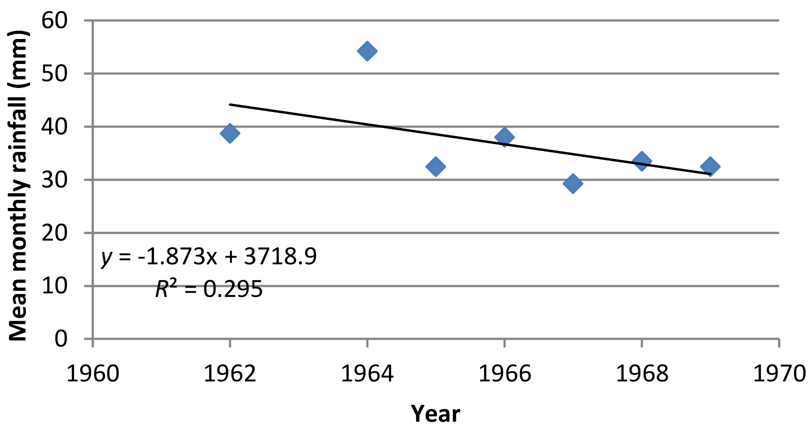
Thinking Ecologically 1.2. Use Table 1.1 to draw a scatterplot showing how rainfall in the Serengeti varied over time. Year should be the *x*-axis label, and mean monthly rainfall (mm) should be the *y*-axis label. Is this a strong or weak correlation? Is this a positive or negative correlation?

Thinking Ecologically approaches

Thinking Ecologically 1.1. Two primary problems with any type of observation are accuracy and observer effect. Both of these may present themselves in the context of an aerial survey. The problem of accuracy is straightforward: even at high altitude, a researcher has only a limited view of the ground below, meaning only a fraction of the subjects being surveyed – wildebeest, for example – will be tallied. Terrain and obstructive features such as foliage could also be factors. A further limit to accuracy is that many animals, including wildebeest, do not stand still for the duration of a survey. This movement could cause some animals to be missed and others to be double-counted. The observer effect in this case could be that the sound and/or sight of the airplane taking the survey may cause the animals to actively seek to avoid the researcher. Or, alternately, it could attract the animals to the researcher or effect other behavioral changes, potentially causing a skewed tally.

These are both difficult problems to solve. The best solution would be to increase the area that could be observed at one time, such as through a higher-altitude aircraft. This would have the double benefit of reducing problems associated with accuracy – provided that the available imaging equipment could give an acceptable resolution – and reducing the effect of the observer upon the observed subjects. Of course, researchers in the real world are limited by such things as funding, so it becomes necessary to strike a compromise between the ideal and the affordable.

Thinking Ecologically 1.2. This would be a moderate negative correlation. It would be difficult to draw any conclusions because of the small sample, but clearly rainfall did not increase (which is what Sinclair was interested in):



($r = -0.543$, $P = 0.208$).

Synthesis and Application questions

1. In Sinclair's exclosure experiments (Figure 1.3), grasshoppers and rodents were able to access the exclosures and eat some of the grass. This might decrease grass growth within the exclosures. Is this a problem for Sinclair's using rainfall as a measure of food availability? Why or why not?

2. Dennis Normile (2008) wrote an article entitled "Driven to extinction," in which he argues that rinderpest may be the second disease that has been driven to extinction by an aggressive vaccination campaign (smallpox being the first). What types of evidence would you need before you felt confident that an infectious virus had indeed been driven to extinction? How would you collect those data?

3. What do you think would happen to lion cub survival following an unusually wet and cool dry season in the Serengeti? Explain your reasoning.

4. Think of a model that influences your everyday life. Why is this model useful? In what way is this model a simplification of reality? Is the model primarily descriptive, or predictive, or both?

5. If you were given three years to do research in the Serengeti, what question might you ask? How would you go about answering it?

Synthesis and Application: possible answers

1. The relative effect would probably be minor, because rodents and grasshoppers would also be grazing in the non-exclosed environment as well. There are a few considerations, however. First, the exclosure presumably has taller grass, which may be coarser and have fewer nutrients, and make grass in exclosures less desirable to rodents and grasshoppers.

Also, buffalo fertilize the grass with their droppings, so that could influence grass nutrient levels and make rodents and grasshoppers less likely to eat grass from exclosures. Alternatively, the small grazers may be annoyed by buffalo, or prefer exclosures for a variety of reasons, and be more likely to spend time in the buffalo-free exclosures. In reality, none of these issues are likely to be very important (but are worth considering).

2. Time is a big issue. Historically, has there been a cycle to rinderpest eruptions? If so, we would need to have a much longer rinderpest-free period elapse than the period of the cycle. These data should be available from historical records. Second, I would journey to regions of the world that historically had been rinderpest reservoirs to confirm that there are no infections in those areas. To do that, I would need to know which species are possible hosts. Third, I would learn more about the virus itself. Can it live in soil or water, or does it need a host? If it can exist outside of a host, how long does it retain its ability to be transmitted to a host?

3. Based on Figure 1.3, a wet and cool dry season is associated with high grass production. According to the model described in Figure 1.6, high dry-season rainfall should dramatically increase wildebeest populations. This bodes well for increased survival rates of wildebeest juveniles, which should translate to greater lion cub survival (and perhaps higher lion cub birth rates as well).

4. There are many models to choose from. The key is to emphasize three points: the usefulness of models, their inherent limitations, and their descriptive and/or predictive capacity. Common examples include weather forecasts (predictive models used in nearly every walk of life, largely based upon comparisons of current atmospheric conditions to historical trends), statistics often cited on the news (usually descriptive models that reduce entire populations, or segments of populations, to easy-to-digest categories – the average weight of middle-aged men, for example), or medical recommendations (models that are both descriptive and predictive, such as identifying a certain category of people who are susceptible to heart disease). Animal models (such as mice, rats, or zebrafish) are used to test medicine and other products and to gain insight into how these products might be expected to affect humans. Any type of personal schedule, recipe, research protocol, or even a paper outline could be considered a model. Even less obvious (bordering on philosophical) is any individual's perception of the world around them. Since a model is simply a representation or approximation of reality, and human beings process their surroundings indirectly through electrochemical interactions within the nervous system, then the experience of existence itself is a model. This model is both descriptive (that apple is green) and predictive (the car will move forward when you push the gas pedal).

5. The answer should be a logical follow-up of a topic considered in Chapter 1. Some possible research questions could include: (1) Is rinderpest really extinct worldwide? (2) Do different species of large mammals prefer different types or ratios of grass species? (3) Is there a pattern to grass preferences in relation to the amount or ratio of available nutrients, or to time of year? (4) Do the same factors that favor increases in buffalo also

influence other grazers? (5) Is there a relationship between abundance and richness of large mammals? (6) Is there a relationship between tree density and grass nutrient levels? (7) Are other factors, in addition to fire and elephants, important in determining whether a particular ecosystem in the region is woodland or grassland? (8) Do other regions of the world show ENSO-related cycles? Each of these questions can be approached using a variety of observational and experimental methods.

Chapter 2

Thinking Ecologically exercises

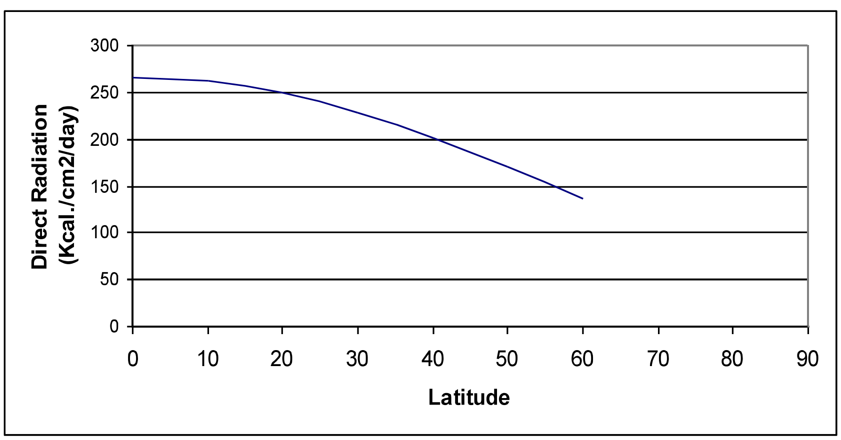
Thinking Ecologically 2.1. John Buffo and his colleagues (1972) wanted to know how much direct radiation struck the Earth at different latitudes. Can you extrapolate from Table 2.1 an estimate of the direct radiation striking the North Pole over a one-year time period (see Dealing with Data 2.1)?

Thinking Ecologically 2.2. What assumptions does Erwin's extrapolation make? How might you test whether these assumptions are valid?

Thinking Ecologically 2.3. There were many different types of diatoms and chironomids at different depths of the Lake Yoa core. Modern African lakes vary in salinity and in the species composition of diatoms and chironomids, with lakes of similar salinity levels tending to have similar species composition. The researchers inferred salinity levels in the past 6000 years by comparing the species composition of the core with salinity levels and species composition of modern lakes. What assumptions does this inference make, and does it seem valid to you?

Thinking Ecologically approaches

Thinking Ecologically 2.1. The values in Table 2.1 follow a curve, depicted in the graph below.



By extending the curve through to the 90° line, we can estimate that the poles receive somewhere around 20 kcal/cm^2/day. This extrapolation, however, assumes that the amount of solar radiation received by latitudes beyond 60° north or south follows the same pattern as the lower latitudes. As mentioned in Dealing with Data 2.1, this assumption may not be valid owing to the nonstandard day/night cycle for higher latitudes.

Thinking Ecologically 2.2. Erwin's major assumption was that linden trees contained a population of arthropods that was representative of other trees within the rainforest. Given the estimate of approximately 50 000 unique species of tree within the forest, this assumption could be subject to severe sampling error. For example, linden trees may be more attractive to insects owing to greater size, greater diversity of microhabitats or lower defenses than other tree species. Or, for a variety of reasons, linden trees may have a higher or lower proportion of beetles in their canopy. Researchers should survey arthropod species density living upon and within a wide range of rainforest trees to test whether this assumption was valid, overstated, or understated.

Thinking Ecologically 2.3. The primary assumption made here is that the salinity preference of the reference species has not changed in the past 6000 years. Given what we know about the rate of evolutionary change, this assumption seems very valid. There exist several ways to test the validity of this approach, such as a comparison of other salinity estimates for the same time period (oxygen isotope analysis of fossilized foraminiferan shells, for example) to the presence or absence of the diatoms and chironomids used in the Lake Yoa study. Such crosschecking increases the confidence of salinity estimates and helps prevent potential mistakes in data analysis.

<u>Synthesis and Application questions</u>

1. The angle of the Earth's axis fluctuates between 22.5° and 24° over a regular 41 000-year cycle. How do you think this periodic fluctuation would affect global temperature patterns?

2. There is a dispute among conservation biologists regarding whether fire suppression leads to larger fires. As it turns out, fire suppression has been practiced extensively in the USA, but only to a very small extent in Baja California, Mexico. Based on Figure 2.20, can you conclude that fire suppression has led to larger fires? Why or why not?

3. Use Figure 2.26 to calculate the turnover time for ocean water. Why is this value so much larger than the value for atmospheric water?

4. Reconsider Schindler and Fee's experimental design for Experimental Lakes 226 and 227. Would the results be more convincing if the researchers had tried adding only carbon (C) to one lake, phosphorus (P) to a second lake, nitrogen (N) to a third lake, C and P to a fourth, C and N to a fifth, P and N to a sixth, and C, P, and N to a seventh lake? What would be the advantages to such a design, and in what way(s) would it be inferior to Schindler and Fee's experiments?

5. The mangrove/sponge interaction (Ellison et al. 1996) is an example of a mutualism. Do you think that mutualisms should be more common in stressed biomes such as mangroves, or in less-stressed biomes such as coral reefs? Explain your reasoning and suggest how you might go about answering this question.

6. Based on Table 2.3, which of the village biomes seems most distinct from the other five? Which two village biomes seem most similar? Explain your answers.

Synthesis and Application: possible answers

1. Presumably the differences between the seasons would increase as the tilt approaches 24° and decrease as it approaches 22.5°. You would also expect that monsoons would wander further north and south as the angle increases.

2. This is difficult to measure, but the fires seem about the same size – perhaps the fires north of the border are a bit larger. This could raise the issue of whether recent policies to let fires burn are warranted. We must be careful with drawing this conclusion, however: this figure does not account for other factors that may influence the spread of large fires, such as weather patterns and human population density. Clearly we need to look at other regions, but it is likely that fire policy should be considered on a regional, rather than global, basis.

3. Approximately 3 239 years. The ocean has a very low surface area to volume ratio, so evaporation rate is very low and thus the turnover time is very high.

4. The point here is that the design was not optimal, but that doing science involves making compromises between elegant experimental design vs. practicality and feasibility. Even if all combinations could be tested independently, you would then need to address the issue of replication – each combination should probably be done at least two and maybe three times. So elegance can get out of hand. You could also take the opportunity to raise questions about the ethics of adding nutrients into numerous lakes, given the ecosystem disruption such a manipulation is likely to cause. Finally, the curtain experiment should be discussed in the context of its being very sexy and that it raised public awareness of eutrophication and the influence of phosphates.

5. This, of course, raises a red flag about how you measure stresses in biomes. Assuming that can be done, you might expect mutualisms to be more common if conditions are more stressed (we discuss this in Chapter 15). Presumably natural selection favors the evolution of mutualisms under more stressed conditions, because mutualisms help survival and reproductive success. A meta-analysis of mutualism frequency in relation to stress would address this question. Students will not learn about meta-analyses for several chapters, but they should be able to articulate that they could go through the literature to see how many mutualisms are reported in stressed biomes, and the clever ones will wonder how many interactions have actually been studied within these biomes.

6. The Crop and Pastoral biome has by far the lowest NPP and the highest percentage of bare ground. On the other hand, the Rainfed Mosaic biome has by far the highest NPP and the lowest percentage in crops. And paddy rice has, not surprisingly, the greatest percentage in rice by far, and the lowest percentage in pasture. So you can make a good case for any of these. Irrigated and Rainfed biomes seem to be similar in most attributes

with the exception that Irrigated has a much higher percentage of land that is irrigated (again not surprisingly).

<u>Analyze the Data questions.</u>

Analyze the Data 1. Reconsider the data in Table 2.1. This time do a linear regression analysis of the data. If you entered the numbers properly, you will get a regression equation that looks something like this: direct solar radiation = 283 048 – 2224 (latitude). If you plug in the value for the North Pole, your regression equation will estimate the direct solar radiation there. How does this estimate compare to your extrapolation estimate? Why is your extrapolation estimate likely to be more accurate than the value predicted by the linear regression equation?

Analyze the Data 2. Refer back to Table 2.2. Graph the relationship between elevation and atmospheric pressure. What atmospheric pressure would you predict at 15 km? Did you use extrapolation or linear regression? Explain your choice.

<u>Analyze the Data answers</u>

1. The regression analysis predicts 82 888 cal/cm^2/day at the North Pole. This should be considerably higher than the student's previous extrapolation, because the relationship is clearly not linear, but instead curves downward as latitude increases. This also provides an opportunity for the instructor to explain to the students to be wary of using regression analysis to predict outside of the range of the data set.

2. This is definitely nonlinear, so the best approach would be extrapolation (or nonlinear regression, which we will not worry about). A reasonable extrapolation would be between 10 and 15 kPa.

Chapter 3

Thinking Ecologically questions

Thinking Ecologically 3.1. Looking carefully at the Mauna Loa data, you can appreciate that the slope of the increase in CO_2 levels is somewhat variable from year to year. Use Figure 3.1 to propose hypotheses for this variation. Then propose ways of testing your hypotheses.

Thinking Ecologically 3.2. When glaciers and snowfields melt, they expose Earth's surface underneath. Will this tend to increase or decrease surface temperatures? Is this an example of positive or negative feedback? Explain your answer in terms of the albedo of the surfaces involved in this process.

Thinking Ecologically approaches

1. The rate of increase was lowest until 1977 and increased until about 1988; it then slowed down until about 1995 or 96, and them increased dramatically thereafter. It is now increasing at its most rapid rate. One explanation for the general increase is an increase in the burning of fossil fuels. We could see whether fossil fuel burning has increased, and whether it leveled off between 1988 and 1995. A second hypothesis for the leveling off of the increase in 1988–95 would be an increase in the land sink during that period of time. As I mention in the text, we don't have a great handle on the elements of the land flux, though we do know that heavy rainfall can lead to increases in the land sink as CO_2 uptake by forests increases. So we might look at those data to see how well they explain the leveling off.

2. It depends on the albedo of the glaciers and snowfields, and on the albedo of the surface that exposed by the melting glaciers. Higher albedo reflects more radiation, some of which will escape into space. In general, snow and ice have relatively high albedo, so they will tend to reduce surface temperatures. So when the increased temperature melts snow and ice, it leads to more radiation being absorbed by the high-albedo surface, less radiation being reflected into space, and a subsequent increase in surface temperature. This is a positive feedback interaction, because an increase in temperature sets up a process for a further increase in temperature.

Synthesis and Application questions

1. There are regions of the tropics and subtropics with highly acidic soils. Reflecting on the research of Xie et al. (2009), how might these soils influence the global carbon cycle?

2. Burning coal releases aerosols and soot into the atmosphere (in addition to CO_2). What are the positive and negative feedbacks associated with reducing our use of coal as a fuel source?

3. For each of the following, what ecological effect would you expect to result from global climate change: health of Earth's mangrove forests; distribution, abundance, and composition of coral reefs; geographic range of the tropical forest biome; geographic range of the world's deserts?

4. Some researchers have argued that people are unlikely to act for the general good, because as individuals they may get a very small benefit and incur high costs from doing so. How does this argument tie into the question of climate change, and the role played by individuals, corporations, and nations in addressing the problem?

5. Which of the five SSPs seem most plausible to you?

6. Some researchers have suggested shooting sulfur dioxide gas into the stratosphere as a mechanism of addressing global warming and climate change. How might this work, and why might this be dangerous?

Synthesis and Application: possible answers

1. You would expect the opposite response, with CO_2 efflux from these soils into the atmosphere (the soils would be a CO_2 source).

2. Burning coal introduces soot into the air, which absorbs radiation and raises air temperature at the location at which it is absorbed. Decreasing coal use will reduce the amount of soot, and reduce that warming effect. There will also be less deposition of soot on surfaces, which will increase albedo, reflect more radiation, and decrease surface temperatures. However, there is a possibility that decreasing soot will allow more sunlight to actually reach Earth's surface, which will cause an increase in the amount of radiation absorbed by the surface and thereby increase surface temperatures. Of course the CO_2 released by coal combustion will increase surface temperatures by increasing the absorption of long-wave radiation emitted by Earth's surface.

3. Health of Earth's mangrove forests: As sea level rises, some mangrove forests will disappear, or species composition will change to more flood-resistant species (assuming the correct propagules are present). As temperatures warm, the northern and southern extents of these primarily tropical species may expand in the direction of more temperate biomes.
Abundance and composition of coral reefs: Warmer ocean temperatures will kill many corals through bleaching, and will also select for high-temperature-tolerant zooxanthellae, which may replace the less heat-tolerant strains. In addition, increased ocean acidity has been shown to inhibit coral growth. On a larger spatial scale, coral reefs may also expand towards higher latitude, and will probably disappear from tropical latitudes.
Geographic range of the tropical forest biome: Forest biomes will probably shrink, as high evapotranspiration rates will not support as large a range of tropical forests.

Geographic range of the world's deserts: Deserts are expected to increase with high temperatures and with many areas expected to get reduced rainfall, or fewer episodes of more extreme rainfall.

4. Fighting climate change will require some sacrifice, which, in the short term, individuals, corporations, and nations are unlikely to be excited about supporting. However, climate change is a long-term process whose effects are becoming clearer with the passage of time. As the effects become more pronounced, these three groups will be under greater pressure to act in a way that mitigates the effects of climate change. But many individuals will resist making sacrifices, and will simply deny that change is happening, or use the spurious argument that climate change is natural. National politics can influence how individuals respond, by creating incentives for solar panels or other CO_2 reduction devices. Of course, individuals and corporations both influence national politics in many ways. Individuals, corporations, and nations may find it in their best interest to cooperate, building alliances to help fight climate change directly by reducing emissions or, less likely. by coming up with technical fixes such as the sulfur dioxide gas proposal (see Question 6).

5. Aspects of all five pathways are likely to be important. SSP5 will be most appealing to many, because it has the potential to mitigate climate change while requiring very little sacrifice by individual and corporations. The answer to this question depends, in part, on a person's level of optimism vs. cynicism.

6. Historically, high sulfur dioxide levels in the stratosphere, from volcanic eruption, are associated with global cooling. Two mechanisms are involved: reflection of the sun's rays back into space, and increased cloud formation. So, in theory, increasing sulfur dioxide levels could lead to cooling. However, there are many problems with this approach. First, sulfur dioxide interferes with ozone formation, which will lead to an increase in UV radiation reaching Earth's surface, and most likely an increase in cancer levels. Second, reduced solar radiation may decrease photosynthetic rates. Third, increased atmospheric sulfur will lead to more sulfuric acid raining down upon terrestrial and aquatic ecosystems. Consequent reduction in soil and water pH are likely to have substantial negative effects on biomes across the world.

Analyze the Data questions

Analyze the Data 1. Here are the data for 24 years of carbon flux into oceans, land, and the atmosphere (Le Quéré et al. 2020). How have these fluxes changed, and which are statistically significant? Which trends seem most concerning to you? Which data show the greatest amount of variation from year to year? Use what you have learned about the carbon cycle to suggest plausible hypotheses for this variation.

Analyze the Data answers

1. The approach here is to first look at the data and see which changes seem most consistent. Clearly, fossil fuel + cement is increasing very steadily after 1996, while at the same time ocean sink is also increasing, with some exceptions. The other three variables are much less consistent. We might expect that the processes that are relatively environment-independent would be most consistent, which would explain why fossil fuel emissions continue to climb steadily (though they do have some environment dependence).

Having looked at the data, we could subject each variable to a simple linear regression in relation to year. Again, eyeballing the data, we expect high coefficients of determination for fossil fuel + cement and for ocean sink. Here they are:
Fossil fuel + cement: $R^2 = 0.965$ (strong positive correlation)
Ocean sink: $R^2 = 0.866$ (strong positive correlation)
Looking at the ones that appear less clear from eyeballing...
Land use change: $R^2 = 0.219$ (weak positive correlation)
Atmospheric increase: $R^2 = 0.229$ (weak positive correlation)
Land sink: $R^2 = 0.13$ (very weak positive correlation – not statistically significant)
Your alert students might point out that even the fossil fuel relation is distinctly nonlinear (it curves up between 2001 and 2011, and then flattens out somewhat after that). That's an opportunity to go into nonlinear regression (I'd only do a qualitative discussion of that)!

The next challenge is to figure out which trends show greatest variation from year to year. Again, I always begin with eyeballing the data. Both land sink and atmospheric increase seem quite variable, with land sink showing no clear pattern and atmospheric increase trending up. Analytic approaches to this question are challenging, particularly on an introductory level. One approach is to use a spreadsheet program to subtract one year's value from the previous year's value and then take the absolute value of those differences. Calculating the mean for that value indicates that Atmospheric increase and Land sink are the two variables with the greatest mean change in value from year to year.

Mean year–year change for Fossil fuel + cement = 0.16
Mean year–year change for Land-use change = 0.13
Mean year–year change for Atmospheric increase = 1.11
Mean year–year change for Ocean sink = 0.09
Mean year–year change for Land sink = 0.74

You might be content with that, but your ever-alert students might point out that maybe we should be thinking about the percent change from year to year. In that case, Land sink and
Atmospheric increase show very similar variation from year to year (which again is easy to show with a spreadsheet).

Chapter 4

<u>Thinking Ecologically questions</u>

Thinking Ecologically 4.1. How does the mean beak depth of juveniles in Figure 4.7 compare to the mean beak depth of drought survivors (Figure 4.6B)? Given that drought survivors were the parents of the juveniles in 1978, would you expect the mean beak depth to be identical? Why or why not?

Thinking Ecologically 4.2. Although natural selection favored shallow beaks after the El Niño of 1983, sexual selection might still favor large-beaked males. What types of data could you collect to understand the relative influence of natural selection and sexual selection in this population?

Thinking Ecologically 4.3. Propose two potential benefits to the alternative migration route to Britain. What data would you collect to test the predictions of each proposed benefit?

<u>Thinking Ecologically approaches</u>

Thinking Ecologically 4.1. The mean beak depth of juveniles born to survivors (ca. 9.7 mm) is lower than that of the survivors themselves (ca. 10.1 cm). Beak depth is influenced by factors other than strict genetics. Body size is a strong influence on beak depth, which can be a result of environmental pressures and juvenile nutrition. Chance could also play a role, as the population size of survivors decreased dramatically. This decrease in population would amplify the effects of random mating success and offspring survival. We should expect that the mean beak depth of juveniles born to drought survivors would increase from the predrought mean, but it would be unlikely to exactly match the mean beak depth of the parental generation due to nongenetic influences.

Thinking Ecologically 4.2. For effects of natural selection on beak size, I would see whether there was an inverse relationship between beak size and survivorship after the El Niño (and after wet years in general). To see whether sexual selection still favored large beaked males in those years, I would measure beak size of all males, and attempt to study mating success by counting numbers of females they associated with (or copulated with, but that is easy to miss). In addition, I would do a DNA fingerprinting study of males and all of the offspring produced in the population after wet years, to see how mating success relates to beak size.

Thinking Ecologically 4.3. First, it is a much shorter flight to Britain, and presumably less energetically expensive to get there for overwintering. Second, changing climate (or other factors) might be making the overwintering grounds warmer and/or better supplied with insects for them to eat during the winter. Third, there may be less resource competition in Britain. These hypotheses are not mutually exclusive. The energetic argument could be tested by weighing birds before departure from Germany and after arrival on the wintering grounds. This hypothesis predicts the British birds should have lost less weight. The second hypothesis could be tested by looking at temperature and wind speed data over the past years at the wintering areas in Britain. The prediction would be for increased warming and greater insect abundance. The competition hypothesis would be a serious challenge. It might be possible to initially measure insectivorous bird density in Iberia and Britain – predicting that it might be lower during the British winters.

Synthesis and Application questions

1. Why might some species of bacteria show antibiotic resistance, even if their parent cells never encountered antibiotics?

2. If you were to take eggs from large-beaked finch parents and exchange them with eggs from small-beaked finch parents, what size will the beaks of these offspring be when the birds reach adulthood? What information would you need in order to answer this question?

3. Why is it important to consider antibiotic resistance as a local or global phenomenon? How might the answer to this question influence the way your physician might decide how to treat an infection?

4. What strategies would you recommend for curtailing the spread of antibiotic-resistant strains of bacteria?

5. Finding a positive correlation between parent and offspring beak depth supports the hypothesis that variation in beak depth is heritable. Can you think of alternative (nongenetic) explanations for a positive correlation? What other factors, besides genetics, might influence the size of a body part?

6. As discussed in the text, we have evidence that European blackcaps mate assortatively. We don't know if they are in the early stages of speciation. Imagine you were given the task of evaluating whether these two different migratory routes will ultimately lead to speciation. What hypotheses would you test, and what data would you collect to help you evaluate the predictions of these hypotheses?

7. Reconsider Andrade's (1996) data testing the predictions of the paternal effort hypothesis and the mating effort hypothesis (Table 4.4). Are the two hypotheses mutually exclusive? How confident are you with rejecting the mating effort hypothesis?

8. Consider Bell and colleagues' (2004) data (Table 4.3) on the changes in phenotype frequency in Logan Lake. What would be your prediction for the frequency of the low-plated phenotype in 2002?

9. Does the association between overwintering in Britain and larger clutch size mean that British blackcap males are providing more for their females than are Iberian blackcap

males? Can you think of alternative explanations for this finding? What might be a better measure of fitness than clutch size?

10. Lukas Keller and his colleagues (2002) showed that approximately 65% of the variation in beak depth is heritable in finches. What are the consequences of this finding for the rate of evolution of beak depth and the amount of variation in beak depth you might observe after a flood or drought?

Synthesis and Application: possible answers

1. Antibiotic resistance, at least in many cases, arises from random mutations. Because bacteria reproduce so quickly, random mutations conferring resistance may spontaneously arise in a population.

2. Since 65% of beak depth is heritable in these finches, we would assume this figure as a starting point. Thus there should be a pretty good correlation between parent and offspring beak size. Since the rest of the variation in beak depth is not explained by genetic factors, we need to consider external influences. Do large-beaked finches care for their young differently? Do the young get more food from large-beaked parents? Does the increased body size of the large-beaked parents encourage beak growth in offspring (by providing more heat to growing young, for example)? Do large-beaked parents tend to select different microclimates for nest construction, or have territories with more food or less?

3. Pathogens such as bacteria do not simply affect a single patient. They are contagious and spread from host to host. If the bacteria are normally combated with an antibiotic, and resistance to that antibiotic develops in even one host, that resistant strain has the potential to spread unchecked throughout a population. If a patient takes the entire course of antibiotics, it is more likely that the vast majority of the bacteria will be killed, with the remainder handled by the patient's immune system.

Resistant bacteria are normally at a fitness disadvantage compared with susceptible bacteria in the absence of an antibiotic, and so are fairly limited within such an untreated environment (though compensatory mutations are becoming more of a problem). If an antibiotic is introduced, however, natural selection then favors the resistant bacteria in the novel environment.

Presumably your physician knows all of this, but there can be substantial pressure from patients to prescribe something, even if that something will be ineffective (like an antibiotic to fight a viral infection such as a cold). Over time, the effectiveness of most antibiotics has declined substantially, from overprescription and also from overuse by the agriculture industry.

4. There are several possible approaches to combat the rise of bacteria resistant to antibiotics. These include making sure that patients take their full course of antibiotics, limiting the over-use of antibiotics, and treating certain infections known to have resistant