Fish Management (Zool 466)
Lecture 4

Limnology Overview for Fish Management

I. What is limnology?
   A. Study of freshwater - both lakes (lentic) and streams (lotic)
   B. Integrates many disciplines - chemistry, biology, physics
   C. Focus of this course will be lentic ecosystems (also called lacustrine)

II. Properties of water
   A. Strong solvent - lots of things dissolve in it (both gases and solids)
   B. Most dense at 4°C - important because ice floats over colder water
   C. High heat capacity - takes a lot of energy input to see a thermal change

III. Lake formation - many different ways that lakes are formed; history of formation often has influence on lake characteristics; glacial, rifts, oxbows, volcanic craters, natural/human-made impoundments

IV. Physical factors characterizing lakes
   A. Average depth ($\bar{z}$; usually in meters)
   B. Surface area (often in hectares or acres)
   C. Shoreline length (determines the amount of inshore habitat for fish; meters)
   D. Shoreline development (smoothness of the shoreline; unitless)
   E. Fetch (maximum length of water lying parallel to the prevailing winds)
   F. Latitude (determines the length of season and heating)
   G. Light (changes on a seasonal and daily basis; varies as a function of lake characteristics)
      1. Heat, visual predators are affected by the duration and intensity of sunlight
      2. PAR - photosynthetically active radiation; wavelengths of light that foster photosynthesis
      3. Attenuation - this is how light becomes extinct as it penetrates the water column; light hitting the water surface is *incidental light;* the quantity of light below the surface is always less than incidental light
      4. Compensation point - point where the amount of light allows photosynthesis to equal respiration; below this point, it is too dark for photosynthesis to offset respiration.
      5. Euphotic (or photic) zone - water column above the compensation point. This is also called the trophogenic zone because this is where food is produced.
      6. Photometer - this is used to quantify light; measured in many ways, lumens, lux, joules; Einstein = 1 mol photons; all of these measures are expressed as unit m^{-2} s^{-1}
      7. Secchi disk - "cheap" alternative to photometer; euphotic zone roughly corresponds to 2-3 times the secchi depth.
   H. Turbidity - scattering of light by suspended particles and dissolved substances; turbidity impedes light availability for phytoplankton
      1. Organic turbidity -living matter and dead matter; often corresponds to primary productivity
      2. Inorganic turbidity - clay and other mineral products; clay can remain suspended indefinitely due to electric charge; often inhibits primary productivity.
      3. Measured with a nephelometer or turbidimeter (measures transmittance of light)
   I. Temperature - important factor affecting fish growth, fish reproduction, fish foraging, seasonal production, lake stratification, etc.
      1. High heat capacity of water allows temperatures to remain relatively stable while air temperature fluctuates considerably
      2. In general, density of water declines with increasing temperature; however, recall water is MOST DENSE at 4°C
      3. At temperate latitudes, lakes stratify as a function of seasonal temperature

a. Winter - ice on surface; warmer water is on the bottom

b. Spring - water will reach "critical" thermal input that causes ice to transform back to liquid; since all water will initially be the same temperature, wind mixing is common. This is called *spring turnover*. Nutrients can cause a spring "bloom" of phytoplankton and then zooplankton.

c. Summer - strong temperature heats the surface more rapidly than the bottom; less dense, warm water floats on top of the cool, dense bottom water, in a process called *stratification*. The hotter it gets, the more intense the stratification.

(1) Epilimnion - warm, upper layer; wind mixed; often has high oxygen; *not the same as the euphotic zone*.

(2) Thermocline - point where temperature begins to drop from the epilimniotic temperature

(3) Metalimnion- layer where temperature declines rapidly to the hypolimnetic temperature; often a point of peak phytoplankton activity.

(4) Hypolimnion - layer of cold, often anoxic water; a "sink" for organic matter

(5) Fish are usually restricted to the metalimnion and the epilimnion.

d. Fall - rapid cooling of the epilimnion can cause wind mixing between the layers; Influx of anoxic, nutrient-rich water. Could cause a fall "bloom" of plankton.

J. Mixing of water column - temperature and wind are primary factors (see above). Water depth, altitude/latitude, or water density can affect the frequency and intensity of mixing.

V. Chemical factors characterizing lakes

A. pH - this is the negative log of the number of protons (H^+) in the water; high pH (low acidity) corresponds to few H^+; low pH (high acidity) corresponds to high H^+.

1. Lakes vary tremendously relative to pH (typically pH ranges from 6.5 to 8.5 depending on geology, biology, human activities, etc.)

2. Fish do not tolerate low (< pH 4) and high (> pH 11) pH conditions. pH is integral regulator of ionic and acid-base balance in fish blood. A fishes' ability to regulate H^+ and other substances is sensitive to pH.

3. Low pH increases solubility of heavy metals such as Al and Hg

4. CO_2 and pH are intimately linked in water (discussed in a few moments)

B. Alkalinity - ability of water to resist (i.e., buffer) changes in pH

1. Can be affected by any buffering substance

2. Measured as milliequivalents or mg/L (ppm) of $CaCO_3$

C. Oxygen - not particularly soluble in water; problem for fish and other organisms that require it. Fish often cannot tolerate drop below 4 ppm for extended time.

1. Physical factors affecting oxygen

a. Temperature - cold water holds more than warm

b. Water pressure - high pressure holds more than low

2. Concentration versus partial pressure versus percent saturation

a. Concentration of oxygen is the amount per unit volume (ppm); often is the same throughout mixed portion of lake

b. Partial pressure is the pressure exerted by oxygen; measured in mmHg or atmospheres; increases with water pressure. A fish brought to the surface might rapidly form gas bubbles as the gas is forced out of solution by the pressure drop.

c. Percent saturation - the amount of oxygen dissolved relative to the theoretical holding capacity of water.

3. Biological factors affecting oxygen
   a. Photosynthesis - produces oxygen; phytoplankton are primary photosynthesizers
   b. Phytoplankton also may consume most of the oxygen in the water column at night when photosynthesis is not occurring (fish only consume about 1% of the oxygen)
4. Stratification of oxygen
   a. Spring - oxygen is well mixed throughout the water column
   b. Summer - oxygen is usually restricted to the epilimnion; although the hypolimnion might have high oxygen at the start of summer, respiration consumes it all.
   c. Fall - may be a short period of low oxygen following turnover
   d. Winter-
      (1) No ice present - high oxygen
      (2) Ice present - without snow cover, high oxygen; snow cover extinguishes light and can cause *winterkill* of fish

D. Nutrients
1. Phosphorus - often the limiting nutrient for phytoplankton in freshwater lakes; Adding P will increase primary productivity; Trophic status linked to P
   a. Oligotrophic
   b. Mesotrophic
   c. Eutrophic
2. Nitrogen - an important nutrient that becomes limiting when P is very high.
   a. Sources of nitrogen include terrestrial systems, excretion by organisms, atmosphere
      (1) Nitrification - conversion of ammonia to nontoxic forms. Phytoplankton can absorb these various forms.
         (a) NH_3 to NO_2 - ammonia to nitrite; *Nitrosomonas* responsible
         (b) NO_2 to NO_3 - nitrite to nitrate; *Nitrobacter* responsible
      (2) Ammonia (NH_3; toxic form) versus ammonium ion (NH_4^+; nontoxic form) depends on temperature and pH; high temperature and high pH lead to abundant ammonia
      (3) Nitrification lowers pH

E. Salinity - low in freshwater; fish are salty relative to their surroundings. Fish must compensate for constant influx of water by producing copious urine. Freshwater fish do not drink.

F. Hardness - divalent cations in water; *not alkalinity*; Ca^{++} and Mg^{++}

G. Total dissolved solids - inorganic solids dissolved in water; MEI - morphoedaphic index

H. MEI - can roughly predict fish production in lakes

VI. Biological characteristics of lakes - the main focus of this course following this lecture, particularly regarding fish; applies to streams and rivers to some extent