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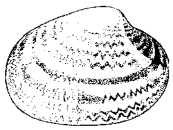

Bulletin

# Water Quality and Its Role on Hard Clam Production

**April 2002**

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A practical understanding of water quality is necessary for the clam farmer to assess environmental conditions and apply effective management strategies. Important water quality parameters controlling the growth and survival of hard clams include temperature, salinity, dissolved oxygen, chlorophyll, and turbidity. The following is a summary of each of these parameters, including influencing factors and their effects on clams. While all these water quality parameters are interrelated, for clarity they are discussed separately.

Within the estuarine environment, clams can be exposed to water quality fluctuations that exceed their normal physiological tolerance limits. Clams are able to survive short-term changes by closing their valves and thereby preventing exposure to unfavorable conditions. It is important to note that the ability of clams to survive one adverse parameter (for example, low dissolved oxygen) depends on the severity of all other water quality parameters. Furthermore, the clam's physiological condition, age and size, as well as acclimation history, can be very important regarding the effect of an unfavorable environment and the clam's tolerance. Finally, it should be noted that the environmental tolerance range for one physiological or behavioral function might differ from that for some other function.

## Water Temperature

Definition

Water temperature is a measure of the water's warmth or coldness with reference to a standard value. Water temperature is usually expressed as either Celsius (C) or Fahrenheit (F). The freezing point of full seawater is -2°C or 28°F. To convert Celsius to Fahrenheit, simply multiply the value by 1.8 and add 32. For example, 20°C = (20x1.8)+32 or 68°F.

Characteristics

Measurement of water temperature is essential for water data collection. Determinations of conductivity, dissolved oxygen concentrations, and biological activity rely on accurate temperature measurements. Temperature plays many roles in the estuary. As water temperature increases, for example, the capacity of water to hold dissolved oxygen decreases. Water temperature also influences the rate of plant photosynthesis, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Influencing Factors

Water temperature is a function of season, depth, and amount of mixing due to wind, storms and tides, and temperature of water flowing in from the tributaries. Seasonal weather changes have the greatest effect on water temperature, but the mixing of the water in the estuary will also cause the temperature to fluctuate. In deep bodies of water, the temperature is not the same throughout. It is warmer at the surface, cooler towards the middle and coolest at the bottom. In shallow bodies of water, there is less likely to be any temperature change from surface to bottom. Water heats up as it absorbs energy from the sun and in shallow water the sun can heat the water more completely, as well as the mud and sand sediment.

Effects on Clams

Clams, like most aquatic animals, are poikilotherms, or cold-blooded. This means their metabolic rate (for example, feeding, respiration, and burrowing capabilities) is directly influenced by water temperature. The rate increases with increasing temperature. Consequently, temperature greatly affects the growth of juvenile and adult clams. The optimum temperature for clam growth is approximately 68°F. Growth rate is reduced above or below this temperature, with growth ceasing below 48°F and above 88°F. The optimum temperatures for burrowing are 70°F to 88°F. The upper lethal temperature of the hard clam is around113°F. However, temperatures above 90°F can have adverse effects as pumping rates are reduced to zero. Consequently, if metabolic rates are still high, energy expenditure would exceed energy gain. Adult clams can survive temperatures below freezing for short durations as long as the clams are covered by flowing water or sediment. Clams die when over 60% of the water in their tissues has changed to ice. In Florida, growth is generally greatest in early spring and late fall, reduced in winter and summer.

## Salinity

Definition

Salinity refers to the relative salt content in waters and is usually expressed in parts per thousand (ppt or $^{0}/_{00}$). Monitoring equipment used in the CLAMMRS project is actually measuring conductivity and converting the value to salinity. Conductivity is a measure of a fluid's ability to transfer an electrical charge and is expressed as micro-Siemens per centimeter (µS/cm).

Characteristics

Typically, fresh water will have a salinity of 0 ppt and seawater will have a salinity of 34 to 35 ppt. The majority of clam aquaculture occurs in estuaries - bodies of water in which fresh and seawater join and mix. Estuaries can range between the fresh water and seawater extremes. In some cases, salinity can exceed the value of normal seawater during long periods of drought coupled with warm temperatures and associated evaporation. Short-term (hours) and long-term (days, months, years) fluctuations in salinity are a natural occurrence in estuaries.

Influencing Factors

An estuary usually exhibits a gradual change in salinity throughout its length as fresh water flowing from the tributaries mixes with seawater moving in from the ocean. Even at a single place in the estuary, salinity will fluctuate with movement of the tides, dilution by rainfall, and mixing of the water by wind. Salinity, along with water temperature, is the primary factor in determining the stratification of an estuary. When fresh and salt water meet, the two do not readily mix. Warm, fresh water is less dense than cold, salty water and will overlie the wedge of seawater pushing in from the ocean. Therefore, salinity increases with water depth unless the estuarine water column is well mixed vertically. Storms, tides, and wind, however, can eliminate the layering caused by salinity differences by thoroughly mixing the two masses of water. The shape of the estuary and the volume of freshwater inflow also influence this two-layer circulation.

Effects on Clams

Juvenile and adult hard clams experience greatest growth at salinities ranging from 20 to 30 ppt. Optimum growth occurs around 27 ppt. Growth is reduced above or below this range. Below 18 ppt, growth ceases. Adult clams are able to withstand periodic salinity fluctuations, as well as long periods of low salinity, due to their ability to close their valves, or shells. This effectively prevents exposure to the salinity extreme. Clams can maintain valve closure for days by respiring anaerobically (without oxygen). Adults have been shown to survive salinity as low as 10 ppt for up to 4-5 weeks. However, extended valve closure leads to decreased growth rates. Seed clams are more vulnerable to lower salinity than adults and will die when subjected to extended periods of salinities below 15 ppt. Geographic location, source of freshwater and rate of salinity change all influence effects of salinity declines on both juvenile and adult clams. Water temperature is also of primary importance regarding the effect of salinity. Growth and survival decreases sharply when salinity is low and temperature is high. Clams begin to die when salinity exceeds 40 ppt.

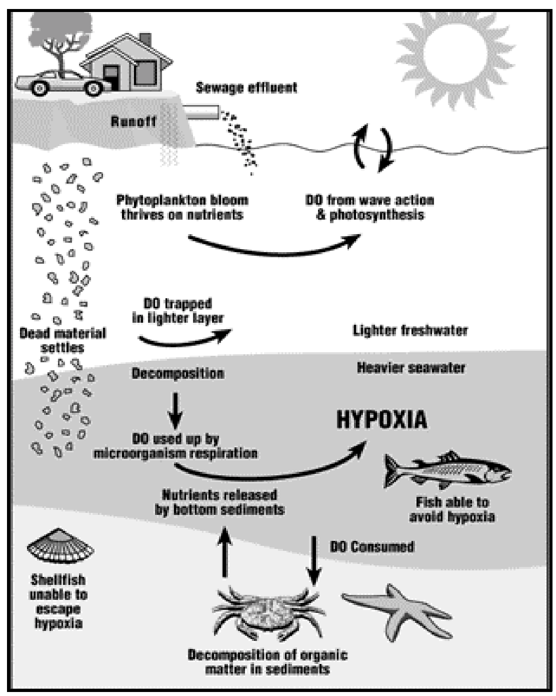
## Dissolved Oxygen

Definition

Dissolved oxygen (DO) refers to the concentration of oxygen gas dissolved in water, usually expressed in milligrams per liter (mg/L), parts per million (ppm), or percent of saturation (%).

Characteristics

The main sources of oxygen in the aquatic environment include direct diffusion from the atmosphere, wind and wave action, and photosynthesis. Of these, photosynthesis, or the process of using sunlight to convert carbon dioxide into oxygen, by aquatic plants and phytoplankton is the most important. The amount of oxygen that can be dissolved in water is also dependent on temperature and salinity. Warm water is much less capable of holding oxygen gas in solution than cool water because it is less dense. Water with higher salinity also holds less oxygen because the dissolved salt takes up room the oxygen could be using. Therefore, warm estuarine water can contain very little dissolved oxygen. When the concentration of DO is the maximum amount the water can hold at a given temperature and salinity, the water is considered saturated. Therefore, percent of saturation compares the amount of DO actually in the water to the amount of oxygen the water could hold if it were saturated. Values expressed as mg/L refer to the actual amount of DO in the water. A clam metabolizes a certain mg of oxygen per hour but exchange between the clam's gill tissue and environment also depends on differences in partial pressures of the dissolved gas. Because of this, it is important to consider both percent of saturation and mg/L when evaluating DO. For example, seawater with 100% DO equals 10.4mg/l at 40°F compared to 6.6mg/L at 80°F.




*Physical, chemical, and biological processes that affect dissolved oxygen concentrations in estuaries. (Redrawn USEPA, 1998)*

Influencing Factors

Since the concentration of dissolved oxygen depends upon several variables (for example, temperature, salinity, wind and water turbulence, atmospheric pressure, the presence of oxygen-demanding compounds and organisms, and photosynthesis), levels may change sharply in a matter of hours, making it difficult to assess the significance of any single DO value. At the surface of an estuary, the water at midday is often close to oxygen saturation due both re-aeration and the production of oxygen by plant photosynthesis (an activity driven by sunlight). As night falls, photosynthesis ceases and plants consume available oxygen, forcing DO levels at the surface to decline.

Effects on Clams

Changes in DO do not affect clams as much as changes in temperature and salinity. Optimum growth occurs when DO concentrations are above 4.2 mg/L. Growth is reduced at DO concentrations less than 2.4 mg/L. While growth is limited or ceases entirely, clams are able to survive for extended periods of time in the presence of greatly reduced (hypoxia) or zero levels (anoxia) of oxygen. In fact, clams can maintain their ability to burrow even after being exposed to DO levels less than 1 mg/L for weeks. When DO levels are reduced, clams are able to carry on metabolic activity by using enzymes in their tissue (anaerobic metabolism) rather than dissolved oxygen pumped across their gills (aerobic metabolism). Anaerobic metabolism requires that clams close their valves. As a result, clams are unable to filter food from the water and they must rely on stored energy to survive. Survival at low DO levels is critically dependent on temper-ature; at high temperatures, survival capacity is notably less than at low temperatures. Physiological condition and size can also be important with larger healthier clams able to withstand longer periods of low DO.

## Chlorophyll *a*

Definition

Chlorophyll *a* is the primary photosynthetic pigment found in all algae and plants. In aquatic environments it is one of the most widely used measures of algal abundance because there is typically a good relationship between chlorophyll *a* concentrations and algal biomass. Chlorophyll *a* concentration is typically determined by spectrophotometric analysis of filtered-water samples and reported as micrograms per liter (mg/l) or milligrams per $m^3$ (mg/ $m^3$). In recent years methods have been developed for field measurements of chlorophyll *a*. Some of the monitoring units used in CLAMMRS are equipped with chlorophyll *a* probes. However, the effectiveness of the field probes may vary depending on the specific character of the ecosystems in question (for example, turbidity, color).

Characteristics

Chlorophyll *a* concentrations range from less than 1 mg/$m^3$ to over 300 mg/$m^3$ in different ecosystems. Chlorophyll values encountered in particular ecosystems are commonly used to define productivity, or trophic state. The specific chlorophyll a values associated with unproductive (for example, oligotrophic), moderately productive (for example, mesotrophic), highly productive (for example, eutrophic) and extremely productive (for example, hypereutrophic) ecosystems is only loosely defined for the marine environment, unlike the freshwater environment where rather specific definitions are available. The boundary values for the four productivity levels may be roughly defined as 5, 10, 20 and 40 mg/$m^3$. These boundary levels are subject to other controlling factors. For example, in highly flushed ecosystems these boundary levels could be lower, while in ecosystems with very low flushing rates the boundary levels might be set higher.

Influencing Factors

In general, chlorophyll *a* concentrations are directly related to nutrient levels in individual ecosystems. However, the specific relationship between nutrient loading rates and chlorophyll *a* concentration can vary between ecosystems. Part of the problem in establishing succinct chlorophyll ranges for different productivity levels is the fact that chlorophyll *a* concentrations are subject to change due to factors not directly reflective of nutrient loading, like tidal flushing.

Effects on Clams

Phytoplankton production in aquatic ecosystem is a key component of food availability for benthic (bottom-dwelling) filter-feeding animals, like clams and oysters. As a measure of phytoplankton abundance, chlorophyll *a* concentration provides important information about the relative availability of food. Of course, more food does not always mean better nutrition. Very high chlorophyll *a* values associated with algal blooms can be a warning sign for potential problems if the phytoplankton community is dominated.

## Turbidity

Definition

Turbidity is a measure of the optical properties of water related to the absorption and refraction of light by particles in the water. As such, it is an indicator of the amount of particulate material in water. Turbidity is generally reported as NTU, or nephelometric turbidity units. The unit designation stems from the use of nephelometer in the determination of turbidity. The nephelometer measures the proportion of light refracted by particles at a 90 degree angle from an incident beam. The proportion of refracted light is directly correlated to NTU by way of a standard curve derived from samples of known turbidity, typically using formazin.

Characteristics

The components of turbidity include a wide range of particles found in natural waters, including clay, sand, plankton, organic aggregates or other inorganic particles (for example, precipitated calcium carbonate). The specific impact of a particular particle on turbidity measurements light.
depends on any characteristic that effects refraction of light. These characteristics include size, shape, color or other absorption properties of particles. For example, a white inorganic particle may refract more light than an algal cell containing chlorophyll that absorbs a large proportion of incident

Influencing Factors

Turbidity can be influenced by any factor that alters the concentration of particles in the water column. For example, rivers can introduce large amounts of sediment into estuaries. Similarly, nutrient loading to an aquatic ecosystem can induce algal blooms, thereby increasing turbidity. Internal processes can also change turbidity. For example, high wind speeds in shallow ecosystems can result in significant resuspension of bottom particles into the water column. In some environments organic or inorganic dissolved material can form particulate aggregates through flocculation or precipitation caused by physical or chemical changes in the environment.

Effects on Clams

As a measure of particles in the water column turbidity can serve as an indicator of the particulate load facing the filtration apparatus of clams. Excessively high sediment loading can be a stress factor for clams from the standpoint of filtration capacity. From an optical point of view, turbidity can be used as an indicator of light availability for photosynthesis. Excessively high turbidity can result in light limitation of algal productivity, which in turn can impact the overall productivity of an ecosystem, including clams.

# Particulate Organic Carbon

Definition

Particulate organic carbon, or POC as it is commonly referred to, is the concentration of the element carbon in it's organic forms (like glucose). POC does not include inorganic forms of carbon like $CO_2$, or carbon dioxide. POC is generally reported as grams per liter (g/l) for water samples, and is determined from particulate material collected by filtration from a water sample. Filters with particulate material on them are then analyzed for POC using a coulometer, or other analytical apparatus.

Characteristics

POC can include a wide range of carbon-based organic material, both living and dead. The living elements of POC include bacteria, algae and zooplankton. The non-living elements of POC include an immense array of degradation products of bacterial, plant and animal origin. POC concentrations can vary widely between ecosystems from well below 0.1 mg/l to over 10 mg/l.

Influencing Factors

POC concentrations and composition can exhibit wide variation over time and space. For example, coastal environments subject to river inflows from productive watersheds can contain high levels of POC. These inputs can vary dramatically over time depending on patterns of biological decay (for example, leaf fall) and rainfall flushing rates (for example, drought versus flood years or wet versus dry seasons). The specific composition of POC also varies between ecosystems, depending on the character of the biological communities in the ecosystem and it's watershed.

Effects on Clams

Since all animals are carbon-based life forms, POC concentrations can be an important measure of food availability for clams in aquatic ecosystems. Unlike chlorophyll *a* concentration which focuses on the abundance of living plant material, POC incorporates a wider range of potential carbon sources. However, it is not a perfect measure of nutritional value of a water body because many elements of POC can be non-digestible or even toxic. Therefore, POC is just one of several tools needed to evaluate food availability for clams in aquatic ecosystems.

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