Shell Games

Introduction

One of the more obvious features of many sandy beaches in the Chesapeake Bay region is the collection of shells visible between the tide lines. These shells are the creations of a wide variety of molluscs as well as prizes for beachcombers. Molluscan shells are calcium carbonate structures made by soft-bodied invertebrates in the phylum Mollusca (Figure 1). The shell is secreted by the animal and grows with the animal. Unlike hermit crabs, molluscs do not ever leave their shells to transfer to others.

The molluscan shell has two main functions:

1. The shell is a hard protective barrier for the soft body of the animal. When a mollusc is threatened by a predator or unfavorable environmental conditions, it simply retreats into its shell. When the threat has passed, the mollusc emerges unharmed.

2. The shell provides muscle attachment points for the soft bodied animal. The external skeleton or shell anchors the mollusc to its muscle systems allowing it to move, eat, breathe, or burrow effectively.

The shell is the most recognizable feature of many molluscs. The form of a molluscan shell is directly related to its function and the lifestyle of the resident mollusc. The shells themselves are treasure troves of biological and ecological information provided the observer is attuned to the "clues" or morphological features that tell the animal's story. Muscle scars, shell shape, and shell thickness all can be used to infer details of the animal's lifestyle and habitat.

This sort of forensic ecology provides a simple, cost-effective means to encourage students of all ages to develop qualitative and quantitative skills including observation, hypothesis testing, data presentation, and communication. The classroom activities described herein begin with a simple overview of common Chesapeake Bay bivalves (Bay Bivalves). The second activity (Oyster vs. Oyster) focuses on the Eastern oyster (*Crassostrea virginica*), one of the historically dominant species in the Bay. It sets the stage for the third activity (Oysters and Reefs: How Shell Shape Defines the Habitat) which describes the importance of oyster reefs within the Chesapeake Bay ecosystem.

Figure 1: Representative Chesapeake Bay bivalve shells.

Related educational resources:

Harding, J.M., Mann, R., and V. 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.

Harding, J.M., Mann, R., and V. 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. (see the ORCCB CD website: http://www.vims.edu/fish/oyreef/orccb.html for release notes and CD updates).

The VORTEX (Virginia's Oyster Reef Teaching EXperience) website. http://www.vims.edu/fish/oyreef/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/fish/oyreef/reef_page.html (provides a technical overview of ongoing oyster reef research and restoration activities in Virginia).

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 11/99.

www.vims.edu/fish/oyreef/vortex.html

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Bay Bivalves

Although the waters of the Chesapeake Bay are home to many molluscs, the Bay's bivalves are the most commonly recognized and commercially important. They historically dominated intertidal habitats in terms of both ecology and physical presence. Bivalve molluscs have paired shell valves (Figure 1.1) joined at the hinge by a ligament. This ligament is much like our own ligaments and cartilage. The shell valves grow outwards from the hinge structure. The shell valves are also held together by adductor muscles. The hinge ligament and adductor muscles work together to enable the animal to open and close its valves at will. The valves must be open for the animal to breathe, feed, and release gametes (eggs and sperm). Bivalves are filter feeders whose gills are specially modified for both respiration and food capture.

The shape of a bivalve shell relates directly to the animal's lifestyle and habitat. This activity uses four common Chesapeake Bay bivalves - the hard clam (*Mercenaria mercenaria*), the Eastern oyster (*Crassostrea virginica*), the Atlantic Bay scallop (*Argopecten irradians*), and the Atlantic ribbed mussel (*Geukensia demissa*) - to provide a broad overview of bivalve diversity and biology within the Chesapeake Bay.

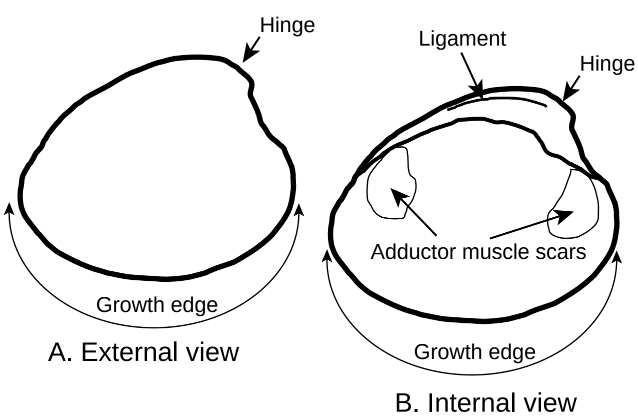


Figure 1.1. Generalized bivalve valves

Objective: Examine Chesapeake Bay bivalve shells and relate shell shape and morphology to the lifestyle (How do they live?) and habitat (Where do they live?) of the animal.

Skills: Observation, communication, hypothesis testing, and group collaboration.

Relevant Virginia SOL:
- LS.5 Classification of organisms
- LS.10 Organism adaptation to biotic and abiotic factors
- BIO.5 Life functions

Materials: For each small group, at least one set of four types of bivalve shells including one each of hard clam, oyster, bay scallop, and ribbed mussel. Use matched pairs of valves if available; otherwise a single valve from each species will do.

Procedure:
1. Divide students into small groups or "research teams".
2. Provide each group with one set of shells including hard clam, oyster, scallop, and ribbed mussel valves.
3. Using the worksheet on page 7, have students describe and compare the shell valves within and between species in terms of:
   - general shape - qualitative descriptions (round, wing shaped, flat, etc.)
   - quantitative measurements of shell height and shell width (see Figure 1.2 below)

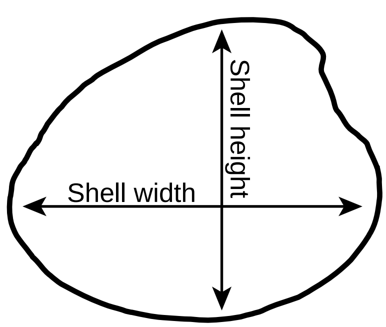


Figure 1.2. Generalized shell valve showing locations of measurements

- general appearance (texture, color, etc.)
- specific morphological features including location of the hinge and adductor muscle scars (see Figure 1.1)

4. After they have initially examined the shells, give each group of students a set of local habitat descriptions (given below). Ask students to pair each bivalve with a habitat. (Where do you think you would find this animal?). Have them include justification for their answers based on their observations of shell morphology . Some bivalves may be found in more than one habitat.
5. Review each group's responses as a class using the illustrated key on the following pages to emphasize relationships between bivalve form and function.

Habitat 1: Sand bottom. Sand bottom habitat is easy to burrow into and is often intertidal and adjacent to seagrass beds or oyster reefs.

Habitat 2: Reef structures. Natural reefs are three-dimensional structures made exclusively of attached bivalves and their shells.

Habitat 3: Tidal salt marshes. Tidal marsh habitat has sediment suitable for burrowing and grasses suitable for attachment of molluscs.

Related vocabulary:

adductor muscle: one of the muscles that closes the valves of a bivalve shell.

aggregate: group or gather together.

anterior: the forward or front section of an animal that goes first during locomotion.

elliptical: oval or egg shaped, not round.

posterior: the rear or last section of an animal.

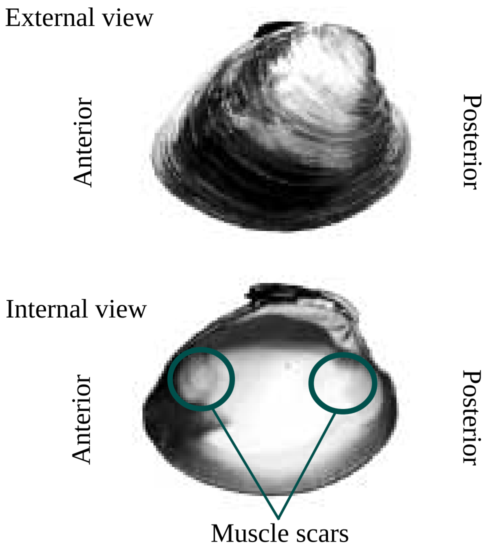
substrate: the bottom or surface to which an animal attaches

Suggested discussion questions:

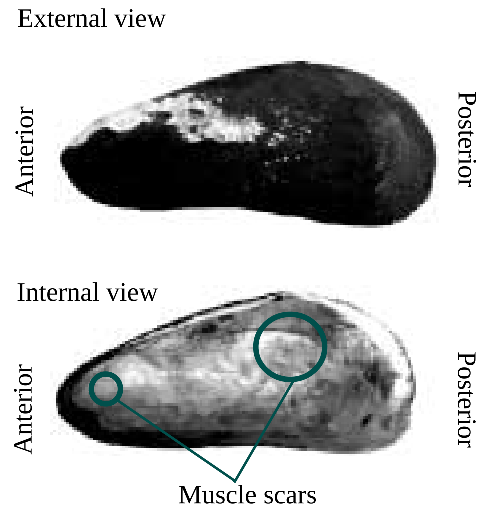
1. External fouling and attachment scars are two of the features that distinguish attached bivalves from burrowing bivalves. Why do you think burrowed bivalves lack either or both of these characteristics?

2. What are some of the risks and benefits associated with burrowing? How do these compare with those encountered by a bivalve attached to an exposed surface?

3. Compare the four types of shells in terms of shell thickness. How do you think shell thickness relates to a bivalve's habitat and lifestyle?



Hard Clam
Mercenaria mercenaria



Atlantic Ribbed Mussel
Geukensia demissa

Description: Convex shell valves give this animal a wedge-shaped profile. Anterior and posterior adductor muscles are approximately the same size and muscle scars are clearly visible on the shell interior as are hinge and ligament structures. Shell valves may be large and quite thick. Leading edge of the interior valves may be dark purple. Shell exterior is gently ridged.

Habitat: Sand bottom.

Lifestyle: The wedge-shape of the shell valves combined with a large muscular foot to enables these animals to effectively burrow into the sand. Once burrowed, the animal extends its two siphons to the sand surface where they are faintly visible (called "keyholes" by clammers). The siphons transfer water into and out of the animal's body enabling it to feed, breath, and release gametes while completely buried. Hard clams are usually found in groups or beds.

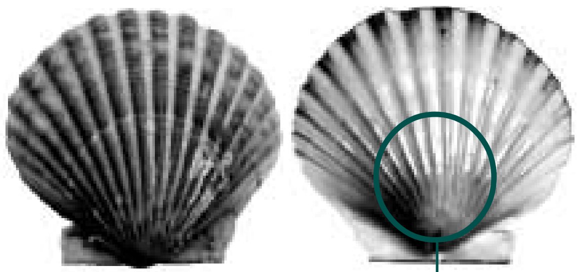
Comments: Hard clams are the target of a commercial fishery in the Lower Chesapeake Bay. Hard clam aquaculture is a growing industry, especially on Virginia's Eastern Shore. Natural predators include cownosed rays, blue crabs, and several species of locally occurring whelks (Channeled, Knobbed, Rapa).

Description: Wing-shaped shell valves have obvious exterior fluting or ribs. Anterior end is gently rounded, posterior end is flared. Anterior adductor muscle is smaller than the posterior adductor muscle. Shell valves are thin. Exterior color ranges from greyish white to brown.

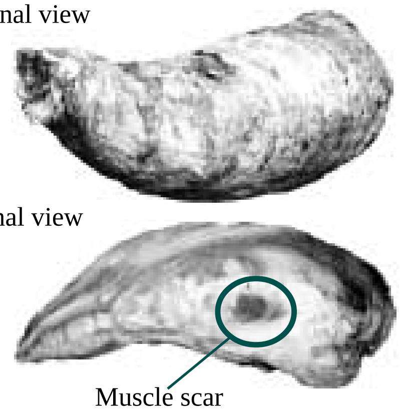
Habitat: Tidal salt marshes. May be half-buried in the mud/peat bottom or attached to either the roots and/or stems of marsh grass or a hard surface.

Lifestyle: The wing-shaped valves help the animal partially burrow into the soft marsh bottom. Mussels may also attach themselves with protein threads to hard surfaces, they do not have to be burrowed. If the animal is attached to an exposed surface, the wing-shaped ribbed shell is hydrodynamically suited to help prevent the mussel from being washed from its location. In either case, siphons extend from the posterior (flared) region and transfer water into and out of the animal's body enabling it to feed, breath,and release gametes.

Comments: Ribbed mussels are common in local salt marshes. Natural predators include marsh crabs, raccoons, and several species of marsh birds and fishes.



Atlantic Bay Scallop
Argopecten irradians



Eastern Oyster
Crassostrea virginica

<u>Description:</u> Disk-shaped shell valves that have obvious exterior fluting or ribs. Shell valves are very slightly convex and almost completely round. Single adductor muscle is very well developed and muscle scar is centrally located. Shell valves are thin. Exterior color is greyish white.

<u>Habitat:</u> Sand bottom especially near and in seagrass beds.

<u>Lifestyle:</u> The powerful adductor muscle can quickly and repeatedly contract, forcing water out of the animal's body by clapping the shell valves together. This enables the animal to swim quickly via "jet-propulsion". The streamlined shell valve shape and exterior ribs enhance swimming hydrodynamics. Resting scallops may be partially buried in sandy depressions that they excavated with water jets created by the adductor muscle. Scallops posses a well-developed sensory system that helps them detect and avoid potential predators.

<u>Comments:</u> Bay scallops rely heavily on seagrass habitat. The decline of seagrass (particularly eelgrass) beds in the Chesapeake Bay since the 1960s has reduced suitable habitat for these animals. Seagrass restoration efforts in the Bay and seaside estuaries of Virginia's Eastern Shore are also helping Bay scallop populations. Natural predators include rays (cownose and Atlantic stingray), starfish, and several species of locally occurring whelks (Channeled, Knobbed).

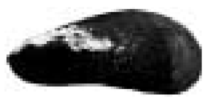
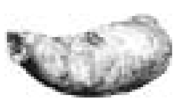
<u>Description:</u> The shell valves are slightly oval with a cupped left shell valve and a flattened right shell valve. Left shell valve is cemented to the bottom and contains the body of the animal. Elliptical purplish adductor muscle scar is obvious. Exterior of the shell is greyish white, roughened, and thick. Leading growth edges are thin, paler in color and may be quite sharp.

<u>Habitat:</u> Sand bottom in flat beds (bars) or in three-dimensional reef structures.

<u>Lifestyle:</u> The oyster begins its life as a microscopic planktonic larva. Eventually, it settles onto hard substrate and cements its left shell valve to the hard surface. As the animal grows, the left shell valve cups and provides protection for the animal's soft body. Growth occurs in a direction opposite the hinge. Migration of the adductor muscle (and scar) from the hinge or oldest region toward the growth edge or youngest region continues throughout the oyster's life.

<u>Comments:</u> Oysters naturally aggregate and can form large reef structures over time. Historically, oyster reefs dominated the ecology and physical geography of the Bay. Oyster shells, either in reefs or flat bars, provide habitat for numerous other invertebrates (crabs, mussels, worms, etc.) as well as many fishes. Oysters have been fished in the Chesapeake Bay since colonial times and before; shell piles or "middens" left by native Americans are quite common in the Tidewater region.

Bay Bivalves Worksheet

	Description of shell shape	Height or width	Description of texture, color, etc.	Sketch showing muscle scars, hinge, and other features	Habitat
Hard Clam 					
Atlantic Ribbed Mussel 					
Atlantic Bay Scallop 					
Eastern Oyster 					

Habitat 1: Sand bottom. Sand bottom habitat is easy to burrow into and is often intertidal and adjacent to seagrass beds or oyster reefs.

Habitat 2: Reef structures. Natural reefs are three-dimensional structures made exclusively of attached bivalves and their shells.

Habitat 3: Tidal salt marshes. Tidal marsh habitat has sediment suitable for burrowing and grasses suitable for attachment of molluscs.

OYSTER VS. OYSTER

The Eastern oyster (*Crassostrea virginica*) is often described as one of the Chesapeake Bay's "keystone" species. The term "keystone" species refers to an animal that plays a central ecological role within a habitat. Prior to the late 1800's, oysters dominated the Chesapeake Bay both ecologically and physically. Oysters were so abundant that they could filter most of the Bay's water once every three to five DAYS (Newell, 1988[1]). Captain John Smith described these pre-colonial oyster reefs in his log books as navigation hazards.

Reef oysters are usually exposed to favorable biological conditions in Chesapeake Bay tributaries. However, not all oysters are found on subtidal reefs. Oyster bars or flat clumps of oyster shell may also be found in many parts of the Bay. On Virginia's Eastern Shore, especially in the seaside estuaries, oysters commonly occur in small groups or clumps.

Although the seaside oysters are the same species as the reef-building oysters commonly observed in the Bay tributaries (both are *Crassostrea virginica*), there are noticeable differences in shell shape or morphology. These morphological differences are largely due to differences in the animals' habitats. Comparison of reef oysters and seaside oysters can reveal the influences of habitat conditions including tidal currents, bottom type, and salinity on shell morphology - within the same species.

<u>Objective:</u> Examine representative oyster shells from the seaside and from western shore Chesapeake Bay tributaries and relate observed differences in shell morphology (shape) to habitat conditions.

<u>Skills:</u> Observation, hypothesizing, communication, and group collaboration.

<u>Relevant Virginia SOL:</u>

- LS.10 Organism adaptation to biotic and abiotic factors in a biome
- LS.11 Dynamic nature of organisms
- BIO.5 Organism response to environment

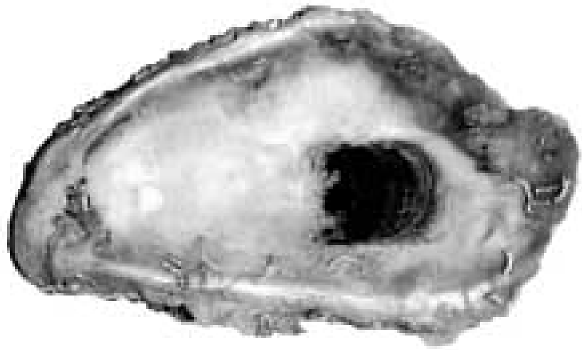
<u>Materials:</u> Oyster shells from western shore Chesapeake Bay tributaries (reef oysters) and seaside estuaries (seaside oysters).

<u>Procedure:</u>

1. Divide students into small groups or "research teams".
2. Give each group at least one reef oyster valve and one seaside oyster valve. At this point, do not identify the shells as oyster shells.
3. Using Worksheet A on page 11, have the students describe and compare the two different types of shell valves in terms of:
   - general shape - qualitative descriptions (round, wing shaped, flat, etc.)
   - quantitative measurements of shell height and shell width
   - general appearance and texture
   - specific morphological features including location of the hinge and adductor muscle scars
4. Ask the students which of the shells are oyster shells. Have each research team present its answer (and reasons for the answer) to the class. If the students don't recognize that both shells are oyster shells, highlight the basic similarities between the shells. Tell them that the observed differences in shell morphology are due to differences in habitat conditions.
5. List various habitat conditions (e.g., temperature, salinity, tidal currents, bottom type [sand vs. mud]) on the board to help the groups with #6 below.
6. Using Worksheet B on page 12, have the groups make predictions as to which habitat conditions are responsible for the observed differences in the shells. Ask each group to put together a habitat description for each shell type (3 or 4 sentences) and descriptions of potential habitat-specific advantages of each morphology to present to the class.
7. Following the group reports, review the group habitat descriptions and advantages as a class and compile class habitat descriptions and advantages for each shell type. Compare these descriptions with the descriptions given on pages 9 and 10.

[1]Newell, R. 1988. Ecological changes in Chesapeake Bay: Are they the result of overharvesting the American oyster, *Crassostrea virginica*? pp. 536-546. In: Lynch, M.P. and J.A. Mihursky (eds.). Understanding the Estuary: Advances in Chesapeake Bay research. Chesapeake Research Consortium Publication 129.

Chesapeake Bay Tributary or REEF Oysters



Shell Morphology

A reef oyster's shell is almost half as wide as it is long and somewhat oval shaped.

Shell exterior is covered with worm tubes, barnacles, young oysters (oyster spat) and other fouling organisms.

Related habitat characteristics

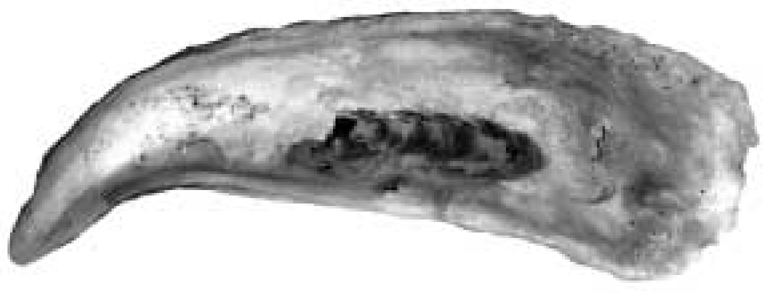
Reef oysters occur in deeper areas below the tide line, where tidal currents are relatively slow.

- Because water velocity or flow around the animal is relatively low, a slim, streamlined shell is not necessary. In calm water, the oyster's shell grows more or less equally in each direction.

- Low tidal currents mean reduced movement of sand along the bottom. Because bottom sediments are not usually stirred up into the water column, reef oysters can grow near the bottom with less risk of suspended sediments clogging their gills.

Lower tidal currents make it easier for many invertebrates including other oysters to settle onto the hard surfaces of oyster shells. These invertebrates are able to establish themselves and begin to grow because the shells are not scoured by water and sand twice a day during changing tides.

SEASIDE OYSTERS



SHELL MORPHOLOGY	RELATED HABITAT CHARACTERISTIC
A seaside oyster's shell is long and narrow with a slightly hooked hinge area.	Seaside oysters occur in habitats with high tidal currents. - These oysters are usually attached to small bits of shell or other hard material in the sand bottom. The oysters grow vertically off the bottom and up into the water column. The hooked hinge area helps prevent the animal from being dislodged by tidal currents. - The long, narrow shell is streamlined, reducing the force of water movement over the shell. This helps keep the animal from being dislodged. - High tidal currents stir up and move sand near the bottom. Filter feeding, oysters are vulnerable to "clogging" of their filtering surfaces by excess sand in the water.
The seaside oyster's shell lacks or shows little evidence of barnacles, worm tubes, oyster spat, or other fouling organisms.	It is difficult for organisms such as barnacles oyster spat, and worms to settle and grow on seaside oysters' shells. Swift tidal currents sweep over the oysters twice a day scouring the shells with a mixture of water and sand.

Oyster vs. Oyster Worksheet A

	Sketch both sides of each oyster shell below.	Describe the shape of each shell.	Height and width	Describe the texture, color, and other shell features.
REEF oyster				
SEASIDE oyster				

List the major differences between the shells.

Oyster vs. Oyster Worksheet B

Compare the physical and chemical characteristics of each oyster habitat using the table below. Rank the characteristics from 1 (lowest) to 5 (highest) in terms of their influence on oyster shell shape in each habitat. Explain your rankings.

Relevant habitat characteristics	**Western shore Chesapeake Bay tributary (REEF oyster habitat)**	**Seaside tidal creek (SEASIDE oyster habitat)**	**Relative influence on oyster shell shape**	
			REEF	SEASIDE
Annual water temperature range (°C)	4 to 30°C	4 to 30° C		
Salinity range (ppt)	7 to 18 ppt	20 to 35 ppt		
Tidal currents (speed)	Low to Moderate	High		
Bottom type	Sand, mud, or oyster shell	Sand, mud, or oyster shell		
Tidal range (exposure due to tides)	Less than 2 m	2 m or more		

Oysters and Reefs: How shell shape defines the habitat

Eastern oysters (*Crassostrea virginica*) dominated the ecological and physical landscape of the Chesapeake Bay prior to the mid-19th century. The oyster played a central role in the Bay's food web because of its abundance and feeding capacity. *Crassostrea* is a reef-forming oyster species. The large reefs created by the Bay's oysters were the foundations of complex shallow water communities whose members included HUNDREDS of species.

A living oyster reef is a complex structure in which many species can both live and feed. It is this complexity that makes the reef both unique and important. An oyster reef is not just a pile of dead shells but a veritable condominium for many other species. All the nooks and crannies within the reef are occupied by species that specialize in occupying these very special nooks and crannies. The spaces between the oyster shells come in all sorts of shapes. Flat spaces are occupied by flat species such as skilletfish. Tall thin spaces are occupied by thin profile fish such as blennies. More regular-shaped spaces are occupied by gobies, whose bodies are about equal in height and width. All of these species of fish may eat similar things, but they coexist in the greater reef structure because individual fish species occupy different types of small spaces. Thus each species has its own unique microhabitat requirements within the reef. Successful species are able to make the most of available space and resources.

These small fish species not only live and feed in the reef, they breed there also. Their larval forms eat oyster larvae, so the interdependence of the reef residents is strengthened. These fishes are called intermediate reef fishes because they are resident on the reefs and intermediate in the reef food chain. These small fishes are eaten by other resident species like mud crabs, and by larger non-resident predators, such as striped bass, bluefish, and others that seasonally move into the rivers to feed. The food chain becomes a food web, growing in complexity.

Figure 3.1. A look at the surface of an oyster reef. The spaces between the shells provide favorable habitat for many small animals.

Figure 3.2. An underwater close-up of an oyster reef. Note the spaces between the oyster shells and the 3 small fishes that are visible on and between the shells.

In essence, the nooks and crannies or spaces between and within the oyster shell matrix are defining features of the oyster reef habitat. These spaces provide:

- increased surface area for settlement by oyster larvae as well as algae and other invertebrates (such as barnacles and polychaete worms) that are eaten by larger species.
- protected places for oyster larvae to settle and avoid predation by blue crabs.
- nesting sites and sheltered habitat for small fishes and invertebrates that are prey for larger species.

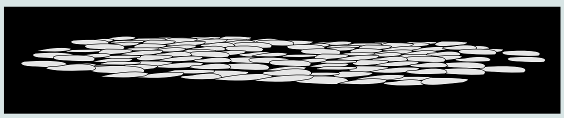
Since the spaces within the oyster shell matrix are so critical to the function of oyster reef habitat, these nooks and crannies provide a logical starting point for any examination of oyster reef communities and the related food web or trophic structure.

Surface Area: Why reefs are successful habitat

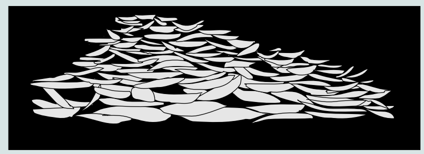
In the context of oyster reefs, surface area describes the actual amount of oyster shell that is exposed to the water column. Reef structures are essentially large piles or mounds of oyster shell. These mounds provide more surface area for settlement of oysters and other animals than oyster bars, or flat lawns of oyster shell.

Why does a mound have more shell exposed to the water than a lawn?

When oyster shell is lying flat on the river bottom, only one side of each shell is exposed to the water:



When oyster shell is made into a mound or reef structure, most of the shells have a portion of BOTH sides of the shell exposed to the water. Remember that oyster shells are irregularly shaped and do not fit nicely together like building blocks. An oyster shell pile has lots of spaces between the shells - and lots of exposed surface area.



Part I. The Reef Matrix: High profile real estate

Objective: Examine the relative differences between oyster bars (shell lawns) and oyster reefs (shell mounds) in terms of available surface area for settlement by other species.

Skills: Observation, communication, demonstration of the surface area concept, and math (averaging).

Relevant Virginia SOL:

6.9 Living systems
LS.4 Animal needs
BIO.9 Analysis of local ecosystems

Materials: Two or three dozen oyster shell valves per student research team.

Procedure:

1. Divide class into small groups or "research teams" of two to four students each.
2. Provide each group with two or three dozen oyster shell valves.
3. Have half of the groups use their oyster shells to make an oyster bar, a flat lawn of oyster shells in a single layer. When the bar is completed, have the students count the number of oyster shell sides that are exposed to the air.
4. Instruct the other groups to use their oyster shells to build small mounds or reef strucutures. Remind the students that it is acceptable to have spaces between the shells. Have the students count the number of exterior and interior oyster shell sides (total or partial) that are exposed to the air.
6. Average the number of exposed shell sides in the oyster bars and the number of exposed shell sides in the oyster reefs. Compare the difference. Discuss the biological consequences of these differences keeping in mind that:
    1. Oyster spat (larvae) prefer to settle on exposed oyster shell. Increased availability of hard surfaces may translate into increased oyster recruitment and continued reef growth.
    2. Polychaete worms, bryozoans, and many local algal species settle preferentially onto exposed hard substrate like oyster shells. All of these organisms are eaten by other members of the reef community; thus more surface area means more food for upper level consumers.
    3. Mussels and other filter feeders (barnacles) settle on exposed surfaces. Increased numbers of filter feeders (including oysters) translates into increased consumption of phytoplankton. This reduces chances of seasonal algal blooms that can cause unfavorable water quality conditions. Increased filtration activity also provides more nutrients (by-products of filtering activity) for benthic grazers.

Part II. Reef Residents: Matching body shapes with houses

Objective: Demonstrate the importance of spaces within the reef matrix as habitat for small reef fishes.

Skills: Observation, communication, and math (graphing).

Relevant Virginia SOL:

- 6.9 Living systems
- LS.4 Animal needs
- LS.7 Organism dependence on living/non-living components of the environment
- LS.8 Competition, behavior within a population
- LS.9 Population interactions within a community
- BIO.5 Organisms response to environment
- BIO.9 Dynamic equilibria within communities, analysis of local ecosystems

Materials: Oyster shell valves (2-3 dozen per group), small (< 1 inch long) white foam packing peanuts (2 dozen per group), larger (1-2 inch long) foam packing peanuts (2 dozen per group), colored markers.

Procedure:

1. Divide students into small groups or "research teams".
2. Provide each group with two or three dozen oyster shells, foam peanuts, and a marker.
3. Instruct each group to make an oyster reef with all of their shells.
4. Have students use colored markers to label the smaller foam peanuts as naked gobies (G) and the larger peanuts as striped blennies (B).
5. When the reefs are completed, have students place as many naked gobies and striped blennies as possible in their reef without disturbing the reef matrix. Only one "fish" should be placed in each space.
6. Have each group report the total number of gobies and blennies that "live" in their reef. Display class results as a chart. Discuss how the differences in the shapes of the reef's nooks and crannies might be related to the differences in the shapes and sizes of the fish profiles as well as fish behavior (see Figures 3.3 and 3.4 below).
7. The table on page 16 shows typical numbers of gobies and blennies that might be found living in a Chesapeake Bay oyster reef. Using the data from Table 3.1, have students graph fish abundance in relation to bottom type (see worksheet on page 19).
8. Use the resulting graphs to discuss the relationship between habitat availability and the abundance of naked gobies and striped blennies. After the students understand that increased habitat availability (reef nooks and crannies) translates into increased abundance of gobies and blennies, use the Oyster Reef Trophic Diagram (Figure 3.6) to apply this concept to the overall reef community. Resident fishes are fish species that live in the reef matrix. Semi-resident fishes spend a majority of their time on the reef but may move off-reef occasionally.

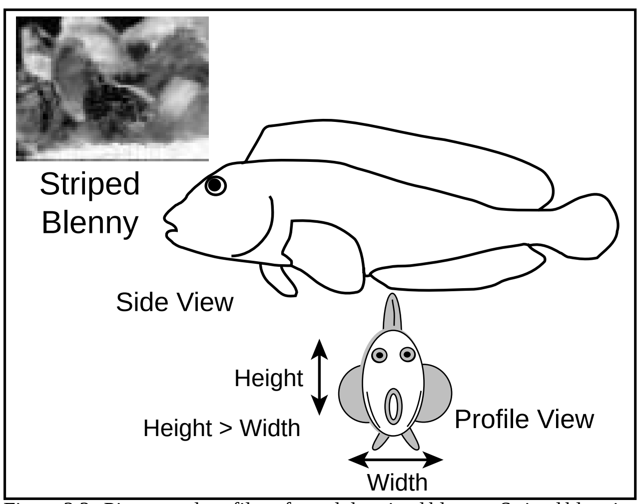


Figure 3.3. Picture and profiles of an adult striped blenny. Striped blennies are larger and more aggressive than naked gobies. Blennies use larger reef spaces for hiding places, feeding grounds, and nesting sites.

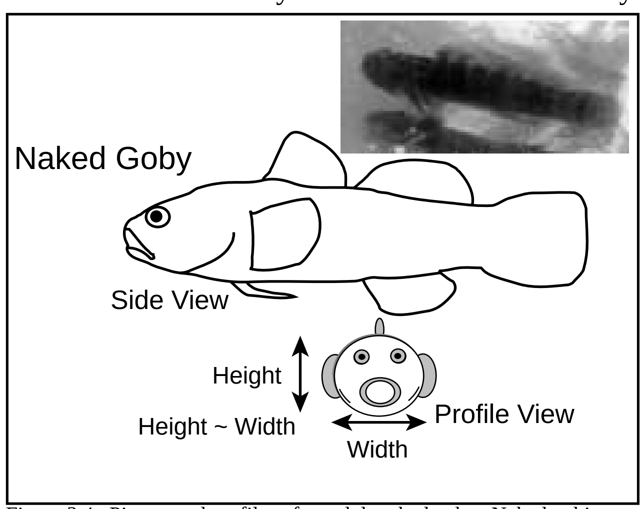
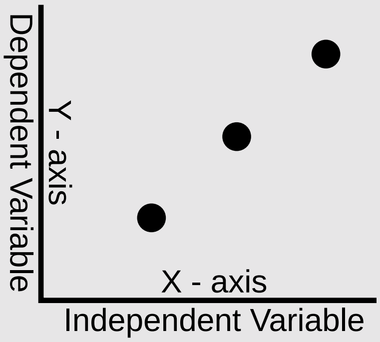


Figure 3.4. Picture and profiles of an adult naked goby. Naked gobies are small docile fish. They use smaller oyster reef spaces as hiding places, feeding grounds, and nesting sites.

Cartesian Coordinate Graphing: A review



Graphing data using the Cartesian Coordinate graphing system requires that the data be arranged in (X, Y) pairs; that is for every value of the independent variable there is a corresponding value for the dependent variable. Keep in mind that zeroes are valid data points. Each point on the graph represents the location coordinates given by an (X, Y) data pair. In the goby/blenny data set, bottom type is the independent variable and fish abundance is the dependent variable.

Site	Bottom Type (% oyster shell)	No. of naked gobies	No. of striped blennies
1	0	1	0
2	25	1	1
3	100	10	8
4	75	9	7
5	50	4	2
6	100	12	14
7	0	0	1
8	100	16	10
9	50	5	8
10	25	4	1
11	100	21	7
12	100	8	19

Table 3.1. Data from a diver survey of 12 sites on and immediately adjacent to an oyster reef. The type of bottom or substrate is described in terms of the percentage of oyster shell within a one meter square area. The number of adult naked gobies and striped blennies observed within the same one meter square area is also reported.

Transient fishes move onto the reef to feed but spend most of their time elsewhere. Keep in mind that:

1. Increased abundance of gobies and blennies provides more food for benthic predators such as blue crabs. Increased blue crab abundance provides more food for larger fishes that eat blue crabs including striped bass.
2. Gobies and blennies "graze" or feed on algae and small invertebrates such as barnacles and polychaete worms that are found on the reef's surface. An increased abundance of gobies and blennies may result in the removal of more algae and other invertebrates. High levels of grazing may help to keep at least part of the reef surface available for continued settlement of spat and other invertebrates throughout the season.
3. Increased abundance of naked gobies and striped blennies provides more food for larger fishes like striped bass, bluefish and weakfish.
4. Increased amounts of food for larger fishes may positively affect fish abundance and individual fish growth, survival, and reproduction.

The relationship between increased shell surface area and the reef community food web is pretty amazing, isn't it?

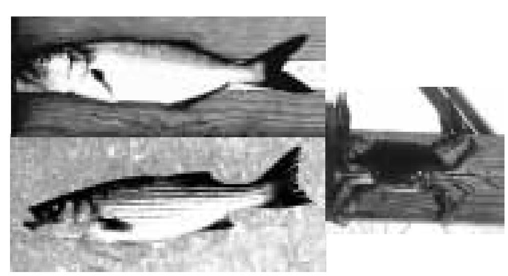
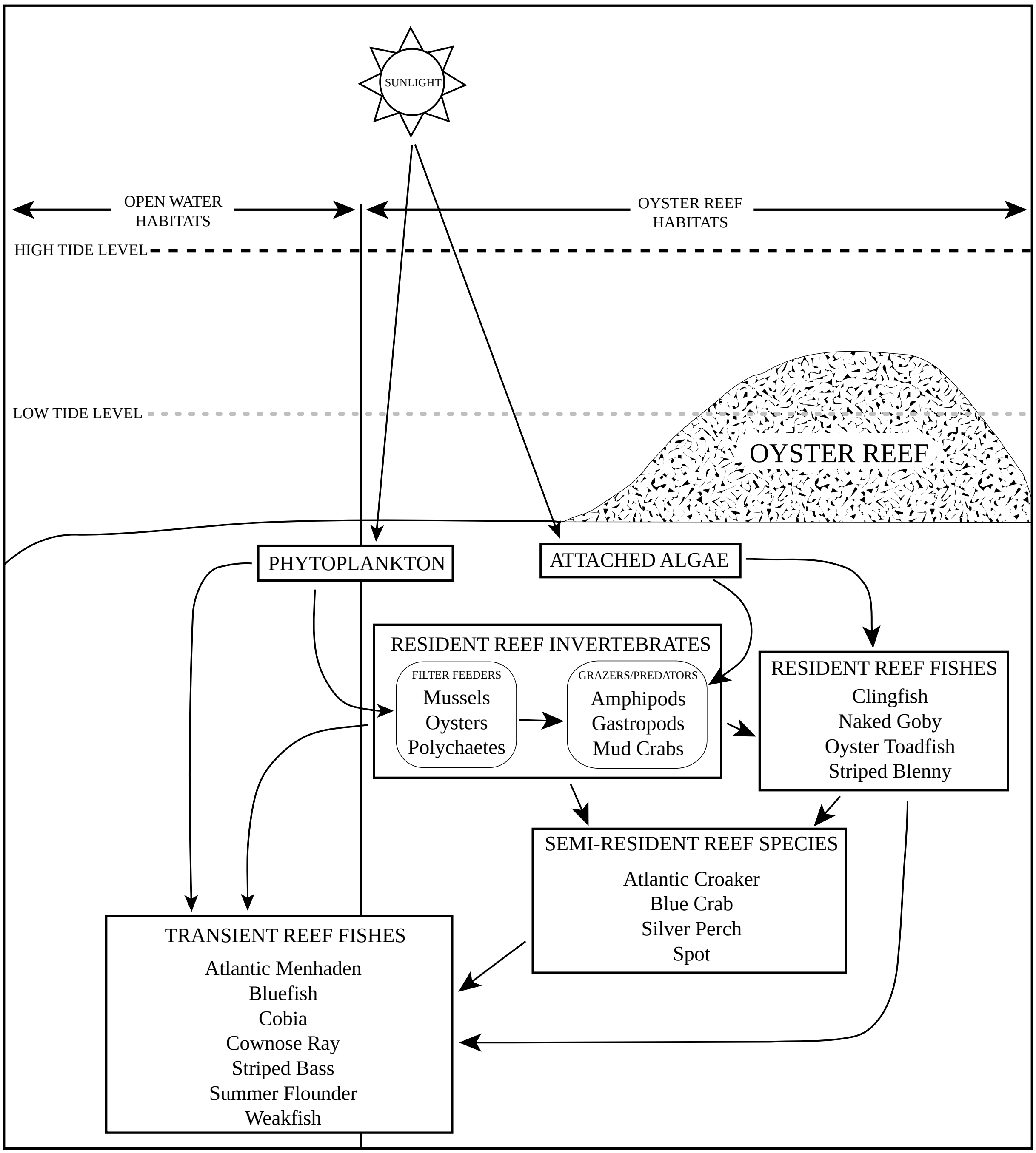


Figure 3.5. Representative oyster reef predators (consumers): bluefish (upper left), striped bass (lower left), and a blue crab (right).

Figure 3.6. A simple food web for Chesapeake Bay oyster reefs indicating the main trophic levels. The species that are listed for each trophic level are common representatives. In some cases, there may be at least 20 other species within a particular level. This figure is modified from: O'Beirn, F, Luckenbach, M, Mann, R, Harding, J, and Nestlerode, J. 1999. Ecological functions of constructed oyster reefs along an environmental gradient in Chesapeake Bay. Virginia Institute of Marine Science, Gloucester Point, VA. Annual report submitted to U.S. E.P.A. Chesapeake Bay Program, Annapolis, MD.



Related vocabulary:

benthic: referring to organisms that live in or on the bottom.

matrix: the complex three-dimensional structure formed by the oyster shells in an oyster reef.

recruitment: successful settlement of an oyster larvae from the plankton to a hard surface such as an oyster shell.

settlement: the process by which larval oysters change from a free-swimming planktonic body form to a permanently attached benthic body form.

spat: young oysters that have recently settled from the plankton onto a hard surface.

trophic level: one link in a food chain or food web; part of the trophic "pyramid" that represents the energy flow through the living components of the ecosystem.

Suggested discussion questions:

Part I. The Reef Matrix: High profile real estate

1. When oysters reproduce, the males and females release eggs and sperm into the water at the same time. Fertilization and development of the embryo take place in the water column. How could the physical structure of an oyster reef improve the reproductive success of oysters in the Chesapeake Bay?

2. Severe storms and floods can send large volumes of sediment flowing down rivers into the Chesapeake Bay. How would this sediment affect oysters? Which type of oyster structure might suffer the most negative impact from this sediment, an oyster bar or an oyster reef? Why?

3. Why might it be important or beneficial for a filter feeding organism, like the oyster, to live up off the bottom in or on a three dimensional structure like an oyster reef? How might these benefits relate to the long term success or failure of an oyster reef community?

Part II. Reef Residents: Matching body shapes with houses

1. Given that oyster reefs attract juvenile striped bass, bluefish, weakfish, and blue crabs, why might it be important for small reef fishes to be able to hide in the reef structure?

2. Which type of oyster structure do you think could support more blennies and gobies, an oyster bar or an oyster reef? Give at least two reasons for your answer.

3. If a striped blenny attempts to move into an oyster shell where a naked goby has established a nest, what do you think will happen? How could a goby avoid this situation?

Reef Residents Worksheet

Fish abundance in relation to bottom type on and near oyster reefs

Site	Bottom Type (% oyster shell)	No. of naked gobies	No. of striped blennies
1	0	1	0
2	25	1	1
3	100	10	8
4	75	9	7
5	50	4	2
6	100	12	14
7	0	0	1
8	100	16	10
9	50	5	8
10	25	4	1
11	100	21	7
12	100	8	19

Table 3.1. Data from a diver survey of 12 sites on and immediately adjacent to an oyster reef.

	Fish Abundance (Number of fish per meter $^{-2}$) Y variable	
Bottom Type (% oyster shell) X variable	No. of Naked Gobies	No. of Striped Blennies
0		
25		
50		
75		
100		

VORTEX

Virginia's Oyster Reef Teaching EXperience

An Educational Program for Virginia Science Educators

What is VORTEX?

Virginia's Oyster Reef Teaching EXperience (VORTEX) is a multi-component program focusing on the importance of oyster reef communities in the Chesapeake Bay ecosystem. VORTEX is designed specifically for science educators by the Virginia Insitute of Marine Science. The program includes a series of workshops and multimedia materials (i.e., a CD ROM and Internet web sites). All program components are designed to provide a basic biological and ecological background to enable participants to integrate program materials into hands-on science lessons that support selected Virginia Standards of Learning in Science.

Program partners and co-sponsors include:

Virginia Institute of Marine Science Department of Fisheries Science
Virginia Sea Grant Marine Advisory Program
Virginia Environmental Endowment
Chesapeake Bay Restoration Fund Advisory Committee

For more information, visit the VORTEX web site at: www.vims.edu/fish/oyreef/vortex.html or contact Juliana Harding (jharding@vims.edu), Vicki Clark (vclark@vims.edu), or Roger Mann (rmann@vims.edu).

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