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CONTAMINANT PROBLEMS AND MANAGEMENT OF LIVING CHESAPEAKE BAY RESOURCES

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THE AMERICAN OYSTER
CRASSOSTREA VIRGINICA IN
CHESAPEAKE BAY

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ABSTRACT

The American Oyster (Crassostrea virginica) is widely distributed in Chesapeake Bay where it grows in the intertidal zone to depths of about 6.5 m. The salinity range over which it occurs, is from about 5 to 34°/oo. It is most abundant in protected embayments where bottoms are a firm sand-clay mixed with shelly material. This bivalve is a filter feeder, and ingests planktonic material which it strains from the water with its gills. Spawning occurs in Chesapeake Bay from June through September, and the eggs and resulting larvae are widely distributed during their 10-20 day planktonic life. Mortality is high during this stage, and only a very few survive to attach to a firm substrate. After oyster larvae attach and during the 3 to 4 year period required for them to reach market size many more die due to predators, diseases, and other associated factors. During recent years there has been a major decline in commercial landings of oysters in Maryland and Virginia. The cause for this reduction in harvest has been associated with a decline in recruitment, overfishing, poor management practices, and pollution.

The American oyster Crassostrea virginica is widely distributed in Chesapeake Bay (Figure 1) where salinities range from about 5.0°/oo to that of seawater, about 34°/oo. Within this range, it occurs from the intertidal zone to depths of about 6.5 m (21 feet). On the seaside of Maryland and Virginia's eastern shore, and between the barrier islands and the shore, it inhabits the margins of channels, salt marshes and elevated intertidal patches of oyster shell in open bays. In this latter environment large beds are often exposed to the air twice daily

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FIGURE 1. Oyster growing areas in Chesapeake Bay. Shaded areas show areas where oysters grow naturally or where they are cultivated. The dashed line shows the approximate location in spring of the 15 ppt isohaline.
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by tidal action. Oysters occur naturally on a wide range of bottom substrate types, but usually are found where the bottom is firm sand-silt-clay, mixed with oyster shell and oysters.

The hard rough texture of oyster shell is composed of about 94% calcium carbonate; magnesium and other minerals make up an additional 4% while about 2% is organic material. The two shells attached by a leathery hinge at the narrow end enclose the living animal. This mollusc has a mouth, gills for respiration and straining food from the water, and organs of reproduction, digestion and elimination. A strong adductor mussel near the center of the animal closes the shell; when it relaxes the shell gapes allowing entry of seawater (Figure 2).

The oyster obtains its food by filtering minute particles of detritus or living plankton from the water with its gills. These thin, ribbed organs which surround about one-half of the margin of an oyster, also serve as an organ of respiration. They are permeated by many minute pores, and their surfaces are covered

FIGURE 2. Anatomy of the American Oyster showing organs of feeding, respiration, digestion and reproduction (from Galtsoff)!
and lined by innumerable hair-like cilia. By beating in unison, the cilia set up water currents through the pores; and by this action respiration is achieved, and food particles are strained from the water. Other groups of specialized cilia transport the food from the gill surface to the mouth and into the oyster's stomach.

The volume of water pumped through the gills of oysters during feeding and respiration depends largely on water temperature. In winter as temperatures approach 5-6°C (41-43°F) water transport and feeding virtually stops. When water temperature exceeds about 10°C (50°F) oysters become fully active. Volumes filtered by large oysters during the warmer summer months may range from 1.1 to 24 liters per hour.¹,²

Oysters may change their sex from male to female and from female to male. During the first year of growth both male and female gonadal cells occur in the same individual, but at the end of this first growth period the spermatogonia have proliferated more rapidly than the ovogonia, giving them a predominantly male appearance. At the end of the second growth season a further development of the gonadal tissue occurs which results in a population which approaches equality of sexes. Thereafter the sex of individual oysters may or may not change each year.³

Spawning typically occurs in Chesapeake Bay over a long period from early June through late September, when water temperature ranges from about 20-32°C (68-90°F).¹,³ Spawning is generally initiated by a sudden sharp increase in water temperature, but other factors such as nutritional levels in the oyster are involved.⁴ During spawning a large female oyster 8-12 cm (3.1-4.7 in.) long may on the average, produce up to 2.9 million eggs each year; smaller sizes may release less than 100,000.⁵ The mature eggs and sperm are released into the water where fertilization occurs; an unfertilized oyster egg is about 40 microns (0.002 in) in diameter. Fertilized eggs rapidly develop into free swimming larvae termed trochophores about 50 μ in diameter, and then into the veliger stage. Subsequently, they grow into fully mature larvae about 250 μ (0.01 inch) in size termed eyed larvae since they have a pigmented spot in their tissue (Figure 3).⁶ These mature larvae sink to the bottom and cement their shell to any hard object which in Chesapeake Bay is usually another oyster or an oyster shell. Only a very few survive to the end of the pelagic stage.

During the 10-20 day period when larvae are developing they are widely distributed by water currents since they are weak swimmers incapable of significant power to move horizontally. They are however, capable of a slow vertical migration (about 1 cm/s) within the water column, by alternately swimming upward or sinking toward the bottom. This behavioral characteristic may at times modify the direction or speed of transport by water currents.⁷

The time oysters set or strike varies widely and many estuaries having low salinity (5-10 ppt) may receive little or no set over a period of many years. Other areas, where salinities are higher, may or may not receive a good set. Even
estuaries where the set is usually satisfactory may experience years of little or no set. The intensity of set in an estuary during a season also varies, but usually for each area there is a period when the set is highest. Typically, the seasonal peak will occur in late June, July or August in the upper Chesapeake Bay above the entrance of the Potomac River, and in July, August or September in the southern half.⁴, ⁸, ⁹

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**FIGURE 3.** Life cycle of the American oyster showing larval stages, and small recently set spat on an oyster shell.⁴
GROWTH AND DEVELOPMENT

After permanent attachment the small oyster is called a spat, and by the end of its first week it averages about 1 mm (.04 in) in length. By the end of this same season, when growth stops in November due to falling water temperature, its length varies in different areas. In the low salinity regions of the James River, Virginia it averages 0.5 to 2.0 cm long (0.2-0.8 inch), and in many other regions of the bay it may average from about 1.0 to 3.5 cm (0.4-1.4 in.) depending largely on salinity, available nutrients, and the time the spat set. The small spat are very susceptible to crowding and predation, and consequently mortality is very high during their first season, sometimes reaching 90% to 100%. After setting, growth will vary with those in low salinity regions of the upper bay and in the upper reaches of many of its estuaries taking 3-5 years after setting to reach 7.5 to 10.0 cm (3-4 inches). In high salinity areas usually in the lower bay, they may grow to a similar length in 3-4 years.

In the market, shucked oysters are graded according to size, and identified as follows. Standards 300 and up/gallon; Selects 210-300/gallon; Extra selects 160-210/gallon; and Counts 160 or less/gallon.

PREDATORS AND DISEASES

During their life oysters are subject to many predators and diseases which may inhibit their growth or kill them and few of the many which originally set on shell survive to maturity. In high salinity waters over about 15°/oo, there are small gastropods (Eupleura caudata and Urosalpinx cinerea) known as oyster drills which can destroy newly set oysters and even those up to about 5 cm (2 in.) by boring a small hole through the shell and then ingest the meat. The common blue crab (Callinectes sapidus) eats many oysters when they are small. In many areas schools of cow-nosed rays (Rhinoptera sp.) may actually crush shells of oysters up to 12.5 cm (5 in.) long and ingest meats. A small soft bodied crab known as the pea crab (Pinnotheres osterum) is sometimes found inside oysters. It causes only minor injury to the oyster and in former times was in demand for making soup.10

There are three oyster pathogens in the lower bay which may cause extensive mortalities of oysters. These are Dermo (Perkinsus marinus), SSO or Seaside organism (Minchinia costalis) and MSX (Haplosporidium nelsoni). MSX is a haplosporidan systemic disease of oysters which was first observed in 1957 in oysters in Delaware Bay.11 In that area by mid-summer, it killed nearly half the oysters in high salinity regions and the following year nearly all had died in that area. By late summer 1959 it was found in Chesapeake Bay, and by 1961 nearly all oysters growing in locations where salinities exceed about 15°/oo had died. Where salinities were below this approximate level its impact on mortalities
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decayed sharply. Annual variations in salinity in the Chesapeake Bay and its
tributaries above and below 15°/oo, result in a fluctuating zone in which mor-
talities may or may not occur.2 Scientists even after many years of study still
do not know the full life cycle of MSX and the way it is transmitted from oyster
to oyster is still unknown. Today, mortalities from MSX continue but there is
some evidence that native populations are developing some resistance.

Perkinsus marinus (Dermocystidium marinum) (Dermo), a protozoan
parasite infecting oysters, is found in the Chesapeake Bay and along the mid
Atlantic and Gulf of Mexico coasts. In these areas it usually causes limited mor­
talities, but under certain circumstances, its impact may be severe.3

Dermo is primarily a disease infecting oysters in high salinity regions and
it is active in Chesapeake Bay over the same approximate range as MSX (fall
salinities over 15°/oo). Unlike MSX, the life cycle of Dermo is known and the
disease is easily transmitted from one oyster to another. Oysters become in­
fected during early summer or fall by ingesting waterborne spores from
disintegrating tissues of oysters killed by the disease. It is most destructive dur­
ing long periods of above average water temperatures and where oysters are close­
ly crowded on the bottom.

While the 15°/oo isohaline in the bay and its estuaries seems to divide the
high and low mortality regions for MSX and Dermo, neither disease is associated
with significant, or extreme, mortalities in the tidal lagoons of Maryland and
Virginia between the barrier island and the mainland of the Eastern Shore. Here
salinities usually range from about 24-32°/oo, and the reason for the low in­
cidence of both diseases is not known.

The oyster pathogen SSO or Seaside organism was first observed in the tidal
lagoons of the sea side of the Eastern Shore in 1959 and it has probably been
in that area for many years. Only part of the life cycle of this organism is known,
and like MSX its method of transmittal is unknown. It produces sharply peaked
mortalities during May and June and, like Dermo, it seems to impact individual
beds of oysters rather than large areas.4

THE FISHERY

In Chesapeake Bay management of the oyster fishery is by the two states which
border the bay and by a bi-state Maryland-Virginia commission which manages
the Potomac River. In Maryland, nearly all the naturally productive oyster bot­
tom (215,000 acres) have been designated as public bottom where oysters may
be harvested by the public provided they obtain a license, use the proper gear
to obtain the oysters, and follow the laws and regulations related to season, etc.
Only about 9,000 acres are presently leased by companies or individuals.5

Virginia also has naturally productive bottoms (about 243,000 acres) set aside
for public use called Baylor Grounds after Lt. Baylor, USN, who first surveyed
the grounds in 1894. They are subject to many of the same type of laws and restrictions as exist in Maryland, but there are also major differences. Unlike Maryland, large areas outside the designated public bottoms may be leased for private use by companies or individuals for a 10 year period for a fee. About 110,000 acres were leased in Virginia in 1985. Leased bottoms in Virginia are usually not naturally productive as are many of the public bottoms. Consequently, to be productive they must be planted with small oysters termed seed oysters which are juvenile oysters ranging from about 0.6 to 2.5 inches long. These seed are transferred from a good setting area, such as the James River, to areas where setting is poor but where growth is good. The volume of seed oysters harvested annually from the James River is large and in the 1984-85 season about 400,000 bushels were tonged and sold to the lease holders; this source, provides from 75 to 80% of all seed planted by lease holders in Virginia.

A bushel of seed oyster sold by tongers working in the James River, Virginia may contain from 500 to 1000 seed 1.5 to 6.5 cm (0.6-2.5 in) long which are about 1 to 4 years old. Counts of current year spat on seed oysters are generally not considered in these counts. Typically, a bushel of seed oysters, planted in Virginia's rivers will yield one bushel of market oysters two to three years later. A bushel of seed, in 1985 cost about $3.50-3.75 to purchase and plant, and a bushel of mature oysters will sell for $12-16 wholesale. Other aspects of the oyster fishery including harvesting are discussed in Chapters 2, 3 and 4.

FIGURE 4. Oyster landings in Maryland from public beds, and landings for Virginia for leased areas and public bottoms. All data have been converted to Virginia bushels (3003.9 cu. in.)
A DECLINE IN PRODUCTION AND PRODUCTIVITY

Chesapeake Bay today is the largest oyster producer on the Atlantic and Gulf coasts, but production in recent years has declined sharply both in Maryland and in Virginia. In Maryland, average annual state wide production has fallen since the 1971-75 period from about 2.5 million bushels to about 1.6 million for 1980-85. On Virginia public oyster bottoms there has been a downward trend in landings from about 924,000 bushels during the 1945-50 period to about 416,000 for 1980-85. The major part of the decline in Virginia's statewide production occurred in the private sector. Here landings fell from about 2.8 million bushels during the 1955-60 period to about 500,000 for 1980-85 (Figure 4).

The decline in production from the public bottom in both states has occurred despite extensive repletion programs by both states. In these programs, shells to obtain a set and seed oysters have been planted on suitable bottoms to help increase production; without these extensive and costly efforts, the annual harvest from public bottoms in both states would have been much lower.

Much study has been directed toward determining the basic cause for the decline in landings on the public oyster grounds of Maryland and Virginia, and for the absence of production from Virginia's leased areas, and although there is agreement on several important causes of the decline there is not complete agreement as to their relative importance. One factor however, is clear. There has been a decline in recruitment of small oysters on the public bottoms of both states, as measured by numbers of spat occurring each fall on natural bottom cultch after setting has stopped. In Maryland on representative oyster bars, scientists have shown that, with the exception of the 1961-64 period, the general trend was downward from 1945 to 1976. This decline of course, means fewer oysters when the surviving spat grow to marketable size. Available data suggest however, that other factors in Maryland are involved in the decline in natural productivity, including overfishing.15,16

A decline in recruitment has certainly been responsible for at least a portion of Virginia's lowered harvest rates on its public oyster bottoms. Some estuaries have shown little change in recruitment since 1960 but other locations have experienced a major decline. For example, in the James River, Virginia, the source of 75 to 80% of the seed oysters planted on leased bottom, there has been since 1960 a 90% decrease in set on natural bottom cultch on one of the largest oyster reefs10 (Figure 5). In the upper half of the same estuary there has been a 40-50% reduction. Other Virginia estuaries showing a decline in spatfall include the York River and portions of the Rappahannock River.

The causes of the decline in landings from the leased areas in Virginia which usually must be planted with seed if they are to produce, are complex, and there are several aspects. MSX was the cause for the initial drop in productivity after 1960 since oyster culture was no longer economically profitable in the higher salinity areas where most oysters were cultivated. It is still not possible there today.
After 1960 however, the lease holders did not relocate their growing activities to MSX free areas, or to areas where MSX was only occasionally active or marginal. There were many reasons for this and they are all interrelated. Economic conditions in the post 1960 period were changing and costs of culturing oysters had increased even in good areas, profits were sometimes marginal; costs of seed and planting had increased. Moreover, the private sector had not adopted cost effective culture techniques, such as mechanized planters or harvesters etc. Adding to their problems was competition in the form of imported oysters from Maryland and the Gulf Coasts and the pollution of good growing areas.

The lowered levels of natural recruitment discussed above may be responsible for a major part of the decline in landings from the public bottoms, and factors related to overfishing may also be involved, but the basic cause(s) for the decline is not too apparent. Factors such as the destruction of bottom cultch, increased levels of sedimentation, higher levels of larval and spat mortality, and pollution have been discussed and studied. In respect to pollution, many commonly used petrochemicals, herbicides, pesticides, and heavy metals have been shown in laboratory studies to be toxic or have a sublethal effect on oysters and oyster larvae. Many of these same substances occur in bay waters, where they probably have an adverse impact on survival and growth of oysters and

![Graph](image-url)

**FIGURE 5.** Number of spat per bushel on natural bottom cultch during late fall at Wreck Shoals in the Lower James River, Virginia from 1947 to 1986.
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Oyster larvae. For most of these substances cause and effect relation in the estuary
have yet to be fully demonstrated.

In conclusion, oyster production in the Chesapeake Bay has declined in re­
cent years, but large areas are still productive; and these still have an enormous
potential for oyster culture. Studies have shown however that unless the pre­
sent antiquated management policies and practices for the bay are drastically
modified, this potential will not be realized. Such changes are possible and prac­
tical and have been successfully used in other areas. Moreover, they may be used
with little or no damage to the environment. Toward this goal the Virginia
Marine Resources Commission in 1986 and 1987 began developing a long range
Virginia Fisheries Management Plan to enhance oyster production. If this plan
is fully and correctly implemented with sufficient funds and personnel, much
improvement will result.

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