SHELLFISH STALKERS: THREATS TO AN OYSTER

INTRODUCTION

Eastern oysters (*Crassostrea virginica*) were one of the dominant species in the Chesapeake Bay prior to the mid 20th century. Only recently have scientists begun to appreciate the ecological importance of oysters and the large three-dimensional reef fields that they created in the lower Chesapeake Bay. Ongoing restoration efforts in Virginia are actively supported by federal, state, and local resource management agencies as well as civic groups and private citizens. Successful restoration and rehabilitation efforts for Virginia's oysters must recognize and compensate for the ecological and anthropogenic threats faced by modern Chesapeake oysters.

Adult oysters (Figure I.1) are sessile, filter-feeding bivalves. These molluscs extract both oxygen and food particles from seawater as they pump water over their gills (thus the term "filter feeder"). Usually, oysters are attached or cemented to hard surfaces including rocks, pilings, and, ideally, other oysters. Thus, they cannot run or swim away from threatening circumstances. The oysters' hard shell valves provide a protective barrier that is effective against some threats. When an oyster is threatened by a predator or unfavorable environmental conditions, it can shut its shell to protect its soft body. However, when the oyster shuts its shell, it is effectively holding its breath and fasting. Sooner or later, the oyster has to begin pumping water again so that it can breathe and eat. When the oyster opens its shell, it becomes vulnerable to environmental conditions and predators. In some cases, predators do not have to wait for the oyster to open its shell; they are capable of opening the oyster's shell themselves!

Three of the main threats faced by an oyster are:

1. Predators or animals that eat oysters.
2. Diseases that infect and kill oysters.
3. Changes in the environment that lower environmental quality below oysters' tolerances, resulting in death.

This booket includes classroom activities that address each of these threats to an oyster. **Oyster Predators** gives descriptions of the animals that eat Chesapeake oysters and places both oysters and predators in context of local food webs. **Oyster Diseases** discusses the history, mechanisms, and current status of the two diseases that threaten Chesapeake oysters. The final section, **Trapped in a Shell**, addresses modern oyster habitat degredation resulting from changes in salinity, sediment load, and dissolved oxygen.

Figure I.1: A group of live Eastern oysters.

Related educational resources

COMPANION ACTIVITY BOOKLET FOR EDUCATORS:
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, 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-xx, VIMS-ES-xx. 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-xx, VIMS-ES-xx. 10/2002.

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 oyster reef research and restoration activities in Virginia).

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www.vims.edu/mollusc/meeduc/vortex.html
Virginia Institute of Marine Science
Gloucester Point, VA 23062

OYSTER PREDATORS

Oysters are often described as a “keystone” species in Chesapeake Bay. The term “keystone” refers to the fact that oysters were central to the physical and ecological development of oyster reef communities. Oyster shells created large mounds or reefs with lots of spaces that provide favorable habitat for other animals. The presence of living oysters in the oyster shells maintains the reef’s physical structure. Healthy oysters within a reef make food available for other animals by filtering plankton from the water and depositing both waste and undigested material on the bottom. The material deposited by oysters provides food for many small bottow dwellers. A healthy oyster reef is a like a vibrant, bustling neighborhood. The large reefs created by the Bay’s oysters were the foundations of communities whose members included hundreds of other species.

Like many molluscs, the oyster makes its own shell. The hard shell is secreted by the animal and grows with the animal. The soft-bodied oyster never voluntarily leaves its shell. At first glance, a hard shell would seem to be the perfect defense against enemies. However, oysters share living space or habitat with a variety of animals that are uniquely suited to penetrate or, in some cases, completely crush an oyster shell. When confronted by one or more of these predators, the sedentary oyster has no chance for escape.

Fortunately for the oysters and the ecosystems that they occupy, oysters and oyster predators are all members of a food web. Food webs graphically describe the predator-prey relationships among animals within the same habitat. A food web is a picture of who eats whom within the same neighborhood. Many of the animals that eat oysters are also at risk of being eaten by other animals. To a certain extent, nature maintains a balance between predators and prey.

The main oyster predators in Chesapeake Bay include several species of snails and crabs as well as cownose rays and oyster toadfish. A small part of an oyster reef community food web highlighting the oysters, oyster predators, and predators on oyster predators is shown in Figure 1.1.

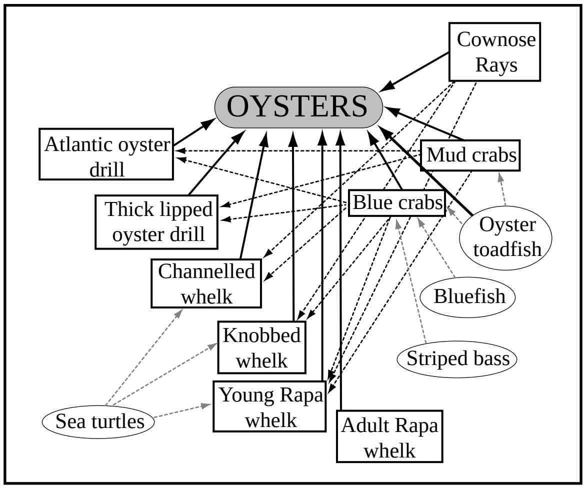


Figure 1.1: Part of an oyster reef food web. Upper level predators that consume oyster predators but not oysters are shown in ovals. Arrows indicate predation with the arrowhead pointing toward the prey item. Black lines indicate direct predation on oysters. Dashed black lines indicate predation on oyster predators by other oyster predators. Dashed grey lines show predation on oyster predators by upper level predators that do not eat oysters directly.

Oyster predators: Snails

Snails, like oysters, are molluscs, and they also make their own shells. Unlike oysters, snails are mobile predators. Native snails like Atlantic oyster drills (*Urosalpinx cinera*) and thick lipped oyster drills (*Eupleura caudata*) have names that describe how they attack oysters. These predators literally drill their way through an oyster’s shell using a specially designed tongue. This tongue-like structure is called a radula and is studded with sharp teeth. Using its radula combinedwith powerful chemicals or enzymes

Collecting Oysters: Time honored methods

Oysters are sedentary bottom dwellers. When the animal dies, the shell valves open or gape lacking the force of the muscles that normally keep them shut.. The dead oyster is eaten by scavengers or washed out of the shell by currents. All that remains of the oyster is its empty shell valves, which are commonly referred to as "boxes".

Scientists use a variety of methods to collect oyster samples and bring them to the surface for examination. When an oyster sample arrives at the surface, scientists usually count the numbers of live adult, juvenile, and recently settled oysters as well as recent and older boxes. Scientists may examine the boxes in an attempt to determine what killed the oysters. After being counted, the live oysters are returned to the bottom. Some of the methods used by scientists to sample oysters have also been used for years by watermen to harvest oysters and include:

Hand tongs: With handles 18 or 20 feet long attached to rake-like ends which form a basket, it is possible to scrape oysters from the bottom into a pile and then grasp them in the basket and bring them to the surface (Figure 1.2).


Figure 1.2: A pair of hand tongs in use.

Dredges: These large metal sleds are towed behind a boat. As they are dragged across the bottom, the teeth dig into the bottom and scoop up oysters which are then caught in the mesh bag. When the dredge is brought to the surface, the contents of the bag come with it (Figures 1.3 and 1.4).


Figure 1.3: An oyster dredge.

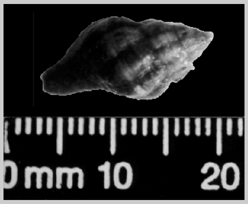

Figure 1.4: A pair of dredges being pulled onto a commercial oyster boat circa 1900. (Photograph courtesy of the VIMS Archives).

Patent tongs: This large, heavy claw is dropped onto the bottom and retrieved with a winch. When the claw is dropped, it is open. As the winch pulls it up toward the surface, the claw closes grabbing a sample of the bottom including oysters (Figure 1.5).


Figure 1.5: A pair of hydraulic patent tongs (Photograph courtesy of J. Wesson).

Atlantic Oyster Drill

Size: Adults are less than 40 mm long
Habitat: Oyster reefs, shell piles, bars
Primary prey: Oysters
Method of attack: Drilling through the oyster's shell
Possible predators: Blue crabs and mud crabs.
Notes: This snails were displaced by Hurricane Agnes from most traditional Chesapake Bay habitats but are slowly moving back.



Thick Lipped Oyster Drill

Size: Adults are less than 40 mm long
Habitat: Oyster reefs, shell piles, bars
Primary prey: Oysters
Method of attack: Drilling through the oyster's shell
Possible predators: Blue crabs and mud crabs
Notes: Distinguished from the Atlantic Oyster drill by the thick opercular margin and fluted opercular teeth visible in the picture below.

made by the snail to soften the shell, the snail is able to rasp or drill its way completely through the shell (Figure 1.6). This process is not necessarily speedybut it is effective. Once the snail drills all the way through the hard shell, it extends its radula into the oyster and begins scraping away at the oyster's soft tissue. If the drill is successful, the end product is an empty oyster shell with a small round hole in it.

Oyster drills were common in the lower Chesapeake Bay before Hurricane Agnes came in 1972. The heavy rains from Hurricane Agnes briefly lowered the salinity in many of Virginia's rivers below the levels which oyster drills needed to survive and most of the drills in the rivers died. Drills near the mouth of the Chesapeake Bay survived and gradually, generation by generation, oyster drills have been walking their way back toward Virginia's rivers ever since. As you might imagine, movement of the drills up the Bay is a slow process. Even in 2001, almost 30 years after Hurricane Agnes, oyster drills are not nearly as abundant in the James, York and Rappahannock Rivers as they were before Hurricane Agnes.

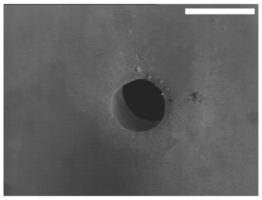


Figure 1.6: Close-up of a hole through an oyster shell made by an oyster drill. Note how the hole goes completely through the shell. The white bar in the upper right hand corner represents 1 mm.

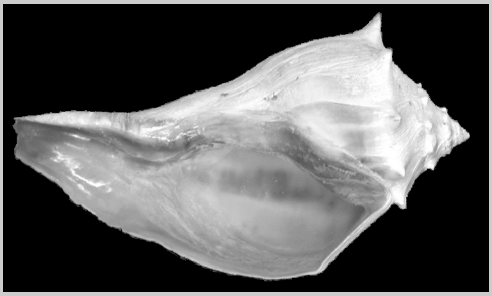
Oyster drills are not the only predatory snails native to Chesapeake Bay. Channelled whelks (*Busycotypus canliculatus*) and knobbed (*Busycon carica*) whelks also eat oysters. These whelk species live up to 20 years while oyster drills have life spans of less than 5 years. Both of these whelks grow to be larger than either species of oyster drill. An adult whelk may be longer than 150 mm while an adult drill is usually less than 40 mm long. The whelk's size gives it an advantage when it attacks an oyster. Unlike the drills, whelks often use their large, solid shells to forcibly wedge or chip open the oyster's shell at the end opposite the hinge. This part of the oyster is often referred to as the growth edge or growth margin since this is where the newest shell growth is most visible. When a whelk opens an oyster shell, notches or chips occur in the growth margin. Once the whelk has bro-

CHANNELLED WHELK

Size: Adults may be more than 150 mm long
Habitat: Sandy or muddy bottom
Primary prey: Bivalves including oysters
Method of attack: Chipping through the oyster's shell at the growth margin
Possible predators: When small, blue crabs or mud crabs. Adults are eaten by sea turtles.
Notes: The shells of these whelks are often found washed up on beaches.

KNOBBED WHELK

Size: Adults may be more than 150 mm long.
Habitat: Sandy or muddy bottom
Primary prey: Bivalves including oysters
Method of attack: Chipping through the oyster's shell at the growth margin
Possible predators: When small, blue crabs or mud crabs. Adults are eaten by sea turtles.
Notes: The shells of these whelks are often found washed up on beaches. The opercular opening is usually bright red or orange around the edge.



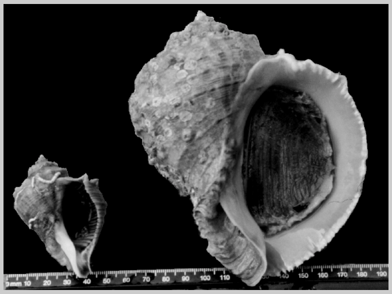
ken enough of the oyster shell to expose some of the oyster's body, it sticks its radula into the soft tissue and begins eating. When the whelk is done, all that remains is an empty oyster shell with chip marks on the edges.

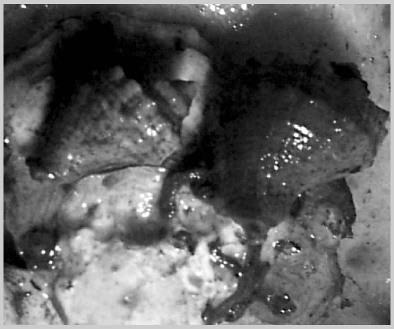
Since the 1990s, the lower Chesapeake Bay has been home to yet another large predatory snail. Although, the veined rapa whelk (*Rapana venosa*) is native to the waters off Japan and Korea, scientists discovered adult rapa whelks in the Chesapeake Bay in 1998. Since then it has become clear that rapa whelks are well established in the lower Bay. Both large and small rapa whelks eat oysters (Harding and Mann, 1999). Small rapa whelks usually drill oysters much like the native oyster drills. Larger rapa whelks force open oysters like the native whelks or by simply grasping the oyster's growth edge with their muscular foot and holding on until the oyster opens in an attempt to breathe. In either case, Chesapeake oysters have yet another predator to face.

Throughout their lives, native oyster drills risk being eaten by both blue crabs and mud crabs. It is relatively easy for crabs to crush the oyster drills' shells. Once the drill shell is crushed, the crab uses its its claws to eat the snail. Small channelled and knobbed whelks are also vulnerable to predation by crabs. Larger channelled and knobbed whelks have relatively fragile shells and run the risk of being crushed and eaten by either sea turtles or cownose rays. Unlike all of the native Chesapeake snails, adult rapa whelks do not have a specific predator in the Chesapeake food web (Figure 1.1). Certainly small rapa whelks may be eaten by blue crabs and mud crabs. Medium rapa whelks are probably vulnerable to predation from sea turtles or cownose rays. However, large rapa whelks may reach the size of softballs and their shells are very thick, at least three times thicker than channelled and knobbed whelk shells. Once a rapa whelk grows beyond a shell length of four or five inches (approximately tennis ball-size), there is no common Chesapeake predator that can crack its shell and eat it. The presence of a large oyster-eating snail without potential predators of its own poses a new threat to Chesapeake oysters.

VEINED RAPA WHELK

Size: Adults may be more than 150 mm long.
Habitat: Sandy or muddy bottom as well as hard substrates including rocks and oyster shell
Primary prey: Bivalves including oysters
Method of attack: When small, drilling through the oyster's shell. When larger, forcing the oyster open by attacking at the growth margin.
Possible predators: When small, blue crabs or mud crabs. Snails < 100 mm long are probably prey for sea turtles or cownose rays. Large adults do not have a known local predator.
Notes: Native to Japan and Korean waters. Introduced to the Chesapeake Bay during the 1990s.





Oyster Predators: Crabs

The Chesapeake Bay is home to several species of crabs including blue crabs (*Callinectes sapidus*) and mud crabs (*Panopeus herbstii* and *Eurypanopeus depressus*). These crabs are equipped with powerful claws or chelae which they use to crack or crush an oyster's shell. Both mud crabs and blue crabs have similar habitat requirements to oysters and the distribution of all three tends to overlap for a majority of their life cycles. Thus, oysters are vulnerable to crab predation for most of their lives.

Mud crabs do not usually grow larger than 30 or 40 mm long. Because of their relatively small size, mud crabs tend to eat small oysters whose shells are neither very thick nor very large. These crabs can easily crush the thin shells of young oysters with their claws. Depending upon the time of year and the water temperature, a single mud crab may eat up to 19 young oysters per day (Bisker and Castagna, 1987).

Oysters are on the menu for a wide size range of blue crabs. Blue crab size is related to the size of an oyster that it can successfully attack. For instance, if a 30 mm blue crab found a 100 mm oyster, the blue crab would have a very difficult time grasping such a large oyster simply because of the small size of its own claws. On the other hand, if a 100 mm crab met the 100 mm oyster, the large crab would have little difficulty opening its claws wide enough to grasp and chip away at the oyster shell. In general, blue crabs tend to crush small oysters and chip away at the edges of large oysters' shells. They pull the tissue out of the crushed shell using their mouth parts and the tips of their claws.

Mud crabs

Size: Adults are usually less than 40 mm wide.
Habitat: Sandy and muddy bottom as well as around and within hard substrate such as rocks, oyster shells, or other debris
Primary prey: Benthic invertebrates including oysters
Method of attack: Crushing the entire shell or chipping away at the growth margin
Possible predators: Benthic feeding fishes including oyster toadfish and striped bass
Notes: Very common in Chesapeake waters

Blue crabs

Size: Adults may be more than 100 mm wide.
Habitat: Sandy and muddy bottom, seagrass beds, around and within hard substrate such as rocks, oyster shells, or other debris.
Primary prey: Benthic invertebrates including oysters
Method of attack: Crushing the entire shell or chipping away at the growth margin
Possible predators: Benthic feeding fishes including oyster toadfish and striped bass
Notes: Commercially fished in both Maryland and Virginia waters

Oyster Predators: Fish

Cownose rays (*Rhinopterus bonasus*) are not the only fish that eat oysters but they are some of the most impressive! These graceful swimmers are common visitors to lower Chesapeake Bay estuaries during warmer months. Cownose rays forage for food on the bottom. These fish are equpped with an impressive set of dentition: their "teeth" are flattened plates that they use very effectively to crush mollusc shells. When feeding, their large pectoral fins stir up the sand or mud around them. Then the rays use their mouths to sift through the disturbed sediment crushing any molluscs that they find. The resulting hollowed out portions of the bottom are usually round and may be three feet across and up to a foot deep!

Oyster toadfish (*Opsanus tau*), like cownose rays, have dentition that is specially adapted to crush hard shells. Unlike cownose rays, oyster toadfish live on the bottom and are usually found under objects or tucked into crevices between objects. These fish have huge jaws and a flattened profile. They are memorable not only for their looks but also for the grunting sound that they may make when brought out of the water. Although toadfish are equipped to eat oysters, they reportedly prefer to eat small crabs (McDermott, 1964).

COWNOSE RAYS

Size: Adults may be bigger than 50 cm across.
Habitat: Sandy and muddy bottoms
Primary prey: Bivalves including oysters
Method of attack: Crushing the entire shell
Possible predators: None
Notes: Seasonally abundant in the lower Bay

References

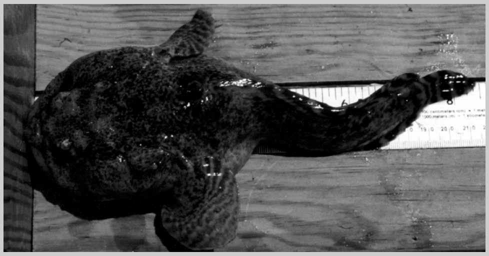
Bisker, R. and M. Castagna. 1987. Predation on single spat oysters *Crassostrea virginica* (Gmelin) by blue crabs *Callinectes sapidus* Rathbun and mud crabs *Panopeus herbstii* Milne-Edwards. J. Shellfish Res. 6:37-40.

Harding, J. and R. Mann. 1999. Observations on the biology of the veined rapa whelk *Rapana venosa* (Valenciennes, 1846) in the Chesapeake Bay. Journal of Shellfish Research. 18(1): 9-18.

McDermott, J. 1964. Food habits of the toadfish, *Opsanus tau* (L.), in New Jersey waters. Proc. Penn. Acad. Sci. 38: 64-71.

OYSTER TOADFISH

Size: Adults may be more than 30 cm long.
Habitat: Sandy and muddy bottom as well as around and within hard substrate such as rocks, oyster shells, or other debris
Primary prey: Benthic invertebrates including oysters
Method of attack: Crushing the entire shell
Possible predators: None
Notes: Common in Chesapeake waters



OYSTER DISEASES

Although it might seem unlikely, oysters are vulnerable to and suffer from diseases. It is impossible to tell just from looking at an oyster if it is sick. Oyster diseases are chronic and unfortunately they are almost always fatal. Disease may actually be a larger source of mortality for oysters than mortality from either predators or environmental degradation. Humans are not susceptible to oyster diseases. If someone eats an infected oyster, they will not get sick.

Before the mid 1800s when oysters began to be harvested commercially, there were many millions of oysters in the Chesapeake Bay. By 1875 the annual oyster harvest in the Chesapeake Bay was approximately 17 million bushels. Since the late 1800s, Virginia's oyster fishery has revolved around Baylor Grounds, designated areas of river bottom considered to be favorable oyster habitat and set aside by law for public use under the management of the Commonwealth. Public oyster grounds are commercially fished by watermen. Private oyster grounds are portions of the public Baylor grounds that are leased to private oyster growers. Every year the lease holders pay a fee to renew their leasing rights. The Commonwealth owns the river bottom but the leaseholders plant oysters on it and eventually harvest these oysters to sell. After harvesting the oysters from their grounds, leaseholders traditionally replenish their stock with "seed" oysters. These small, yearling oysters were harvested from public Baylor grounds in certain Virginia rivers. The James River, and to a lesser extent, the Piankatank River, Great Wicomico River and Mobjack Bay were all considered excellent sources of small oysters. Seed oysters were taken from these rivers and sold to leaseholders throughout the Bay to be planted on leased bottom and grown. Rivers such as the Rappahannock River were traditionally known as good growout areas.

Even after the Chesapeake oyster population began to decline in the early and mid 1900s, the practice of moving seed oysters throughout the estuary continued. Since the mid 1900s, the Chesapeake Bay oyster population has steadily declined in abundance from millions to thousands of oysters. In recent years, the annual oyster harvest in Virginia waters has declined dramatically (Figure 2.1). This noticeable decline is due in part to oyster mortality caused by the two oyster diseases that are most prevalent in the Chesapeake Bay: Dermo and MSX.

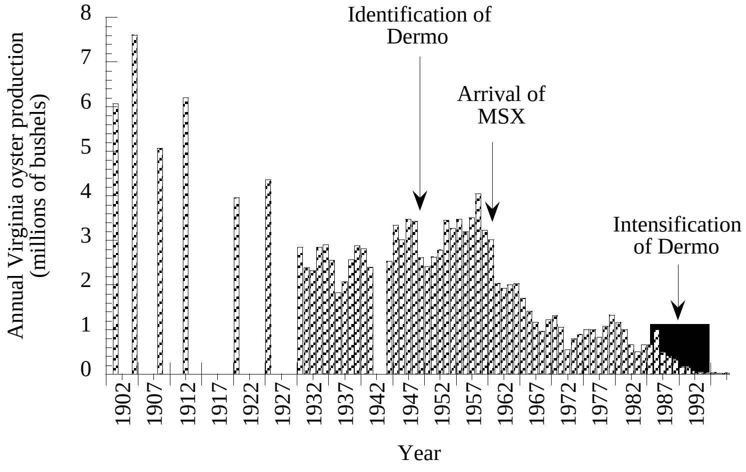


Figure 2.1: Annual Virginia oyster fishery production from 1900 through the present. Note the decline in oyster production after the arrival of Dermo in the early 1950s and MSX in 1959.

Dermo disease

Dermo is the common name for the oyster disease caused by *Perkinsus marinus*, a protistan parasite. Although Dermo has probably always been present in the Chesapeake Bay, it was formally identified as a threat to oysters during the 1950s. Historically, Dermo probably always caused some oyster mortality. Since losses to the disease were small in relation to natural oyster recruitment and planted seed oysters, the overall oyster harvest did not decline appreciably. During the late 1980s, extreme environmental conditions exacerbated by traditional oyster management practices that shuttled oysters from place to place resulted in the spread of Dermo throughout the Chesapeake Bay. Since 1987, Dermo has been the most important oyster pathogen in the Bay and has become established on all natural oyster beds in both Maryland and Virginia (Burreson and Ragone Calvo 1996).

The microscopic parasites usually infect oysters in August or September when water temperatures are above 20°C (Andrews 1996, Burreson and Ragone Calvo 1996). Dermo is spread from oyster to oyster by microscopic particles that are released into the water by infected oysters (Andrews 1988). These infective particles are filtered from the water by other oysters and eaten along with food particles. Once in the digestive tract of another oyster, the parasite infects its new host (Mackin 1951). The parasites live in the oyster through the colder winter months and multiply rapidly in the spring and early summer when the water is warm. Oysters usually die from Dermo within a year after being infected (Andrews 1996). Thus, if an oyster were infected with Dermo in August of 2002, it would be dead by August of 2003. Since oysters usually take at least two years to grow to "market" or harvestable size and oysters are usually infected with Dermo during their first summer of growth, it isn't hard to see why there are so few oysters available to harvest.

What is a *protozoan parasite*?

A *protozoan* is a very small organism that has only one cell or lives as part of a colony. A *parasite* is an organism that lives in or on another organism (the host) and gets its nutrients from the host without providing any benefit to the host. A protozoan parasite cannot make its own food - it gains its nutrients from its host. Often, the parasitic relationships are detrimental to the host and may result in the host's death. The parasitic relationship that both Dermo and MSX form with oysters kills the oysters and spreads the parasite.

While water temperature controls the seasonal cycle of infection and mortality due to the disease, the salinity of the water controls the distribution of the disease in a habitat (Burreson and Ragone Calvo 1996). In habitats where the salinity is above 12 ppt, the parasites infect oysters, multiply within them, and cause mortality (Andrews 1996). In places where the salinity is below 12 ppt, even though an oyster may be infected with Dermo, mortality rates are usually minimal (Andrews 1996). However, if infected oysters from low salinity areas are moved to higher salinity areas, as they could be if transplanted and sold as seed oysters, the Dermo parasites that are still present in the animal will become active in the high salinity waters and eventually kill the oyster.

Given the impact of temperature and salinity conditions on the progression of Dermo, the combination of warm temperatures and low rainfall would facilitate the spread of the disease. Warmer temperatures year-round would increase the time window in which the parasites are active and multiplying. Lower rainfall in a region would increase the salinities so that places where salinities were usually below 12 ppt might have salinities above 12 ppt enabling the disease to become active and kill oysters. From 1985 through 1988, the Chesapeake Bay watershed experienced warmer than usual temperatures and lower than normal rainfall. The resulting changes in water temperature and salinity enabled Dermo to spread throughout the Chesapeake's oyster grounds including many places where the disease had not previously been reported (Burreson and Ragone Calvo 1996). In the years since, even though temperatures and rainfall have returned to more normal conditions, Dermo has not retreated to its historical boundaries and persists throughout the Bay.

MSX disease

MSX, the oyster disease caused by the protozoan parasite *Haplosporidium nelsoni* was discovered in Chesapeake Bay oyster stocks in 1959. This disease is thought to have been introduced to the Bay from the Orient, possibly with oysters transplanted from another estuary. When *H. nelsoni* was first identified, scientists found multiple nuclei in its cells and were not sure exactly how to classify the organism. Thus, they gave it the acrononym "MSX" for "multinucleated sphere unknown". Unlike Dermo, which spreads directly from oyster to oyster, MSX spreads quickly over broad geographic areas (Andrews 1996, Ford and Tripp 1996). In the 1960s and 1970s, MSX was the dominant oyster pathogen in the Chesapeake. It was superseded by Dermo in the 1980s due to the enhancement of Dermo by higher than normal salinities and water temperatures.

Scientists are not sure what the life cycle of the MSX parasite is like or how the MSX parasite enters an oyster (Ford and Tripp 1996). Once the parasite is in an oyster, MSX infects the gill and tissue around the mouth. The parasite quickly multiplies and spreads to all types of cells and tissues killing the oyster within a month (Ford and Tripp 1996).

As with Dermo, high salinities enhance the spread of MSX up and down the Chesapeake Bay. The MSX pathogen requires salinities of 12-15 ppt to develop and cause oyster mortality (Andrews 1996). In habitats with salinities less than 10 ppt, the pathogen dies in less than two weeks (Andrews 1996). When salinities throughout the Bay are relatively high due to drought or low rainfall conditions, MSX extends further up in Virginia tributaries as well as the Maryland portion of the Bay. Winter rains and cooler temperatures force the parasite back down the tributaries and Bay proper. Rainfall brought by a summer hurricane would potentially reduce MSX infections by lowering salinities. However, Hurricane Agnes in 1972 was the last major hurricane experienced by the region and, as you will see in the next chapter, hurricanes are both a blessing and a curse for oysters.

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TRAPPED IN A SHELL

Since adult oysters are sessile, benthic animals that are usually cemented to hard substrate, if the environmental conditions around the oysters become unfavorable, the oysters are literally trapped with no way out. The most basic of habitat requirements for an oyster is water. The water around an oyster must contain certain elements for an oyster to stay alive. Salt is one of the most basic. An oyster will die if salinity levels fall below a certain range.

When soil or sediment washes into a river or body of water, the particles are suspended or mixed with the water and carried out into the habitat. Eventually, the sediment will start to settle out of the water much like dust settles out of the air. Sediment in the water is a threat to oysters before and after it settles. Excessive amounts of sediment in water will gradually kill oysters.

Environmental threats: Salinity

Salinity is a term that refers to the total amount of dissolved salts in seawater and is usually measured in parts of salt per thousand parts of water or ppt. Water in the open oceans has an average salinity of 35 ppt. Freshwater has a very low salt content as is usually considered to have salinities of less than 1 ppt. Saltwater is denser than freshwater. Unless the two types of water are physically mixed by wind or tidal currents, the lighter freshwater tends to be on top of the heavier, denser saltwater. These salinity-based density differences stratify the water column into two distinct layers; a large change in salinities between water masses is called a halocline. Haloclines are common in deeper areas such as shipping channels or the mainstem of the Chesapeake. In Chesapeake habitats with depths of less than 20 feet the combination of tides and wind mixes the water so that the surface salinities are within a few parts per thousand of those recorded at the bottom.

The term estuary describes an area where a river meets the sea i.e., freshwater from the river mixes with more saline (saltier) sea water. The salinity of the water at a particular point in an estuary varies depending on the distance from the sea, the amount of freshwater discharge from the river, and the strength of local tidal currents. The Chesapeake Bay is one of the major estuaries on the North American continent. Chesapeake Bay salinities range from < 1 to 35 ppt depending upon where the sample is taken in the watershed (Figure 3.1).

While oysters function normally at salinities as low as 7 ppt, the optimal salinity range for oysters is 14 to 28 ppt. Oysters can survive for very short periods of time at salinities as low as 2 ppt. Exposure to periods of very low salinity disrupt

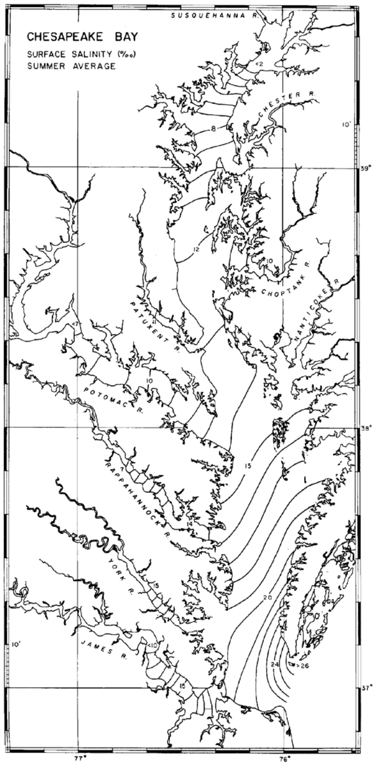

Figure 3.1: Salinity regions of Chesapeake Bay during summer months from Stroup and Lynn (1963).

an oyster's physiology and negatively affect oyster feeding, growth, and reproduction even if the oyster does not die. High temperatures may compound the effects of low salinity causing greater mortality than would be expected in situations with normal or low temperatures and low salinities.

Since oysters usually live in flowing water, the water immediately around an oyster changes over time as new water comes by the stationary oyster. Thus, if salinity conditions become unfavorable, the oyster may simply close its valves and wait until new water with more favorable salinity or dissolved oxygen levels comes to it. This "close and wait" strategy works well over short periods of time. However, this is not a viable long term strategy because the oyster must open and pump water over its gills to breathe. If an oyster opens its valves to begin breathing when the salinity conditions are still unfavorable, it will die.

In the Chesapeake Bay, the tide changes twice a day. Thus, twice a day salt water moves up the rivers and mixes with the freshwater running from the land to the sea. The tidal cycle usually maintains reasonably stable salinity conditions at particular locations within an estuary. Rain is the source of most freshwater input to a river. Very heavy rains within a river basin or watershed may result in a large volume of freshwater moving downstream in the hours after the storm. This large volume of freshwater or freshet disrupts the normal mix of fresh and salt water within the river and will dramatically lower the local salinities. Freshets may linger for hours or even days and the duration of the freshet event depends upon the volume of freshwater input.

Case study for salinity: Hurricane Agnes

Consider the following as an extreme example of the environmental hazard posed to oysters by low salinity. In June 1972, Hurricane Agnes passed over the Chesapeake Bay. During the week prior to Agnes' arrival, the Bay watershed had received several soaking rains with total accumulations of as much as 4 inches in Virginia (DeAngelis and Hodge, 1972). Rain showers on June 17 and 18 deposited as many as 3 additional inches of rain on Virginia (DeAngelis and Hodge, 1972). Thus, when the main body of Agnes arrived on June 20, the ground was already saturated and the rains that fell went straight into the estuaries. On June 21 and 22, 1972 a total of 4 to 10 inches of rain fell in Virginia (DeAngelis and Hodge, 1972). This massive volume of water quickly filled small estuaries in the upper part of the James River and began moving downstream.

Scientists knew that such a large volume of freshwater into the Bay would have a major impact on the ecosystem including the oysters. The Chesapeake Bay Research Council began studies to assess the storm's damage on environmental conditions and organisms within days (Andersen et al. 1973). Dexter Haven and the Virginia Institute of Marine Science (VIMS) Bivalve Ecology research group began surveys of the oyster populations in Virginia waters on June 24, 1972 to evaluate oyster mortality due to the dramatically lowered salinities caused by Agnes. Mortalities due to low salinity were estimated at 10%, 2%, 50%, and 70% for the James, York, Rappahannock, and Potomac River systems respectively. It is estimated that in total, over 6 hundred thousand bushels of oysters or over 318 million individual oysters died because of Hurricane Agnes in Virginia waters alone.

The surviving oysters did not escape unscathed. Many oysters were beginning to spawn or release their eggs or sperm into the water at the same time that Hurricane Agnes arrived. After fertilization in the water, oyster embryos/larvae develop in the plankton for two to three weeks after which time the larvae settle onto hard substrates, attach and take up life as sessile bottom dwellers. Scientists monitor oyster settlement patterns as an index of the success or failure of reproductive activity in any given year. In 1972, after Hurricane Agnes, VIMS scientists reported "there has been an almost complete absence of (oyster) set in almost all major river systems in Virginia with the exception of the Mobjack Bay region and the Seaside of the Eastern Shore" (D. Haven in Andersen et al. 1973). Thus, Hurricane Agnes not only killed adult oysters but also effectively destroyed an entire year class as well as the ecological and economic benefits derived from them.

Environmental effects: Sediment

Almost all of the sediment or soil particles found in an estuary come from the surrounding land. Weathering and erosion of coastal shorelines produce several types of sediment including rock fragments, quartz grains and clay particles. Clay particles are the most common sediments found in estuaries. In most parts of the Chesapeake Bay, modern shoreline development and erosion are major sources of sediment for the estuaries. Once in the water, the sediment particles stay suspended in the water, usually by tidal or wind-related mixing, for a period of time. Sediments are eventually removed from the water in one of two ways: flocculation or biological aggregation. Flocculation, the grouping of very small clay particles into larger particles that are heavier and settle to the bottom by chemical forces, is an important process in dynamic estuaries like the James River, Virginia. Flocculation ensures that most fine clay particles are retained in an estuary. Biological aggregation, the incorporation of sediment particles into mucus pellets by animals, is a major pathway for sediments to move from the water to the bottom especially in estuaries with many filter feeders.

Sediment on the bottom of an estuary may be resuspended or moved up into the water by tidal activity, wind, or human disturbances such as dredging. Sediment levels, or turbidity, in an estuary is usually quantified as total suspended solids (TSS) in units of milligrams of sediment per liter of water (mg L^{-1}). Turbidity levels are one of the parameters that scientists monitor regularly to evaluate the health of an estuary.

Abnormal sediment or turbidity levels pose two major threats to oysters: burial and suffocation. Sediment settling out of the water via flocculation onto an oyster may eventually cover it up much like dust covers the top of a table. Since oysters cannot get up and move or brush themselves off, they may become buried as sediment accumulates and eventually suffocate and die.

High levels of suspended sediment may impare an oyster's ability to feed and breathe. Oysters are filter feeders and their gills act as both respiratory and feeding structures. As water moves over the oyter's gills, particles are removed or filtered out of the water by tiny hair like structures called cilia. Some cilia trap and remove particles from the water like tiny combs. Other cilia accept particles from the comb-like cilia and move the particles toward the animal's mouth. Food particles including algae and diatoms are bound in mucus and move toward the mouth as part of long mucus strings. Particles that are unacceptable as food are not sent to the mouth but are eventually bound in mucus and deposited on the bottom without ever having been through the animal's gut.

Oysters cannot process an infinite number of particles at once. While they may filter water and, subsequently, capture particles almost continuously, they do not feed or ingest the particles constantly. Particles that are captured when the animal is not feeding are bound in mucus and deposited outside the animal (biological aggregation as described above).

Under normal conditions, a majority of the particles removed from the water are potential food items such as algae, diatoms, or other microorganisms. In high sediment conditions, an oyster may be processing the same number of particles but more of those particles are sediment and fewer of them are food. Thus the animal receives less nutrition for the same amount of filtering activity. Chronic exposure to high sediment concentrations may result in slow starvation of the oysters or at the least, reduction in growth rates and reproductive potential due to poor nutritional status. At worst, high concentrations of sediment particles may cause an oyster to shut its valves entirely for long periods of time. At the least, high concentrations of sediment slow down the oyster's filtering rates presumably because the animal must pause frequently to clean its gill surfaces and remove the sediment clogging the filtration surfaces.

Case study for sediments: Hurricane Agnes

The massive freshwater input to the Chesapeake from Hurricane Agnes' rains not only dramatically altered the normal salinity patterns, these rains also carried record amounts of sediment into the Bay. For example, Hurricane Agnes "caused a record influx of more than 0.9 million tons of sediment into the Rappahannock River. More sediment was carried into this river during 15 days of flooding than during six years of average inflow. " (Andersen et al. 1973). In 1970, turbidity levels in the lower Chesapeake Bay during June and July normally ranged from 3.1 to 4.2 mg L^{-1} (Andersen et al. 1973). In July 1972, immediately after Hurricane Agnes, sediment levels recorded in the lower Bay ranged from 17.6 to 37.4 mg L^{-1} (Andersen et al. 1973), a 5 to 10 times increase in the sediment load! Much of this sediment accumulated in the lower parts of the Virginia estuaries or tributaries of the Chesapeake Bay. Ironically, the lower, more saline parts of Virginia's estuaries were also the location of large natural oyster populations and areas of oyster planting.

Yet another side effect of the increase in sediment load or tubidity caused by Hurricane Agnes was a dramatic decrease in the depth to which sunlight was able to penetrate. In the upper Bay, "less than 1% of the sunlight incident on the water surface reached a depth of 10 cm during the flooding period" (Andersen et al. 1973). Algae and other primary producers rely on sunlight to fuel photosynthesis. A reduction in sunlight would reduce the amount of algae available throughout the photic zone (depth in the water column which usually receives some sunlight) and, consequently, the amount of food available for primary consumers, such as oysters, that eat algae.

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VORTEX

Virginia's Oyster Reef Teaching EXperience

An Educational Program for Virginia Science Educators

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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.

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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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