1.6) INSTRUCTOR'S GUIDE TO CARBON CYCLING BETWEEN FISH AND PRODUCERS

Overview: The amount of *Elodea* on the materials list is more than what you are likely to use so as to take into account that some of it may be old or discolored.

The fish-to-plant ratio resulting in no net change in dissolved oxygen is somewhere between 1:1 and 2:1. Based on the same source of data, the predicted fish-to-plant ratio is roughly 1.5:1.

Sample Results Part A (fish only)

◊	A	B	C	D	E	F	G	H	I
1	Flask	ppm O_2	ΔO_2 ppm	Vol. (L)	Δ total mg O_2	Biomass (kg)	mg O_2 /kg	Δ Hours	mg O_2 /kg/hr
2	1	8.4	N/A	0.27	N/A	0.0029	N/A	0	N/A
3	1	6.9	-1.5	0.27	-0.41	0.0029	-140	0.50	-280
4	1	5.3	-1.6	0.27	-0.43	0.0029	-150	0.50	-300

Sample Results Part B (plants only)

◊	A	B	C	D	E	F	G	H	I
1	Flask	ppm O_2	ΔO_2 ppm	Vol. (L)	Δ total mg O_2	Biomass (kg)	mg O_2 /kg	Δ Hours	mg O_2 /kg/hr
2	2	7.75	N/A	0.27	N/A	0.004	N/A	0	N/A
3	2	10.4	0.9	0.27	0.24	0.004	190	0.50	370
4	2	13.27	1.2	0.27	0.32	0.004	250	0.50	500

Sample Results Part C (fish + plants)

◊	A	B	C	D	E	F	G	H
1	Flask	ppm O_2	ΔO_2 ppm	Vol. (L)	Δ total mg O_2	Fish kg	Plant kg	Ratio
2	3	8.1	N/A	0.27	N/A	0.0030	0.0026	1.2
3	3	8.4	0.3	0.27	0.081	0.0030	0.0026	1.2
4	3	9.0	0.6	0.27	0.16	0.0030	0.0026	1.2

Answers to Questions: 1) Based on this table, the consumption following the first half hour is 280 mg O_2. The consumption following the second half hour is 300 mg O_2. 2) The production following the first half hour is 370 mg O_2. The production following the second half hour is 500 mg O_2. 3) 435 mg O_2 (plants) / 290 mg O_2 (fish) = 1.5 (1.5 kg fish per kg plants to maintain constant levels of oxygen) 4) 20/1.5 =13 5) All items must be subject to the same conditions. 6) The water might absorb oxygen from the air. 7) Answers may vary. 8) Photosynthesis requires carbon dioxide. 9) You will need more plants because the lights are turned off half the time during a 12-hour photoperiod and the plants will also need to provide food. 10) Rats will need more plants because they are warm blooded, so they need more food. 11) Ferrets will need more plants to feed their prey because ferrets are carnivorous.

Logistics: If only one period is available for lab, it may be better to spread this procedure over a period of 3 days: *Day 1:* Weigh all organisms, then discuss how to complete the spreadsheet template. *Day 2:* Do parts A and B. *Day 3:* Do part C. Because the first and last oxygen measurements are one hour apart, they cannot be accomplished during a 40-minute period. If this is your only option, you can have the students take the first measurement while you or another group of students take the last measurement. If you have only one oxygen meter for the entire class, you can have students take turns taking readings. This will amount to 18 readings for Parts A, B, and C. Those who do not get a chance to take oxygen readings can be involved in weighing the fish. The spreadsheet template for this lab can be found in a folder titled "Sample Spreadsheets."

Degree of Difficulty: 3—It is recommended that the instructor rehearse this before involving the students.

Materials: 16-20 feeder goldfish; 10-20 bunches of *Elodea* or 12-15 grams of *Spirogyra*; an oxygen meter; a fluorescent lamp with a bulb that is at least 3 feet long; 9-16 250-mL Erlenmeyer flasks with rubber stoppers; an electronic balance.

Supplemental instructions for generating the spreadsheet from scratch:

Parts A and B:

Column A corresponds to the flask number. Label the column and place a "x" (or whatever label you choose for your first flask) in the cells A2 to A4 (the spaces below your column label). In other words, all the data in rows 2 to 4 correspond to this flask. It also is a good idea to specify in these cells whether this flask contained goldfish or plants.

Column B corresponds to the dissolved oxygen reading in parts per million (ppm O_2). Label the column and write in the oxygen reading at time 0 in cell B2. In cells B3 and B4 write in the oxygen readings at 30 minutes and 60 minutes respectively.

Column C corresponds to the change in oxygen concentration (Δ O_2 ppm). Label the column and write N/A in cell C2. In cell C3 insert the following equation: **= B3 – B2**

In cell C4 insert the following equation: **=B4 – B3**

Column D corresponds to the number of liters that were contained in flask x. Label the column and place this value in columns D2 to D4.

Column E corresponds to the total milligrams of oxygen consumed or produced in flask x (Δ total mg O_2). Because 1 liter water = 1 kg, it follows that 1 mg per liter of water = 1 ppm. Therefore, total mg is equivalent to multiplying the ppm by the total liters. Label the column and write N/A in cell E2. In cell E3 insert the following equation **= C3*D3**

In cell E4 insert the following equation: **= C4*D4**

Column F corresponds to the total kilograms of biomass. This is obtained by dividing the total grams of fish or plant by 1000. Label the column and write in these corresponding values in cells F2 to F4.

Column G corresponds to the total amount of oxygen per kg biomass (mg O_2 / kg). Label the column and write N/A in cell G2. In cell G3 insert in the equation: **= E3/F3**

In cell G4 insert the following equation (or copy and paste from G3 to G4): **= E4/F4**

Column H corresponds to the change in hours that have passed since the previous entry. Label the column and write "0" in cell H2, and "0.5" in cells H3 and H4. This represents the two half-hour intervals when oxygen is measured (one hour total).

Column I corresponds to the milligrams of oxygen produced or consumed per kg biomass per hour. Label the column and write N/A in cell I2. In cell I3 insert in the equation: **= G3/H3**

In cell I4 insert the following equation (or simply copy and paste from I3 to I4): **= G4/H4**

Now you have all the information you need about what happened in flask x. You can cut and paste these functions to obtain the same information about all the other flasks that contained only fish or only plants.

◊	A	B	C	D	E	F	G	H	I
1	Flask	ppm O_2	ΔO_2 ppm	Vol. (L)	Δ total mg O_2	Biomass (kg)	mg O_2 /kg	Δ Hours	mg O_2 /kg/hr
2	x		N/A		N/A		N/A	0	N/A
3	x		=B3-B2		=C3*D3		=E3/F3	0.5	=G3/H3
4	x		=B4-B3		=C4*D4		=E4/F4	0.5	=G4/H4

Part C:

Column A corresponds to the flask number. Label the column and place a "z" (or whatever label you choose) in the cells A2 to A4 to indicate that all the data in rows 2-4 correspond to flask z.

Column B corresponds to the oxygen reading in parts per million (ppm O_2). Label the column and write in the oxygen reading at time 0 in cell B2. In cells B3 and B4 write in the oxygen readings at 30 minutes and 60 minutes respectively.

Column C corresponds to the change in oxygen concentration (Δ O_2 ppm). Label the column and write N/A in cell C2. In cell C3 insert the following equation: **= B3 – B2**

In cell C4 insert the following equation (or copy and paste from C3 to C4): **= B4 – B3**

Column D corresponds to the number of liters that were contained in flask z. Label the column and place the value in cells D2 to D4.

Column E corresponds to the total oxygen consumed or produced in flask z (Δ total mg O_2). Label the column and write N/A in cell E2. In cell E3 insert the equation**:** **= C3*D3**

In cell E4 write the following equation (or copy and paste from E3 to E4): **= C4*D4**

Column F corresponds to the biomass of goldfish in flask z. Label the column and write the corresponding biomass (in kilograms) of the fish in cell F2.

Column G corresponds to the total kilograms of biomass of plant material in flask z (total grams divided by 1000). Label the column and write in the corresponding values in cell G2.

Column H corresponds to the fish:plant biomass ratio. Insert the following equation in cell H2.

= F2/G2

◊	A	B	C	D	E	F	G	H
1	Flask	ppm O_2	ΔO_2 ppm	Vol. (L)	Δ total mg O_2	Fish kg	Plant kg	Ratio
2	z		N/A		N/A			=F2/G2
3	z		=B3-B2		=C3*D3			
4	z		=B4-B3		=C4*D4			