Environmental Control and the NA Bloom

I. Biogeography

a. The term ***Biogeography*** refers to the study of biology (species distributions specifically) in relation to the geography of the environment.
b. This has been adapted from the terrestrial literature (again), and people interested in Biogeography are often trying to answer the question, "why are the species where they are, in terms of both the present day environment and the evolutionary (geological) record?"

In the marine environment, biogeography is often used to look at the spatial distribution of species, and to attempt to classify those species into one of several categories:

<u>Cosmopolitan</u>: a species or group that is found everywhere in the oceans (all ocean basins)

<u>Indicator Species</u>: an organism that is representative of some environmental or biological condition. For example, Monterey is often considered to be a biogeographical boundary between the northern and southern California Current. As northern/southern species become more/less abundant in Monterey, that's considered an indicator of the larger patterns….

<u>Functional Group</u>: a species or organism that fulfills the same role in an environment or biogeographical region. For example, there are many species of krill associated with different regions, but they all play the same role in the food web, so they are ***functionally equivalent***. This is a major simplifying factor in models (we don't model species, we model phytoplankton and zooplankton)

<u>Tropical, Subtropical, Temperate, Sub-Polar, Polar</u>: these are large groupings based primarily on temperature of species found in the respective provinces

c. In general, there is less species richness in the marine environment, so biogeography is relatively less interesting (see diversity notes for discussion of species richness, etc.).

II. Biogeochemical Provinces

a. Although biogeography is less interesting in the marine environment because of the lack of boundaries and the prevalence of cosmopolitan species, patterns within the world's oceans are easily identified.
b. With the introduction of ocean color measurements, which give us a proxy for biomass (chlorophyll), many biological oceanographers recognized

that there are both unifying patterns, and underlying complexity in the oceans.

Side Note: Ocean Color was introduced with the OceanSat satellite, which flew in 1977. It was followed by the first successful ocean color instrument, the Coastal Zone Color Scanner (CZCS), which flew from 1978-1986, a major turning point for biological oceanography. After CZCS, many countries saw the value of having these measurements, but it wasn't until 1996 that the next generation, ADEOS, was launched by Japan (primarily for fisheries). It was lost in 1997, and was replaced by SeaWiFS, which lasted from 1997-2004 (it still works, but was discontinued by NASA). Today we (in the US) primarily use MODIS, although there are ocean color satellites operated by Europe, Japan, China, Korea, and India as well. They all essentially measure the same thing.

c. In 1995, Alan Longhurst combined the idea of biogeography with ocean color measurements from satellites to partition the world's oceans into "functional groups"
d. Initially, he developed ***ocean biomes***, or major types of ocean, similar to the terrestrial biomes (desert, savannah, rain forest, etc.). These biomes consisted of:
    i. Polar—permanently cold or ice covered
    ii. Westerlies (subpolar)—regions dominated by seasonal mixing. Includes the NA Spring Bloom
    iii. Subtropical Gyres—approximately 30°N-30°S, the largely steady-state, desert-like open ocean
    iv. Equator—the band around the equator where the physics is completely different from the gyres
    v. Coasts—nutrient rich, high biomass regions associated with coasts

e. Soon after developing this concept, Longhurst realized there were more groups, such as the **High Nutrient, Low Chlorophyll** (HNLC) regions associated with iron limitation. He subsequently ended up with 54 ***biogeochemical provinces*** based on the interaction of phytoplankton and zooplankton with the environment
f. Following on from that, the United Nations and NOAA (among others) developed the concept of ***Large Marine Ecosystems***, which are biogeographical provinces divided up based on oceanography and ecosystem management strategies—as a result, much of the way governments (and NGOs) approach management of the marine environment is based on the concepts of biogeography and biogeochmical provinces—this leads to ***Ecosystem Based Management***

III. The North Atlantic Bloom

a. The North Atlantic has long been recognized as "unique", and has served as the basis for much of our understanding of biological oceanography
b. As part of the "westerlies" or subpolar biome, we expect these regions to be dominated by seasonal mixing

c. In the NA, there are two blooms: a large spring bloom, and a smaller fall bloom. These are controlled by:
    i. Winter time, deep mixing, low light, low temperature = no phytoplankton and high nutrients
    ii. Spring, increased light, thermal stratification, high nutrients, = diatom bloom
    iii. Late Spring, zooplankton respond to food availability
    iv. Summer, chlorophyll maximum moves from surface to depth because of low nutrients and grazing pressure… develop a ***Deep Chlorophyll Maximum*** at the thermocline because that's where the nutrients are still available. Zooplankton crash because of lack of food
    v. Fall, thermal stratification starts to break down, leading to a second phytoplankton bloom, and followed by a second zooplankton increase
    vi. Fall bloom is terminated by winter conditions

d. So why isn't there a North Pacific Bloom? Several possibilities have been suggested:
    i. No deep winter mixing (not as deep, anyway), so the zooplankton life cycle keeps the copepods closer to the surface, meaning no de-coupling between zooplankton and phytoplankton
    ii. Not as many diatoms, which are necessary for a bloom (remember, to increase biomass, you have to increase average size of the organisms)
    iii. Iron limitation because there are not as many sources of dust or deep water

e. None of these reasons explains all of the data for the NA versus NP:
    i. The mixing is still pretty deep in the NP
    ii. There are diatoms in the NP
    iii. Rates of primary production (carbon fixation) are similar between the NA and NP, suggesting that Fe-limitation isn't severe

f. To explain what is going on, the ***Ecumenical Iron Hypothesis*** was formulated: This states that it's a combination of all these factors. The large zooplankton stay closer to the surface because there's not a lot of deep winter mixing; the diatoms are present, but never really take off because of iron stress (remember, large cells are more easily stressed than small cells at low nutrient concentrations). In combination with the zooplankton, this keeps the bloom of large cells from occurring. The small phytoplankton are easily grazed by microzooplankton, which grow almost as fast as the phytoplankton. So, ***rates of primary production*** are high in the NP, as in the NA, but iron limitation and grazing pressure keep the diatoms from blooming.