Lecture 7 questions – life in the ocean

(1) As deep water moves away from where it formed, it becomes:
(a) richer in oxygen, nitrate and phosphate
(b) richer in carbon dioxide, nutrients and poorer in oxygen
(c) less acidic and richer in metals
(d) richer in carbon dioxide, oxygen and nutrients

Surface waters in the ocean are rich in oxygen mostly because of:
(a) equilibrium with the atmosphere
(b) production of oxygen during respiration by bacteria in the surface
(c) production of oxygen during photosynthesis by organisms in the surface waters
(d) the dissolution of terrigenouse material in surface waters
(e) none of these

Which of these parameters can be considered conservative?
(a) AOU
(b) OUR
(c) Preformed phosphate
(d) NAEC
(e) DOC

(2) Environmental meddler, "Jean Splizer" genetically engineered a species of marine phytoplankton that has no hard body parts and behaves (and is treated) just like its natural counterparts. The only tiny hitch is that in her zeal to reduce atmospheric fossil fuel CO_2, Dr. Jean (who is left-handed) designed all the biochemicals in her phytoplankton with reversed stereochemistries, which makes them completely resistant to degradation of all types. Discuss briefly how the following aspects of the ocean-atmosphere system would be changed (after the indicated time interval) if this indestructible phytoplankton were suddenly (and permanently) to replace all other types of phytoplankton throughout the world ocean:

(a) The position and extent of the O_2 minimum zone in open ocean water columns after 5000 years.
(b) The O_2 content of the deep ocean (assume circulation like today) and the atmosphere after 5,000,000 years.

(a) The O_2 minimum will probably disappear all together as there will not be any organic matter that could be decomposed and consume the oxygen at depth of maximum regeneration. Surface water will be supersaturated due to photosynthetic input of O_2.
(b) The O_2 content of the deep ocean will be at equilibrium with the atmosphere as it will be non-reactive at depth and solubility will determine the content. The atmospheric O_2 concentration will rise, as no consumption due to organic mater degradation will occur.

(3) You have been given a data set from an unknown site in the ocean, where gross production is 500 mg C m^{-2} day^{-1}, and respiration is measured at 450 mg C m^{-2} day^{-1}. Please use ***short* answers** for the following questions:

a) Calculate the new production at this location and the f ratio. (new production = 50 mg C m^{-2} day^{-1} P-R/P= 50/500 = 0.1)
b) Based on this limited information, where would you predict that this site is located in the ocean? (Most likely mid ocean low productivity areas)
c) What can you say about nutrient distribution and cycling at this location? (very low concentrations in the surface and high recycling relative to export)

(4) Scientists believe that a meteorite collided with the earth 65 million years ago resulting in the loss of most animal and plant life. If all animal and plant life were eliminated from the planet how would you expect this catastrophic event to affect the oceanographic distributions of the nutrient elements. What will happen one hundred years after the event and 100,000 years after?

Since surface water equals ~1/10 of deep water and has a mixing time of ~100 years (1/10 of 1000) it would take about 100 years to replenish the surface and distribute things evenly but the deep waters will not "feel" the change on this time scale. After 100 years the composition of surface and deep water would become nearly equal. As the volume of deep water is much grated than that of surface water the resulting composition would be similar to that of average deep water. Because the organisms had dominated the removal of the nutrient elements if no organisms were to survive the event over the next several hundred thousand years the nutrients concentrations in the sea would rise. The rise would continue until inorganic removal mechanism achieves a balance with river input.

(5) Label the plots and explain your choices.
(Si, PO_4, pH and O_2)

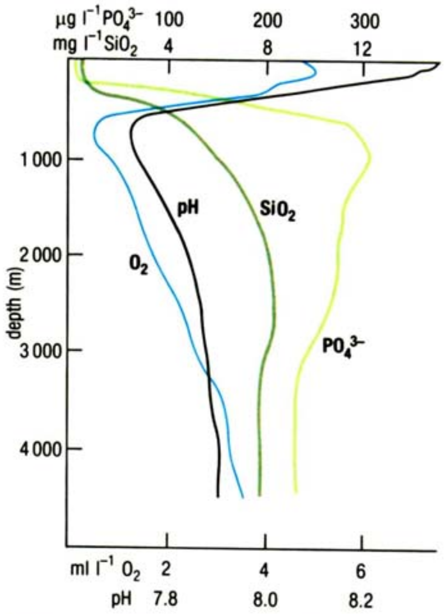
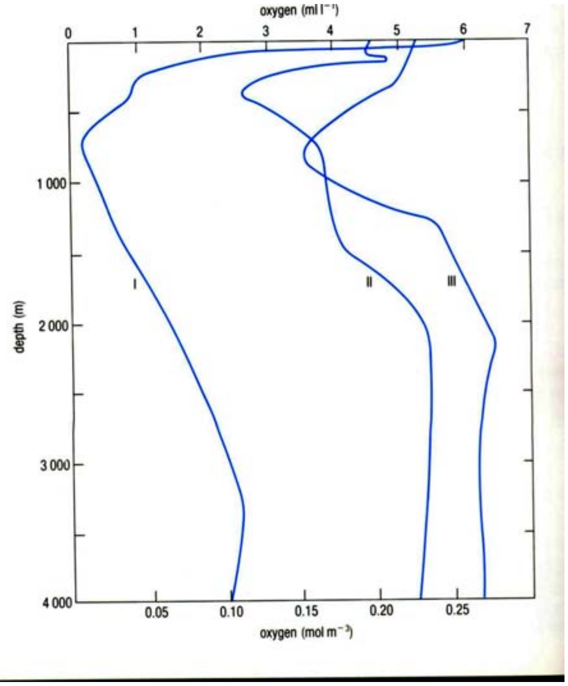


Figure 2.21 Concentration–depth profiles from 24°22′N, 145°33′W, to show the contrasted patterns for nutrients and oxygen. Note that the maximum for silica is reached at greater depth than that for phosphate (*cf.* Figures 2.9 and 2.13). For pH profile, see Question 2.15.

(6) Which of these oxygen depth profiles is from the South of California; Eastern part of the South Atlantic; Gulf Stream. Explain. What determines the minimum in all profiles between 200 and 1000 meters.



I- California, II- South Atlantic, III Gulf Stream. The minimum at the thermocline is largest because strong stratification inhibits vertical mixing (no O_2 from above) and the flux of POM is largest so O demand is higher; Horizontal advection is relatively sluggish at this depth zone.

(7) At a site being considered for the culture of clams, the seawater that is supplied to the region was found to have total phosphate concentrations of 0.5µM and the nitrate was 20 µM. The clams are filter feeders, they eat the phytoplankton that is growing in the same seawater. The aquaculture plant economic advisor wants to increase the clam yield. Would you recommend fertilization of this water? If so why and with what?

You would want to increase the phytoplankton biomass by providing them with the needed nutrients, assuming they utilize these at the Redfield ratio the N:P should be 16:1 it is actually 20:0.5 = 40 so we need to add P to enable the phytoplankton to utilize all of the nitrate. The desired P concentration should be 1.25µM.

(8) The concentration of phosphate in a local bay increases by 0.01µM over a 4-hour period during the night. Calculate the expected change in nitrogen and oxygen. State all assumptions used.

Assuming the P increased due to net oxidation of organic matter over uptake (respiration) and that Redfield ratios apply for 0.01µM change in P you would expect 0.16µM change in nitrate and a reduction of about 1.36µM in the oxygen. But oxygen might not show this due to equilibration with the atmosphere.

(9) Define AOU; what are the units for AOU;
The O_2 concentration at 4000m depth in the north Pacific is 90µM the temperature where this water mass originated is 10 degrees; calculate the AOU for that station.
Calculate how much organic matter was oxidized.
The P concentration at this station is 2.37 µM what is the preformed phosphate?
Calculate how ΣCO_2 changed assume that for every mole of OrgC respired and 0.2 mole of shell dissolves.

AOU is the "apparent" amount of oxygen consumed since the water mass was last at the sea surface. It is calculated by subtracting the measured in-situ oxygen concentration from the concentration in equilibrium with the atmosphere at the sea surface.
AOU = NAEC – O_2 in situ. The units are in µmol/kg.

The NAEC of oxygen at 10 degrees is 280 µmol/kg; 280-90 = 190; So AOU is 190 µmol/kg.

The oxygen to carbon ratio assuming Redfield for organic matter degradation is 106C:138O_2
So 190 x 106/138 = 146 µM Organic C oxidized.

Preformed P will be the "excess" P after accounting for that added from organic matter degradation at Redfield ratios (138O_2:1P). So 190µmol/kg O_2 consumed will result in addition of 190/138 µmol/kg P which is = 1.37µmol/kg and the preformed P will correspond to the measure P minus this value thus = 1µmol/kg

If for every mole of organic C respired 0.2 moles $CaCO_3$ is dissolved then for the the above calculated 146 µmol/kg organic the C total DIC addition is expected to be 1.2 x 146µmol/kg = 175 µmol/kg.

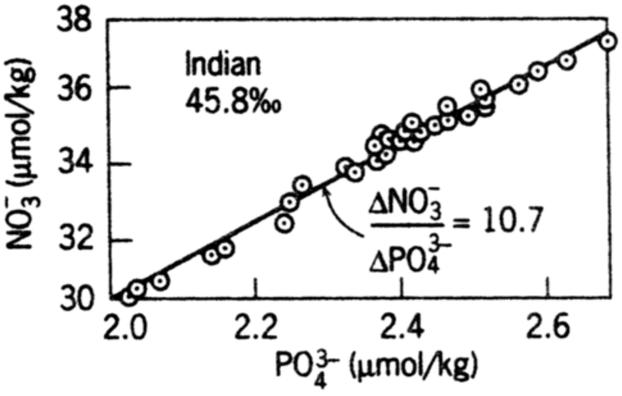
(10) Organic tissue containing 0.2 moles of C is added to a 1000 liter sample of deep water from the North Pacific. The bacteria in the sample respond and consume the organic matter drawing on the oxygen in the sample (100 x 10^{-6} moles/l). Which respiration ingredient will run out first C or O, by how much CO_2 will be produced?

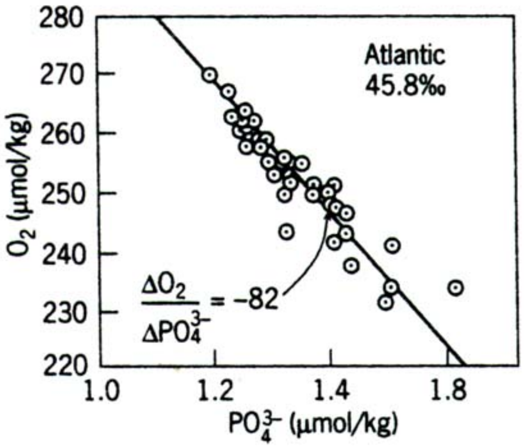
$\Delta O_2/\Delta C_{org}$ =~ -1.35
0.2 x 1.35 = 0.27 moles of O_2 (demand)
1000 x 100 x 10^{-6} = 0.10 moles O_2 (available)
Hence O_2 will run out before the organic matter is consumed.
(100 x 10^{-6})/ 1.35 = 74 x 10^{-6} moles l^{-1} CO_2

(11) Can you explain the following curves? Why is the Arabian sea P:N not that expected from RKR? (the figures are along the 45.5‰ isopycnal surface, ~2500 meters depth)

The saturation for O_2 where the water formed in the Atlantic is 280 µM can you determine what the preformed P for this water mass is? The N:P ratio in these surface water is 16:1 are the phytoplankton in this area are nutrient limited?

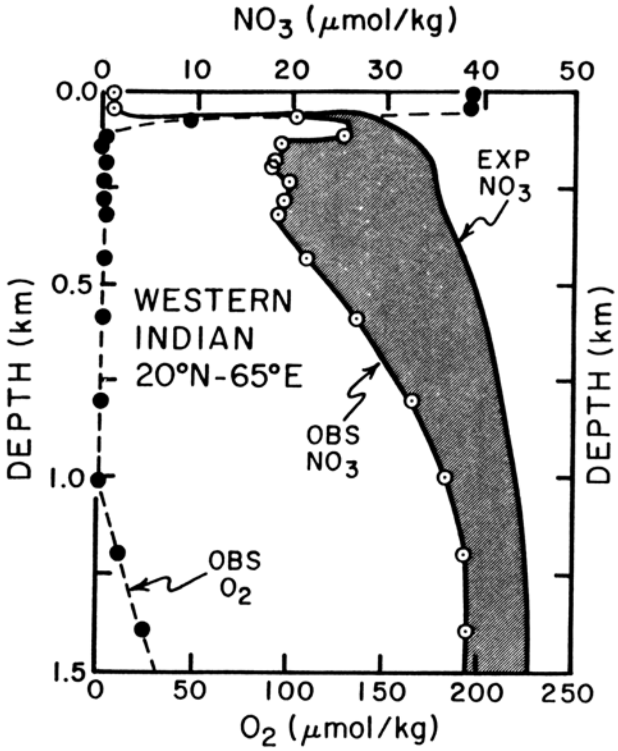
Can you try to draw a plot of the oxygen and nitrate concentrations vs. depth in the Arabian Sea? Indicate the expected vs. observed nitrate in the water column.



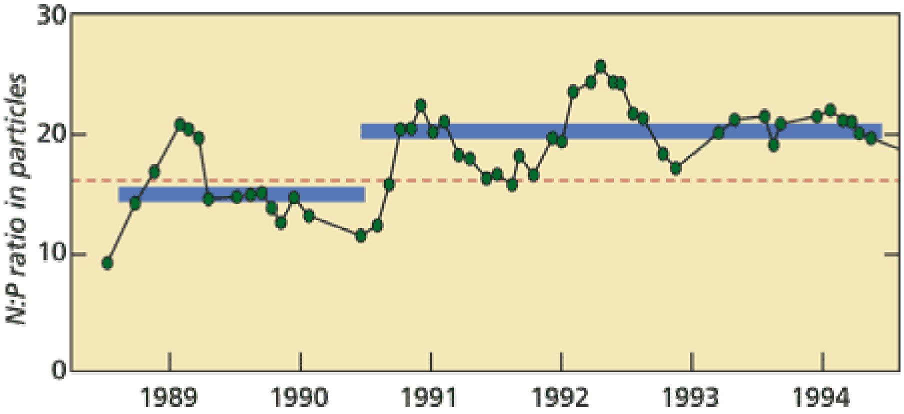


The observed nitrate to phosphate ratio in the Arabian Sea is less than expected from RKR ratios. The reason is that in this area nitrate is utilized by bacteria as an oxidizing agent leading to nitrate deficiencies in the water column (denitrification). The expected nitrate concentration could be calculated by multiplying the measured phosphate concentrations by 15.

According to the figure the preformed phosphate is about 1.15µmol/kg (extrapolating the line to 280µmol/kg). Since the P in the surface water is not zero (preformed P) and the RKR value is 16:1 the organisms are probably not nutrient limited there.

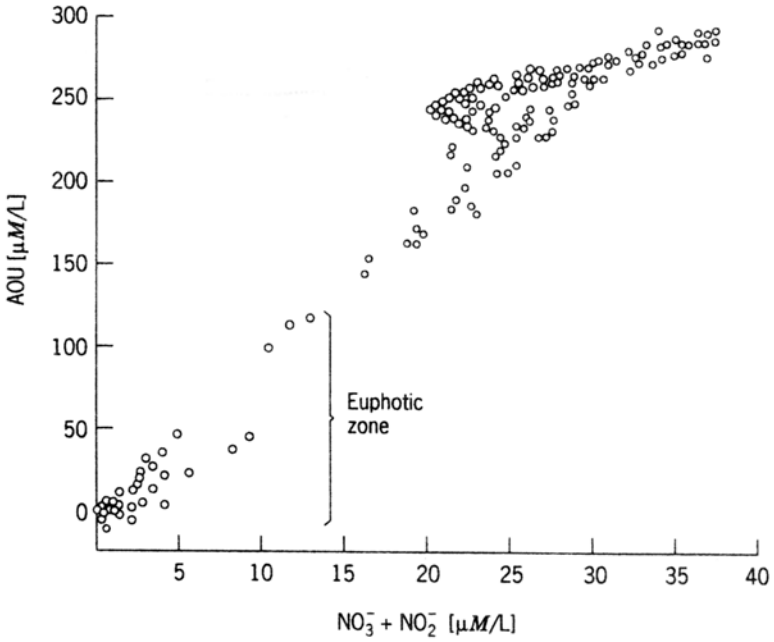


(12) A detailed look at the N;P ratios in surface waters off Hawaii indicate that this ratio has changes over time What happened? What is the limiting nutrient during each of these time periods?



From 1989 to 1991 the system seems to be nitrate limited and since then it shifted to phosphate limitation. There are also seasonal fluctuations with winters being more phosphate limited relative to summers. The best explanation is drastic shifts in the organisms dominating the system with periods of increased stratification (summers) being more P depleted e.g. maybe nitrogen fixing organisms more abundant.

(13) Can you explain this figure?



In the deep water the AOU to nitrate change is about what expected from RKR ratios. The high AOU areas and where nitrate is lower than expected denitrification takes place and at the surface in some locations you can find oxygen super saturation.