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SEASONAL CHANGES IN HYDROGRAPHIC FACTORS AND BREEDING IN TWO POPULATIONS OF *CRASSOSTREA TULIPA* (LAMARCK)

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Summary

The seasonal changes in breeding activity of two populations of *Crassostrea tulipa* (Lamarck) in Ghana, and some hydrographic factors of their brackishwater habitats were investigated between February 1988 and April 1989. Temperature and *p*H were relatively stable and their fluctuation patterns were similar in both habitats. Transparency and salinity fluctuations were less apparent in the lagoon, but a distinct seasonal pattern occurred in the estuary where high and low regimes corresponded with the dry and wet seasons, respectively. The variations in dissolved oxygen concentrations did not fit a well-defined seasonal pattern in both water bodies. The oysters bred continuously in the lagoon while the reproductive activity was seasonal in the estuary where the non-breeding season coincided with the period of low transparency and salinity. However, there was an apparent lack of direct relationship between individual hydrographic factors and the breeding of oysters in the lagoon.

Introduction

The West African mangrove oyster, *Crassostrea tulipa* (Lamarck, 1819) has a wide distribution extending from Senegal to Angola (Nicklés, 1950; Afinowi, 1975). The species is commonly found attached to the stilt roots of the red mangrove (*Rhizophora* spp.) fringing lagoons and estuaries; it also occurs on estuarine intertidal rocks (Eisawy, 1974; Okera, 1976; Edmunds, 1978).

The potential of this oyster as a cheap source of protein has been reported by many workers (Afinowi, 1975; Kamara & McNeil, 1976; Kamara, McNeil & Quayle, 1979; Ajana, 1980; Moses, 1983), yet its exploitation is so far limited to the harvesting of wild stocks by coastal villagers to supplement their protein supply. Yankson (1990) successfully reared the species from artificially-fertilized eggs through to settled spat in laboratory cultures as part of studies on ways of producing this oyster on a large scale. The few studies on its biology have been generally of a preliminary nature (e.g. Yankson, 1974; Afinowi, 1975; Ndomahina, 1976; Obodai, 1979) and do not provide adequate basis for its commercial exploitation.

This study examines the gonadal stages and spatfall of two brackishwater populations of *C. tulipa* in relation to the seasonal changes in some hydrographic factors of their respective habitats.

Experimental

The two water bodies, Benya (Elmina) lagoon and River Pra estuary (at Shama) sampled for the work are located between latitudes 5° and 5° 3' N and longitudes 1° and 2° W (Fig. 1). Benya lagoon is 'open' and maintains contact with the sea throughout the year. It has a surface area of about 192 ha and is fringed by red and white mangroves. The River Pra estuary is located about 45 km west of the Benya lagoon. It is approximately 100 m wide at the point of entry into the sea, and its banks are fringed by mangroves up to about 10 km inland. In both water bodies, the stilt roots of the red mangrove form the main substratum for the oysters.

Hydrographic factors

Five hydrographic factors, namely transparency, temperature, salinity, dissolved oxygen and *p*H of

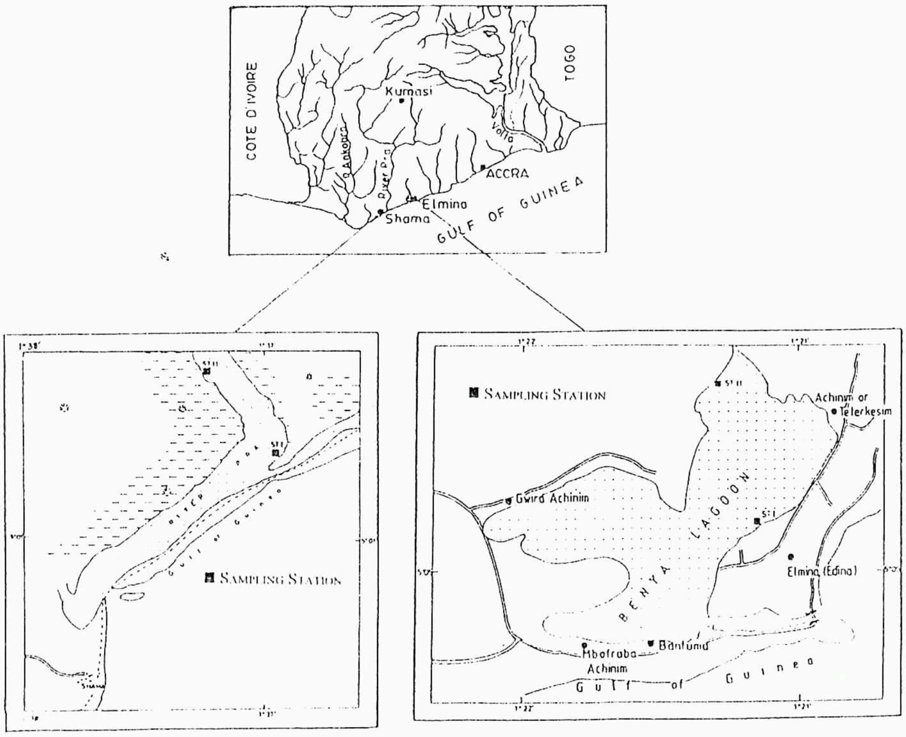

Fig. 1. Map of southern Ghana showing the positions of the two water bodies: Pra estuary at Shama, (showing the two sampling stations) and Benya lagoon at Elmina (two sampling stations).

the surface waters of the two water bodies were monitored monthly at two stations (Fig. 1) from February 1988 to April 1989. Two readings of each factor were taken at low tide at both stations and as there were no differences in their averages, the data were pooled for each water body. Transparency was measured with a Secchi disc (15 cm diameter), surface water temperature with a hand-held mercury-in-glass thermometer, and salinity with a refractometer (AO TC) in the field. Dissolved oxygen concentration was determined by Winkler's titration method, and a *p*H-meter (Kent EIL, 7020) was used in measuring the *p*H of water samples in the laboratory within 2 h of collection.

Gonadal stages

Monthly samples of 30-60 oysters, collected b hand picking from each population, were examine for seasonal changes in gonadal condition. Th oysters were sexed and their gonads assigned arbi trary stages of development by means of macrc scopic examination of the viscera and the gonad smears.

Spatfall

Dry coconut shell cultches found to be attractiv to oyster spat in an earlier study (Obodai, unpul lished data) were used as collectors to investigat the spatfall patterns in the two populations. A cultc consisted of five coconut shells strung on a nylc rope and separated by knots 5 cm apart. Eight such cultches were suspended in the vicinity of wild oyster colonies in each water body. The number of spat that settled on the collectors were recorded monthly after which the spat were removed and the collectors re-set.

Results

Fluctuations in hydrographic factors

The fluctuations in the hydrographic factors of the two brackishwater bodies are shown in Fig. 2.

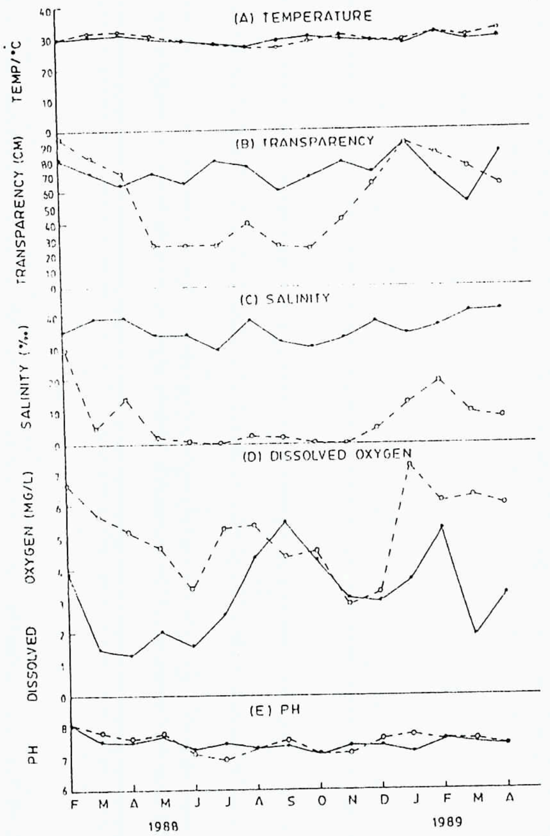

Fig. 2. Seasonal changes in some hydrographic factors in Benya lagoon (solid line) and Pra estuary (broken line) between February 1988 and April 1989.

Temperature remained fairly stable and its variation was similar in the two habitats. It ranged from 27.0 to 31.5 °Cin the Benya lagoon averaging at 29.8 °C, and 27.0 - 32.0 °C in the Pra estuary with an average of 29.8 °C. Transparency was generally higher in the Benya lagoon than in the Pra estuary except in February and March 1989. A narrower range was recorded in the Benya lagoon (52.5 - 91.0 cm) than in the Pra estuary (24.0 to 96.4 cm). The respective averages were 72.7 and 55.8 cm.

Salinity was relatively stable in the Benya lagoon ranging from 30.0 to 40.0 per cent but it fluctuated considerably in the Pra estuary from 0 to 29.0 per cent. The respective average salinities were 34.7 and 7.2 per cent. In the Benya lagoon, high salinities (>35 per cent) were recorded in February-April, August and December 1988. In the Pra estuary, salinity remained below 10 per cent for a greater part of the study period i.e. in March, May - December 1988, and April 1989.

Dissolved oxygen content of the Benya lagoon ranged between 1.29 and 5.47 mg l^{-1} with an average of 3.23 mg l^{-1} while in the Pra estuary the range was from 2.86 to 7.33 mg l^{-1} with an average of 5.16 mg l^{-1}.

The *p*H of the two water bodies showed little fluctuation. In the Benya lagoon, it ranged from 7.17 to 8.05 averaging at 7.45 while in the Pra estuary the range was from 6.95 to 8.10 with an average of 7.50.

Seasonal changes in gonadal condition of the oysters

The gonads of adult oysters were broadly categorized into three developmental stages and their frequencies of occurrence in monthly samples are presented in Fig. 3.

(i) *Developing stage.* The gonad covered less than 50 per cent of the viscera with the umbonal end being transparent. Smears of the gonadal material revealed immature germ cells clumped together. It is seen from Fig. 3 that oysters with developing gonads occurred in both water bodies throughout the study period except August in the Pra estuary. In the Benya lagoon, the frequency ranged from 2 to 63 per cent while in the Pra estuary the range was 0 to 90 per cent.

(ii) *Ripe/Spawning stage.* The gonad covered

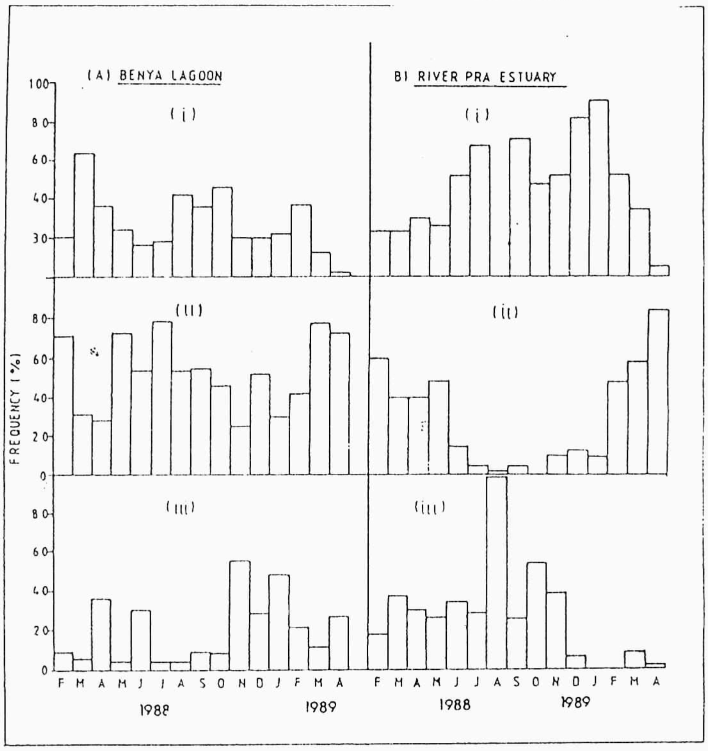

Fig. 3. Seasonal changes in gonadal conditions of oysters from Benya lagoon (A) and Pra estuary (B) between February 1988 and April 1989. i. Developing; ii. Ripe/Spawning; iii. Spent gonad.

more than 50 per cent of the viscera or completely enveloped it. Ripe ovaries were creamy in colour while the testes were whitish. Ovarian smears revealed a preponderance of pear-shaped ova while active spermatozoa dominated testicular smears. The gonoducts of spawning oysters were enlarged due to pressure exerted by the sexual products. In the Benya lagoon, individuals in this stage comprised >25 per cent of monthly samples throughout the study period and exhibited a polymodal fluctuation which peaked in February, May, July and December 1988 and March to April 1989. In the Pra estuary, the ripe/spawning individuals attained monthly frequency compositions of >25 per cent only during the dry season (February to May 1988 and February to April 1989). The frequencies of such oysters ranged from 25 to 78 per cent in the Benya lagoon and 0 to 83 per cent in the Pra estuary.

(iii) *Spent stage.* The gonads of oysters in this condition were watery and transparent with scanty ova or spermatozoa. The flesh was generally very soft. Spent oysters occurred in both populations throughout the study period except January and February 1989 in the Pra estuary. Their frequencies ranged from 4 to 55 per cent in the Benya lagoon and 0 to 98 per cent in the Pra estuary.

Spatfall

Fig. 4 indicates the seasonal changes in the number of oyster spat settling on the coconut shell cultches. There was settlement in the Benya lagoon throughout the study period with distinct peaks in May and September 1988 and January 1989 when 0.9, 1.5 and 0.4 spat per 10 cm^2 respectively, were recorded. In the Pra estuary, spat settlement occurred from February to June 1988 with a peak of 2.2 spat per 10 cm^2 in May. This was followed by a

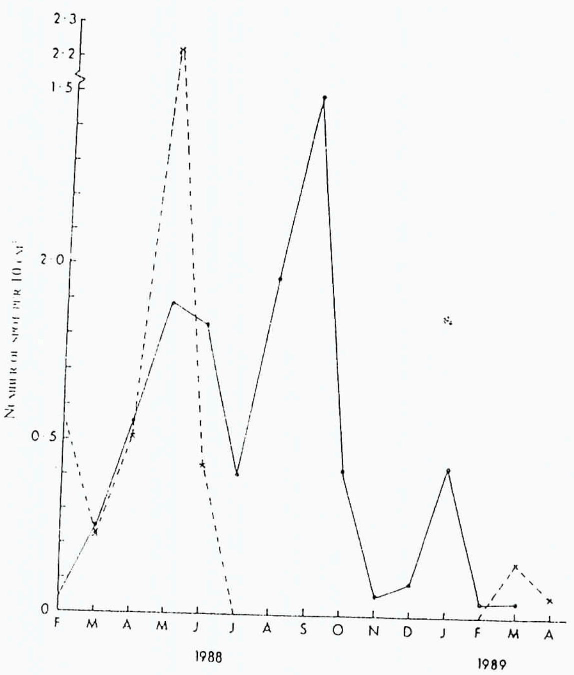

Fig. 4. Seasonal changes in the number of oyster spat settling on coconut shell cultches in Benya lagoon (solid) and Pra estuary (broken line) between February, 1988 and April.

period of 8 months without spatfall until March 1988.

Discussion

The results show a lack of seasonal thermal fluctuation in the two water bodies. This is not uncommon in such tropical habitats. For example, Afinowi (1975) reported that temperature is a stable hydrographic factor in West Africa. The narrow *p*H ranges recorded in the Benya Lagoon and Pra estuary fall within the ranges reported by Calabrese (1972) and Zhong-Quing (1982) for successful breeding of oysters.

Seasonal fluctuations in transparency and salinity were less pronounced in the lagoon than in the estuary. The lagoon was generally less turbid than the estuary except during the height of the dry season. The low transparency regime in the estuary coincided with the rainy season when land run-off most probably brought more silt and other suspended particulate matter into the system. Freshwater inflow from the moderately large Pra river was perhaps responsible for the generally low salinity regime in the estuary unlike the Benya lagoon which has very little freshwater inflow. In the latter, the occasional salinity values above 35 per cent could be due to inflows from the nearby saltpans and/or high evaporation rates. It should be noted that only low tide salinity values were recorded in this study, and that the estuary normally exhibits semi-diurnal fluctuations in salinity from almost freshwater at low tide to brackishwater at high tide (unpublished observations). However, inundation by large volumes of freshwater during and immediately after the rainy season (from May to November 1988) lowered the salinity to<1 per cent, even at high tide.

Solubility of oxygen in water decreases with increases in salinity and temperature (Green, 1968; Barnes, 1980). Since the two habitats showed similar temperature regimes, the lower levels of dissolved oxygen content in the Benya lagoon compared with the Pra estuary may be attributed partly to the higher salinity of the former. Furthermore, water movement during tidal changes can influence dissolved oxygen levels more in a bigger area (Pra estuary) than in a smaller area (Benya lagoon).

The high monthly representation of ripe/spawning oysters in the Benya lagoon may explain the uninterrupted spatfall in this brackishwater habitat. This suggests a continuous breeding activity in the lagoonal population in contrast to the seasonal pattern in the estuarine population. The period of low breeding activity in the estuary coincided with that of low salinity and low transparency and *vice versa*. These factors may be the most important in determining the breeding of oysters in this habitat as temperature, dissolved oxygen and *p*H levels were similar to those in the Benya lagoon. The presence of silt and other suspended matter during this period (low transparency) could have impaired the feeding mechanisms of the oysters. Furthermore, many bivalve species are known to close their shell valves in low salinity environments (Holyeaux, Gillies & Jeuniaux, 1976; Shumway, 1977; Djangmah, Shumway & Davenport, 1979; Widdows, 1985). The latter author demonstrated the cessation of feeding in *Mytilus edulis* exposed to low salinity regimes. It is, therefore, conceivable that the energy that could have been utilized by the estuarine oysters during this period for gonadal ripening and spawning was probably channelled into other physiological activities like maintenance of basic metabolism and osmo-regulation.

Among the hydrographic factors that were investigated, transparency and salinity tended to have a more direct influence on the breeding activity of the estuarine oysters as indicated above. The lack of such a direct influence of these factors on the reproductive activity of Benya lagoon oysters is similar to Yankson's (1977) observation on the cockle *Anadara senilis* occurring in this lagoon. This further shows that hydrographic factors may interact in an intricate fashion in directing the biological processes in this tropical lagoon. It is also possible that in this open lagoon, the magnitude of seasonal oscillations in the ecological factors was not significant as to impose a seasonal pattern on the gonadal development. However, the same cannot be said for spatfall which fluctuated widely in spite of the apparent high levels of gonadal development throughout the study period. The conditions for spawning, successful larval development and settlement would, therefore, appear to differ from those for gonadal development.

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References

Afinowi, M. A. (1975) The biology of *Anadara senilis* and *Gryphaea (Crassostrea) gasar* in West African waters. *FAO/CIFA Symposium on Aquaculture in Africa,* pp. 386-406. Rome: FAO.

Ajana, A. M. (1980) Fishery of the mangrove oyster *Crassostrea gasar,* (Adanson, 1757) in the Lagos area. Nigeria. *Aquaculture* **21**, 129-137.

Barnes, R. S. K. (1980) *Coastal lagoons*, 106 pp. Cambridge: University Press.

Calabrese, A. (1972) How some pollutant affect embryos and larvae of American oyster and hard-shel clam. *Mar. Fish. Rev.* **34**, 66-77.

Djangmah, J. S., Shumway, S. E. & Davenport, J. (1979) Effects of fluctuating salinity on the behaviour of the West African blood clam *Anadara senilis* and on the osmotic pressure and ionic concentration of the haemolymph. *Mar. Biol.* **50**, 208-213.

Edmunds, J. (1978) *Sea shells and other molluscs found on West African coast and estuaries.* 146 pp. Accra Ghana Universities Press.

Eisawy, A. M. (1974) Spawning and larval development in the Red Sea oyster, *Crassostrea forskali* Chemmitz *Bull. Inst. Oceanogr. Fish.* **4**, 203-220.

Green, J. (1968) *The Biology of Estuarine Animals*, 40 pp. London: Sidgwick and Jackson.

Holyeaux, J., Gilles, R. & Jeuniaux, C. (1976) Osmotic regulation in molluscs of the intertidal zone. *Comp Biochem. Physiol.* **53**A, 361-365.

Kamara, A. B. & McNeil, K. B. (1976) Preliminary oyster culture experiments in Sierra Leone. *Fisheries Division of Ministry of Agriculture and Natural Resources Freetown. Occasional Paper* No. **1**, 50 pp.

Kamara, A. B., McNeil, K. B. & Quayle, D. B. (1979 Tropical mangorve oyster culture: Problems and prospects. In *Advances in aquculture. FAO Technical Conference on Aquaculture, Kyoto, Japan, 1976* (ed. T. V. R Pillay and W.A. Dill) pp. 344 - 348. Rome, FAO.

Moses, B. S. (1983) *Introduction to tropical fisheries* 117 pp. Ibadan: Ibadan University Press.

Ndomahina, E. T. (1976) Preliminary studies on the reproductive cycle of the mangrove oyster, *Crassostre tulipa.* In *Bulletin of the Institute of Marine Biology an Oceanography* (ed. W. Okera), pp. 31 - 34. Freetown Fourah Bay College, University of Sierra Leone.

Ncklès, M. (1950) Mollusques testaces marin de la côt accidentale d'Afrique. *Manuels Ouest-Africains*. **2**: 1-269.

OBODAI, E. A. (1979) *The growth of oyster (Ostrea tulipa) spat in Elmina Lagoon*, 27 pp. (BSc Hons Dissertation). Cape Coast: University of Cape Coast.

OKERA, W. (1976) The cockle fishery in Sierra Leone. In *Bulletin of the Institute of Marine Biology and Oceanography* (ed. W. Okera), pp. 24 -25, Freetown: Fourah Bay College, University of Sierra Leone.

SHUMWAY, S. E. (1977) Effect of salinity fluctuation on the osmotic pressure and Na^{1+}, Ca^{2+} and Mg^{2+} ion concentrations in the haemolymph of bivalve molluscs. *Mar. Biol.* **41**, 153-177.

WIDDOWS, J. (1985) The effects of fluctuating and abrupt changes in salinity on the performance of *Mytilus edulis*. In *Biology of Polar Regions and effects of stress on marine organisms* (ed. J. S. Gray and M. E. Christiansen), pp. 555-566. Brisbane, New York: John Wiley and Sons.

YANKSON, S. C. K. (1974) *Preliminary study of some aspects of the biology of the mangrove oyster (*Ostrea tulipa*?) in the Elmina Lagoon*, 30 pp. (BSc Hons Dissertation.) Cape Coast: University of Cape Coast.

YANKSON, K. (1977) *Some aspects of the biology of the West African bloody cockle,* Anadara senilis *(L.) occurring in some coastal waters in Ghana*, 135 pp. (M Sc Thesis.) Cape Coast: University of Cape Coast.

YANKSON, K. (1990) Preliminary studies on the rearing of West African mangrove oyster, *Crassostrea tulipa*, in the laboratory. *Discovery and Innovation* **2**, 45-51.

ZHONG,-QUING, N. (1982) Bivalve culture in China. In *Bivalve culture in Asia and the Pacific.* (ed. F. B. Davy and M. Graham), pp. 21-28. Ottawa, Ontario: IDRC-200e.

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