

# Biological Aspects of Edible Oysters: A Review

Ganapathi Naik. M<sup>1\*</sup>, Gangadhara Gowda<sup>2</sup>

Associate Professor, Department of Aquaculture, College of Fisheries, Mangalore, India<sup>1\*</sup>

Professor, Department of Aquatic Environment Management, College of Fisheries, Mangalore, India<sup>2</sup>

\*Corresponding Author

**ABSTRACT:** Environmental factors influence on the feeding, growth, maturation, spawning and development of oysters. Fundamentally, the water temperature and salinity influence on the growth, survival, reproduction, larval growth and metamorphosis. The oyster's shape and size also change in response to variations in the environmental factors. Oyster growth varies considerably with size, temperature, quantity and quality of food and seasons of the year. Wide differences in growth rates between species and locations occur that would be expected due to the influence of water conditions, culture systems and the inherent growth potential of a species. Once the oysters attain full sexual maturity, slight variations in the environmental factors such as rise or decline in salinity/temperature trigger spawning. Feeding activities in larval oysters are generally well understood, particularly as a result of the development of commercial hatcheries. Oysters are parasitized with many microorganisms, some of which are responsible for extensive mortalities.

**KEYWORDS:** Oyster, Biological aspect, Environment, Growth, Reproduction

## 1. INTRODUCTION

The biology of oysters is greatly influenced by the environmental factors in the habitat (Purchon *et al.*, 1968). Feeding, growth, maturation, spawning, development and setting of oyster spat are greatly influenced by the varying environmental factors such as temperature, salinity, pH, dissolved oxygen, sediments and food (Galtsoff, 1964). The temperature and salinity of the water greatly influence the growth, survival, reproduction and larval growth and metamorphosis (Van *et al.*, 2004). Several healthy oyster beds were recorded in the May River, Beaufort County, South Carolina, USA by assessing the environmental and biological conditions of the oyster beds (Coen *et al.*, 2004, 2006).

The oyster's shape and size also change in response to variations in the estuarine environment (Juliana *et al.*, 2008). Its shells may be small and white if the oyster is growing in low salinity areas, long and thin under crowded conditions or broken and pitted when other organisms use the shells as home. Along with shell variations, the colour and condition of oyster meat can change depending on the presence or lack of food organisms and the compounds in the water.

## II. FOOD AND FEEDING

The diatoms, dianoflagellates and other groups of phytoplankton and zooplankton, bacteria, organic detritus and mineral salts are taken in as the principal food (Ronald and Ronald, 1989). Spores and particulate matter of seaweeds are also found in the stomach. Nelson (1947) found that the abundance of the diatom *Skeletonema* has been responsible for the healthy growth and good condition of oysters of Delaware Bay, USA. Jorgensen (1975) observed correlation between rapid growth of oysters and the presence of the diatoms, *Skeletonema* sp., *Chaetoceros* sp. and *Thalassiosira* sp. The combination-algal diet promotes better growth in oysters than the diet consisting of only a single species (Epifanio, 1979).

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

The mechanism of feeding in adult oysters has been well documented (Jorgenson, 1975; Owen, 1974). When the shell of the oyster is open, millions of tiny, hair-like structures (cilia) on the gills beat back and forth, causing the circulation of water into one side of the mantle chamber and out of the other. The planktons, detritus, microorganisms and other particulate matter are filtered from water by ciliary action of gills and transported to the mouth and from there passed to the stomach and digestive diverticula for digestion and absorption.

The high concentrations of phytoplankton which occur during blooms are not desirable features for feeding and can be harmful to the oysters. The ideal condition for the feeding of oysters is pollution free water containing a low concentration of small diatoms and dinoflagellates in a nonturbulent flow (Jorgenson, 1975). Food particles are selected primarily according to size and shape. Jorgenson (1975) observed that the American oyster filters about 10 to 20 L of water for each milliliter of oxygen consumed. At this rate, under normal conditions, an oyster has the capacity to filter approximately 1500L of water daily. Actual food requirements of oysters do not exceed 0.15mg of utilizable organic matter per liter of water used. The oyster is also capable of absorbing dissolved organic matter in the water through the surface of the gills, palps and mantle. Feeding activities in larval oysters are generally well understood, particularly as a result of the development of commercial hatcheries ((Ronald and Ronald, 1989). In the artificial conditions of an oyster hatchery, mixed cultures of various small algae provide adequate nutrition for the growing oysters. Since the diet and food requirements vary seasonally due to food variability and spawning, the volume and consistency of the oyster meat will vary (Narashimham, 2005).

### III.GROWTH OF OYSTERS

Growth of oyster is largely influenced by the availability of food and hydrographic conditions (Rajapandian and Rajan, 1983). The growth of oyster is expressed in terms of increment in height of the shell and weight. The shell growth is correlated with growth of living tissue. Oyster growth varies considerably with size, temperature, quantity and quality of food and seasons of the year. Wide differences in growth rates between species and locations occur, that would be expected due to the influence of water conditions, culture systems and the inherent growth potential of a species. Growth is more rapid in warm waters such as the Gulf of Mexico, where a marketable size of 3.5 inches may be reached in 2 years (Croft, 1998). In Northern waters characterized by shorter summer and generally lower water temperatures, oysters reach 3.5 inches height in 4 or 5 years (Bartol *et al.*, 1999). The elevated temperatures of the tropics can produce high oyster growth rates if adequate food is available. Juliana *et al.* (2008) compared the growth rates between triploid eastern oysters (*Crassostrea virginica*) and triploid suminoe oysters (*C. ariakensis*) and found that growth rate was better in triploid eastern oyster. The growth of the oysters is also effected by tidal height and substrate level (Bartol *et al.*, 1999). Rao and Nayar(1956), Nagappan Nayar and Mahadevan (1983), Rao *et al.*(1983), Purushan *et al.* (1983) and Reuben *et al.* (1983) have made investigations on the growth of *C. madrasensis*. It was observed that the growth of spat of *C. madrasensis* was rapid during the first 3 months. A size of 38mm was attained in 90 days registering a growth of 12.6mm per month and at the end of the first year oysters attained an average size of 84mm with a total shell and meat weight of 120-130g per oyster. An average size of 86.7mm and maximum of 110mm were reached in *C. madrasensis* at the end of one year at Athankarai estuary (Rao *et al.*, 1983). Purushan *et al.* (1983) recorded an average growth of 60-62mm in *C. madrasensis* in a period of 5 months in Cochin backwaters. Reuben *et al* (1983) reported a growth of 77-81.8mm in 12 months in the oysters of Bheemunipatnam backwaters. Durve and Bal (1962) recorded a growth of 37.2mm and 47.9mm at the end of six months and one year respectively in *C. gryphoides* of Kerala backwaters.

The growth and survival of oyster populations along the east coast of India appear to be relatively better perhaps due to the stable salinity and temperature conditions prevailing along the coast (Rajapandian and Rajan, 1989). *C. madrasensis* exhibited higher growth in the Adyar estuary whenever exchange with the Bay of Bengal increased (Rao and Nayar, 1956). Shell growth in *C. madrasensis* was retarded during periods of high salinity and was totally absent when low salinity water prevailed (Durve and Bal, 1962). *C. gryphoides* grew best in moderate salinity (Rajapandian and Rajan, 1989).

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

Studies suggest that adequate nutrition for growth and maturation of tropical oysters require food sources which are more abundant in higher salinity water (Narasimham, 2005). This water may intrude into estuaries and lagoons from the adjacent sea. High runoff would dilute intruding sea water, alter temperature, salinity and light penetration affecting the growth of phytoplankton as well as the species composition of the phytoplankton community. This may affect the oyster growth.

A study conducted by Narasimham (2005) observed that in the natural beds, during the first year *C. madrasensis* attained 49mm in the Vellar estuary and 92mm in the Pulicat Lake showing wide variation in the growth rate. In the experimental culture studies (off-bottom culture) in which both hatchery and natural seeds were used, *C. madrasensis* attained 72mm in the Kakinada Bay and 86.7mm in the Vaigai estuary during the first year. Both in the Kakinada Bay and Vellar estuary oysters have grown faster in experimental culture than in the natural beds. Yavari (2001) reported that growth and survival of *C. madrasensis* was greater at low intertidal levels (12.32% daily mean aerial exposure) when compared to subtidal or mid and higher intertidal levels. Enhanced feeding during immersion time has been considered as a possible reason. Based on a study on the growth and survival of *C. madrasensis* at 3 stations in the Tuticorin Bay, Yavari (2002) stated that greater food availability and lower turbidity may be the principal factors favouring faster growth. In the Asthamudi Lake, Kripa(1998) reported that the *S. cucullata* attained 36.2mm, 51.1mm and 57.2mm length in 1, 2 and 3 years respectively. Kripa and Salih (1999) observed that these oysters grew faster in subtidal areas when compared to their growth in the intertidal zone. Ruwa (1990) made similar observation in Kenya. The faster growth in subtidal populations was attributed to longer feeding time (Morton, 1977).

## IV.REPRODUCTION

Oyster reproductive organs (gonads) consist of a mass of tissue made of microscopic tubules, sex cells, and connective tissue which envelops the stomach, digestive diverticula, and the fold of the intestine and during the time of ripeness, constitutes a significant portion of the entire oyster body. The gonads become larger and thicker as their eggs and sperm mature. Once the oysters attain full sexual maturity, slight variations in the environmental factors such as rise or decline in salinity/temperature trigger spawning (Narasimhan, 2005).

## V.MATURATION OF GONADS

Cole (1942), Bargeton (1942) and Loosanoff (1942) have described the process of maturation of gonads and the factors influencing them. Among exogenic factors temperature is more important than any other factors. Oysters usually mature by one year of age. Paul (1942) and Rao (1951) have recorded partially spent conditions of the gonad of *C. madrasensis* at Madras all round the year. Among oysters found in Adyar backwaters in Tuticorin Bay, gonads with fully ripe and partially spent conditions have been recorded in high percentages during February-April and July- September (Rajapadian and Rajan, 1983). The peak of gametogenetic activities was recorded during the months February-March (64-78%) and August-September (59-73%). Further, the diurnal variations in minimum and maximum temperatures had well defined relation to the development of gonads and spawning. The drop in temperature during the months of June and July showed corresponding decline in the spawning activity of the oysters. In September this value of temperature increased and there was rise in the spawning population. In Northern climates, gametogenesis sets in European oysters during the middle of May and spawning commences in early June and continues till July or early August (Rand, 1973).

## VI. SEX RATIO

Oysters generally are dioecious (having separate sex) but hermaphrodites (having both sexes in one individual) are not uncommon. It has been well documented that young oysters function primarily as males (60-70%) and later become female. In oysters of the zero year class (which are upto 78mm in size), 75% are males and in one year old and above (ranging in size from 80-118.5mm) females represent 72% (Rajapadian and Rajan, 1987).

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

## VII. HERMAPHRODITISM

A number of studies have shown the presence of hermaphroditism in tropical *Crassostrea* species. Seasonally changing sex ratios have been observed which indicate sex changes were occurring. In case of *C. rhizophorae*, sex changes occur in 90% of the population (Angell, 1986). In India, among *C. gryphoides*, sex change in favour of females occurs principally during the monsoon season (Durve, 1965). Histological evidence substantiated this because gonads could be seen with varying proportions of oocytes and spermatocytes, indicating the transition from one sex to the other (Angell, 1986).

True and functional hermaphrodites probably do not occur but are only transitional phase containing both sperms and developing eggs (Rao, 1956). Galtsoff (1964) has observed hermaphrodites only among 2, 3 and 4 year old oysters of *C. virginica* and none in 5-8 year old oysters. Rao and Nagappan Nayar (1956) recorded hermaphrodites in *C. madrasensis* throughout the year. Further, his observations on the changing pattern of sex from male to female and female to male evidently shows that hermaphroditism is a feature found during the transitional phase of sex change. The American oyster is dioecious, but once a year some members of a given local population change their gender from male to female (protandry) or from female to male (protogyny) (Rondal and Rondal, 1989).

## VIII. FECUNDITY

In the larviparous oyster, *Ostrea edulis*, the egg is about 100 $\mu$  in diameter and is very large when compared to those of the oviparous oysters, *Crassostrea* genus. The egg of *C. madrasensis* is about 48-60  $\mu$  in diameter. Cole(1941) found that the number of eggs spawned by *O.edulis* to be 91,600 by one year old oysters and 218,100, 462,000 and 902,000 eggs were spawned by 2, 3 and 4 year old oysters respectively. Cerruti (1941) reported that the number of eggs depends on the size of oyster than the age. Oysters of the genus *Crassostrea* release more eggs than larviparous oysters. In a season *C. virginica* can release 100 to 200 million eggs (Galtsoff, 1964). In *C. gigas*, almost same numbers of eggs per spawning have been recorded (Tomiyama, 1980).

## IX. SPAWNING

After oyster gonads reach maturity in a local population, a temperature (or salinity) shock triggers the emission of sperm from one or more males (Ronald and Ronald, 1989). The two genera of oysters, *Ostrea* and *Crassostrea* have different spawning habits (Ronald and Ronald, 1989; Rajapandian and Rajan, 1987). In *Ostrea* the eggs when released from the gonad are retained in the mantle cavity while the sperms are discharged to the exterior. Eggs are fertilized by sperms from outside and the larval life partly takes place inside the shell before being released into the water. In *Crassostrea*, at spawning, both eggs and sperms are discharged by the contraction of muscles in the walls of the genital ducts. The emission of sperm from male oysters occurs via the exhalant chamber of the mantle. A chemical constituent of the sperm stimulates the females in the area to release their eggs resulting in a spawning chain reaction that can sweep rapidly through a dense population, turning the water in a nonturbid area white (Ronald and Ronald, 1989). Larvae of European oyster are usually released from the female by the time they reach a length of 143-190 $\mu$ m (Newkirk, 1996) and set at a length of 280 -300 $\mu$ m (Uyan, 2000).

## X. FERTILIZATION

Eggs lose their fertilizability totally at the end of 24h in temperate climate. In tropical conditions, it is lost within 4h. The fertilizing power of sperms lasts for 3 to 4h. Temperature and dilution factors decrease the fertilizing power of sperms (Dupuy *et al.*, 1977). Concentrated suspension of sperm stored at 10-12°C will increase the longitivity upto 24h. Abnormal fertilization can occur if large proportions of sperms are mixed with small quantities of eggs. This may result in several sperms penetrating the membrane of a single egg and this phenomenon is polyspermy will cause irregular cleavage of egg.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

Duppy *et al.* (1977) observed that a delay of one hour or more in adding sperms to newly spawned eggs will increase the incidence of abnormality among the larvae.

## XI. DEVELOPMENT

Fertilization occurs in the water column via chance encounters of eggs and sperm and larval development begins. In *C. madrasensis* after fertilization the first polar body was observed within 20 to 40 minutes and subsequently the second polar body appeared (Rajapandian and Rajan, 1989). In larviparous oysters, *Ostrea*, early embryonic development and transformation of larvae take place in the inhalant chamber. These larvae cover densely the surface of the gills and lower mantle lobe which gives the appearance of sprinkled flour. At the time of their release the congregation of larvae is purplish black. After fertilization the larvae are retained in the gill chamber for 7 to 8 days and attain a size of 220 $\mu$  before release (Yonge, 1960).

The free-living larvae function as zooplankters (meroplankton) in the water column and probably are significant as a food source for planktivores in local areas. Depending on water temperature and food availability, the larval life stage of *C. virginica* will last approximately 10-20 days (Ronald and Ronald, 1989). Some larvae will remain planktonic for up to 2 months during cooler periods or in the absence of sufficient food. The sequence of events in the development and growth of the larvae of the American oyster, *C. virginica* and the Pacific oyster, *C. gigas* are almost similar to that of *C. madrasensis* under laboratory and natural conditions (Rajapandian and Rajan, 1989). The larvae attain eyed stage on 13<sup>th</sup> day in all these oysters and setting takes place on the 14 to 15<sup>th</sup> day after fertilization. The growth of spat has been observed to be faster in *C. madrasensis* than in *C. virginica* and *C. gigas* which may be probably due to the differences in the prevailing temperature.

## XII. DISEASES OF OYSTERS

Oysters in all stages of development are susceptible to attack by numerous enemies. The oyster eggs, early embryos and larvae are eaten in large numbers by protozoans, ctenophores, jellyfish, hydroids, worms, bivalves, barnacles, numerous larval and adult crustaceans, especially crabs, many varieties of larval and adult fish, ascidians and others (Lotze *et al.*, 2011). It is probable that under natural conditions oyster larvae are parasitized by fungi, such as *Sirolopidium zoophthorum*, and are infected by certain bacteria such as *Vibrio* and *Pseudomonas* (Victor, 1987). Perhaps viruses also kill oyster larvae and adult oysters (Grohmann *et al.*, 1981).

Oysters are parasitized with many microorganisms, some of which are responsible for extensive mortalities (Nell, 2007). One of the most destructive cases of this nature is the so called Malpeque Bay disease, which struck oysters of Prince Edward Island, Canada, around 1915 (Kohn *et al.*, 1997). Oysters affected by this disease become thin and emaciated and sometimes have yellowish pustules and abscesses. It took 13 years for the oyster beds of Malpeque Bay to recover. This disease outbreak remains a mystery to scientists who have been unable to identify a cause for the epizootic.

Two other infectious oyster diseases, commonly known to oyster growers as “MSX” and “Dermo”, have had a much more significant and chronic effect on oyster populations in the northern region of the United States (Kohn *et al.*, 1997). The combined impact of both diseases has caused hundreds of millions of dollars in losses over the last 35- 45 years in Mid-Atlantic States (especially Chesapeake and Delaware Bays) and seriously threatens both natural and cultivated oyster populations in the New England states. Although both parasites are lethal to oysters, they are not harmful to humans.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

## XIII. MSX DISEASE

MSX disease was first recognized as the cause of massive oyster mortalities (90-95%) in lower Delaware Bay in 1957. Two years later, the disease was discovered in the lower Chesapeake Bay. The causative agent, a single-celled parasite, *Haplosporidium nelsoni*, was observed as a Multinucleated Sphere with unknown affinity ("X"). The means by which MSX disease is transmitted is not known. All attempts to pass *H. nelsoni* from infected to uninfected oysters in the laboratory have been unsuccessful (Ford and Tripp, 1993). Many investigators believe that an alternate or intermediate host may be involved in the life cycle. Distribution of MSX disease is fairly uniform over a large area within the higher salinity (>15ppt) portion of affected estuaries (Ford and Tripp, 1996). With favorable salinities, the disease is capable of spreading rapidly over large distances. The American oyster is the only oyster known to be infected, but similar parasites infect a variety of other bivalve molluscs. Oysters become infected during the warm months, with peak mortalities in late summer and early fall and again in the following summer. The disease reappears or increases in severity in drought years. The parasite appears to be sensitive or disappear when temperatures exceed about 20°C (Ford and Haskin, 1988).

## XIV. DERMO DISEASE

Dermo disease was first identified as the cause of extensive oyster mortalities in the Gulf of Mexico nearly 50 years ago (Ford and Haskin, 1988). It was originally thought to be a fungus and was named *Dermocystidium marinum*. Even though subsequent research led to its reclassification as a protozoan parasite *Perkinsus marinus* in 1978, the disease is still commonly referred to as "Dermo". From its discovery until 1990, Dermo disease was primarily restricted to southern waters from the western Gulf of Mexico to Chesapeake Bay where it caused chronic and occasionally epizootic mortalities (Ford and Tripp, 1993). In the mid 1950s, *P. marinus* was introduced into Delaware Bay when infected seed oysters were transplanted from lower Chesapeake Bay (Ford and Tripp, 1987). Dead and disintegrating oysters release infective stages back into the water column where they infect other oysters and repeat the cycle (Ford and Tripp, 1993). Oysters infected with Dermo disease die primarily from extensive tissue lysis and blockage of major blood vessels (Lafferty *et al.*, 2004). Unlike *H. nelsoni*, transmission of *P. marinus* between oysters was easily accomplished both in the field and the laboratory (White *et al.*, 1987).

## XV. CONCLUSION

Since the diet and food requirements vary seasonally due to food variability and spawning, the volume and consistency of the oyster meat will vary. Therefore, supply of adequate food item is necessary to get desirable quality of oyster meat. In the artificial conditions of an oyster hatchery, mixed cultures of various small algae provide adequate nutrition for the growing oysters. Oysters in all stages of development are susceptible to attack by numerous enemies. The oyster eggs, early embryos and larvae are eaten in large numbers by protozoans, ctenophores, jellyfish, hydroids, worms, bivalves, barnacles, numerous larval and adult crustaceans, especially crabs, many varieties of larval and adult fish, ascidians and others. So that oyster farmers must try to avoid oyster enemies in their culture systems to achieve better production.

## REFERENCES

1. Angell, C.L., "The biology and culture of tropical oysters", ICLARM Studies and Reviews, Manila, 13: 42, 1986.
2. Bargeton, M., Les, "Variations saisonieres du tissu conjonctif vesiculeus De L'huite", French Bull.Bio., 76: 175-191, 1942.
3. Bartol, I.K., Mann, R. and Luckenbach, M., "Growth and mortality of oysters (*Crassostrea virginica*) on constructed intertidal reefs: effects of tidal height and substrate level", J. Exp.Mar. Biol and Ecol., 237: 157-187, 1999.
4. Coen, L.D. and Luckenbach, M.W., "Developing success criteria and goals for evaluating oyster reef restoration: ecological function or resource exploitation?", "Ecological Engineering", 15: 323-343, 2000.
5. Coen, L.D., Warberg, M.B., Bobo, Y., Richardson, D., Ringwood, A. H. and Scott, G.I., "Oyster beds- a baseline assessment of environmental and biological conditions in the Mary river, Beaufort country, South Carolina", Final report submitted to the town of Bluffton, 2004.
6. Cole, H.A., "Primary sex-phases in *Ostrea eduli*'s", J. Mar.Micro.Sci., 83: 317-356, 1942

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

7. Croft, H. G., "Tray cultivation of oysters", *The Fisherman*, 3(1): 12-14, 1998.
8. Dupuy., J.L., WINSOR., N.J. and SUTTON. C.E., "Manual for design and operation of an oyster seed hatchery for the American oyster *Crassostrea virginica*". VIMS, Gloucester Point, Virginia, Spl.Rep., 142: 1-104, 1977.
9. Durve, V.S. and BAL, D.V., "Preliminary observations on the growth of spat of the oyster *Crassostrea gryphoides*", *J. Mar. Biol.Ass.India.*, 4(2): 200-213, 1962.
10. Durve, V.S., "On the seasonal gonadal changes and spawning in the adult oyster *Crassostrea madrasensis*", *J.Mar.Biol.Ass. India.*, 7: 328-344, 1965.
11. Epifanio, C.E., "Growth in bivalve mollusks; nutritional effects of two or more species of algae in diets fed to the American oyster *Crassostrea virginica* and hard clam *Mercenaria mercenaria*", *Aquaculture*, 18: 1-2, 1979.
12. Ford, S.E. and Tripp, M.R., "Diseases and disease mechanisms". *J. Shellfish.Dis.*, 18: 52-68, 1993.
13. Ford, S.E. and Tripp, M., "Diseases and defence mechanisms. In: The eastern oyster *Crassostrea virginica*", A Maryland Sea Grant Book, College Park, Maryland, USA, PP 581-660, 1996.
14. Ford, S.E. and Haskin, H.H., "Management strategies for MSX(*Haplosporidium nelsoni*) disease in eastern oysters" *Amer.Fish.Soc. Spec.Publ.*, 18: 67-78, 1988.
15. Grohmann, G.S., Murphy, A.M., Christopher, P.J., Auty, E. and Greengerg, H.B., "Norwalk virus gastroenteritis in volunteers consuming depurated oysters". *Ajeback*, 59(2): 219-228, 1981.
16. Galtsoff, P.S., "The American oyster *Crassostrea virginica*". *U.S. Fish and Wildlife Serv. Fish.Bull.*, 64: 1-48, 1964.
17. Joroensen, C.B. and Goldberg, "Quantitative aspects of filter feeding in invertebrates", *Biol.Res.*, 30: 391-454, 1975.
18. Juliana, M.H., Roger, M. and Melissa, J.S., "Shell length at age relationships in James river, Virginia, oysters (*Crassostrea virginica*) collected four centuries apart". *J. Shellfish. Res.*, 27(5): 1109-1115, 2008.
19. Kohn, A.J., "Molluscs and man in tropics", *Phuket Marine Biological Centre Special Publication*, 17(1): 157-163, 1997.
20. Kripa, V., "Studies on the biology and experimental culture of the rock oyster *Saccostrea cucullata*," Ph.D. thesis, Cochin University of Science and Technology, Cochin, 1998.
21. Kripa, V. and Salih, K.Y.M., "Oyster resources of Ashtamudi Lake, southwest coast of India". *The Fourth Indian Fisheries Forum Proceedings*, 267-369, 1999.
22. Lafferty, K.D, Porter, J.W. and Ford S.E., "Are diseases increasing in the ocean?" *Ann. Rev.Ecol.Syst.*, 31-54, 2004.
23. Loosanoff, V.L. and Davis, H.C., "Repeated semiannual spawning of northern oysters". *Science*, 115: 675-676, 1942.
24. Lotze, H.K., Bergquist, D., Hale, J.A. and Baker, S.M., "Development of ecosystem indicators for the Suwanee river estuary". *Estuary. Coasts.*, 29: 353-360, 2011.
25. Morton, B.S., "The tidal rhythm of feeding and digestion in the Pacific oyster, *Crassostrea gigas*". *J. Exp. Mar.Biol. Ecol.*, 26: 135-151, 1977.
26. Narasimham, K.A., "Oysters. In: Molluscan Fisheries of India", Edt. K.A.Narasimham. Edn.1<sup>st</sup>, B.R.Publishing Corporation, 40-80, 2005.
27. Nayar, K.N. and S.mahadevan, "Oyster culture in Tuticorin". *Proc.Symp. Coastal Aquaculture. Mar.Biol.Ass.India.*, 2: 427-435,1983.
28. Nell, J., "Diseases of Sydney rock oysters". *Primefact 289*, NSW Department of Primary Industries, Port Stephens Fisheries Centre, Nelson Bay, NSW, pp 4, 2007.
29. Nelson, T.C., "Some contributions from the land in determining conditions of life in sea". *Ecol.Monogr.*, 17(3): 337-346, 1947.
30. Owen, G., "Feeding and digestion in bivalvia". *Adv.comp.Physiol.Biochem.*, 5: 1-125, 1974.
31. Paul, M.D., "Studies on the growth and breeding of certain sedentary organisms in the Madras harbor". *Proc.Indian. Acad.Sci.*, 33(B): 231-56, 1942.
32. Purchon, R.D., "The Biology of Mollusca". Pergamon Press. Oxford, 1968.
33. Purushan, K.S., Gopalan, U.K. and Rao, T.S.S., "On the setting of spat and growth of edible oyster *Crassostrea madrasensis* in Cochin backwaters". *Symp.Ser.Mar.Biol.Ass. India.*, 6: 444-450, 1983.
34. Rajapandian, M.E. and Rajan, C.T., "Biological aspects of oysters". *Bull.Cent.Mar.Fish.Res.Inst.*, 38: 30-39, 1989.
35. Rajapandian, M.E. and Rajan, C.T., "Studies on maturity stages and spawning periodicity of *Crassostrea madrasensis* at Tuticorin Bay". *Proc. Symp. Coastal Aquaculture.*, 2: 475-478, 1983.
36. Rao, K.V., "Observations on the probable effects on spawning, development and setting of the Indian back water oyster *Crassostrea madrasensis*". *Proc.Indian Acad.Sci.*, 33(B): 231-56,1951.
37. Rao, K.V. and K.nagappan Nayar," Rate of growth of spat and yearlings of the Indian backwater oyster *Crassostrea madrasensis*". *Indian J. Fish.*, 6: 213-260, 1956.
38. Rao, K.V., Sathyanarayana, K., Sivalingam. and Unnithan, "Observations on the setting of spat and growth of *Crassostrea madrasensis* in Vaigai estuary at Athankarai", *Proc.Symp.Coastal Aquaculture. Mar.Bio.Ass.India*, 2: 436-443, 1983.
39. Rande, W.M., "A stochastic model of the temporal aspects of breeding strategies oysters". *J. Theor. Biol.*, 40: 337-351, 1973.
40. Reuban, S.T., Appa Rao. and Manickam, "Culture experiments on the larvae of the edible oyster *Crassostrea madrasensis* in the Bheemunipatnam backwater". *Proc.Symp.Coastal Aquaculture. Mar. Biol.Ass. India.*, 2: 456-459, 1983.
41. Ronald, H.K. and Ronald, J.D., "The ecology of oyster reefs of the northern Gulf of Mexico: an open file report". *NWRC-open file rep.*, pp 89-102, 1989.
42. Ruwa, R.K., "Growth of *Saccostrea cucullata* at different levels in the intertidal zone". *Aquaculture*, 88: 303-312, 1990.
43. Thomiyama, R., "Fisheries of Japan: Abalone and oyster", *Marine Products Photo Association*, Tokyo, 4: 201-221. 1980.
44. Uyan, O. and Aral,O, "A study on the possibilities of obtaining larva from native flat oyster (*Ostrea edulis*) living in the Black sea and larval metamorphosis stage". *Turk. J. Zool.*, 24: 343-350, 2000.



ISSN(Online): 2319-8753  
ISSN (Print): 2347-6710

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

**Vol. 4, Issue 6, June 2015**

45. Van Dolah., Sanger, D.M. and Filipowicz, "A baseline assessment of environmental and biological conditions in the May river, Beaufort County, South Carolina". Final report submitted to the Town of Bluffton by South Carolina Department of Natural, United States Geological and the National Ocean Service, pp 243, 2004.
46. White, A.W, "Blooms of toxic algae worldwide: their effects on fish farming and shellfish resources". Conference 2: The impact to toxic algae on mariculture, AQUANOR 87, Trondheim, Norway, 9-14, 1987
47. Yavari, V, " Subtidal versus intertidal culture of *Crassostrea madrasensis*". J. Mar.Biol. Ass. India., 43(1&2): 102-109, 2001.
48. Yonge, C.M, "Oysters". Collins, London Publications, pp 209, 1960.