Journal of the Marine Biological Association of the United Kingdom, 2019, 99(2), 385–392.
doi:10.1017/S0025315418000309

Biometrics, condition index and meat yield of edible rock oyster, *Saccostrea cucullata* (Born, 1778)

YAMBEM TENJING SINGH*

Department of Biosciences, Mangalore University, Mangalagangothri 574 199, India, *Present address: Conservation of Coastal and Marine Resources Division, National Centre for Sustainable Coastal Management, Chennai 600 025, India

Rock oysters of the genus Saccostrea *are the dominating group of filter-feeding communities on rocky beaches worldwide. The edible rock oyster (*Saccostrea cucullata*) is used as food and fish bait along the Indian coast. Morphometric analyses of* S. cucullata *from Baindur, Karnataka (India) were performed from June 2010 to May 2011, aiming to establish relationships between length and weight (total weight, shell weight, meat wet weight and meat dry weight). Morphometric relationships between length (L)-breadth (B) and length (L)-width (W) were* $B = 6.4952 + 0.4619\ L$ *and* $W = 3.1806 + 0.3276L$*, respectively. The equations of the length (L)-total weight (TW), length (L)-shell weight (SW), length (L)-meat wet weight (WW) and length (L)-meat dry weight (DW) were* $TW = 0.001227L^{2.3973}$, $SW = 0.001165L^{2.3164}$, $WW = 0.000037L^{2.1327}$ *and* $DW = 0.000030L^{2.3289}$*, respectively. The allometric growth pattern revealed changes in shell shape and weight variation throughout ontogeny in rocky habitats. The condition index and meat yield of* S. cucullata *exhibited seasonality, with higher values recorded during the periods post-monsoon and pre-monsoon.*

Keywords: Shell morphometrics, weight-length relationship, condition index, meat yield, Baindur, India

Submitted 5 September 2017; accepted 27 March 2018; first published online 7 May 2018

INTRODUCTION

Edible rock oyster, *Saccostrea cucullata* (Born, 1778) is a primary consumer that provides significant biomass and abundance to the marine ecosystem. This oyster is widely distributed in the Indo-Pacific and subtropics. Studies on a variety of *Saccostrea* species have illustrated that many aspects of shell morphology, most notably external shell sculpture and shell dimension, vary with environment (Thomson, 1954; Stenzel, 1971; Tack *et al.*, 1992). *Saccostrea cucullata* is an edible rock oyster that inhabits brackish and marine environments where it cements onto rocks, other hard substrates (beacons, jetties, ship hulls etc.) and mangroves. Lewis (1964) and Hartnoll (1976) stated that this species is abundant in the upper eulittoral zone where they grow to a maximum size up to 65 mm in shell length (van Someren & Whitehead, 1961), but experience stunting in crowded conditions.

This oyster is widely distributed around the coast of India, occurring in both near-shore brackish and offshore environments on substrates that vary from rocks to mangroves (Maran & Ayyakkannu, 2002; Stanley, 2002). Morris (1985) stated that in the mangrove area of Hong Kong this species is thin shelled and stunted, but develops other morphological features when placed in an exposed area. In spite of the diverse habitats, the genus *Saccostrea* shows highly variable shell morphology. Most species have been focused to be a single species. However, some researchers have disagreed on whether to call this species *S. cucullata* (Amornjaruchit, 1988; Nateewathana, 1995; Sanpanich, 1998) or *S. commercialis* (Brohmanonda *et al.*, 1988; Tookwina, 1991). Two other species, *S. mordax* (Gould, 1850) and *S. echinata* (Quoy & Gaimard, 1835) have also been included in species lists for the Gulf of Thailand (Nielsen, 1976) and offshore islands in the Andaman Sea (Bussarawit, 1995), respectively. The identification of *S. cucullata* is problematic as a number of authors considered *S. mordax* and *S. echinata* to be synonyms (Thomson, 1954; Morton & Morton, 1983).

Amin *et al.* (2008) studied the allometry and growth rate of the oyster, *Crassostrea madrasensis*, in the Moheskhali Channel (south-eastern coast of Bangladesh). The allometric relationships for the combination of shell weight, total weight, dry meat weight, wet meat weight, height and length were computed in the oyster, *Crassostrea virginica*, from subtidal and intertidal waters of South Carolina (Dame, 1972). Joseph (1979) carried out biometric studies of *C. madrasensis* inhabiting Mulki estuary (Karnataka). Nagi *et al.* (2011) analysed the multi-dimensional relationship in *Crassostrea madrasensis* and *C. gryphoides* in the mangrove ecosystem of the Mandovi estuary. Kripa & Salih (1999) studied the shell dimension and length-weight relationships of *Saccostrea cucullata* from Ashtamudi lake along the south-west coast of India. Biometric relationships of the black winged pearl oyster, *Pteria penguin*, were reported by Libini *et al.* (2011) from the Andaman and Nicobar Islands. Seasonal variation in biochemical composition of *S. cucullata* from the Indian Sundarbans was studied by Mitra *et al.*

Corresponding author:
Y.T. Singh
Email: yambemtenjing@gmail.com

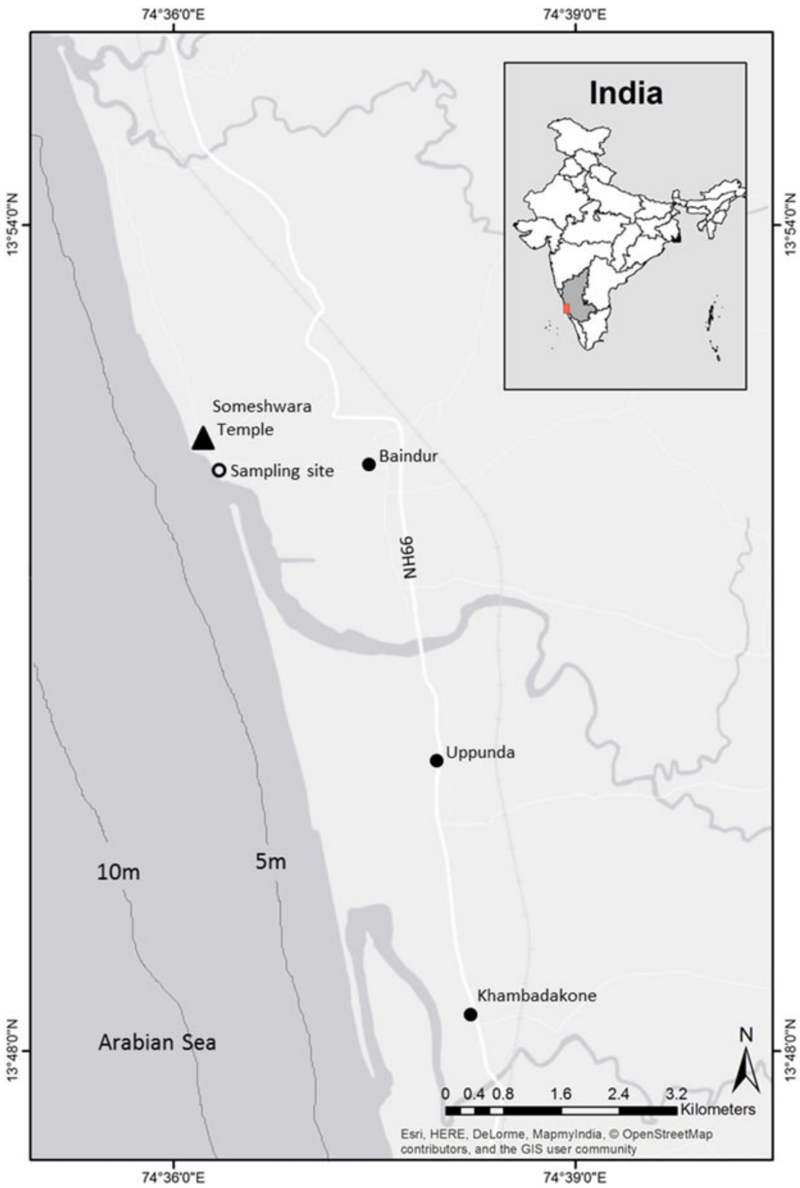

Fig. 1. Location of sampling site in the coastal area of Karnataka.

(2008). Evaluation of the biometric characteristics and relationships in oyster provides better understanding of the relative growth of their various body parts (Chatterji *et al.*, 1985). Studies on morphometrics, condition index and meat yield of rock oyster are scarce in India. Therefore, the present study aimed to study the biometric relationships, relative growth, condition index and meat yield of *S. cucullata* from Karnataka coast, south-west coast of India.

MATERIALS AND METHODS

Characteristics of study area

Karnataka is a state located in the southern part of India. It consists of three coastal districts, namely Dakshina Kannada, Udupi and Uttara Kannada. It is increasingly subjected to urban development (Tenjing, 2013). The south-west coast of India is characterized by three seasons, pre-monsoon (February–May), south-west monsoon (June–September) and post-monsoon (October–January). The present sampling site is located in an unpolluted area in the rocky beach of Baindur, near to the Someshwara Temple (Figure 1).

Sample collection and analysis

Saccostrea cucullata oysters were collected from rocky intertidal zones of Baindur (13°52′N 74°36′E) from June 2010 to May 2011. The colonies of this oyster grow on hard rock and are very difficult to remove. Therefore, oysters were collected with the help of a chisel and hammer, then cleaned with tap water and blotted. A total of 2328 oysters ranging in size from 4.7 to 55.2 mm were analysed for shell morphometrics, weight-length relationships, condition index and percentage of edibility. Total weight of the oyster was determined to the nearest 0.001 g using electronic scales. Shell dimensions were measured using a Vernier calliper. The meat was removed from the shells with the help of a scalpel, blotted to remove excess moisture, weighed and subsequently dried to a constant temperature in an oven at 60 °C for 48 h. The weight (total weight, shell weight, wet meat weight and dry meat weight) was examined to establish relationship with length.

Condition index (CI)

After the dry weights were measured to the nearest 0.001 g, the CI was calculated following Helen (1997):

$$CI = \frac{\text{Meat dry weight (g)}}{\text{Shell dry weight (g)}} \times 100$$

Edible portion or meat yield

The edible portion or percentage of edible biomass or meat yield in *S. cucullata* was determined by calculating the percentage ratio of the wet meat weight to the individual whole weight (Hickman & Illingworth, 1980):

$$PE = \frac{\text{Meat wet weight}}{\text{Oyster total weight}} \times 100$$

Statistical analysis

Estimation of the morphometric relationships between the shell dimensions (length, breadth and width) was performed using the linear equation $Y = a + bX$, where a, intercept and b, slope are constants (Pauly, 1983). The relationships between length and weight were established by the equation: $W = aL^b$. This equation can be expressed in its linearized form: Log W = Log a + b Log L, where W is the weight (g), L is the length (mm), a the intercept (initial growth coefficient) and b the slope (relative growth rates of the variables). The degree of association between variables was calculated by the correlation coefficient (r).

When the slope b is equal to 1, relationships between linear variables (measurements) are isometric. In case of relationships between linear (measurements) and ponderal (weightings) variables, the slope (b) being equal to 3 indicates isometry. For weight-length relationships, a t-test (H_o, $b = 3$) was performed with a confidence level of 95% to confirm if the values of b obtained in the linear regressions were significantly different from the isometric value ($b = 3$), expressed by the equation (Sokal & Rohlf, 1987): $t_s = (b-3)/S_b$, where t_s is t-test value, b is slope and S_b is the standard error of the slope (b). Similarly, for length-breadth/width relationship, a t-test (H_o, $b = 1$) was performed with a confidence level of 95%. Statistical significance of b values and their inclusion in the isometric range indicates when b is equal to 3 (= 1 for length-breadth/width), negative allometric when the b is lower than 3 and positive allometric when the b is greater than 3. The condition indices recorded from three seasons (pre-monsoon, monsoon and post-monsoon) were compared using ANOVA, and a pairwise multiple comparison test, i.e. Student-Newman-Keuls (S-N-K), was conducted after a significant ($P < 0.05$) ANOVA result was obtained. Spearman's rank correlation coefficients were calculated to examine relationships between the measured parameters using a significance level of $P < 0.05$.

RESULTS

Specimen size and weight

Data specimen size and weight were pooled and expressed on an average basis (Table 1). The length of specimens ranged between 4.7–55.2 (28.1 ± 8.6) mm, while breadth and width were in the ranges of 3.6–48.8 (19.5 ± 6.5) mm and 2.2–34.2 (12.4 ± 5.1) mm, respectively. The total weight of the individuals ranged between 0.075–25.350 (4.4 ± 3.5) g, and the wet meat weight ranged between 0.003–2.237 (0.4 ± 0.7) g. The shell weight and dry meat weight varied from 0.045–17.361 (3.3 ± 2.5) mm and 0.001–0.487 (0.1 ± 0.1) mm respectively.

Shell morphometric relationships

The relationships between length (L)-breadth (B) and length (L)-width (W) were $B = 6.4952 + 0.4619\ L$ and $W = 3.1806 + 0.3276\ L$ respectively (Figure 2). The correlation coefficients (r) of $L-B$ and $L-W$ were 0.6151 and 0.5577, respectively. Length-breadth and length-width displayed negative allometries as shown by the b values which were significantly less than unity ($P < 0.001$; Student's t-test) (Table 2), i.e. shell length increased relatively faster than both breadth and width as reflected by the significant $b < 1$ values.

Weight-length relationships

The relationships between the length (L)-total weight (TW), length (L)-shell weight (SW), length (L)-meat wet weight (WW) and length (L)-meat dry weight (DW) were $TW = 0.001227L^{2.3973}$, $SW = 0.001165L^{2.3164}$, $WW = 0.000037L^{2.1327}$ and $DW = 0.000030L^{2.3289}$, respectively (Figure 2).

Condition index (CI)

Variations in the CI of *S. cucullata* during the study period are shown in Figure 3. In general, the CI showed evidence of seasonality with relatively higher values in December (post

Table 1. Size and weight ranges of *Saccostrea cucullata* analysed during the study period.

	Length (mm)	Breadth (mm)	Width (mm)	Total weight (g)	Shell weight (g)	Meat wet weight (g)	Meat dry weight (g)
Mean	28.11	19.48	12.39	4.505	3.299	0.435	0.094
SD	8.59	6.45	5.05	3.45	2.54	0.67	0.080
Min.	4.7	3.6	2.2	0.075	0.045	0.003	0.001
Max.	55.2	48.8	34.2	25.350	17.361	1.237	0.487

https://doi.org/10.1017/S0025315418000309 Published online by Cambridge University Press

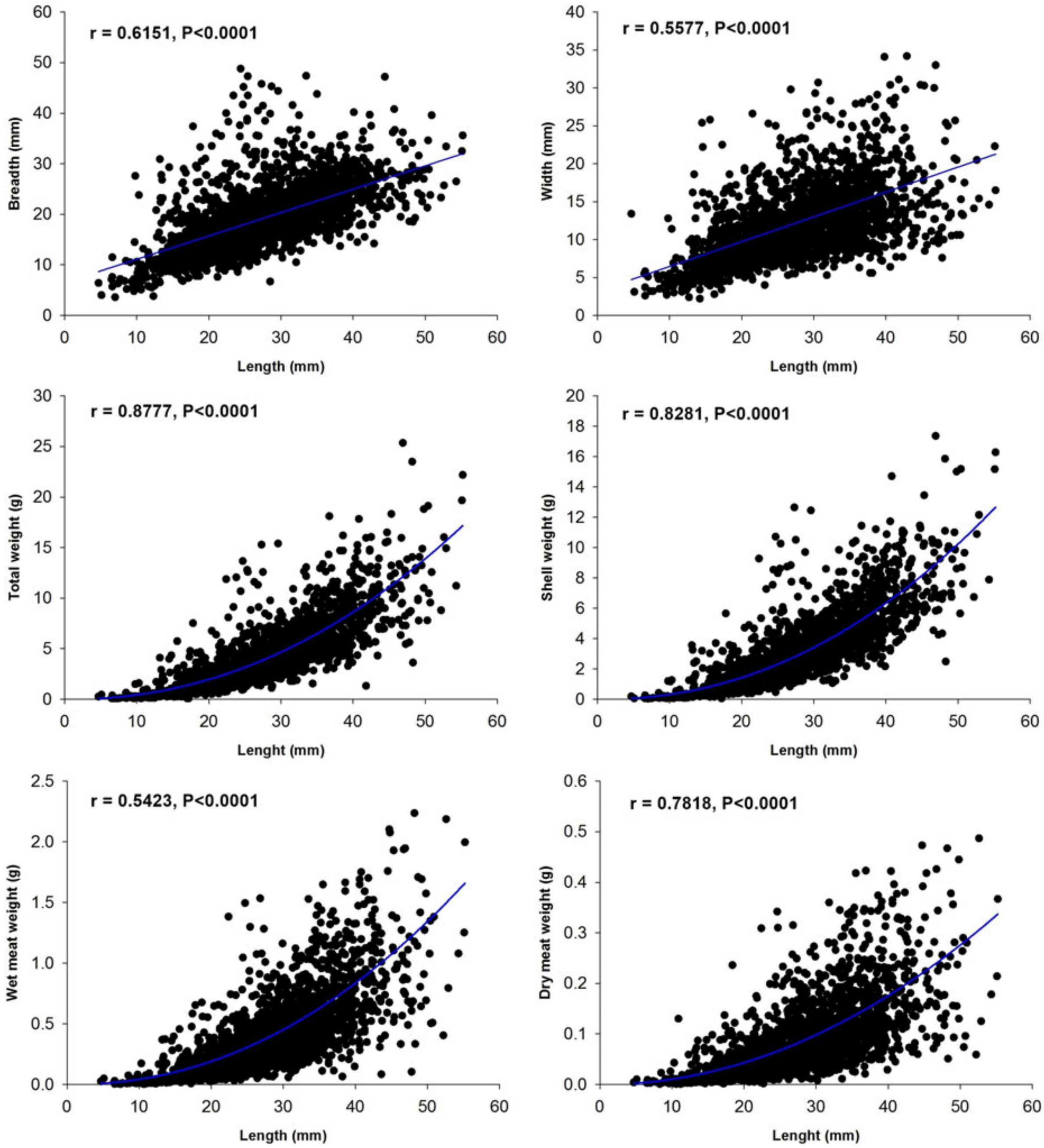

Fig. 2. Bivariate scatter diagram of length-breadth, length-width, length-total weight, length-shell weight, length-meat wet weight and length-meat dry weight relationships.

monsoon) and April (pre-monsoon). The lowest mean CI (2.2) occurred in September and the highest mean CI (4.1) in December followed by January (3.9). The ranges of mean CI values were 2.9 (September)–3.2 (July) in monsoon, 2.5 (October)–4.1 (December) in post-monsoon and 2.9 (March)–3.8 (April) in pre-monsoon. The mean CI values of rock oyster were 2.5 in monsoon, 3.4 in post-monsoon and 3.2 in pre-monsoon (Figure 3).

Table 2. Morphometric relationships and relative growth in *Saccostrea cucullata* from Baindur (India).

Relationship	*b*	*F*-value	*P*-value	Relative growth
L *vs.* B	0.4619	1415.482	<0.0001	−ve allometry
L *vs.* W	0.3276	1049.979	<0.0001	−ve allometry
LogL *vs.* LogTW	2.3973	7803.038	<0.0001	−ve allometry
LogL *vs.* LogSW	2.3164	5076.795	<0.0001	−ve allometry
LogL *vs.* LogWW	2.1327	969.016	<0.0001	−ve allometry
LogL *vs.* LogDW	2.3289	3657.163	<0.0001	−ve allometry

Edible proportion or meat yield

Variation in the meat yield of oysters is shown in Figure 4. Meat yield displayed similar patterns as CI (Figure 3), with distinct peaks in December and April. Generally, meat yield of rock oysters was low in September (7.9%: monsoon) and October (7.2%: post-monsoon) and March (8.6%:

https://doi.org/10.1017/S0025315418000309 Published online by Cambridge University Press

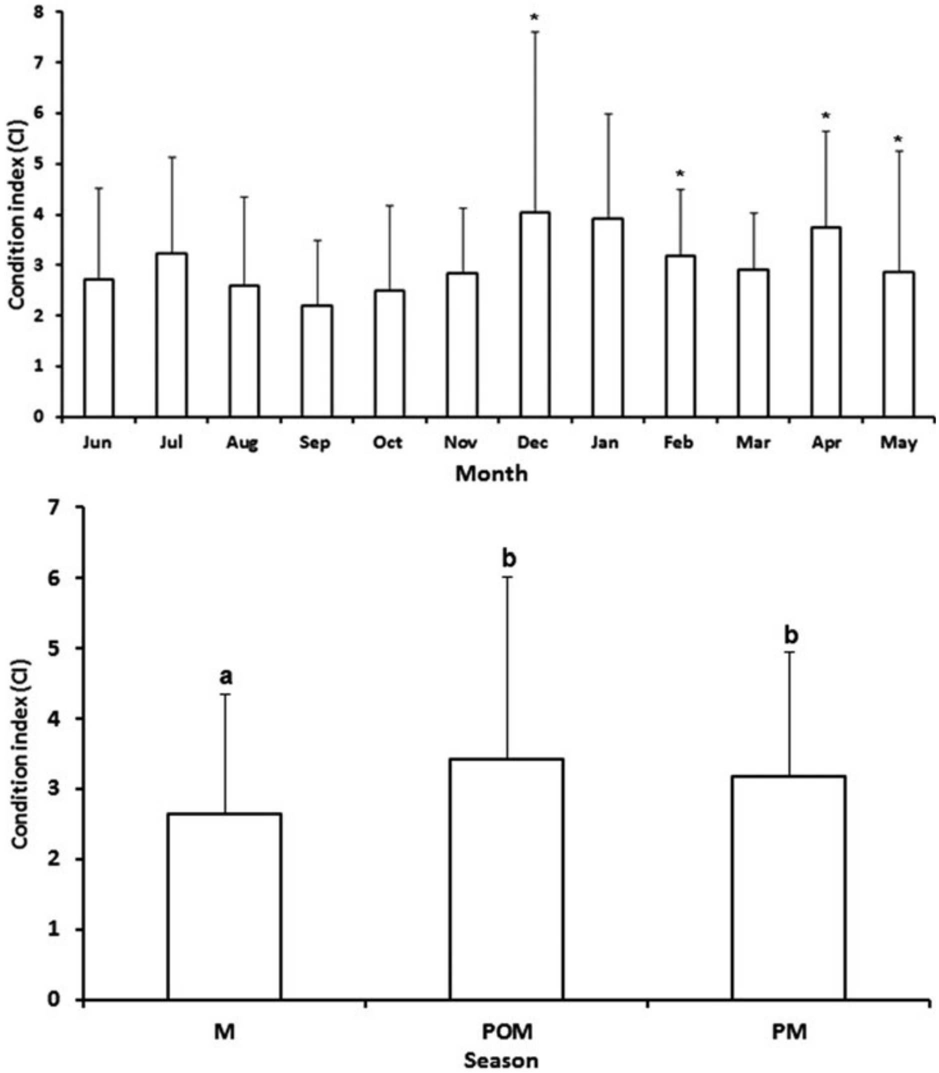

Fig. 3. Monthly variation (upper figure) and seasonal variation (lower figure) in mean condition index of *Saccostrea cucullata* (M = monsoon, POM = post-monsoon, PM = pre-monsoon). Vertical bars represent the standard deviation. Means with different superscript letters are significantly different ($P < 0.05$).

monsoon). Highest values were recorded in July (10.1%: monsoon), December (12.0%: post-monsoon) and January (10.7%: pre-monsoon).

DISCUSSION

Oysters are known to show large variations in their meat quality depending on their physiological conditions and associated environmental factors (Durve, 1964). Allometric relationships in a number of bivalve species have been reported by earlier workers. Hamai (1934, 1935a, b) showed that physical nature of the substratum, salinity, temperature and other chemical characteristics of the water influence the dimensional relationships. Variation in deformed/proper size of shell reported during the study period conforms with the findings of Hamai (1934, 1935a, b).

Dame (1972) and Ansari *et al.* (1978) stated that height of shell is considered to be effective in predicting biomass parameters. Oysters were irregular in shape and they lived in an overcrowded colonial pattern attached to the hard substratum (rock) in the present study. They are subjected to a process called xenomorphism in which their shape is determined by contours of the substrate on which they grow (Quayle & Newkirk, 1989). The infestation by other specimens on oyster along the colony compels an alteration of its growing pattern to accommodate itself within the colony. Dimensional relationships are changed by the environmental conditions under which the oyster grows (Seed, 1968, 1973; Hickman, 1979; Jones *et al.*, 1979). Overcrowding results in the assumption of a variety of crooked forms in India (Rao & Nayar, 1956). This was observed in *S. cucullata* collected from Baindur during the present study.

Regional differences in oyster allometry have been reported by Dame (1972) and Soong *et al.* (1992). Significant inter-site variability in the allometric relationships was reported in *S. cucullata* by Helen (1997). The general pattern of growth at the study site is not for individuals to become proportionately longer and flatter and such changes in shell form do not have important adaptive significance. Increases in shell length and width relative to shell height could effectively enhance the physical stability of animals on the rocks (Helen, 1997).

Helen (1997) found that population density, growth rate and degree of exposure to wave action influenced differential

https://doi.org/10.1017/S0025315418000309 Published online by Cambridge University Press

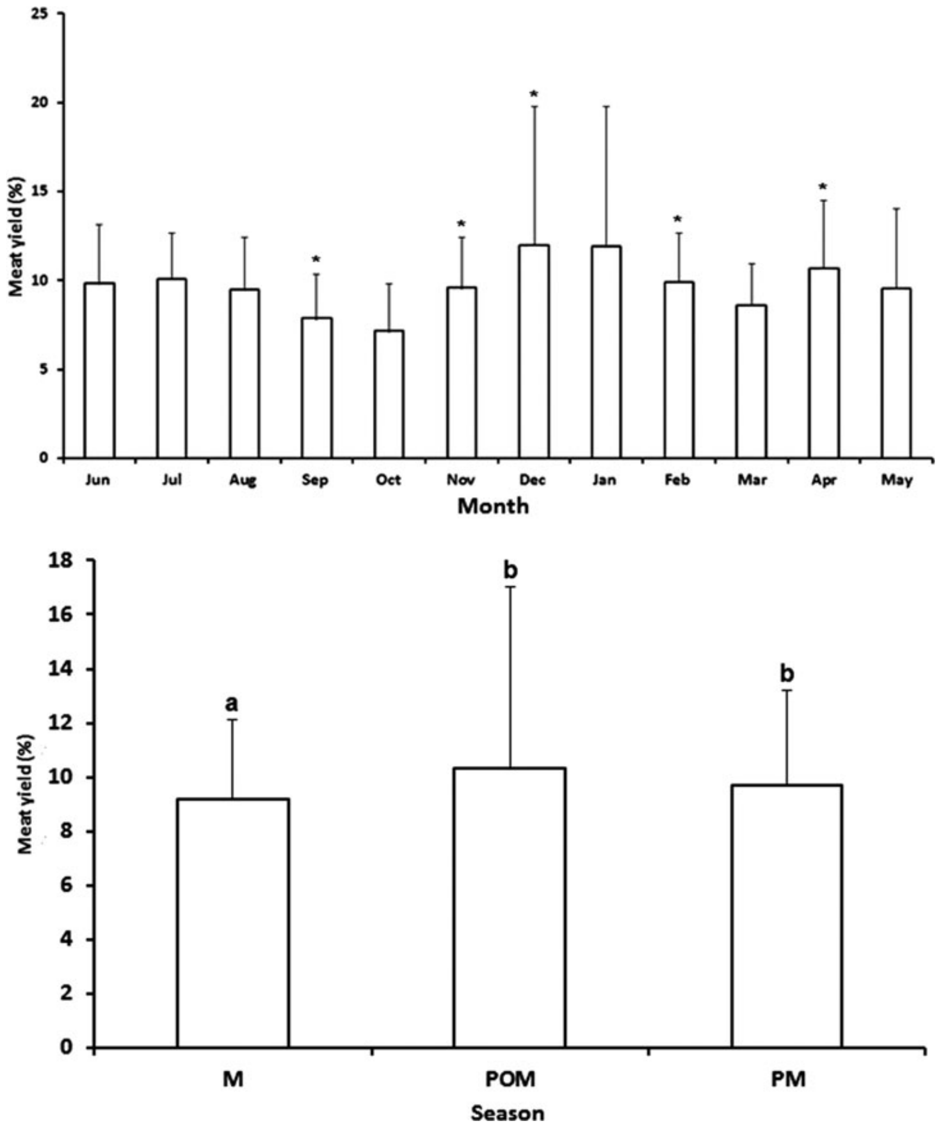

Fig. 4. Monthly variation (upper figure) and seasonal variation (lower figure) in mean meat yield (edible proportion) of *Saccostrea cucullata* (M = monsoon, POM = post-monsoon, PM = pre-monsoon). Vertical bars represent the standard deviation. Means with different superscript letters are significantly different ($P < 0.05$).

growth of oysters, producing a considerable array of shell forms. The oyster colonies from the study area were generally overcrowded, covered with sediments, with individuals having irregular shapes with different sizes. However, shell cavities in *S. cucullata* were generally found to be deep, except in some organisms, which were shallow.

Environmental stresses such as food deficiency, high copper concentrations, elevated suspended sediment loadings and limited water exchange are possible agents causing shell thickening in oysters (Brown & Hartwick, 1988). The concept of '*condition*' is defined as a measure of the meat content of a shellfish (Hickman & Illingworth, 1980). Measurement of condition is a well-established technique for assessing the 'health', or fatness, of bivalves and the index, relating the amount of shell to the quantity of living tissue, has been used for many decades, both in commercial practice and scientific research (Davenport & Chen, 1987). The use of condition measurement in environmental monitoring was suggested because a reduction in condition is associated with physiological stresses (Goldberg, 1980). Pridmore *et al.* (1990) studied marine pollution effects in the condition of *Crassostrea gigas* from Manukau Harbour (New Zealand), suggesting that CI values agreed well with known pollution gradients. In India, a variety of different methods, based on meat and weight, have been used for assessing bivalve condition indices involving shell cavity volumes, ash-free dry meat weights, biochemical contents (e.g. glycogen and protein) and physiological measurements, which are tedious and time-consuming for routine estimates.

The index relating meat dry weight and shell dry weight was employed in the present study for assessing the condition of *S. cucullata*. Based on the seasons, the general pattern of CI was low condition during monsoon and high condition during post-monsoon and pre-monsoon. CI increased during post-monsoon and pre-monsoon generally when there was a considerable increase in water temperature and decreased during monsoon when falling temperatures were recorded in India (Hemachandra, 2009; Tenjing, 2017). Perhaps this is due to food availability and a variety of crooked forms due to overcrowding (Rao & Nayar, 1956). Helen (1997) suggested that low condition of *S. cucullata* in winter when water temperature was low might be attributed to low feeding rate leading to a reduced build-up of food reserves in the body, an increase in the shell weight by production of new material and utilization of stored food products for growth and maintenance. This is in accordance with the present findings. The PE followed similar trends to CI, with highest meat percentage in July, December and April. In monsoon, PI might decline sharply subsequent to spawning. The present range of CI values is comparable to the observations of Kumari *et al.* (1977) who worked on *Meretrix casta* (2.8–3.56) from natural beds of the Indian coast.

It is found that biometric relationships (between length-breadth, length-width, length-total weight, length-shell weight, length-meat wet weight and length-dry meat weight) tended to be stable in a linear/curvilinear pattern. However, the variation difference occurred in the condition index which could be attributed to ecological variations. Seasonal fluctuations in the condition index were probably related to cycles of gonadal maturation and spawning.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the authorities of Mangalore University, Mangalagangothi (Karnataka state, India).

FINANCIAL SUPPORT

The author is thankful to the University Grant Commission, New Delhi for providing a fellowship [BSR-UGC Meritorious Fellowship, UGC No.4-1/2008(BSR)] during the course of work.

REFERENCES

Amin N.S.M., Zafar M. and Halim A. (2008) Age, growth, mortality and population structure of the oyster, *Crassostrea madrasensis*, in the Moheskhali Channel (southeastern coast of Bangladesh). *Journal of Applied Ichthyology* 24, 18–25.

Amornjaruchit S. (1988) Economically important molluscan shellfish of Thailand. *ICLARM Technical Report* 19, 1–18.

Ansari Z.A., Nair A., Harkantra S.N. and Parulekar A.H. (1978) Studies on dimensional relationships in green mussel *Mytilus viridis* from two environments. *Mahasagar* 11, 201–205.

Brohmanonda P., Mutarasint K., Chongpeepien T. and Amornjaruchit S. (1988) Oyster culture in Thailand. In McCoy E.W. and Chongpeepien T. (eds) *Bivalve mollusc culture research in Thailand.* Manila: ICLARM and Eschborn, GTZ, pp. 31–39.

Brown J.R. and Hartwick E.B. (1988) Influences of temperature, salinity and available food upon suspended culture of the Pacific oyster, *Crassostrea gigas*. I. Absolute and allometric growth. *Aquaculture* 70, 231–251.

Bussarawit S. (1995) Molluscs from the marine national parks: Surin and Le-pae islands, Andaman Sea, Thailand. *Phuket Marine Biological Center Special Publication* 15, 119–125.

Chatterji A., Ansari Z.A., Ingole B.S. and Parulekar A.H. (1985) Length-weight relationship of giant oyster, *Crassostrea gryphoides* (Schlotheim). *Mahasagar* 18: 521–524.

Dame R.F. (1972) Comparison of various allometric relationships in intertidal and subtidal American oysters. *Fisheries Bulletin* 70, 1121–1126.

Davenport J. and Chen X. (1987) A comparison of methods for the assessment of condition in the mussel (*Mytilus edulis* L.). *Journal of Molluscan Studies* 52, 293–297.

Durve V.S. (1964) On the percentage edibility and the index of condition of the oyster *Crassostrea gryphoides* (Schlotheim). *Journal of the Marine Biological Association of India* 6, 128–135.

Goldberg E.D. (1980) *The international mussel watch.* Washington, DC: National Academy of Sciences, National Research Council.

Hamai I. (1934) Relation between the weight, volume and linear dimensions in *Meretrix meretrix* (L). *Science Reports of the Tohoku Imperial University* 4, 203–218.

Hamai I. (1935a) A study of one case in which different environmental conditions produce different types of *Meretrix meretrix. Science Reports of the Tohoku Imperial University* 10, 485.

Hamai I. (1935b) On the growth of the shell of *Meretrix meretrix* especially with regard to periodicity of growth relatively to the seasonal variations in the environment. *Science Reports of the Tohoku Imperial University* 9, 339.

Hartnoll R.G. (1976) The ecology of some rocky shores in tropical East Africa. *Estuarine and Coastal Marine Science* 4, 1–21.

Helen C.M.-C. (1997) *The ecology and energetics of* Saccostrea cucullata *(Born) (Bivalvia: Ostreidae) in Hong Kong.* PhD thesis, The University of Hong Kong, Hong Kong.

Hemachandra (2009) *A study on the intertidal biodiversity of islands off Malpe, near Udupi, west coast of India.* PhD thesis, Department of Biosciences, Mangalore University, Mangalagangothri.

Hickman R.W. (1979) Allometry and growth of the green lipped mussel *Pema canaliculus* in New Zealand. *Marine Biology* 51, 311–327.

Hickman R.W. and Illingworth J. (1980) Condition cycle of the green-lipped mussel *Perna canaliculus* in New Zealand. *Marine Biology* 60, 27–38.

Jones A.M., Jones J.M. and Baxter J.M. (1979) Seasonal and annual variations in the allometric relationships of shell and soft body characters of *Patella vulgata* L. In Naylor E. and Hartnoll R.G. (eds) *Cyclic phenomena in marine plants and animals.* Oxford: Pergamon Press, pp. 199–206.

Joseph M.M. (1979) Studies on the biology of the Indian backwater oyster *Crassostrea madrasensis* (Preston). PhD thesis, Mysore University, Mysore.

Kripa V. and Salih K.Y.M. (1999) Growth and reproduction of the rock oyster *Saccostrea cucullata* in Ashtamudi Lake, Kerala. In Joseph M.M., Menon N.R. and Nair N.U. (eds) *The fourth Indian fisheries forum held at Kochi during 24–28 November 1996.* Mangaluru: Asian Fisheries Society, Indian Branch, pp. 317–372.

Kumari L.K., Rajagopal M.D. and Sumitra-Vijayaraghavan (1977) Some aspects of biology and biochemistry of the backwater clam, *Meretrix casta* (Chemnitz). *Mahasagar* 10, 157–163.

Lewis J.R. (1964) *The ecology of rocky shores.* London: English Universities Press.

Libini C.L., Abraham K.J., Shanmugam K., Rao K.P., Kripa V., Velayudhan T.S. and Mohamed K.S. (2011) Biometric relationships of the black winged pearl oyster, *Pteria penguin* (Roding, 1798) from Andaman and Nicobar Islands. *Indian Journal of Fisheries* 58, 139–143.

Maran B.A.V. and Ayyakkannu K. (2002) Parasitic copepods in *Saccostrea cuculatta* (Born 1778), a mangrove associated oyster at Pichavaram backwaters, southeast coast of India. In Quadros G. (ed.) *Proceedings of the national seminar on creeks, estuaries and mangroves – pollution and conservation held at Thane, 28–30 November 2002*. Parangipettai: Annamalai University, pp. 132–134.

Mitra A., Basu S. and Banerjee K. (2008) Seasonal variation in biochemical composition of edible oyster (*Saccostrea cucullata*) from Indian Sundarbans. *Fishery Technology* 45, 209–216.

Morris S. (1985) Preliminary guide to the oysters of Hong Kong. *Asian Marine Biology* 2, 119–138.

Morton B. and Morton J. (1983) *The sea shore ecology of Hong Kong*. Hong Kong: Hong Kong University Press.

Nagi H.M., Shenai-Tirodkar S. and Jagtap T.G. (2011) Dimensional relationships in *Crassostrea madrasensis* (Preston) and *C. gryphoides* (Schlotheim) in mangrove ecosystem. *Indian Journal of Geo-Marine Sciences* 40, 559–566.

Nateewathana A. (1995) Taxonomic account of commercial and edible molluscs, excluding cephalopods, of Thailand. *Phuket Marine Biological Center Special Publication* 15, 93–116.

Nielsen C. (1976) An illustrated checklist of bivalves from PMBC beach with a reef-flat at Phuket, Thailand. *Phuket Marine Biological Center Research Bulletin* 9, 1–7.

Pauly D. (1983) *Some simple methods for the assessment of tropical fish stocks*. FAO Fisheries Technical Papers, Volume 235. Rome: FAO.

Pridmore RD., Roper D.S.and Hewitt I.E. (1990) Variation in composition and condition of the Pacific oyster, *Crassostrea gigas*, along a pollution gradient in Manukau Harbour, New Zealand. *Marine Environmental Research* 30, 163–177.

Quayle D.B. and Newkirk G.F. (1989) *Farming bivalve molluscs: methods for study and development. Advances in world aquaculture, volume 1*. Ottawa: International Development Research Centre.

Rao K.V. and Nayar K.N. (1956) Rate of growth in spat and yearlings of the Indian backwater oyster *Ostrea madrasensis* (Preston). *Indian Journal of Fisheries* 3, 231–260.

Sanpanich K. (1998) An annotated check list of marine bivalves from Chonburi and Rayong provinces, the east coast of Thailand. *Phuket Marine Biological Center Research Special Publication* 18, 297–305.

Seed R. (1968) Factors influencing shell shape in the mussel *Mytilus edulis*. *Journal of the Marine Biological Association of the United Kingdom* 48, 561–584.

Seed R. (1973) Absolute and allometric growth in the mussel *Mytilus edulis* (Mollusca, Bivalvia). *Journal of Molluscan Studies* 40, 343–357.

Sokal R.R. and Rohlf F.J. (1987) *Introduction to biostatistics*. New York, NY: Freeman.

Soong K., Liu L.L., Chen J.L. and Chen C.P. (1992) Regional differences of oyster (Crassostrea gigas Thunberg) size and shape in Taiwan. *Bulletin of the Institute of Zoology, Academia Sinica* 31, 111–119.

Stanley O.W. (2002) Biodiversity and ecology of the Gulf of Kachchh mangrove, Gujarat. In Quadros G. (ed.) *Proceedings of the national seminar on creeks, estuaries and mangroves – pollution and conservation held at Thane, 28–30 November 2002*. Parangipettai: Annamalai University, pp. 78–83.

Stenzel H.B. (1971) Oysters. In Moore R.C. (ed.) *Treatise on invertebrate paleontology, Part N, Bivalvia. Volume 3*. Boulder, CO and Lawrence, KS: Geological Society of America and the University of Kansas Press, pp. 953–1224.

Tack J.F., Berghe E. and Polk P.H. (1992) Ecomorphology of *Crassostrea cucullata* (Born, 1778) (Ostreidae) in a mangrove creek (Gazi, Kenya). *Hydrobiologia* 247, 109–117.

Tenjing S.Y. (2013) Ecology of the genus *Donax* (Family: Donacidae) from Karnataka coast. PhD thesis. Department of Biosciences, Mangalore University, Mangalore.

Tenjing Y.S. (2017) Relationships between environmental factors and biological parameters of edible Asian wedge clam, *Donax scortum*, morphometric analysis, length-weight relationship and condition index: a first report in Asia. *Journal of the Marine Biological Association of the United Kingdom* 97, 1617–1633.

Thomson J.M. (1954) The genera of oysters and the Australian species. *Australian Journal of Marine and Freshwater Research* 5, 132–168.

Tookwina S. (1991) Coastal aquaculture and sea farming in Thailand. *Phuket Marine Biological Center Special Publication* 9, 82–83.

and

Van Someren V.D. and Whitehead P.J. (1961) An investigation of the biology and culture of an East African oyster, *Crassostrea cucullata*. *Fisheries Publications, London* 14, 1–41.

Correspondence should be addressed to:
Yambem Tenjing Singh
Department of Biosciences, Mangalore University,
Mangalagangothri 574 199, India
email: yambemtenjing@gmail.com

https://doi.org/10.1017/S0025315418000309 Published online by Cambridge University Press