Name ____________________ Date __________

ANSWER KEY
Water Chestnut & DO Dynamics

Scientists want to understand how water chestnut impacts the Hudson River ecosystem through time (across the days and seasons) and space (in different locations within a plant bed, in different regions of the river, etc). For example, when water chestnut does have impacts, when and where do they occur? And for how long do they remain? How might these impacts affect the larger river ecosystem? This activity explores results from a study of water chestnut beds in a tidal portion of the Hudson River, Inbocht Bay.

Figure 1. Aerial photo of Inbocht Bay, Hudson River, NY. Photo by Kara Goodwin, Cary Institute of Ecosystem Studies

The beds were sampled using a special device called a *sonde*, which can be programmed to automatically measure important water chemistry parameters throughout the day. The scientists in this study were particularly interested in learning how water chestnut (a.k.a. *Trapa natans*) influences the amount of oxygen in the water. We call oxygen dissolved in water 'dissolved oxygen,' or DO (*dee-oh*). When DO levels get very low, fish and other animals have difficulty getting enough oxygen, become stressed, and can die. In order to learn what impact the water chestnut beds have on DO throughout the seasons and spatially across a bed, the scientists set out the sondes in a line across a large bed at Inbocht Bay. They then programmed them to measure DO every 15 minutes, day and night, for the better part of two years (2005 and 2006).

In 2005, the scientists stopped measuring around the middle of August (Day 218). However, when the data were analyzed in the winter of 2005, they realized that they needed more data, so they decided to run the experiment again, this time until the end of September (Day 268).

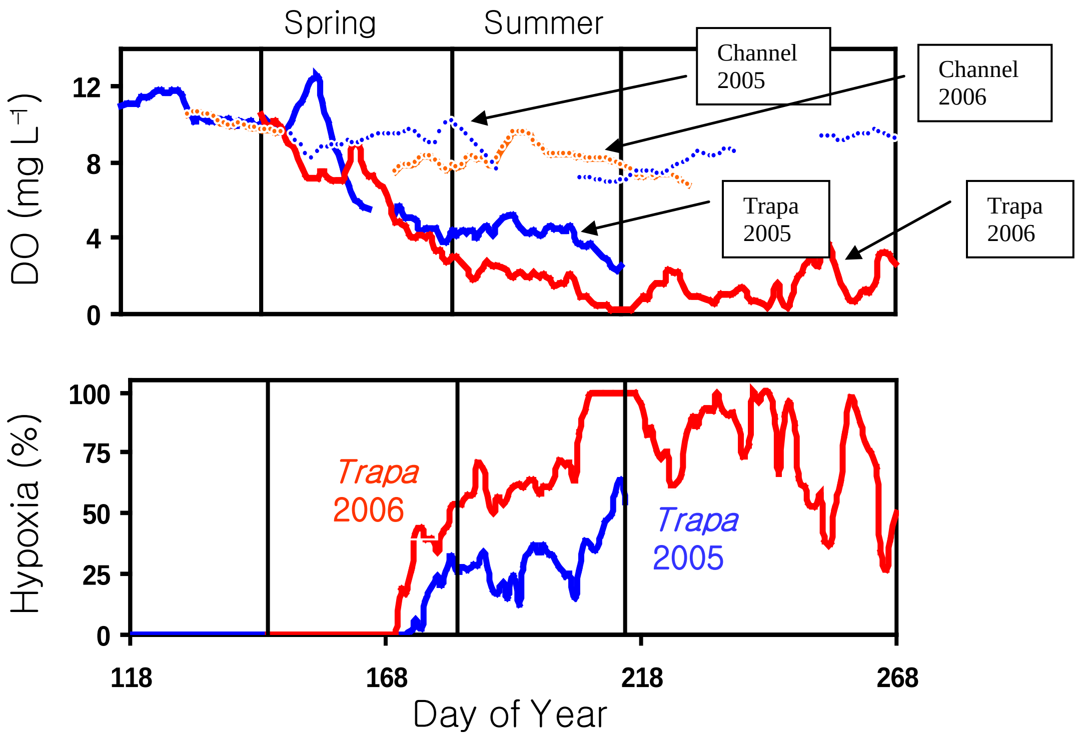

Figure 2. Seasonal variation in dissolved oxygen in *Trapa natans* beds.

The top graph shows average daily dissolved oxygen (DO) for 2005 (blue) and 2006 (red) in the deep water main channel of the Hudson (dashed lines) and inside the *Trapa* bed (solid lines) from 11 May through 25 September. The vertical lines break this period into 4 blocks including the spring (25 May -30 June) and summer (1 July -3 August). The x-axis shows the day of the year, counted from January 1st as Day 1.

In the lower graph, the y-axis shows the percent of time during any given day that the water became **hypoxic**. We call the water hypoxic when oxygen concentrations drop below 2-3 mg L^{-1}. Hypoxia can have negative impacts on sensitive species of fish and invertebrates and cause changes in metal, nitrogen and phosphorus cycling. There are only two lines on this graph, because the main channel never has DO levels that are lowo enough to cause hypoxia (see the first graph). For reference, Table 1 below lists the calendar dates with their corresponding days-of-year.

Calendar date:	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec
Day of the Year:	1	31	59	90	120	151	181	212	243	273	304	334

Table 1. Comparison of calendar dates with days-of-year.

Based on the information above, please answer the following questions:

1. How do DO levels in the main channel differ from those in the *Trapa* beds? *DO level in the channel is more stable and almost always higher*
2. What is the average DO level for the main channel during the spring? *Range in spring approx. 7-10 mg/L* During the summer? *About the same*
3. The % hypoxic days increases dramatically around Day 168 (mid-June). What do you think causes this? (Hint: Think about why DO in the plant bed changes over the seasons.) *In mid-June water chestnut plants leaf out, shading the water which preventing photosynthesis by submerged plants such as water celery*
4. Why do you think the researchers decided to extend their experiment from 2005 into September? *To see for how long the water continued to become hypoxic each day .* How different were their results? *Variability in percent of hypoxia each day mid-Aug through Sept, varying from about 25% to nearly 100%.* What would you expect if you continued measuring into October or November? *Decline in % of time water was hypoxic, with some variability, until water was never hypoxic. In both years, the water was 0% hypoxic when the sonde surveys began in May.*
5. Why do you think the main channel never becomes hypoxic? *Tides bring in fresh oxygenated water twice a day.*
6. American shad are anadramous fish; they spend their first spring and summer in freshwater, leave for the ocean when the waters grow cold, then in later years return to spawn in the freshwaters of their birth. They need at least 4 mg dissolved O_2/L to be healthy and can die if the DO becomes too much lower. Where could juvenile American shad live in Inbocht Bay and during what part(s) of the spring/summer? How might this change from year to year? Refer to Figure 2 in your answer. *Figure 2 shows that DO levels within the Trapa bed are typically greater than 4 mg/L during the spring, but that these decline as the summer progresses. Therefore, a juvenile could live healthfully within the Trapa beds of Inbocht bay through most of the spring, but they may be forced to the edge of the vegetation or into the channel as the summer progresses. There is clearly year-to-year variation: while the DO levels dropped below 4mg/L only a few times during spring/summer in 2005, they remained consistently low in 2006.*
7. What consequences would the high incidence of hypoxia have for other plants and animals in the river ecosystem? *Increasing levels of hypoxia will cause changes to: distribution of organisms, nutrient cycling, and abiotic factors such as light level and DO, which all have consequences for river organisms.*

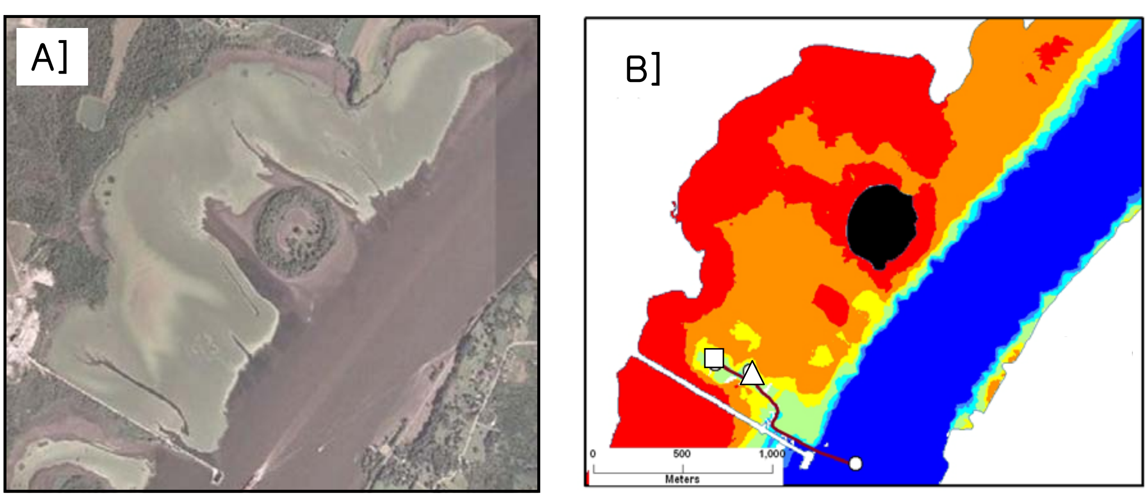

Figure 3. Figure 3A is an aerial photo of Inbocht Bay, taken in September of 2006 (mytopo.com). The light green areas are covered by *Trapa*. Figure 3B shows a bathymetric map of the study area, which is like an underwater topographic map. Red areas are exposed at a very low tide. Blue is the main channel of the Hudson River. The white square, triangle and circle are the sites of sonde deployment in summer 2005 and 2006. The white circle is where sondes were deployed in the main stem during both 2005 and 2006 while the white square and white triangle are the site of the *Trapa* bed deployment for 2005 and 2006, respectively. The dark line depicts the path of travel from open waters into the bed (See Figure 4).

Dissolved Oxygen Measurements From the Shore to the Main Channel

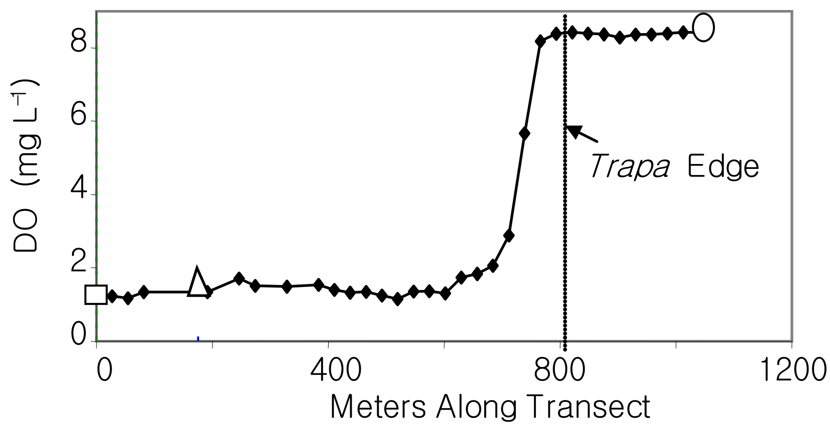

Figure 4. DO across the *Trapa natans* bed. Measurements were taken during low tide along a transect from the back of the *Trapa* bed into the main channel of the Hudson River (See Figure 3 for the mapped transect).

1. What is the DO level at the back of the *Trapa* bed, near the shore? *About 1 mg/L.* How does the DO level change as you move towards to main channel of the Hudson? *The level stays fairly constant from shore to near the edge of the* Trapa *bed when DO rises steeply until it reaches about 8 mg/L.*
2. When does the DO level change dramatically? *Within 100-150 m from the edge of the bed* What do you think causes this change? *Increasing light levels as* Trapa *cover declines and ends.*
3. How do you think this graph would be different if the measurements were taken in April or early May? *DO levels would be fairly steady from shore to channel during April and early May since there would be no water chestnut leaves to shade the water.* What about October or November? *As water chestnut plants lose leaves, difference in DO levels between shore and mid-channel would decrease.*
4. If you knew that baby American shad lived in this *Trapa* bed and wanted to find one, where would you look? *I would look close to the edge, where the DO is higher. The American shad would be more likely to be oxygen stressed in the bed interior.*

5. Tony is a juvenile American shad and uses vegetated shallows as a nursery. There, she has plenty of plankton to eat and can search for food while hiding from predators. Based on what you know about the life history of American shad and DO levels in Inbocht Bay, tell the story of Tony's life from spring-fall 2006. Be sure to include where in Inbocht Bay Tony probably lived during each part of the season. If you think she moved from one place to another or encountered different advantages or threats, be sure to explain why.
   In spring, Tony is born, lives in the middle of the Trapa bed, where there is plenty of food, shelter from predators, and she still has enough oxygen to be healthy (See Figure 2 and previous answers.)
   As spring turns into summer and the Trapa bed begins to become hypoxic, she is forced to live at the edge of the Trapa bed or possibly wander into the channel, where she may be more susceptible to being eaten.
   In fall, she migrates out to the ocean, where she will spend the majority of her life.

References:
Caraco, N. F., J. J. Cole, S. E. G. Findlay, and C. Wigand. 2006. Vascular plants as engineers of oxygen in aquatic systems. BioScience 56(3):219-225.