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I. INTRODUCTION TO ECOLOGY

1. Who invented the term ecology and how did he define it?
2. Describe the relationship between ecology and evolution.
3. Briefly describe the kinds of ecology (i.e., give a few examples of the kinds of what those ecologists might study) as classified according to levels of biological organization.

II. INTRODUCTION TO NATURAL SELECTION

1. Describe the conditions under which natural selection will occur and explain what the result of selection will be. Are those conditions met in nature? Illustrate your description with the example of the increase in frequency of DDT resistance in mosquitoes.
2. Briefly discuss the relationship between natural selection and genetic variation. Does selection cause favorable variation to arise? Use the DDT example to illustrate.
3. Describe the principle of allocation and explain its effect(s) on natural selection.
4. Describe developmental/mechanical constraints on selection.

III. THE ABIOTIC ENVIRONMENT AND NATURAL HISTORY

A. Terrestrial environments - soils

1. What is soil? Describe the basic structure of soil with attention to the processes involved in forming each and the relationship(s) among the layers.
2. What are the major components of soil?
3. Describe the relationship (including underlying causes) between soil particle size and nutrient capacity (cation exchange capacity) and water capacity.

4. Do soils with high cation exchange capacities always hold large quantities of nutrient cations? Explain.
5. Do soils with high water capacity always have high amounts of water available to plants? Explain.

B. *Terrestrial environments - climate & biomes*

1. Describe the general effects of the earth's tilt on its axis on patterns of sunlight, daylength, and temperature.
2. Discuss the mechanism(s) by which variation in sunlight gives rise to global patterns of air circulation and precipitation (and describe those patterns!).
3. Describe the general effects of mountains and ocean currents on local climate.
4. Discuss the general factors that determine productivity in terrestrial biomes.
5. Compare and contrast the general climate conditions, approximate locations, soil properties (not technical names), types of vegetation, and diversity of vegetation (not names or numbers of species), and general levels of productivity in tropical rainforest, boreal coniferous forest, temperate deciduous forest, and temperate grasslands. How do fire and grazing affect the structure of temperate grasslands?

C. *Aquatic environments*

1. List the major reservoirs of water on earth, the approximate proportion of water in each, and the patterns and processes involved in the hydrologic cycle.
2. Describe the major zones of oceanic environments. In which zone(s) does/do PSN take place?
3. Describe the physical characteristics that are primarily responsible for the ecological characteristics of ocean environments. Describe the general patterns of variation for each of those characteristics.
4. List the major types of water movements in the ocean and briefly discuss their effects on ocean ecology.
5. What key factors determine the productivity of oceanic environments (be sure to mention any major limitations on productivity as well)? Describe the general conditions in salt marshes and coral reefs, and explain how those systems overcome limitations to productivity.

IV. THE ECOLOGY OF INDIVIDUAL ORGANISMS

A. *General principles*

1. Describe the general conceptual framework of physiological ecology as presented in class. What kinds of questions do physiological ecologists ask?
2. How does the abiotic environment constrain individual organisms? Define microclimate and contrast variation in microclimate with variation in macroclimate. List (and, if necessary, briefly describe) some of the main factors that cause microclimate variation. Give an example of each.
3. Discuss the consequences for individual organisms of the fact that biological molecules have limited tolerance to abiotic conditions.
4. Outline the general flow of energy through an individual organism. Define the allocation principle, and discuss the implications of that principle for homeostasis. What general rule should organisms follow when deciding how much energy to allocate to homeostasis?
5. Compare and contrast conformers and regulators in terms of their levels of homeostasis and the relative advantages and disadvantages of each strategy. Can most organisms be classified as either strict conformers or strict regulators? Defend your answer.

B. *Illustrating physiological ecology -- temperature relations*

1. Why is temperature considered an important abiotic factor for most organisms?
2. Compare and contrast the thermal properties of air and water and explain how those differences constrain the potential thermoregulatory strategies of aquatic organisms.
3. Write the model for the heat budget we used in class and define each of its terms.
4. Define the terms poikilotherm, homeotherm, endotherm, ectotherm, and heterotherm as used in this course. Be sure to explain the relationships (if any) among them. Describe the relative costs and benefits of each strategy.
5. Explain the thermal challenges faced by desert plants and describe the adaptations of non-succulents to those challenges. Be sure to discuss any constraints that prevent potential strategies from being used.
6. Explain the thermal challenges faced by the alpine lizards of the high Andes. What general kinds of thermoregulatory strategies are available to animals that aren't

available to plants? Describe the adaptations of alpine lizards, including attention to any constraints that they may face.

7. How do large moths maintain constant body temperature? Describe Heinrich's experiments and explain how his experimental design and results confirm his hypothesis.
8. Describe the thermal strategies of skunk cabbage. What advantage do these plants gain from the ability to maintain body temperatures above ambient? What is/are the likely cost(s) of this strategy?
9. What advantage do large pelagic fishes gain from regional heterothermy? Why aren't these animals strict homeotherms? Briefly describe the anatomical/physiological mechanisms of regional heterothermy in these animals.
10. Describe the pattern of heterothermy seen in hummingbirds. Be sure to indicate the conditions under which heterothermy is used.

C. *Applying physiological ecology to conservation*

1. Read selected information from the web site of the Declining Amphibian Population Task Force.
2. Give specific examples explaining and illustrating how studies of physiological ecology are being used to address the problem(s) of world-wide declines in amphibian populations and in the increased prevalence of deformed frogs in the U.S.

V. THE ECOLOGY OF POPULATIONS

A. *Patterns of distribution and density*

1. Discuss the two general factors that determine a species' distribution. Explain why climate is often the key factor limiting distributions. Using the examples of sugar maples, montane tiger beetles, desert *Encelia*, and intertidal barnacles to illustrate, describe the other factors that, along with climate, affect species distributions.
2. Describe the two general factors that determine the dispersion of individuals within a population, and the three general dispersion patterns that result from their interaction. Explain how dispersion patterns may vary with differences in ecology, differences in spatial scale, and over time using the examples discussed in class.
3. What general dispersion pattern is seen across species ranges on a continental scale? Does this pattern hold only for species with wide distributions? What explains this pattern?

4. Describe and discuss Rabinowitz's model of rarity by explaining the three major factors that determine rarity. Under what conditions will a species be considered common? Give examples of each of the major forms of rarity.

B. *Population dynamics*

1. Briefly explain how interactions between birth and death affect patterns of population distribution, abundance, and growth.
2. What is a life table? Compare and contrast cohort and static life tables. Which is generally easier to construct? Which is more useful?
3. Explain the major components of a life table, including where the data come from. Given data on survivorship and fecundity, be able to perform the calculations necessary to use life table data to analyze patterns of population growth.
4. What is a survivorship curve? Describe the three general types of survivorship and give examples of each. Which of the three types most closely resemble(s) patterns actually found in nature? Which least resemble(s) patterns found in nature. Do all species fall into one of the three categories? Justify your answer.
5. For sexual species, how is fecundity defined as used in life tables? Define "iteroparity" and "semelparity." For iteroparous individuals, what are the common patterns of fecundity variation with age?
6. For each of the following terms, give (1) the proper abbreviation; (2) a general description of the pattern or process the term describes (if it's not obvious from the term itself); and (3) the mathematical equation used to calculate it. Given data in the form of a life table, be able to calculate each. Terms: net reproductive rate, generation time, per capita rate of increase.
7. What values of net reproductive rate and per-capita rate of increase indicate a growing population? A stable population? A declining population?
8. Clearly distinguish between the per capita rate of increase and the intrinsic rate of increase. In general, what the relationship between these two be?
9. Briefly explain the role of dispersal in population dynamics.

C. *Population growth*

1. Under what conditions will organisms grow exponentially? Give a verbal description of exponential growth, clearly explaining and distinguishing (1) the

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- change in population size and (2) the change in population growth rate over time. Draw a graph of this process. What part of the graph represents population size? What part represents the rate of population growth?
2. Write the equation for the rate of exponential population growth. In this model, is r constant or variable? Explain why the rate of growth increases over time.
 3. Under what kinds of condition in nature do we expect to see exponential growth? Give examples to illustrate your answer.
 4. Define the term carrying capacity. Explain the general pattern of population growth expected under conditions of limited resources. Clearly explain and distinguish (1) the change in population size and (2) the change in population growth rate over time. Draw a graph of this process. What part of the graph represents population size? What part of the graph represents carrying capacity? What part of the graph represents the rate of population growth?
 5. Write the equation for logistic population growth. To what part of the equation does the term environmental resistance apply? What does the term mean biologically? In this model, is r variable or constant? Explain the relationship between r and environmental resistance. Explain the relationship between the population growth rate and environmental resistance.
 6. Why are biotic interactions like competition, parasitism and disease called density-dependent regulating mechanisms (be sure to address both the density-dependant and regulating parts of that phrase!).
 7. Why are abiotic factors like harsh climatic conditions called density-independent factors?
 8. Are biotic and abiotic environmental factors independent in their effects on population growth rates? Justify your answer with examples.
 9. What is the general relationship between population growth rate and body size? Are there many major groups of organisms that don't exhibit this pattern?
 10. Describe the three general types of age distribution in populations. For populations with type I survivorship, which age structure is associated with increasing population size? With decreasing population size? With stable populations?
 11. What form of population growth do humans as a whole exhibit currently? Why are human populations expected to continue growing fairly rapidly in spite of declines

in fertility (in at least some parts of the world)? Hint: you probably need to refer to patterns of distribution, survivorship, fecundity, and age distributions!

12. Explain the general pattern of correlation among patterns of environmental change, carrying capacity, physiology, life history traits, and population dynamics by comparing selected traits in organisms adapted to relatively stable vs. fluctuating environments.

VI. ECOLOGICAL INTERACTIONS AMONG SPECIES

A. *Classifying interactions according to fitness consequences*

1. List the four major categories of species interactions as classified according to their fitness consequences. For categories that include multiple kinds of interactions, list and briefly define/describe individual interactions.

B. *Competition*

1. Explain the competitive behavior illustrated by threespot damselfish on coral reefs. Briefly describe the important features of competition this system illustrates.
2. Compare and contrast interference and exploitation competition.
3. Describe the relationship between resource limitation and competition. Describe how studies of intraspecific competition in Sorghastrum and planthoppers are used to infer that resource limitation exists and that the intensity of intraspecific competition increases with population density. Be sure to explain specific evidence as well as general reasoning.
4. Define the term ecological niche in both general terms and according to the Hutchinsonian model. Briefly describe the development of this term, including the contributions of Grinnell, Elton, Gause, and Hutchinson. Explain the relationship between the modern niche concept and interspecific competition. Compare and contrast realized and fundamental niches, using examples from class to illustrate.
5. How does interspecific competition affect population size in coexisting competing species? Illustrate your answer with Brown et al.'s studies of desert rodents. Be sure to describe the experimental design used as well as the evidence obtained. Explain the concept of apparent competition, and explain its relationship to exclusion experiments of interspecific competition.
6. Describe the process/pattern of niche (=habitat) partitioning. Clearly explain its relationship to competitive exclusion and its effect on fundamental and realized niches. Illustrate your answer using Tansley's experiments on bedstraw and Connell's studies of barnacles.

7. Briefly describe the phenomenon of competitive replacement. Why is this process of concern to conservation ecologists?
 8. Describe the process of morphological character displacement. Clearly explain its relationship to competitive exclusion, fundamental niches, and realized niches. Illustrate your discussion with the example of Galapagos finches. Does current evidence suggest that this process has been widespread over evolutionary time? Why or why not (hint: be sure to think about what kinds of evidence are required to strongly support the hypothesis that character displacement has occurred)?
- C. *Exploitation*
1. Briefly describe or define the terms herbivory, predation, parasitism, pathogen, and parasitoid. Do these terms adequately express the diversity of exploitative interactions in nature? Why or why not?
 2. Describe the effects exploitation may have on the abundance, distribution, and age structure of exploited populations. Support your answer with evidence from the studies of caddisfly larvae and Australian Opuntia we discussed in class. Be sure to explain each study in detail.
 3. Discuss the examples we used in class of parasites that change the behavior of their hosts. What benefits do the parasites receive from this ability?
 4. Describe the potential effects of predation on species diversity within prey communities, using Paine's studies of Pisaster to illustrate.
 5. Define the terms functional response and numerical response. Describe the common pattern(s) of each and illustrate with an example.
 6. Describe the relationships between snowshoe hare, plant, and lynx populations. What general phenomenon (-a) do these relationships illustrate?
 7. Discuss the various types of refuge hosts/prey may take to persist in the face of exploitation. Illustrate each with a specific example.
- D. *Commensalism and mutualism*
1. List, define, and give at least one example of each of the major types of commensalism.

2. Defend the statement that mutualistic interactions are critical to the structure and diversity of the biosphere.
3. Distinguish between obligate and facultative mutualisms.
4. List, define, and give at least one example of each of the major classes of mutualism.
5. Describe the mutualistic relationship between mycorrhizae and plant roots. Discuss the relationship between the strength of the mutualism and soil fertility as revealed by Johnson's work with Andropogon. Be sure to include a good description of the experimental protocol as well as the reasoning behind the hypothesis tested and the evidence used to support that hypothesis.
6. Discuss the three-way mutualism among corals, zooxanthellae, and crustaceans. Be sure to describe the benefits each species receives, and include any experimental or observational evidence for those benefits. Review the information on coral bleaching linked to the course home page. List some of the major factors leading to coral bleaching and describe, based on what you know about the role of coral in marine systems, the potential consequences of this phenomenon.
7. Describe the mutualism between African honeyguides and traditional honey gatherers, including the evidence that birds are able to provide honey gatherers with information about direction, distance to nests, and location of nests.

VII. THE ECOLOGY OF COMMUNITIES AND ECOSYSTEMS

A. General introduction

1. Define the terms community and ecosystem. Describe the relationship between the two as they are most commonly used.
2. Describe the ways in which community ecologists might subdivide ecological communities. Why do they do this?

B. Community structure I: species abundance and diversity

1. Describe the lognormal distribution of species abundance as documented by Preston and others. What property of community structure, specifically, do these distributions describe? What pattern do they describe?
2. How widespread is the lognormal distribution of species abundance? Are its underlying mechanisms known? If not, what are the major competing hypotheses used to explain it?

3. Describe the important implications and uses of the lognormal distribution for practicing ecologists. What are its possible applications to conservation ecology?
4. Define and describe the two components that collectively define species diversity within communities. Given the appropriate information, be able to calculate H' (the Shannon-Wiener diversity index) and use that calculation to compare species diversity between communities.
5. Describe rank-abundance curves and explain how they illustrate patterns of species diversity. Given rank abundance curves for different communities, be able to accurately interpret differences in species richness and evenness among those communities.
6. Discuss the relationship between species diversity and environmental/habitat complexity (heterogeneity). Explain why a pattern of increasing diversity with increasing heterogeneity should be expected, and describe how Robert MacArthur's studies bear on this question. Is the relationship universal, at least for animal communities?
7. What are the primary limiting resources for algal and plant communities? Do those communities follow the same pattern of increasing diversity with increasing environmental heterogeneity? Be sure to include relevant information about actual environmental heterogeneity as well as examples of studies of plant community diversity in your answer.
8. What is the general relationship between species diversity in plant and algal communities and soil/water fertility? Explain this relationship in terms of environmental heterogeneity and competitive exclusion. Illustrate your answer with examples from class.
9. Define the term disturbance. Describe Connell's "intermediate disturbance hypothesis" for species diversity by stating the hypothesis and explaining Connell's reasoning for it. Describe experimental evidence that supports the hypothesis.
10. Discuss the relationship between the "environmental heterogeneity" hypothesis for species diversity and the "disturbance hypothesis" for species diversity. Are the two mutually exclusive?
11. Describe the conservation implications of the "disturbance" hypothesis.

C. *The trophic structure of communities*

1. Define the terms autotroph, heterotroph, producer, and consumer. Given a food web diagram, be able to identify the category to which organisms in the food web belong.
 2. Describe the two major ways in which complex food webs are simplified for analysis. Illustrate your description using examples from class. What are the advantages and disadvantages of simplifying food webs? Be as specific as possible.
 3. Describe and define the three elements of food web structure that are typically quantified. Why is quantification of food web structure a valuable tool (at least in theory)?
 4. Do ecologists agree on major patterns of food web structure that hold across communities? If so, describe those patterns. If not, describe why general patterns have been difficult to identify. Be specific.
 5. What was MacArthur's (and others') early hypothesis for the relationship between food web complexity and community stability? What general kinds of studies have been done to test that hypothesis? Has that hypothesis been supported?
 6. Compare and contrast dominant and keystone species.
 7. Describe Lubchenko's work on the effects of the keystone species *Littorina littorea* on tidepool algal communities. What major factors did she identify that determine the effect(s) of keystone species on trophic structure? What kind of evidence did she use to support her conclusions? What specific relationships did she find between snail density and algal species richness in tide pool and emergent communities? How do these findings relate to her initial hypothesis?
 8. Briefly discuss the potential consequences of exotic predators on food web structure using aquatic systems to illustrate.
- D. Energy flow within ecosystems*
1. Define the terms primary productivity, net primary productivity (NPP), gross primary productivity (GPP), trophic level, annual evapotranspiration (AET).
 2. Describe the relationship Rosenzweig identified between NPP and AET. In general, what does this tell us about the primary factors affecting productivity in terrestrial systems? What is/are the major secondary factor(s)? Be specific.
 3. What is/are the major limiting factors to productivity in aquatic systems? Under what specific conditions is productivity highest in freshwater and marine systems?

Identify the factors or processes underlying high levels of productivity as appropriate.

4. Using the examples we discussed in class (piscivorous fish, grazers in the Serengeti), describe the possible effects of consumers on productivity. Be sure to identify and describe any relevant underlying mechanisms.
5. Describe the relative amounts of energy (beginning with 100% of incoming solar energy) fixed as NPP and ingested by primary consumers in the Hubbard Brook system. Explain why only a relatively small amount of the energy at one trophic level can be converted to energy at the next level. Discuss the implications of this for trophic pyramid structure in general and for conservation issues.

E. Community succession and stability

1. Define the terms ecological succession, primary succession, secondary succession, sere, seral stage, pioneer community, climax community. Given a description (pictorial or verbal) of a successional sequence, be able to identify whether succession is primary or secondary and be able to illustrate each of these terms with information from that description.
2. List and briefly describe the major model systems that have been important in our understanding of ecological succession. Be sure to explain how we have been able to construct succession timelines for each of these systems (i.e., have we simply been able to observe the full process directly, or have we inferred the process -- and, if so, how?).
3. Identify the major community-level changes that take place during succession. Be sure to describe any general patterns that apply to those changes as well as important elements of variation, using examples from class to illustrate your answer.
4. Identify the major ecosystem-level changes that take place during succession and describe, as appropriate, the processes involved in those changes. Use information from the Hubbard Brook experimental forest to illustrate your answer.
5. Define, describe, and give at least one example each of facilitation and inhibition. Define tolerance.
6. Identify and describe the major abiotic factors that affect species composition and turnover during succession.

7. Compare and contrast the characteristics commonly found in early and late successional plant species. Relate these to our earlier discussion of life history patterns in equilibrial and non-equilibrial habitats.
8. Define the terms stability, resistance, and resilience. Have ecologists identified general patterns of stability that apply across communities? Describe the effects of scale on our perception of community stability using the Park Grass system to illustrate.
9. Using the Sycamore Creek system to illustrate, explain how stability can be a function of complex interactions between biotic and abiotic features of an ecosystem.

F. Nutrient cycling and retention

1. Describe the carbon, nitrogen, and phosphorus cycles with attention to the unique characteristics of each, the major anthropogenic effects on each, and the potential consequences of those effects.
2. Describe the major biotic and abiotic factors affecting nutrient cycling. Use examples as appropriate.

VIII. LARGE-SCALE ECOLOGY

A. Landscape ecology

1. Define landscape ecology by defining the terms “landscape” and “landscape elements (patches)”, giving an example of each, and explaining the kinds of questions/relationships landscape ecologists explore.
2. Of what does landscape structure consist? Explain the kinds of patterns that can be quantified – and why quantification is important – using Ohio forest landscapes as an example.
3. In what two ways is scale important in landscape ecology? Illustrate your answer with specific examples, including Milne’s measurements of the perimeter of Admiralty Bay and the problem(s) posed by trying to study landscape change using satellite imagery.
4. Define the term “metapopulation.” Why is understanding the relationship between patch structure and biological processes in a landscape important?
5. In what specific ways does the patch structure of a landscape affect ecological processes? Illustrate your answer using Diffendorfer et al.’s study of patch size and movement in small mammals, Hanski et al.’s study of patch size and population size in butterflies, and Merriam et al.’s studies of the effects of patch

structure on movement and population dynamics in chipmunks and white-footed mice.

6. What are source and sink patches, and why is being able to identify each important for conservation?
7. Using the landscape of the Tucson Mountain bajadas to illustrate, explain how climate and geology can interact to produce landscape mosaics.
8. Describe some of the ways animals can influence landscape structure using elephants, alligators, kangaroo rates, termites, and beavers to illustrate your answer. For beavers, provide appropriate details.
9. In what kinds of communities is fire an important determinant of landscape structure? What are the general effects of fire on landscapes? Illustrate your answer with information about stand-replacing fires in coniferous forests.
10. Describe the general relationship between rivers and their floodplains. Describe the Kissimmee River landscape, with attention to both landscape structure and landscape function. Why was flood control initiated in this landscape, and how was it carried out? What were the results? Why was restoration initiated, and how has it been carried out? What were the results? What are the long-term plans for this landscape?

B. Global ecology: deforestation

1. To what extent have humans altered the ice-free area of the earth? List the major causes of this alteration and illustrate its extent using specific examples from both forest and non-forest habitats.
2. In what countries is the bulk of current tropical forests found? Which country has the greatest extent of tropical rainforest? What are the major causes of tropical deforestation (be specific if causes vary among countries). Explain how Skole and Tucker measured deforestation rates in Brazil and discuss their major findings.
3. Outline and discuss the major consequences – direct and indirect – of deforestation. Be sure to illustrate your discussion with specific examples as appropriate. Pay particular attention to the causes and consequences of edge effects and the relationship between edge effect and patch shape.
4. What problems limit our ability to predict the specific outcomes of deforestation in specific areas?