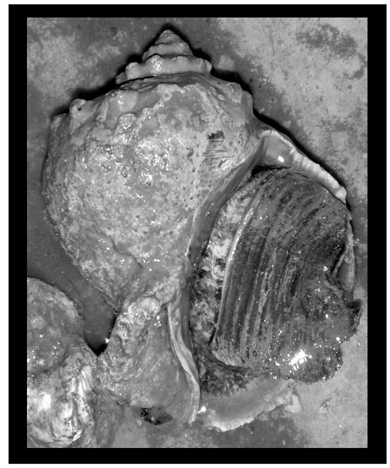
Rapa River Watch
Activity Booklet for Educators

Introduction

This booklet contains background information, graphs, and student worksheets for a classroom activity focusing on the veined rapa whelk, an Asian mollusc that has invaded the Chesapeake Bay. In this activity, students evaluate four hypothetical habitats for risk of invasion by rapa whelks using data describing biology and environmental tolerances of rapa whelks (*Rapana venosa*). This habitat evaluation activity is intended as a follow up to the VORTEX Instructional Booklets *Rundown on the Rapa* and *Rundown on the Rapa Activity Booklet for Educators* (http://www.vims.edu/mollusc/meeduc/vortex.html)



A live adult rapa whelk.

Veined rapa whelks (*Rapana venosa*) are predatory marine snails that have been introduced into the Chesapeake Bay, USA. These large snails eat ecologically and commerically valuable shellfish including oysters (*Crassostrea virginica*) and hard clams (*Mercenaria mercenaria*). There are few predators in Chesapeake Bay that can successfully attack and eat large rapa whelks. Since rapa whelks are long lived (possibly > 15 years) and begin reproducing at 2-3 years old, once introduced, rapa whelks are very likely to become established if the habitat environmental conditions are suitable.

Rapa whelks are native to Asian waters near Japan and Korea. They were introduced to the Black Sea in the 1940s and have since spread into the Aegean, Adriatic, and Mediterranean Seas as well as Chesapeake Bay (USA), the Rio de la Plata (Uruguay and Argentina), and the Brittany coast of France. Recent introductions are most likely the result of

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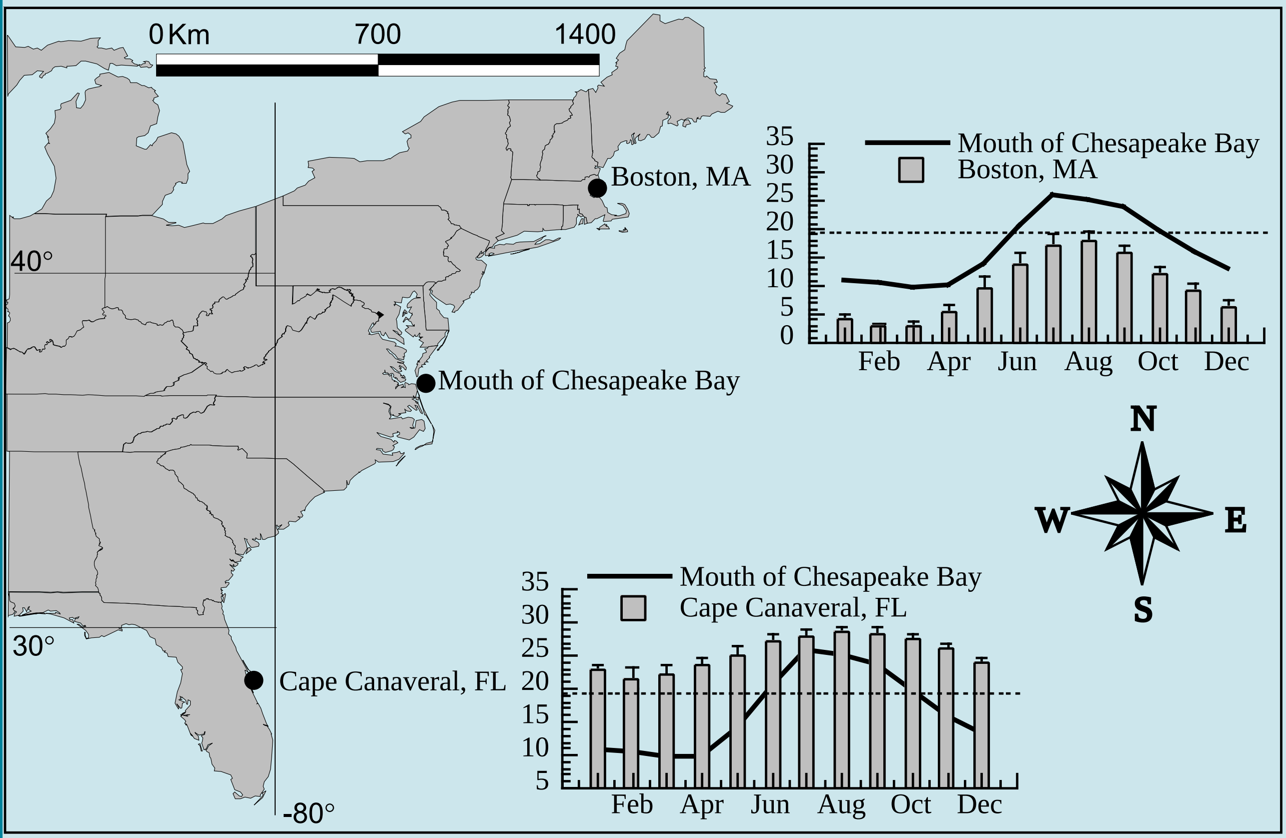
ballast water transport of swimming larval rapa whelks from occupied habitats into new environments.

The Chesapeake Bay is home to several of the largest ports on the US Atlantic coast, notably Hampton Roads-Norfolk. The Chesapeake Bay rapa whelk population is centered around the Hampton

Sidebar 1: Location, location, location - the importance of temperature tolerance.

Assume that rapa whelks require at least three months of water temperatures greater than or equal to 18°C to lay eggs. In the language of invasion biology, egg laying (reproduction) is necessary to establish a self-sustaining population in a new habitat. We know that the rapa whelk population in Chesapeake Bay is self-sustaining, so we can use the annual monthly water temperature data from the mouth of Chesapeake Bay as a guide when evaluating the risk to other habitats. The graphs below show the average monthly water temperatures (with standard error of the mean) for Boston, MA and Cape Canaveral, FL in relation to Chesapeake Bay temperatures. Water temperatures in Boston, MA will not typically be warm enough long enough for rapa whelks to reproduce at all. However, water temperatures at Cape Canaveral, FL are warm enough for rapa whelks to reproduce 12 months per year. Therefore, Cape Canaveral is at much higher risk for the establishment of a self-sustaining rapa whelk population than Boston.



Water temperature data are from the NOAA National Climate Data Center for buoys located at Boston, Massachusetts (Buoy number 44013, 42°35'N, 70°69'W); Chesapeake Bay mouth, Virginia (Buoy number 44014, 36°34'59"N, 74°50'1"W); and Cape Canaveral, Florida (Buoy number 41009, 28°30'1"N, 80°11'3"W).

Roads-Norfolk region. Aquatic scientists, resource managers, and commercial shellfish growers up and down the US Atlantic coast are very concerned that vessel traffic from Chesapeake Bay may introduce rapa whelks into other habitats. The million dollar question for everyone is: <u>If rapa whelks are introduced to this habitat, will they survive and establish a self-sustaining population?</u>

The answer to this question is a complicated one and will vary from place to place. The secret to finding a viable answer lies in understanding the biology and physiology of the rapa whelk. Salinity and temperature tolerances of the larval whelk will determine if the larva will survive if added to a new place via ballast water. Threshold values, values that describe the upper or lower physiological limits for an animal's environmental tolerances, are very important to consider when conducting habitat risk assessments (Sidebar 1).

"Larval period duration", the length of time that a baby rapa whelk stays planktonic (swimming), and the length of time the larva is in ballast water affect whether or not a transported larva will be able to survive and be pumped out with ballast water into a new habitat. If the trip is longer than larval period duration, the rapa whelk may have settled to the sides of the ballast tank during the voyage and it may not be pumped out at the end (Sidebar 2).

Simply arriving in a new habitat does not equal a successful introduction. Typically, introductions of non-native species are considered "successful" if the alien species establishes a self-sustaining population in the new habitat. More than one individual arrives, survives, finds other individuals of the same species AND <u>successfully reproduces in the new habitat resulting in multiple generations</u> that are resident within the habitat. Invasion success is not a forgone conclusion with the arrival of every individual of an alien species.

Sidebar 2: Timing is everything - the interaction of larval period duration and transport time.

Assume a larval period duration of 28 days (d) for rapa whelks and a transit time from habitat A to habitat B of 11 days in a vessel's ballast water tank. If larva 1 is entrained in ballast water at 20 d, the larva will settle 8 d after entrainment, 8 d into the voyage and 3 d away from a new habitat. Thus, larva 1 will NOT be introduced into the habitat B. However, larva 2 was 7 d old when entrained in the same ballast water tank. When the vessel reaches habitat B after a voyage of 11 days, larva 2 will be 18 d old, still planktonic(swimming), and eligible to be pumped out into habitat B with the ballast water. The chances of larva 2 being introduced into habitat B are very high.

Summary of rapa whelk environmental tolerances

Parameter	Activity	Threshold
Water temperature	Feeding	≥ 10 ° C
	Growth	≥15° C
	Egg laying	≥ 18° C
Salinity	Adult survival	≥ 10 ppt
	Adult ideal	≥ 15 ppt
	Larvae - survival for 48 hr	≥ 7 ppt
Substrate	Burrowing	Sand, hard sand
	Egg laying	Rock, shell
	Juvenile settlement and survival	Rock, shell
Food	Larger whelks need larger food	Prey ≥ 0.5 size predator

Threshold values for temperature and food are from J.M Harding (unpublished data). Salinity threshold values are from Mann and Harding (2000, 2003). Substrate threshold values are based on J.M. Harding and R. Mann (unpublished data).

Rapa River Watch

Objectives:

1. Determine the risk of a successful rapa whelk (*Rapana venosa*) invasion for four hypothetical estuaries. If rapa whelks are introduced to a habitat, this "invasion" will be considered successful if the rapa whelks survive to reproduce in the new habitat AND establish a self-sustaining resident population.
2. Justify your conclusions using research information on rapa whelk biology and environmental tolerances.

Skills: Observation, communication, graphing, hypothesis testing.

Relevant Virginia Standards of Learning

6.9	Living systems
BIO.5	Life functions
LS. 4	Life processes
LS. 7	Ecosystem relationships
LS.10	Organism adaptation to biotic and abiotic factors
LS.12	Population dynamics

Materials

1. One copy of *Rundown on the Rapa* Instructional Booklet (http://www.vims.edu/mollusc/meeduc/vortex.html) per student.
2. One copy of rapa whelk environmental tolerances table (p. 4) per student or group.
3. One copy of *Rapa River Watch* Habitat Evaluation instructions and worksheet (p. 6 and 7) per student or group.
4. One set of habitat graphs and corresponding maps for each of four estuaries (p. 11-26).
5. Answer keys are provided on p. 8 and 9.

Procedure

1. Ask students to read the *Rundown on the Rapa* instructional booklet and the Introduction to *Rapa River Watch* including the rapa whelk environmental tolerances table (p. 4).
2. Divide students into small groups or research teams.
3. Have each research team complete the *Rapa River Watch* worksheet (p. 7) for each one of the four hypothetical estuaries.
4. Have each research team present their rankings and justifications to the class.

Related vocabulary

alien or non-native species: species that was not historically found in a location.
donor habitat: habitat from which an invasive species spreads.
invasive species: non-native species that establish self sustaining populations and spread in a new habitat, AND those organisms that cause significant unwanted, negative ecological, economic, or human health impacts.
receptor habitat: habitat that receives non-native species.
self-sustaining population: a population of animals that produces enough offspring to maintain the number of adults present without additional immigration or introductions.
standard error of the mean: a measure of the variance around an average.
veliger: swimming larval mollusc life history stage.
whelk: predatory, carnivorous marine gastropod.

Suggested discussion questions

1. Why are the environmental tolerances of an invading species so critical in the establishment of the animal in a new habitat?
2. Are all alien species harmful?
3. Suggest strategies that scientists, resource managers, and policy makers should adopt to reduce the number of harmful invasive species in the United States.

RAPA RIVER WATCH

Habitat Evaluation Instructions

Background information

Your agency has been asked to conduct a risk assessment for one of four US Atlantic coast estuaries with regard to the potential for a successful invasion by veined rapa whelks (*Rapana venosa*). If rapa whelks are introduced to these habitats, the "invasion" will be considered successful if the rapa whelks survive to reproduce in the new habitats AND establish a self-sustaining resident population.

The four rivers/estuaries of interest are the Little Miami, Truckee, Concordia, and Derry Rivers.

Your habitat evaluation should incorporate available information on rapa whelk life history and environmental tolerances as well as estuary-specific data sets describing:

1. Annual water temperature (degrees C) profile
2. Annual salinity (ppt) profile
3. Substrate coverage within the estuary
4. Abundance of benthic invertebrate populations that could be prey items for rapa whelks.
5. Volume of ballast water entering the estuary.

You will be asked to present the results of your risk assessment and justify your conclusions in light of the factors listed above. Using the accompanying worksheet, rate each factor for your estuary on a scale of 1 to 5 with regard to successful invasion by rapa whelks. A score of 1 indicates that a factor is NOT suitable for successful invasion and establishment of a self sustaining population. A score of 5 indicates that a factor is HIGHLY suitable for successful invasion and establishment of a self sustaining rapa whelk population. Each of these five factors listed above has an important role in the risk assessment and must be assigned a value of 1 or higher.

After you have evaluated each individual factor within an estuary, calculate the estuary's total score by taking the sum of the individual factor scores.

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Habitat Evaluation Worksheet

Using the table below, evaluate each factor for your estuary on a scale of 1 to 5 with regard to successful invasion by rapa whelks where a score of 1 indicates that a factor is NOT suitable for successful invasion and establishment of a self sustaining population and a score of 5 indicates that a factor is HIGHLY suitable for successful invasion and establishment of a self sustaining rapa whelk population. Each of the five factors listed has an important role in the risk assessment and must be assigned a value of 1 or higher. After you have evaluated each individual factor within an estuary, calculate the estuary's total score by taking the sum of the individual factor scores. Make sure to explain the reasons for your ratings in the spaces provided or on the back of this page.

Estuary	Water temperature	Salinity	Substrate	Food	Ballast water volume	Overall ranking	Justification
Little Miami							
Truckee							
Concordia							
Derry							

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Answer Key: Suggested discussion questions

Suggested discussion questions (from page 5)

1. Why are the environmental tolerances of an invading species so critical in the establishment of the animal in a new habitat?

Environmental tolerances of an invading species are critical to the establishment of the animal in a new habitat because environmental tolerances set the physiological boundaries for survival. If the annual water temperature or salinity cycle in a habitat includes months where water temperatures or salinities are above or below the invader's physiological tolerances, the invader will die. Consider a rapa whelk population living in the lower reaches of an estuary at salinities >20 ppt. During a dry year, salinities at upriver sites might also rise from < 10 ppt to >20 ppt due to a lack of freshwater input. If the benthic adult rapa whelks moved upriver, taking advantage of the expanded zone of appropriate salinities, they might find new food resources and expand their range within the estuary. However, when salinities in the upriver habitat return to "normal" levels (< 10 ppt), the rapa whelks in the upriver habitats will die.

2. Are all alien species harmful?

All alien species are not necessarily harmful. Consider all of the non-native species that have been introduced for agriculture or aquaculture purposes. Alien species are typically considered harmful or pest species by resource managers and scientists if the alien species causes a negative economic effect (M. Williamson. 1996. Biological Invasions. Chapman and Hall, London).

3. Suggest strategies that scientists, resource managers, and policy makers should adopt to reduce the number of harmful invasive species in the United States.

Relevant strategies include: ballast water exchange or treatment programs, public education programs to reduce the spread of alien species through release of fishing bait or aquarium trade species, mandatory rinsing and inspection of boat trailers and vessels moving from one body of water to another in either freshwater or marine systems.

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Answer Key: Habitat Evaluation Worksheet

Estuary	Water temperature	Salinity	Substrate	Food	Ballast water volume	Overall ranking	Justification
Little Miami	5	4	2	3	2	16	Water temperature: feeding (11 mon), growth (6 mon), egg laying (5 mon). Salinity: > 10 (12 mon), >15 (7 mon). Substrate: good for burrowing, not much suitable for attachment. Food: good for medium to large whelks, not many mussels for small whelks. Ballast water: at most 3 ships per month.
Truckee	1	5	5	3	1	15	Water temperature: feeding (5 mon), growth (3 mon), egg laying (1 mon). Salinity: >15 (12 mon). Substrate: good for burrowing and attachment. Food: good for small and medium whelks but may be limiting for large whelks. Ballast water: at most 2 ships per month.
Concordia	5	5	4	5	4	23	Water temperature: feeding, growth, egg laying (12 mon). Salinity: >15 (12 mon). Substrate: good for burrowing, natural hard substrate for attachment may be limiting but there is plenty of artificial substrate available. Food: good for all whelk sizes. Ballast water: at least 8 ships per month.
Derry	5	5	2	2	1	15	Water temperature: feeding, growth, egg laying (12 mon). Salinity: >15 (12 mon). Substrate: good for burrowing, not much suitable for attachment. Food: good for small and large whelks, limiting for medium whelks. Ballast water: 1 ship per month.

Related educational resources

Harding, J.M., Mann, R., and V.P. Clark. 1999. Oyster Reef Communities in the Chesapeake Bay: A Brief Primer. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-99-05, VIMS-ES-44. 4/1999.

Harding, J.M., Mann, R., and V. P. Clark. 1999. Oyster Reef Communities in the Chesapeake Bay [CD-ROM]. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-99-06, VIMS-ES-45. 6/1999. (see the ORCCB CD website: http://www.vims.edu/mollusc/meeduc.orccb.html for release notes and CD updates).

Harding, J.M., Mann, R., and V.P. Clark. 1999. Shell Games. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-99-13, VIMS-ES-47. 11/1999.

Harding, J.M., Clark, V.P., and Mann, R. 2002. Rundown on the Rapa. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-02-19, VIMS-ES-51. 10/2002.

Harding, J.M., Clark, V.P., and Mann, R. 2002. Rundown on the Rapa: Activity Booklet for Educators. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-02-20, VIMS-ES-52. 10/2002.

Harding, J.M., V.P. Clark, and R. Mann. 2002. Shellfish Stalkers: Threats to an Oyster. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-02-21, VIMS-ES-53. 10/2002.

Harding, J.M., V.P. Clark, and R. Mann. 2002. Shellfish Stalkers: Threats to an Oyster Activity Booklet for Educators. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-02-22, VIMS-ES-54. 10/2002.

Harding, JM, VP Clark, and Mann, R. 2003. Predators in Action: Rapa whelks vs. Hard clams. Virginia Institute of Marine Science, Gloucester Point, Virginia. VORTEX WAVE No. 1. VSG-03-01. VIMS-ES - 55. 1/2003.

Harding, J.M., V.P. Clark, and R. Mann. 2003. Veined rapa whelks: Aliens in the Chesapeake. [CD-ROM]. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-03-14, VIMS-ES-56. 5/2003.

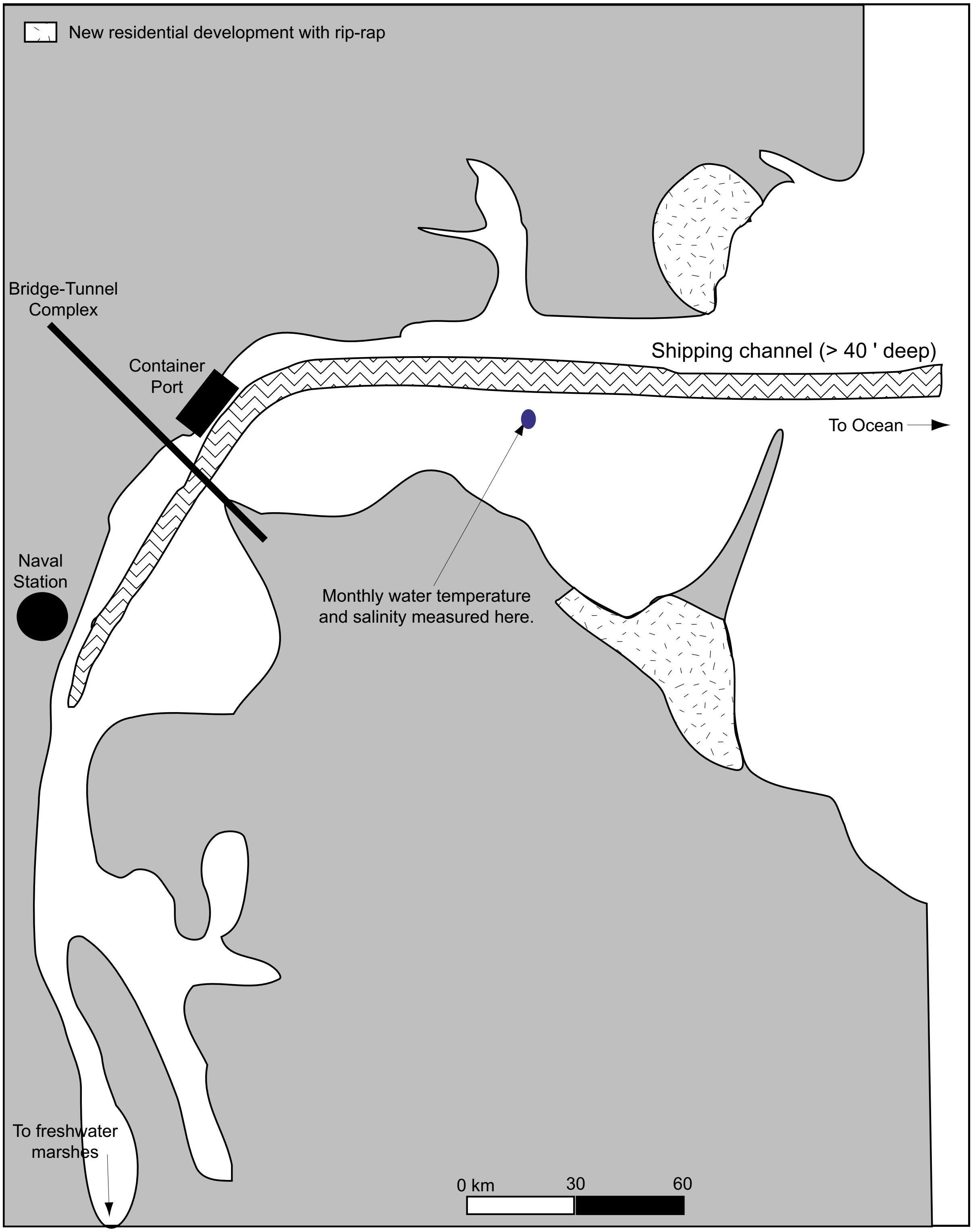
Harding, J.M. and V.P. Clark. 2006. The Shell Detective. Virginia Institute of Marine Science, Gloucester Point, VA. VSG-11-05, VIMS-ES-59. 12/2005.

The VORTEX (Virginia's Oyster Reef Teaching EXperience) website. http://www.vims.edu/mollusc/meeduc/vortex.html (provides regular updates on VORTEX program activities and resource materials).

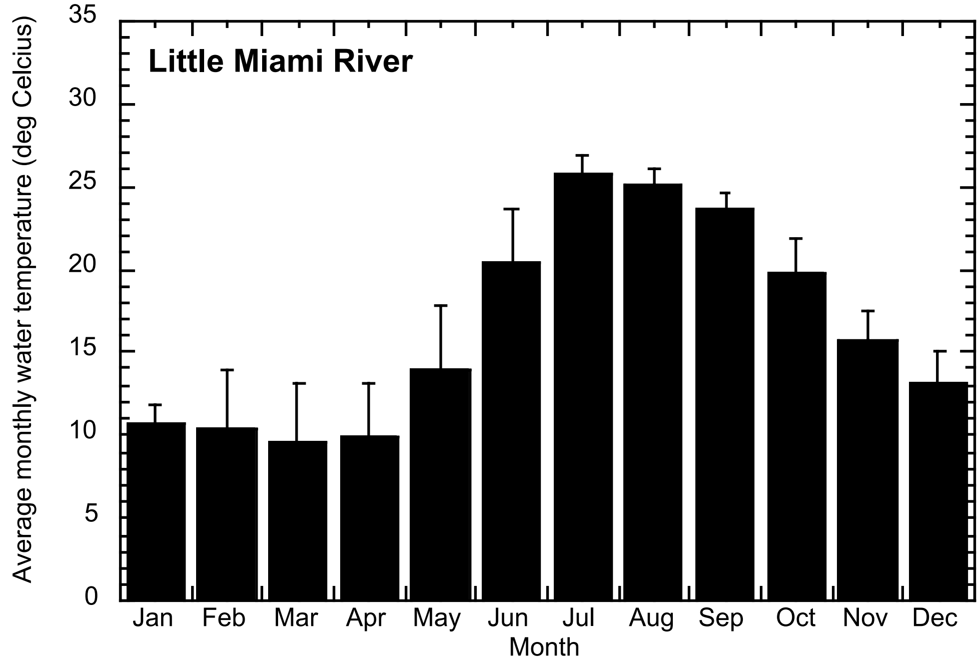
The Bridge: An On-Line Ocean Science Resource Center for Teachers. http://www.vims.edu/bridge/ (see "biology" section for a list of links to websites on oysters and other molluscs).

The VIMS Molluscan Ecology Program website. http://www.vims.edu/mollusc (provides a technical overview of ongoing invasive species, oyster reef research and restoration activities in Virginia).

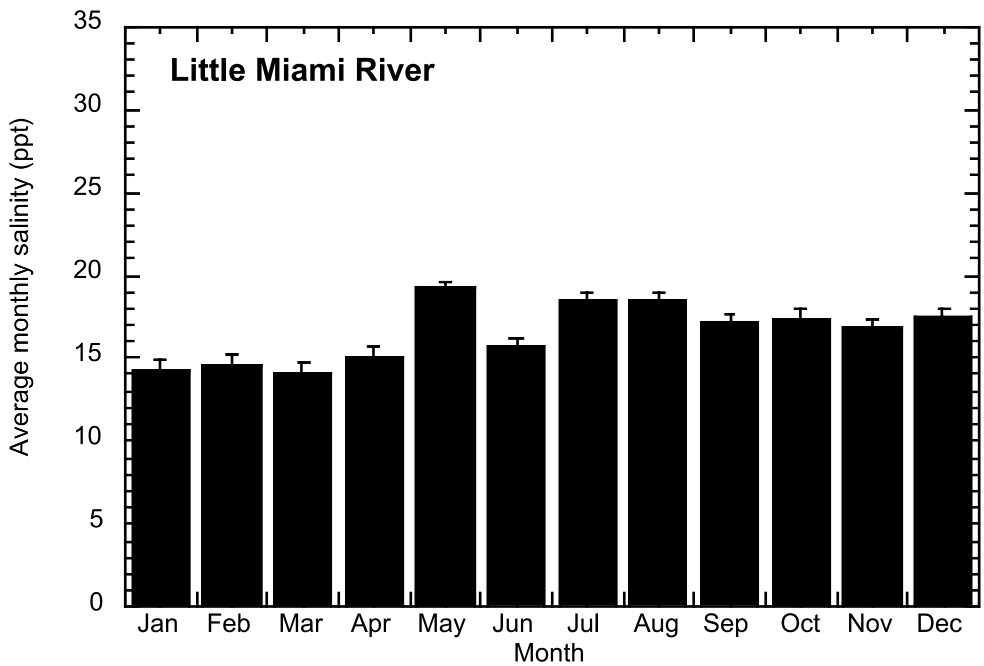
Map of fictitious US Atlantic coast estuary: **Little Miami River**



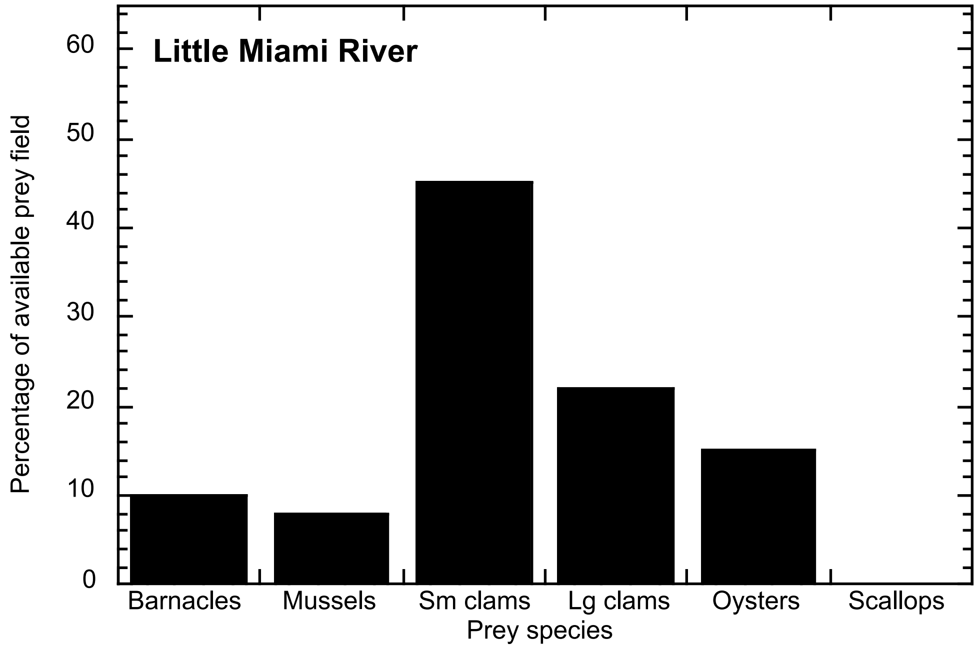
Annual water temperature (•C) data as average monthly water temperature with standard error of the mean over the last 5 years.



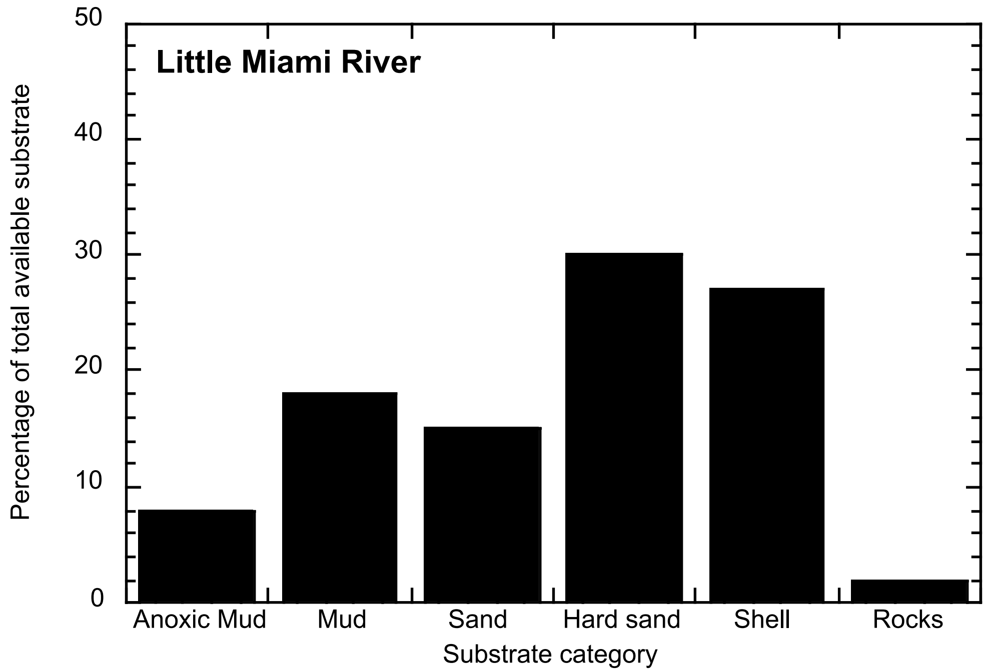
Annual salinity (ppt) data as average monthy salinity with standard error of the mean over the last 5 years.



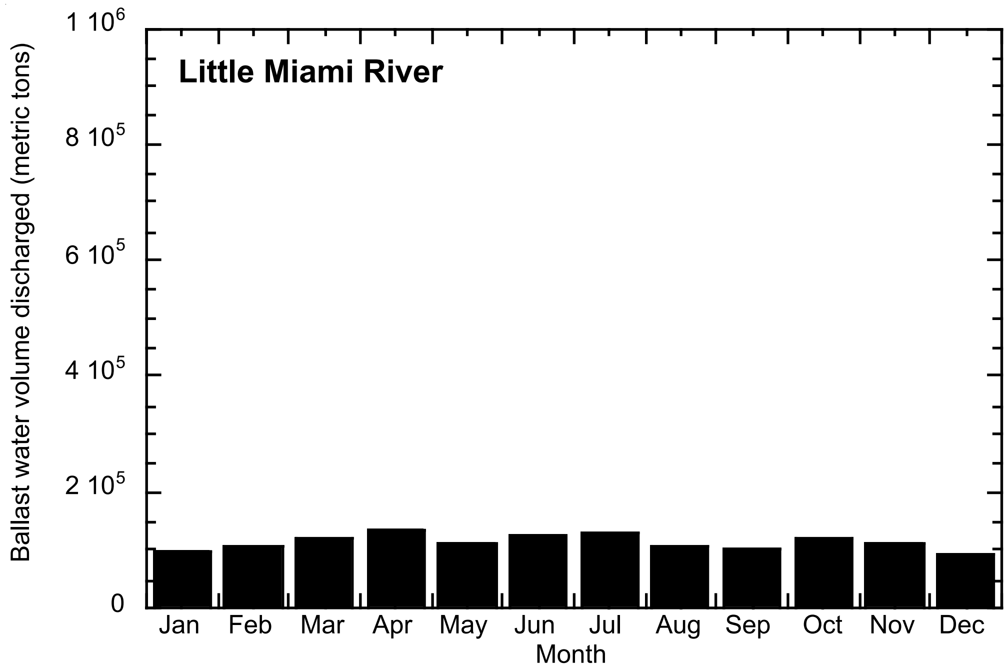
Descriptions of benthic prey available for rapa whelks compiled from recent benthic surveys for portions of the estuary with salinities above 8 ppt.



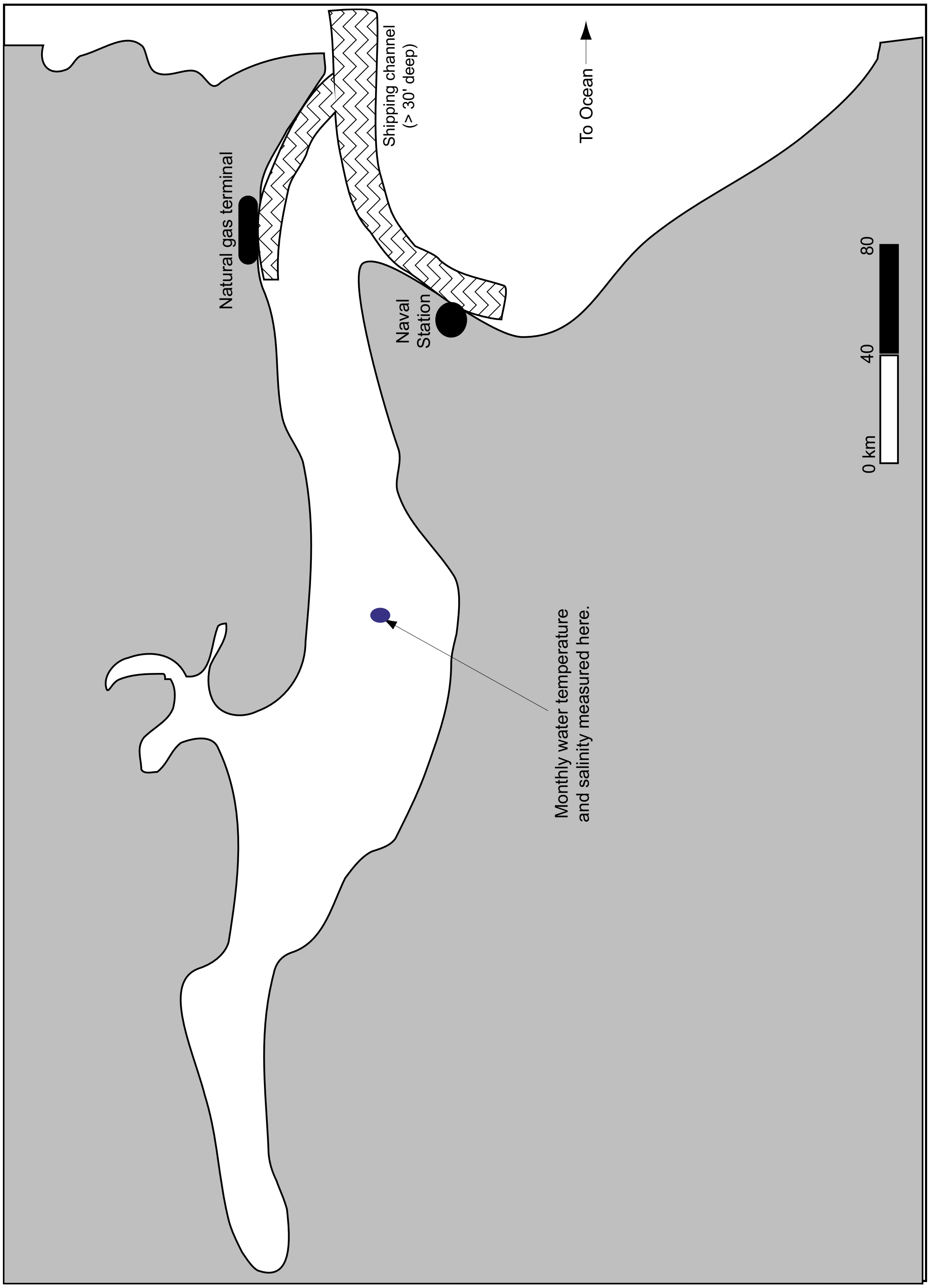
Substrate characterizations from recent benthic surveys for portions of the estuary with salinities above 8 ppt.



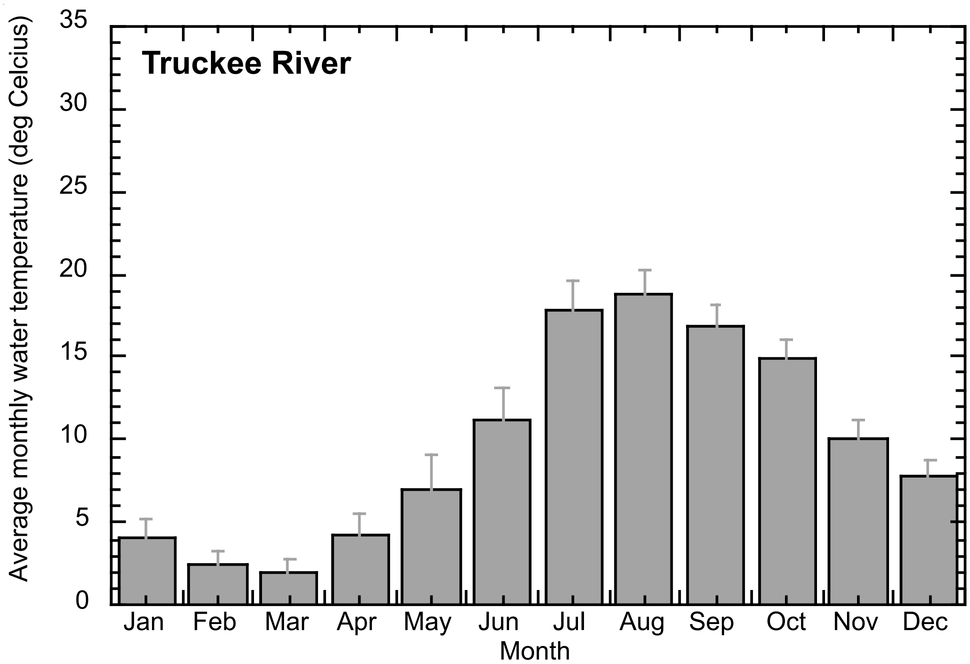
Volume of ballast water discharged into the estuary per month as metric tons. Keep in mind that a single container ship carries approximately 11,000 metric tons (MT) of ballast water.



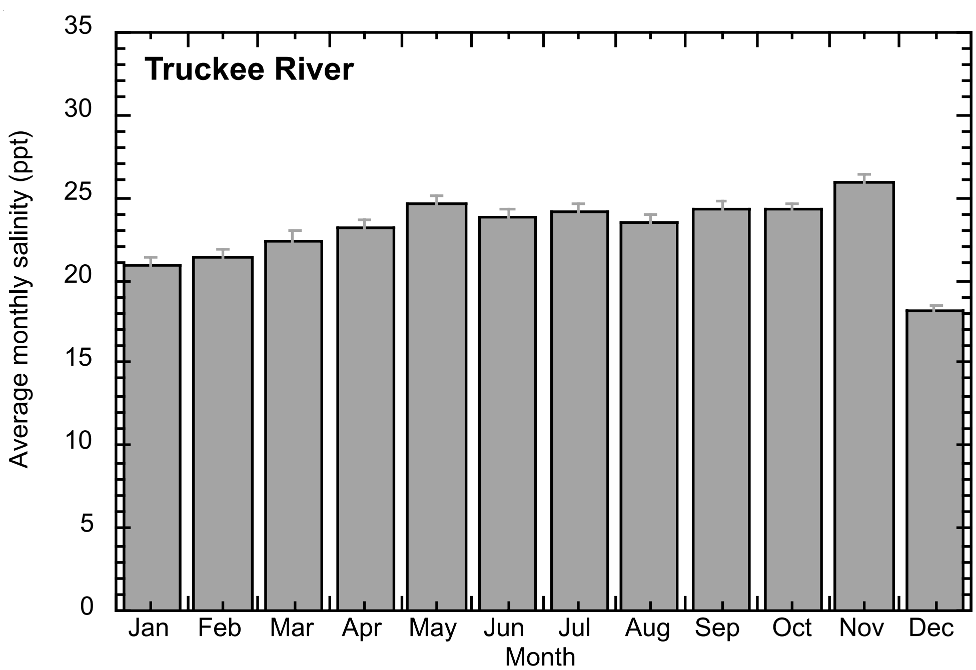
Map of fictitious US Atlantic coast estuary: **Truckee River.**



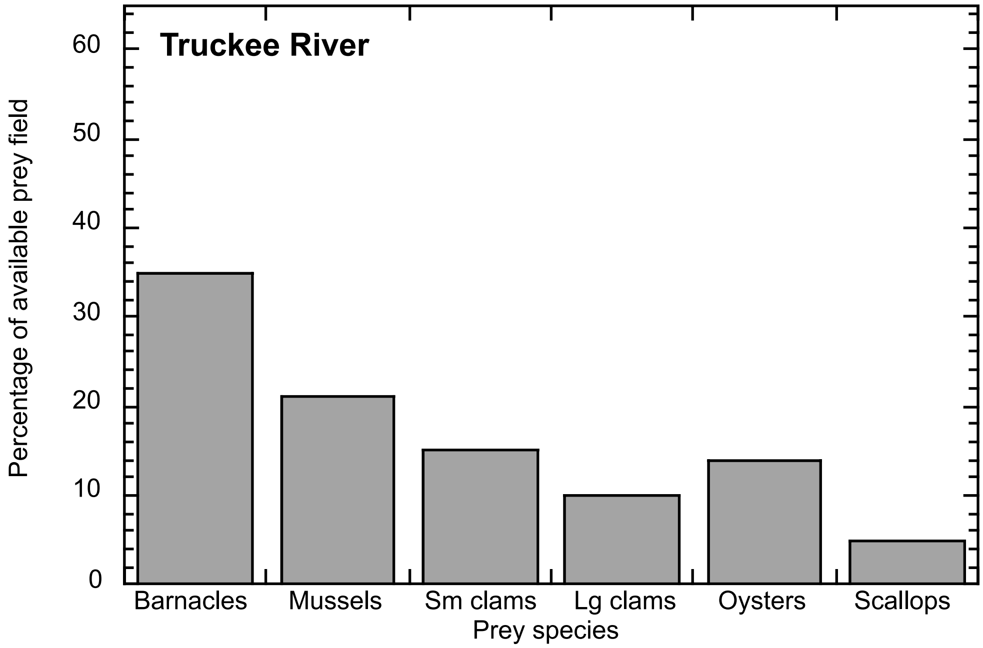
Annual water temperature (•C) data as average monthly water temperature with standard error of the mean over the last 5 years.



Annual salinity (ppt) data as average monthly salinity with standard error of the mean over the last 5 years.



Descriptions of benthic prey available for rapa whelks compiled from recent benthic surveys for portions of the estuary with salinities above 8 ppt.



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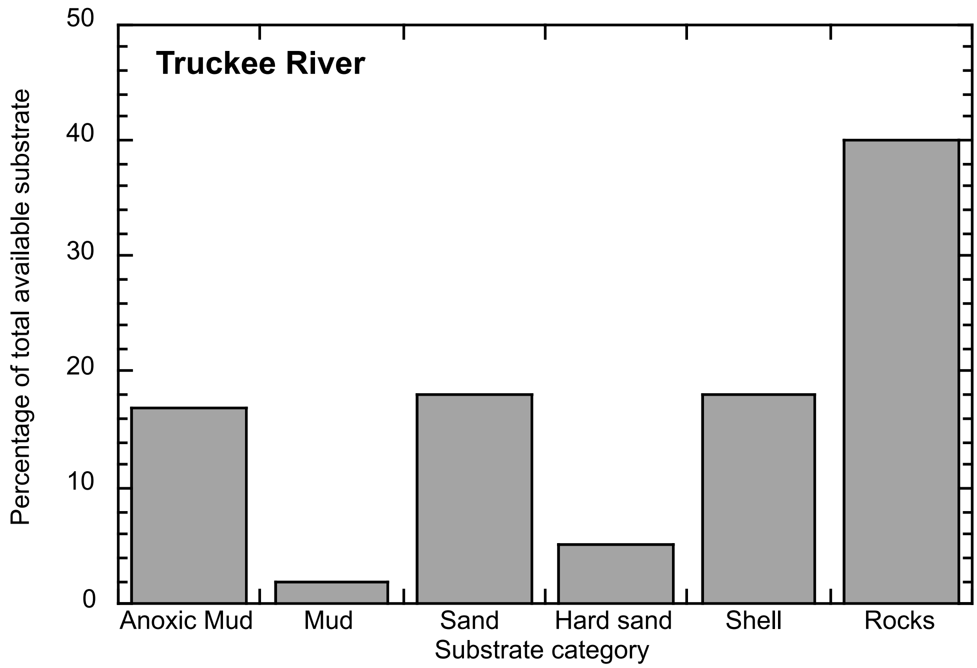
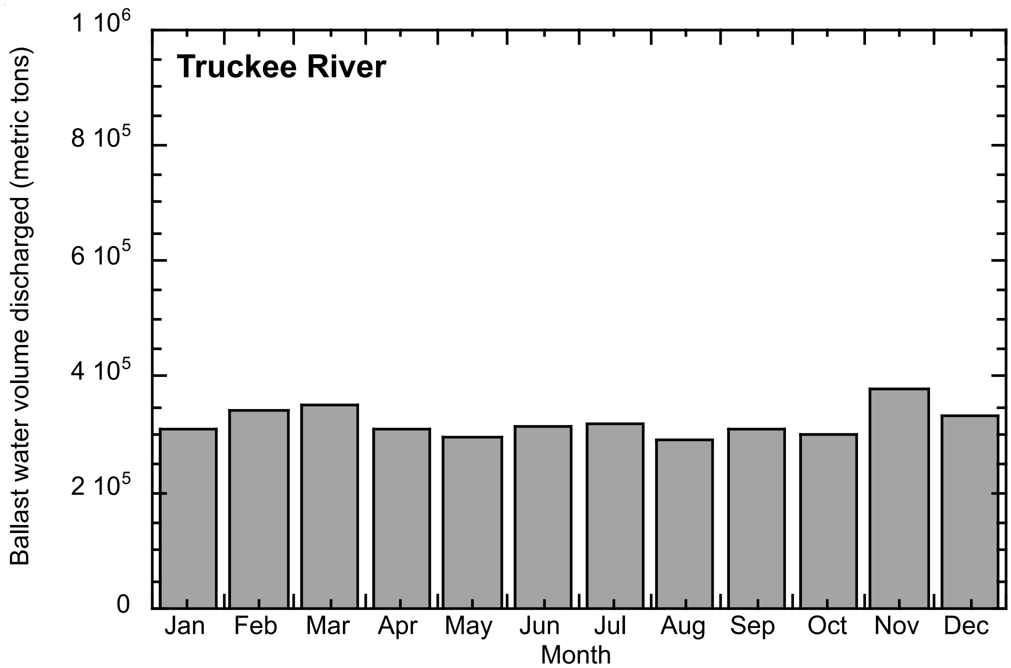
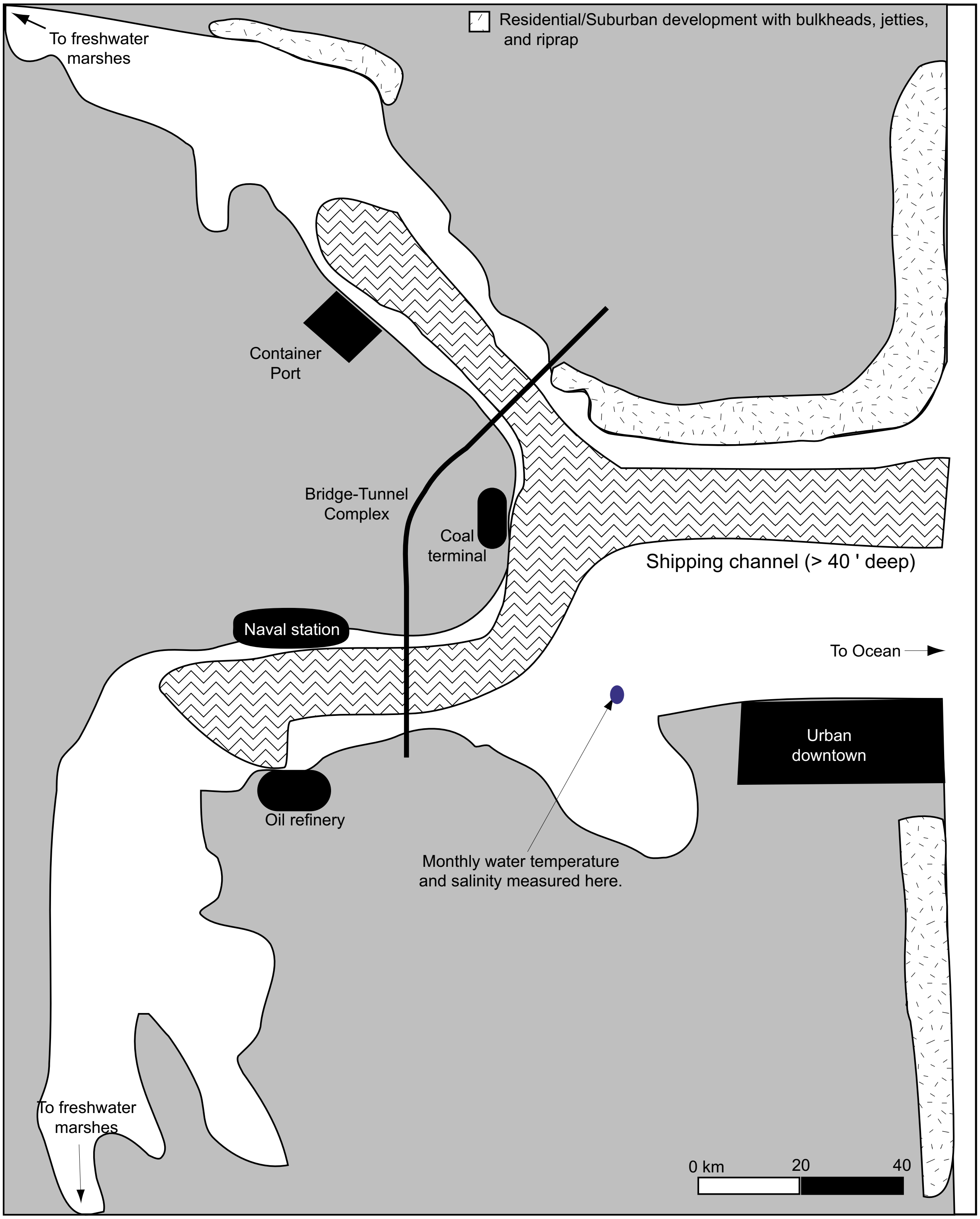


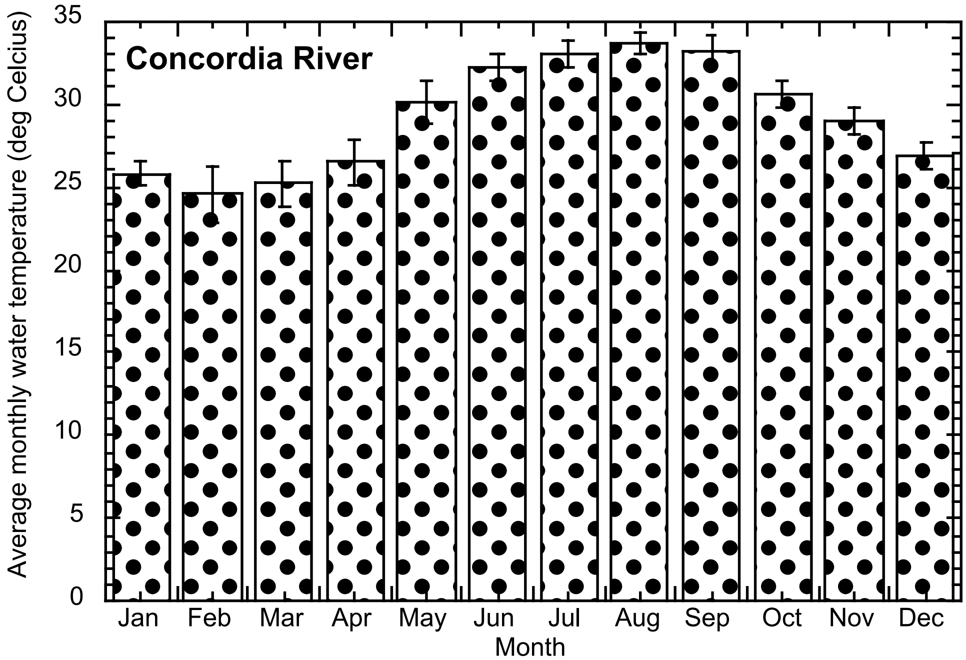
Volume of ballast water discharged into the estuary per month as metric tons. Keep in mind that a single container ship carries approximately 11,000 metric tons (MT) of ballast water.



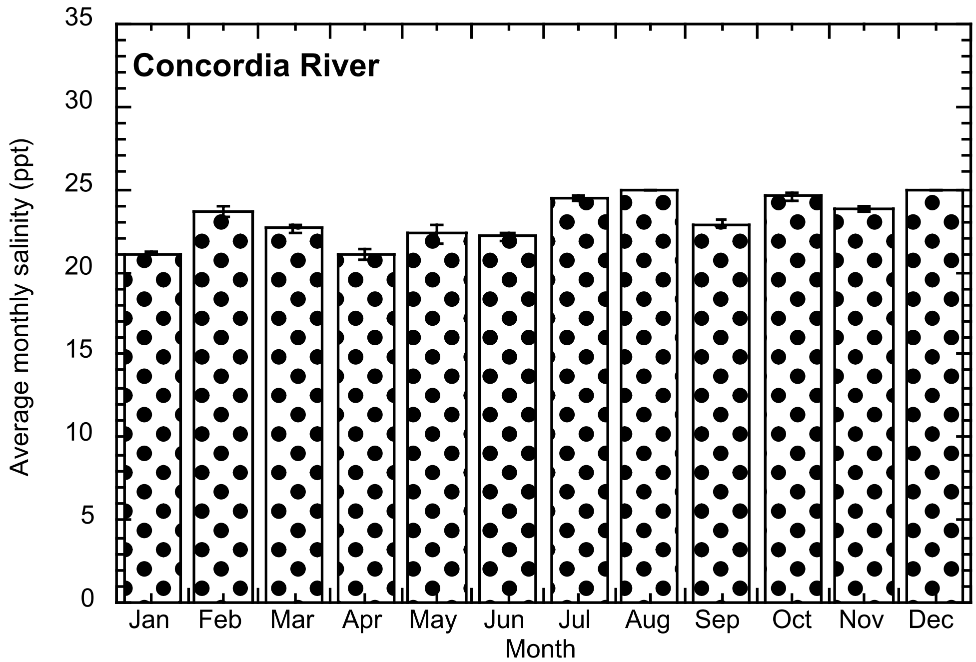
Map of fictitious US Atlantic coast estuary: **Concordia River.**



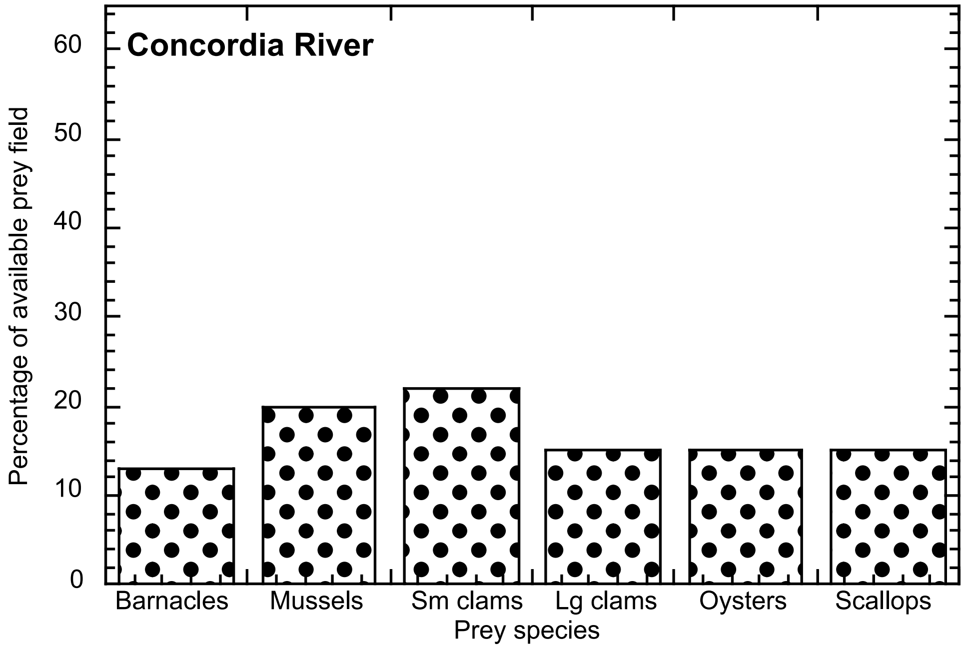
Annual water temperature (•C) data as average monthly water temperature with standard error of the mean over the last 5 years.



Annual salinity (ppt) data as average monthly salinity with standard error of the mean over the last 5 years.



Descriptions of benthic prey available for rapa whelks compiled from recent benthic surveys for portions of the estuary with salinities above 8 ppt.



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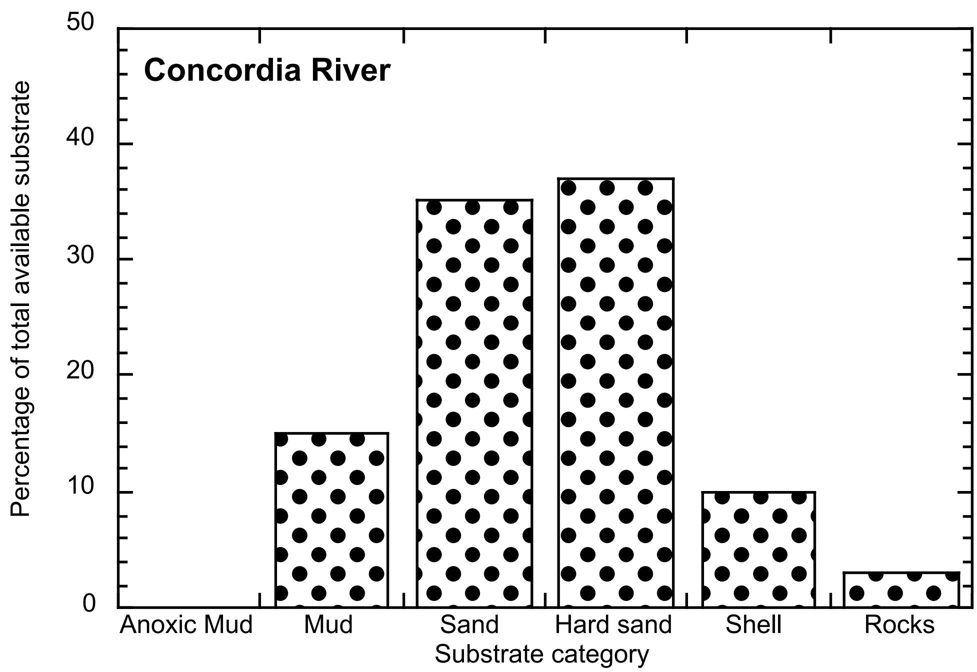
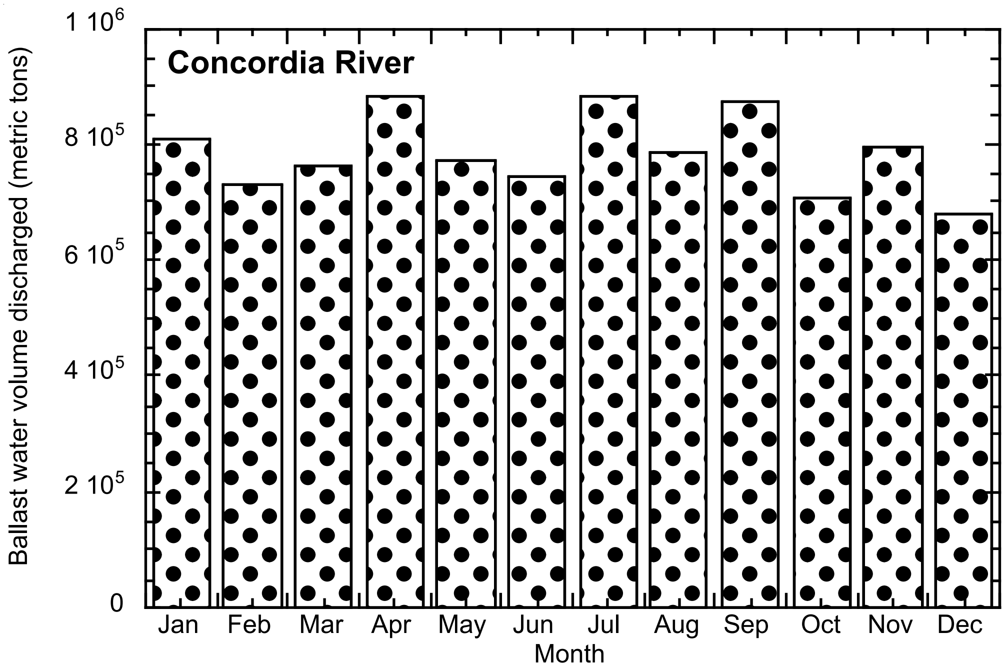
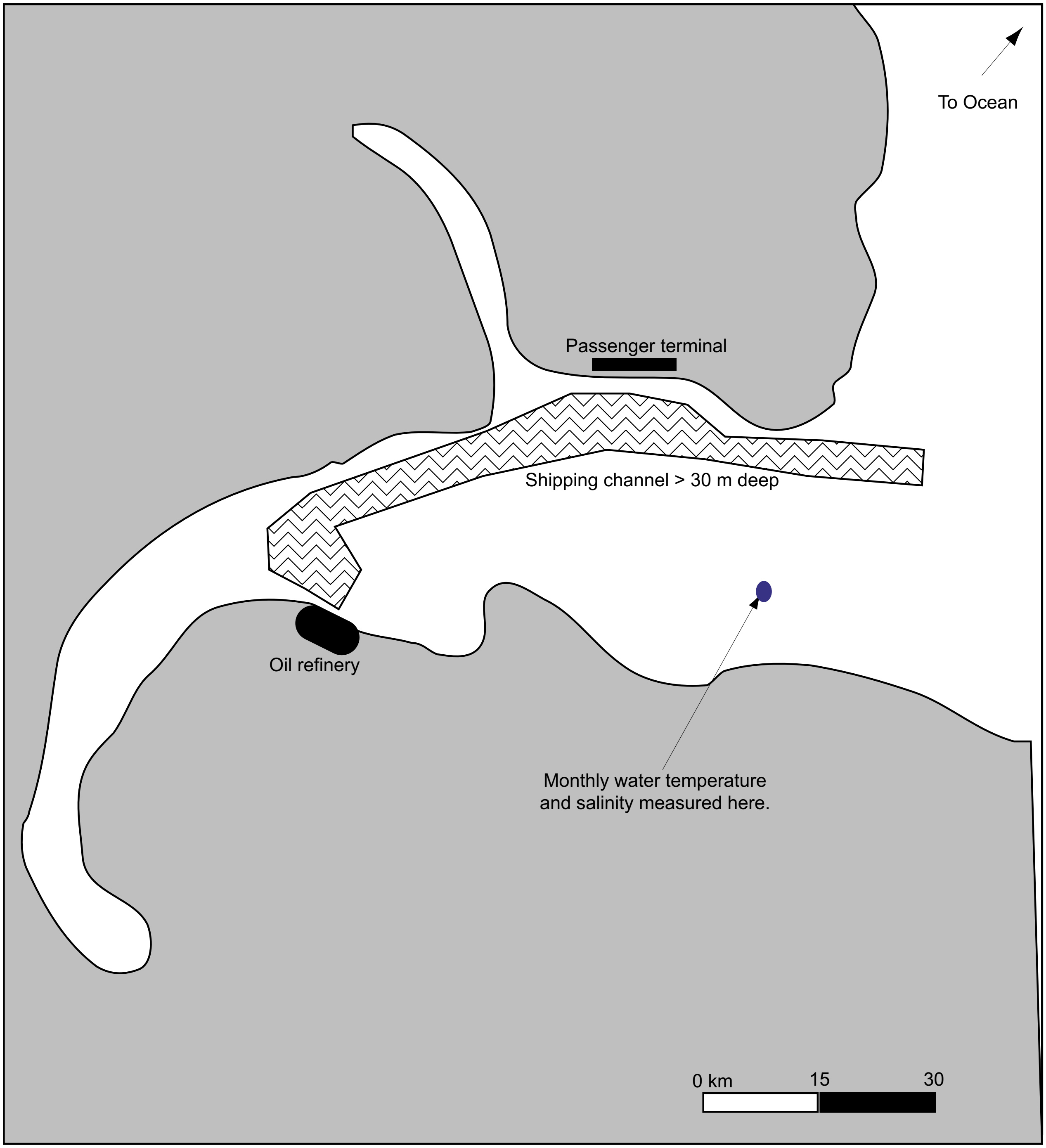


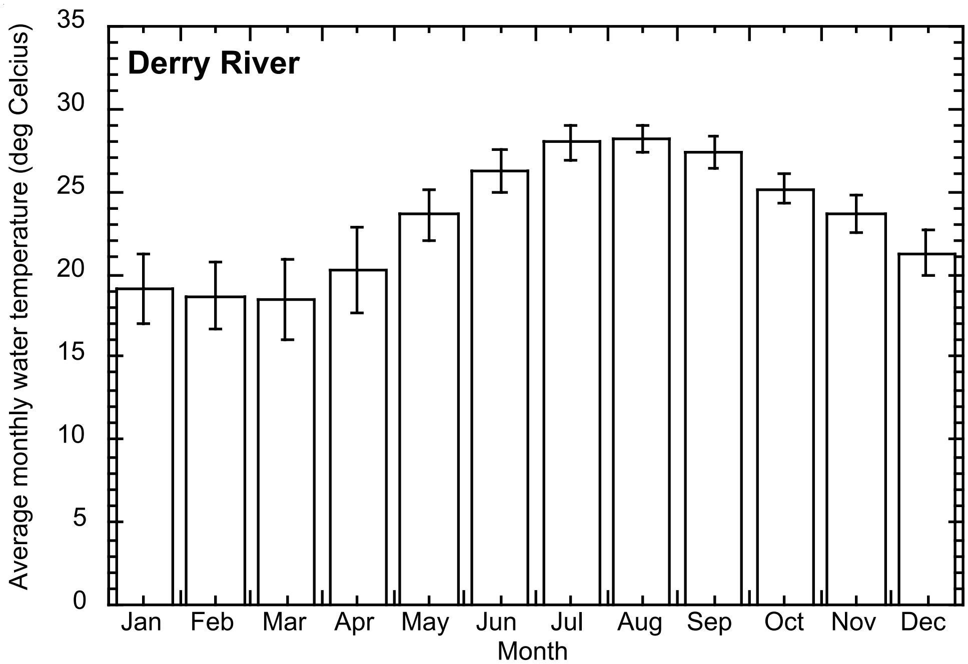
Volume of ballast water discharged into the estuary per month as metric tons. Keep in mind that a single container ship carries approximately 11,000 metric tons (MT) of ballast water.



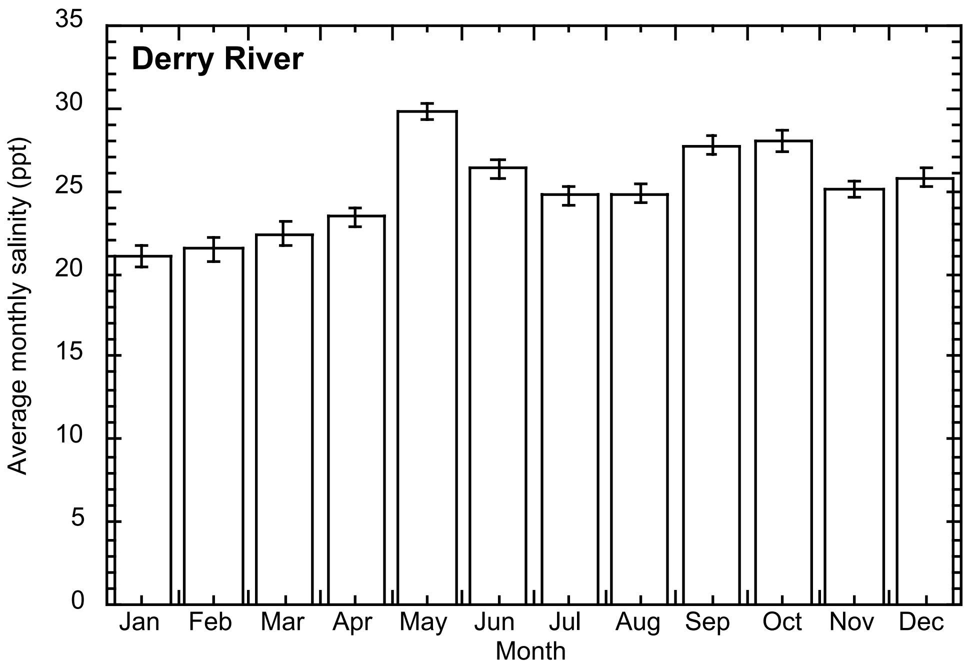
Map of fictitious US Atlantic coast estuary: **Derry River.**



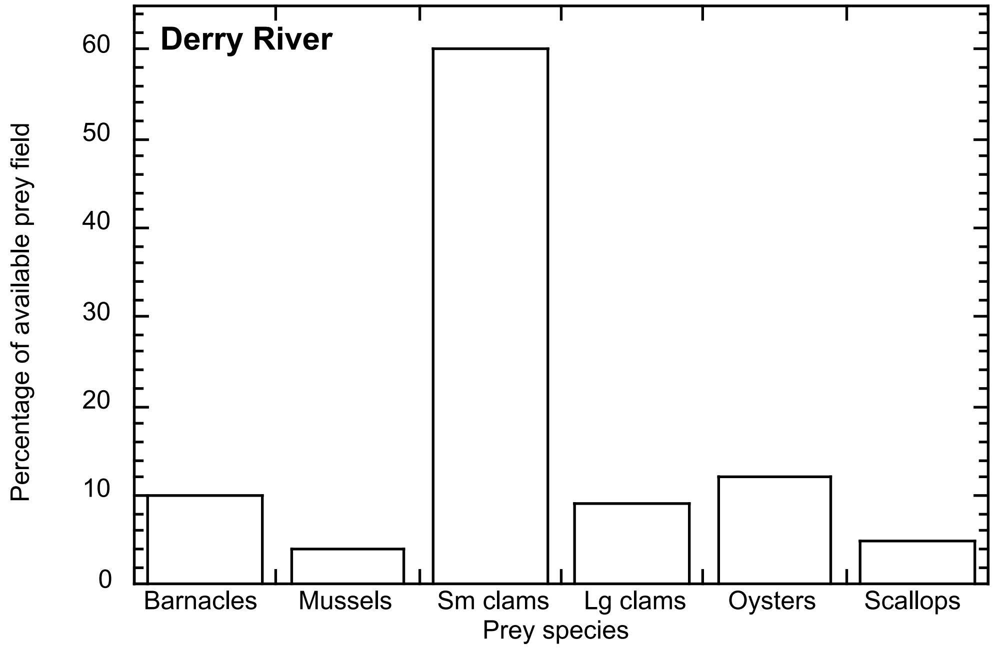
Annual water temperature (•C) data as average monthly water temperature with standard error of the mean over the last 5 years.



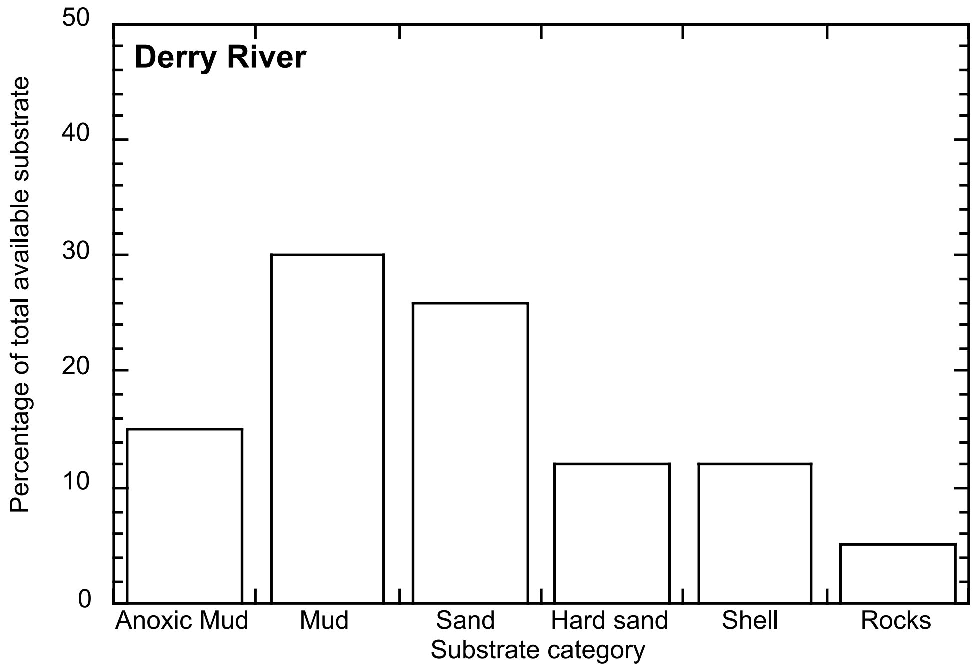
Annual salinity (ppt) data as average monthly salinity with standard error of the mean over the last 5 years.



Descriptions of benthic prey available for rapa whelks compiled from recent benthic surveys for portions of the estuary with salinities above 8 ppt.



Substrate characterizations from recent benthic surveys for portions of the estuary with salinities above 8 ppt.



Volume of ballast water discharged into the estuary per month as metric tons. Keep in mind that a single container ship carries approximately 11,000 metric tons (MT) of ballast water.