Hydrodynamic model of an estuary

Summary:
Students expand on the concepts of salinity, density, and density driven currents by applying these concepts in an estuary and exploring how these concepts affect organisms. Students will be exposed to physical and computer models, tools that scientists often use in their inquiry.

Key concepts:
- Estuaries are enclosed bodies of water, in which the circulation pattern changes at different time scale.
- Changes in circulation patterns have ecological implications for organisms living in estuaries.
- Computer models are useful tools to study natural processes.

Grade level: 9 -12

In class time: one 50 min period and one 1 hour 50 min period

Prep time: 30 min for the modeling lesson and 1-2 hours to build physical model

Session 1 (50 min)
- Students are asked to recall the meaning of density and density driven currents and in groups of 3-4 discuss examples on earth where density-driven currents are formed.
  ○ (In the trial version of this lesson, students will be given a pre-test worksheet and they will be asked to answer question 1 before the discussion begins)
- Ask the students to share their examples and put their answers on the board
  ○ Some examples may include: the Poles, the Strait of Gibraltar (Mediterranean outflow), Amazon river mouth
- Show the students satellite images of the mouth of the Amazon, highlighted by the murky, sediment loaded water and encourage them to think about why this is observed. Tell them the focus of the next two periods is on currents in estuary i.e. where fresh water and sea water meet.

Estuary box model
- In groups of 3-5, have students add yellow food coloring to the prepared pitcher with freshwater and blue food coloring in to the pitcher with salt water.
- Ask the students to pour the freshwater to one side of the “dam” and salt water to the other and hypothesize what would happen when the dam is lifted (Pre-test worksheet Q 2 -3).
- Instruct the students to carefully remove the dam and observe what happen and lead a discussion on what they have observed and why. (Pre-test worksheet Q . 4-5)
  ○ The series of event that should happen in the tub is:
  ○ Salt water pushes into the fresh water
- Salt water sink to the bottom of the freshwater side
- Freshwater is displaced and flowing into the salt water side
- The two water masses will flow in opposite direction with fresh water on top and forming layers (stratification)

- Show the students the power point with images of estuary and ask them to describe what these areas have in common (characteristics of an estuary)
- Show the students a simplified image of estuarine circulation and have them brain storm if that change throughout time. If yes, give examples of how does that change. (Daily with tides, rainfall; Weekly-Monthly with tidal cycle spring vs. neap; Month-Yearly snow melt)
- Show pictures of planktonic organism that are found in estuaries and ask students to think about how they will be affected by the changing flow of estuary (Salinity changes, Duration of stay within an estuary to use the nutrients or the calm water to develop)

Note: Students might not be familiar with the concept of plankton. If that’s the case explain what are planktons and highlight many marine invertebrate spend part of their live in the plankton and they also adapt to life in the estuary through change when and where do they spawn.

- Tell the student that they are doing to use a computer model to explore the how flows affect whether organism and stay in an estuary in the next session.

Session Two (1 hour 50 min)

- Start with asking student to recall how flows in an estuary can affect organisms and brain storm way that organism can avoid being transported out of favorable habitat
  - Swimming, buoyancy control, Timing and Location of release
- Tell the students that you are going to use a computer model to study how timing and location of release will affect the fate of invertebrate larvae. Lead the students in an introduction why computer model can be a good way to study natural phenomena
  - Some things are too difficult to measure in the wild (e.g. plankton are very small and it is hard to count them all in an large area e.g. Puget Sound)
  - Some experiments might be unethical or unrealistic to conduct in the wild. Computer model let us ask hypothetical question (e.g. what if 1000 invasive carbs are introduced to Puget Sound and start reproducing?)
  - Models also allow us to make predictions (e.g. climate change forecast, weather predictions)
- If students mention making predictions, it is good to use that as a spring board to remind students that modeling has their own limitations, e.g. NOAA did not accurately predict the snow storm in Seattle thanksgiving week because they do not have complete knowledge of what the wind pattern. Ask them to reflect on the box model that they have seen yesterday and think whether it really represents what happens in an estuary why and why not?
(The system modeled is closed i.e. the freshwater does not go to the open ocean; the flow will not stop in nature.)

- Show the student the graphical interface (GUI) of the computer model. Ask the student to think of a couple limitations of this model based on the information provided (e.g. there is no behaviors, the timing in the water column is fixed to 14 days, the floor of the estuary is flat etc.)

- With the limitations in mind, student can still use the model to ask interesting question. In group ask them to come up with hypothesis regarding what will happen if they change a) timing, b) location of release and c) the amount of water flow.
- (Modeling worksheet)
- Circulate among groups and encourage student to test their hypothesis strategically i.e., don’t change all the parameters at once.

- Ask each group to present their findings and wrap up with a quick recap of the key concepts.

Remarks:

- Currently the model is located in the shared drop box, ultimately it will be hosted on a website. The model is a collaborative effort of faculty and students at UW Oceanography. The physical dynamic solution is developed by Dr. Parker Mac Cready and the biological routine is developed by Dr. Daniel Grunbaum. The graphical interface is developed by Karen Chan.