Determinants of Community Structure
Fish Ecology
FIW 4614
3/15/07

I. What is an ecological community?

a. Ecologists typically refer to "communities" as all species within a given area, including plants and animals.
b. Fish ecologists often modify this definition to focus on the fishes found in a given area. This is referred to as an "assemblage" of fishes. The terms "community" and "assemblage" are often used interchangeably, but you should understand the difference.
c. An operational definition of a fish assemblage: "fish that occur together in a single place, such that they have at least a reasonable opportunity for daily contact with each other."
d. Note that fish assemblages are defined to some degree by sampling effort.
e. The study of fish communities is essential for fisheries management and conservation.
    1. Fisheries management: Can harvest regulation promote self-sustaining, highly-productive fisheries in multi-species systems?
    2. Conservation biology: What factors regulate fish biodiversity? Where are the most important areas for conservation of fishes? How will invasive species affect fish assemblages?
    3. Water quality managers: How does fish assemblage structure indicate environmental quality?
f. The main goal for this lecture is for you to understand the relationships among multiple factors that influence fish community structure.

II. Historical factors

a. Speciation

1. Older environments provide more time for speciation.
2. Larger environments provide more space for speciation.
3. Isolated environments provide greater probability of divergence (i.e., allopatric speciation)
4. Note that conceptual models of speciation were provided by D.S. Jordan (See American Naturalist 42:73-80; 1908) based in part on his fish surveys of Virginia in 1888. Jordan observed that the closest relative to a fish species was usually in a neighboring drainage, not the same drainage (Why would this be so?)

b. Geological processes

1. Geological processes influence the isolation of fish populations and species.
2. Tectonic uplift influences mountain structure and consequently stream network structure. For example, compare the dendritic-shaped watersheds of the Appalachian Plateau with the trellis-shaped watersheds of the Ridge and Valley physiographic region. In turn, the spatial structure of stream networks may influence opportunities for fish dispersal and fish assemblage structure.
3. Glaciation removes species and creates habitats (e.g., kettle bogs). The absence of "recent" glaciation in the southeastern U.S. is one of the reasons why fish species diversity in this region is relatively high (Figures 1 and 2).
4. Waterfalls may provide barriers for movement. For example, Kanawha Falls in WV prevented many fishes from entering the upper New River. This waterfall helps explain why the New River system contains relatively low diversity of native fish species.

c. Colonization ability

1. Fish mobility influences the probability that geological factors will isolate fish populations and species.
2. Colonization ability may interact with geological factors. For example: Because glaciers move north-south, rivers that run east-west would be less likely to contain refugia than north-south running rivers. This helps explain why species richness is higher in the north-south running rivers of eastern U.S. than in the west-east running rivers of the western U.S. However, use of glacial refugia (and recolonization of post-glaciated habitats) will depend in part on fish mobility.
3. Consider the case of stream restoration in Stroubles Creek: assume that local habitat conditions improve from riparian vegetation (e.g., shade and mesohabitat structure etc). Would you expect highly-mobile or sedentary fishes to recolonize this "restored" habitat? What other factors would be important?

III. Productivity

a. Productivity (P) refers to the "production" of organic compounds from inorganic constituents via photosynthesis in plants and phytoplankton. (Note: marine phytoplankton produces c. 90% of the global oxygen)
b. Respiration (R) is the process of decomposition of organic matter.
c. Sources of Production
    1. Autochthonous production: from within aquatic ecosystem (e.g., algae)
    2. Allochthonous production: from outside the aquatic ecosystem (e.g., leaf inputs from the riparian zone)
d. Note that P and R rates vary among stream sizes (Figure 3 and 4).
e. Note that P and R rates vary among ecosystem types (Figure 5).
f. Note that P does not necessarily lead to species diversity.

1. Example 1: highly productive marine environments may contain relatively low numbers of fish species.
2. Example 2: Stroubles Creek is very productive (i.e., high rates of autochthonous production via algae) but species diversity is relatively low.
3. Why? Competition and competitive exclusion provide a partial explanation. In productive environments, species which can exploit primary production (e.g., central stoneroller) may become numerically dominant in the system. However, remember that competition implies that resources consumed by one organism would have been consumed by another organism, which may or may not be the case in highly productive ecosystems.

IV. Disturbance

a. The term "disturbance" refers to short-term changes in ecosystem condition that affect species distributions and abundances.
b. Marine environments typically support fewer disturbances than freshwater environments.
c. In freshwater environments, headwater streams typically support more disturbances than downstream areas.
d. Extreme physiochemical conditions may cause disturbances (e.g., temporal variation in pH, DO, temperature).
e. Variation in flow regime and climate may cause disturbances (e.g., drought, floods)
f. Several possible mechanisms regulate the effects of disturbances on fishes
    1. Direct mortality (e.g., acute toxicity from NH_4^+ conversion to NH_3 under high temperatures and high pH)
    2. Energetic expenses (e.g., forced movement, respiration and feeding rate inefficiencies)
    3. Consider the fitness costs of disturbances (i.e., reproduction and survival rates).

g. How could these processes affect community structure?
    1. Mortality affects population size and intrinsic rate of increase
    2. Energetic expenses affect reproductive output or success
    3. Indirect mortality could affect both
h. Intermediate disturbance hypothesis
    1. The main idea: species richness will be highest in a place where disturbances prevent competitive exclusions, but not so high that they eliminate all species.
    2. The implication: disturbances aren't always "bad".
    3. To understand the consequences of disturbances, consider the time-scale.

V. Biotic interactions
  a. Competition – already addressed
  b. Predation – already addressed
  c. Commensalisms
    1. Example 1: nest associates with mound-builders
    2. Example 2: algae grazing by stonerollers
  d. Mutualisms?

VI. A synthesis of concepts: the hierarchical filters model (Figure 6)
  a. The "filters" model helps us understand the interaction of historical and current factors that regulate fish assemblage structure.
  b. This model was originally developed for lake ecosystems but also can be applied in lotic and marine environments.
  c. Work through the filters model using Stroubles Creek as an example.
    1. Say you sample Stroubles Creek and find 5 species: stonerollers, rosyside dace, brown bullhead, fantail darter, and golden shiner. Let's work down the filters model.
    2. Global-scale: 24,000 species
    3. North America: about 800 species
    4. Eastern North America: about 500 species

5. New River system: about 70 species (half of which are introduced)
6. What are the "filters" that limit potential fishes at each step in the model?