E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2020; 8(3): 550-555

www.fisheriesjournal.com
Received: 13-03-2020
Accepted: 15-04-2020

Elamin M Elamin
Fisheries Research Centre, Red Sea Fisheries Research Station, Port Sudan, Sudan

Sheikheldin M Elamin
Department of Fisheries, Faculty of Marine Science and Fisheries, Red Sea University, Sudan

Zuheir N Mahmoud
Department of Zoology, Faculty of Science, University of Khartoum, Sudan

Corresponding Author:
Elamin M Elamin
Fisheries Research Centre, Red Sea Fisheries Research Station, Port Sudan, Sudan

Growth performance of the pearl oyster (*Pinctada margaritifera* L. 1758) under different culture systems in Dungonab Bay, Sudan, Red Sea

Elamin M Elamin, Sheikheldin M Elamin and Zuheir N Mahmoud

Abstract
Pinctada margaritifera is naturally occurring in Dungonab Bay and its adjacent areas. Its growth was studied for an annual cycle, from January to December 2010 in hanging, bottom and ground culturing systems as well as from the wild oysters. The asymptotic shell highest (H∞) was 27.59, 9.55 and 7.77 cm in the hanging, bottom and ground system, respectively. In the wild it was 27.59 cm. The growth Index Φ was 4.39, 3.97 and 3.94 in the hanging, bottom and ground system, respectively. In the wild it was 3.66. The average heights shell increment was 0.80, 0.62 in April and 0.48 cm in March in the hanging, bottom and ground system, respectively. The lowest shell increment was 0.00, 0.09 in August and 0.21cm in the ground, bottom and the hanging system, respectively. The linear plot of H (t +Δt) against H_t, for hanging, bottom, and ground culture system as well as and wild oysters yielded very highly significant correlation (p<0.001; r = 0.969 - 0.997). The linear plot of the relationship between t and -ln (1-Ht /H∞) in all system yielded very highly significant correlation (p<0.001; r = 0.990 - 0.998). In all groups, the increase in shell length with time is slow and variable.

Keywords: Growth, shell, *Pinctada*, Dungonab bay, Red Sea

1. Introduction
Pinctada margaritifera is a marine oyster distributed throughout the Red Sea, Indo-Pacific region. It is reared for cultured pearl production. In Sudan the species is well studied in Dungonab Bay. The oceanography, geography and biota of the Bay was well described [1-3]. Crossland [4] summarized his long history of cultivation of *P. margaritifera* the mother of pearl oyster (MOPS) in Dungonab Bay from 1905-1957. Improvements were achieved with respect to MOPS cultivation by the Sudan-Canadian Oyster Culture Research Project (1978-1994), which led to capacity development. The commercial aspects of cultivated MOPS in the Bay was tackled by Ali [5] and Elamin *et al.* [6]. Variability in growth by Nasr [7] and Elnaeim [8], its biometric relationships by Elamin and Elamin [9] and mortality of MOPS were studied by Nasr [10].

Difficulties in collecting spat from the wild led to adoption of hatchery-produced spat from *P. margaritifera* in Fiji islands and Micronesia and from *P. fucata* and *P. maxima* in Japan, Australia, and south-east Asia (Cartier *et al.* [11]). The decline in pearl value led Chin-Iong *et al.* [12] to launch genetic programmes addressing production traits, shell growth, time of grafting, size of the implanted nuclei, and bio-mineralization capacities in *P. margaritifera.*

The growth of *P. margaritifera* was studied from different perspectives worldwide. Sims [13] compared its growth in the wild and under culture while Southgate and Beer [14] compared juveniles' growth using different nursery techniques. Doroudi *et al.* [15] studied the combined effects of temperature and salinity on embryos and larvae of *P. margaritifera*. Taylor *et al.* [16] probed the effects of stocking density on growth and survival of *P. maxima* in suspended nursery culture while in *P. margaritifera* (Pouvreau *et al.* [17]) studied its growth in suspended culture under hydro-biological conditions of Takapoto lagoon. Blay *et al.* [18] investigated the influence of nacre deposition rate on cultured pearl grade. Ram and Morris [19] stated that *P. margaritifera* had better growth on when they were cleaned every 4 and 6 weeks.

The present work compared the growth parameters of *P. margaritifera* from the wild and hanging, bottom and ground culturing systems in Dungonab Bay.

Materials and Methods

Study area

Dungonab Bay (305 km²) is the largest one within the Red Sea. It is length from north to south is about 32 km. The maximum width is 14.5 km at Dokhana Bay and the minimum width is 3.2 km at Ras Adliai [1]. The water exchange between the Bay and the open sea takes place at the southern end of the main Bay. Fresh water enters the bay only from small seasonal streams.

Spat source and culture

Pinctada margaritifera were collected from the shallow coastal waters by skin diving native fishers. About 300 spats were randomly collected from south of Um Elsheikh Island. The shell height ranged from 3 to 7.75cm. Spats were randomly distributed in hanging, bottom and ground culture rearing trays. Each try was stocked with 100 spats. Cleaning of fouling organisms was done monthly by a brush. The three systems were set up within Gulf Pearl Company Oyster Farm. All oysters were tagged. In GPC the dorso-ventral shell height was measured from hinge line to the furthermost edge of the non-nacreous border using a stainless steel calipers.

Growth

The von Bertalanffy [20] (1938) equation was used in order to allow a comparison with previous works on the species. The Ford-Walford (Ford [21]; Walford [22]) and the von Bertalanffy [20] methods were used to estimate the asymptotic height (H∞); the rate at which the asymptotic value is approached in year $^{-1}$ (k) and the age at height zero ($t_{o)}$ for *P. margaritifera* cultured in the three systems. Munro and Pauly [23]; Pauly and Munro [24] were used to calculate a growth performance index Φ; (Φ= log k+ 2 log H_{∞}).

Statistical analysis

The data was analyzed using the SPSS (Version 24.0) as appropriate.

Results

Table 1 showed that the average heights shell increment was 0.80, 0.62 in April and 0.48 cm in March in the hanging, bottom and ground system, respectively. The lowest shell increment was 0.00, 0.09 in August and 0.21cm in the ground, bottom and the hanging system, respectively.

Table 1: Average shell height in cm in the three culture systems at Dungonab Bay

Month	Hanging system		Bottom system		Ground system	
	Initial	Increment	Initial	Increment	Initial	Increment
January	4.44	0.00	4.45	0.00	4.75	0.00
February	4.95	0.55	4.75	0.30	4.86	0.11
Marsh	5.47	0.52	5.00	0.25	5.34	0.48
April	6.27	0.80	5.62	0.62	5.77	0.43
May	6.86	0.59	6.00	0.38	6.04	0.27
June	7.54	0.68	6.28	0.28	6.43	0.39
July	8.03	0.49	6.46	0.18	6.54	0.11
August	8.38	0.35	6.55	0.09	6.54	0.00
September	8.86	0.48	6.80	0.25		
October	9.56	0.70	7.03	0.23		
November	10.30	0.74	7.29	0.26		
December	10.51	0.21	7.48	0.19		

Table 2: Estimating H∞ k and to for the different culturing system using Ford-Walford method

T	Hanging System			Bottom System			Ground System			From the Ground			
	Ht	Ht +Δt	-ln (1-Ht/H∞)	Ht	Ht +Δt	-ln (1-Ht/H∞)	Ht	Ht +Δt	-ln (1-Ht/H∞)	t	Ht	Ht +Δt	-ln (1-Ht/H∞)
0.583	4.447	4.956	0.176	4.457	4.750	0.628	4.751	4.860	0.944	3	6.5	7.5	0.331
0.667	4.956	5.473	0.198	4.750	5.004	0.687	4.860	5.315	0.981	4	7.5	9.2	0.393
0.750	5.473	6.271	0.221	5.004	5.620	0.741	5.315	5.773	1.150	5	9.2	10.4	0.509
0.833	6.271	6.861	0.258	5.620	6.007	0.887	5.773	6.048	1.356	6	10.4	11.5	0.599
0.917	6.861	7.545	0.286	6.007	6.288	0.991	6.048	6.432	1.539	7	11.5	12.5	0.680
1.000	7.545	8.032	0.319	6.288	6.465	1.072	6.432	6.545	1.755	8	12.5	13.25	0.780
1.083	8.032	8.381	0.344	6.465	6.556	1.128	6.545	6.548	1.842	9	13.3	14	0.854
1.167	8.381	8.866	0.362	6.556	6.805	1.158	6.548		1.845	10	14.0	14.8	0.933
1.250	8.866	9.568	0.388	6.805	7.039	1.245				11	14.8	15.5	1.025
1.333	9.568	10.309	0.426	7.039	7.296	1.334				12	15.5		1.113
1.417	10.309	10.511	0.468	7.296	7.467	1.441							
1.500	10.511		0.480	7.467		1.519							

Using Ford-Walford method it is apparent from Table 2 that Ht, Ht +Δt and -ln (1-Ht/H∞) were by far higher in ground system followed bybottom system, the wild and hanging system. In all systems these readings tends to increase with time.

Annual growth

The frequency of occurrence of wild oyster in 126 length rages of 0.1 cm span starting from 6-6.16 to 18.5-18.61 cm was used for age determination.

The highest (H∞) was obtained in the hanging and the least in ground culture system. The growth index (Φ) was high in the hanging culture system and the lowest from the wild (Table 3 and Fig. 1).

Table 3. Growth performance index (Φ) at height in cm at age t years (Ht) at different system

System	Von Bertalanffy equation	Growth Performance Index Φ
Hanging Culture	$Ht = 27.59 [1- exp^{-0.328 (t+0.0794)}]$	4.39
Bottom Culture	$Ht = 9.55 [1- exp^{-0.961(t+0.0619)}]$	3.97
Ground Culture	$Ht = 7.77 [1- exp^{-1.548(t+0.0835)}]$	3.94
Wild	$Ht= 23.08 [1- exp^{-0.0866 (t+0.747)}]$	3.66

Fig 1: Growth curves of *Pinctada margaritifera* in the three culture systems and the wild

From Fig. 2 it is apparent that the fast increase in shell height was obtained in the hanging system (7.5cm at age 2 years). While for the bottom system the highest height increment occurred at age 6 month to 2 years when the shell heights were 3.99 to 5.6cm, respectively. For the ground system the highest height increment occurred at age 6 month to 2 years when the shell heights were 4.63 to 5.5cm, respectively. In the wild oysters the highest height increment occurred at age 1 year when the shell heights was 1.8cm (Fig. 2)

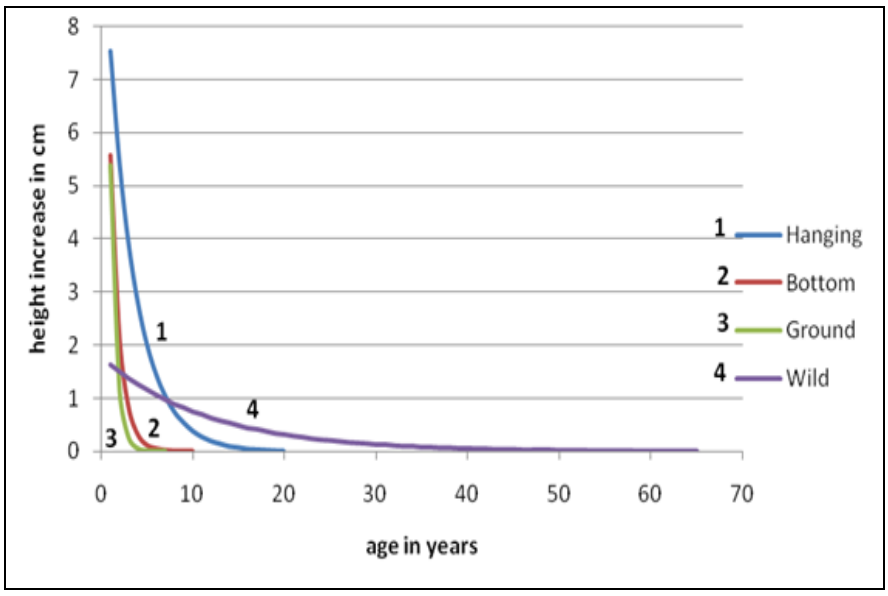

Fig 2: Shell height curves for *Pinctada margaritifera* in the three culture systems and the wild.

The linear plot of $H(t +\Delta t)$ against H_t. for hanging, bottom, and ground culture system as well as and wild oysters yielded very highly significant correlation ($p<0.001$; $r = 0.969 - 0.997$) Fig. 3.

As the constant of the Von Bertalanffy equation (H_∞ asymptotic height in cm) decreases the growth constant ($Kyear^{-1}$) increases and the growth index decreases (Φ) Table 3. The growth constant was 0.328, 0.961 and 1.548 for hanging, bottom and ground culture system, respectively. For wild oyster it was 0.087 $Kyear^{-1}$. The T_{10}: age at which oyster reached 10cm (years) for the hanging system is 1.4cm which is low compared with 5.9cm for the wild oyster.

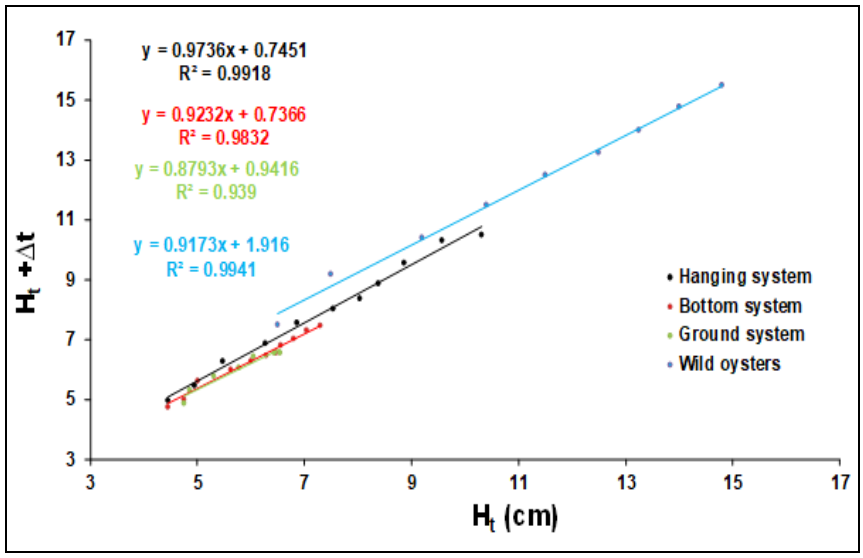

Fig 3: Relationship between H_t and Ht +Δt for hanging, bottom, and ground culture system and wild oysters.

Walford plots based on von Bertalanffy growth function (H_t versus $H_t + \Delta t$) showed high correlations. The linear plot of the relationship between t and -ln (1-Ht /H∞) in all system yielded very highly significant correlation ($p<0.001$; r= 0.990 - 0.998) Fig. 4. In all groups, the increase in shell length with time is slow and variable

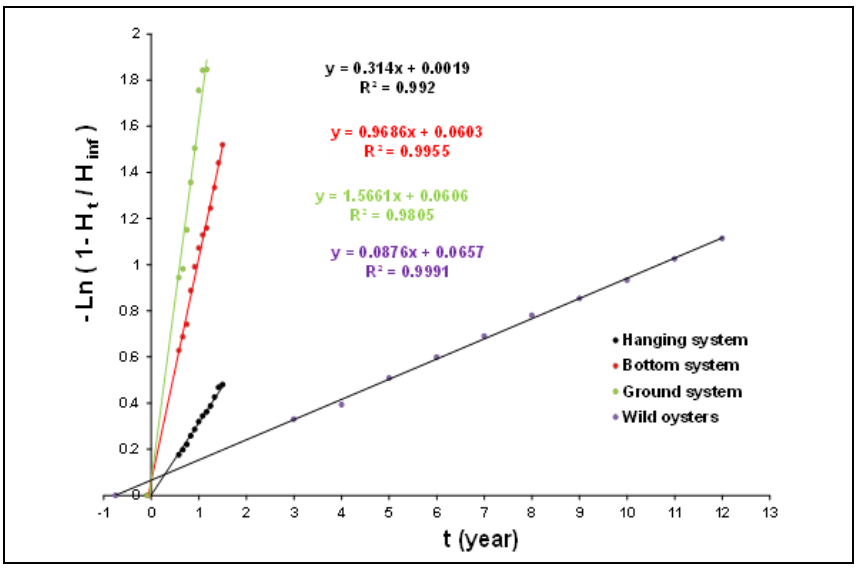

Fig 4: Relationship between t and -ln (1-Ht /H∞) for hanging, bottom, and ground culture system and wild oysters.

The relationship between t and -ln (1-Ht /H∞) for wild oysters gave a very highly significant correlation ($p<0.001$, r = 0.999 which indicates that the regression equation y = 0.0657 + 0.0876x can be used with high accuracy to predict the regression correlates.

Discussion

Fast growth and good health of *Pinctada* are indicated by the length and profusion of growth processes [12-14, 17, 25, 26]. Normal growth is characterized by fast initial increases in height, to a near maximum size, subsequent to which shell thickness increase. In *P. margaritifera* a shell of 7 to 8cm diameter is attained within one year, reaching around 11 cm by the second year, generally after two years increase of shell diameter are small [13].

Shell growth data are important for pearl farming and management since they give useful information concerning pearl oyster health in culture system, deposition rate of nacreous matter on the shell [27] and on the implanted nucleus and suitability of potential pearl farming sites [17]. This is in agreement with Southgate *et al*., [14] and Numaguchi and Tanaka [28]. This slow growth of shell length is due to investment in reproduction and tissue growth.

Pearl oyster seeding operation is carried out on mature oysters, when the shell height greater than 5cm, 10cm and 12cm for *P. fucata*, *P. margaritifera* and *P. maxima*, respectively [29]. According to Pouvreau *et al*., [17] a shell height of 10cm for *P. margaritifera* is appropriate for first pearl nucleus insertion, instead of 12cm in French Polynesia. In the present study in the bottom and the ground systems the H_∞ attained 9.55 and 7.77cm, respectively and in the hanging system the shell heights reached 10cm at age 1.4 year which is suitable for pearl seeding. This age is suitable for Gulf Pearl Company norms in Dungonab Bay and agrees with Gervis and Sims [29] length wise In the preset study the observed decreased increment in shell length after age of 3 years in all culturing systems agreed with Nasr [10] and Gervis and Sims [29]. The present study found that the shell height of wild oyster reached 10cm at the age of 5.9 years rendering it as economically unfeasible for pearl culture.

Bivalves generally display a considerable inter-specific range of growth rates. For Pteriidae, the lowest H_∞ values of 12.55, 7.93, 8.49 and cm have been obtained, respectively for *P. margaritifera*, *Pinctada fucata* and *P. mazatlanica* by Elnaeim [8]; Chellam [26] and Saucedo and Monteforte [30]. The highest H∞ values within the *Pinctada* genera was above 22.9cm reported for *P. maxima* [31]. The H_∞ values recorded during this study were7.77, 9.55, 23.08 to 27.59 cm in the ground, the bottom, the wild and the hanging system, respectively. In the same species the H_∞ of the hanging system was found to be 12.55cm in Dungonab Bay [8] and 13.1 to 31.0cm in Cook Islands [13]. The H_∞ values of 23.08 of the wild oyster was higher than 18.3cm obtained by Sims [13].

In the present study the pearl oyster growth performance (Φ) ranged from 3.66 to 4.39 in *P. margaritifera*. In the same species a Φ value of 3.99 to 4.29 was reported from Cook Islands [13] and in the French Polynesia the Φ values ranged from 4.09 to 4.21[17].

In different systems and within a given genus, growth variations of cultivated oyster can be due interacting endogenous factors such as genetic potentiality and exogenous factors such as food supply, temperature, farming density, depth, trophic competitors etc. Depth, currents, stocking density and bio-fouling are responsible for growth differences in pearl oysters cultures [8, 10, 27, 32].

In the present work difference in depth and availability of food among the different culture systems may explain the different values of the von Bertalanffy parameters obtained. The impact of bio-fouling on growth rate was not quantified in this study. However Ram and Morris [19] stated that *P. margaritifera* had better growth on when they were cleaned every 4 and 6 weeks.

Studying growth of *P. margaritifera* is a useful indicator of its healthiness and the suitability of the culturing environment. There is a vital need to develop a feasible technical package addressing its growth in the wild and under culture [13, 33] and the impact of stocking densities[16]; comparing juveniles' growth using different nursery techniques [14, 15, 17, 34 The influence of water current around the oysters and its role of renewal of food needs to be investigated.

Conclusions

The study of growth of *P. margaritifera* in Dungonab Bay revealed that the oyster exhibits relatively fast total growth, fast increase in shell height when cultivated on the hanging system compared with bottom and ground systems. Although the hanging system has a higher initial deployment cost, its shell production and pearl production is more cost-effective than from the bottom system. Pearl oysters are more worthwhile only when cultivated for pearl culture. Selling harvested oysters after pearl harvesting is also beneficial. The oysters at 10cm height are suitable for pearl seeding. This corresponds to the age1.4 years in the hanging system.

Acknowledgements

Acknowledgments are due to the Fisheries Research Centre, Port Sudan, the Faculty of Marine Sciences and Fisheries, Red Sea University and Gulf Pearl Company Oyster Farm for facilities. We are indebted to Mr. Abdelmohsin Silman, Mr. Abdallah Allahoi and Mr. Mostafah Mohamed.

References

1. Farah OM. The Bathymetry, Oceanography and Bottom Sediments of Dungonab Bay, Red Sea, Sudan. Ph.D. Thesis. University of Delaware, USA. 148 PP. 1982.
2. PERSGA. Survey of the Proposed Marine Protected Area at Dungonab Bay and Mukkawar Island, Sudan. PERSGA, Jeddah, 2003.
3. PERSGA/GEF. Survey of the Proposed Marine Protected Area at Dungonab Bay and Mukawwar Island, Sudan. Report for PERSGA. PERSGA, Jeddah, 2004.
4. Crossland C. The cultivation of the mother of pearl oyster in the Red Sea. Australian Journal of Marine and Freshwater Research. 1957; 8:111-130.
5. Ali SM. A preliminary Study on Shell Production and Trade in Sudan International Development Research Center, Ottawa, Canada. 1984.
6. Elamin ME, Elamin SM**,** Ali SM. Productivity and Economic Values of the Pearl Oyster (*Pinctada margaritifera* var *erythraensis*) Cultured in Dungonab Bay, Red Sea. International Journal of Innovative Science, Engineering and Technology. 2014; 1(7):161-170.
7. Nasr DH. Observation on the mortality of the mother of pearl oyster *Pinctada margaritifera* in Dungonab Bay, Red Sea. Aquaculture. 1982; 28:271-281.
8. Elnaeim AG. Variability in growth of the mother of pearl Oyster *Pinctada margaritifera*.in the Red Sea, Sudan. M. Sc, Thesis. Dalhousie University, Canada. 1984.
9. Elamin ME, Elamin SM. Biometric relationships *of the* mother of pearl oyster (*Pinctada margaritifera var erythraensis*) from Dungonab Bay, Red Sea. International Journal of Science, Environment and Technology. 2014; 3(3):1193-1204.
10. Nasr DH. Feeding and growth of pearl oyster *Pinctada margaritifera* (L) in Dongonab Bay, Red Sea. Hydrobiologia.1984; 110:241- 245.
11. Cartier EL, Krzemnick MS. Ito M. Cultured pearl farming and production in the Federated States of Micronesia. Gems Gemnol. 2013; 48:108-122.
12. Chin-long KY, Christophe L, Manaarii SK, Cedrik L. Growth performance comparison of *Pinctada margaritifera* juveniles produced by thermal shock or gonad scarification spawning procedures. Journal of Shellfish Research. 2015; 34:811-817.
13. Sims NA. Growth of wild and cultured black-lip pearl oysters, *Pinctada margaritifera* (L) Bivalvia, Pteriidae. Aquaculture. 1994; 122:181-191.
14. Southgate PC, Beer AC. Growth of blacklip pearl oyster (*Pinctada margaritifera*) juveniles using different nursery culture techniques. Aquaculture. 2000; 187:97-104.
15. Doroudi MS, Southgate PC, Mayer RJ. The combined effects of temperature and salinity on embryos and larvae of the black-lip pearl oyster, *Pinctada margaritifera* (Linnaeus). Aquaculture Research. 1999; 30:1-7.
16. Taylor JJ, Rose RA, Southgate PC, Taylor CE. Effects of stocking density on growth and survival of early juvenile silver-lip pearl oyster, *Pinctada maxima* (Jameson), held in suspended nursery culture. Aquaculture. 1997; 153:41-49.
17. Pouvreau SJ, Tiapari A, Gangnery F, Lagarde M, Garnier H, Teissier G *et al*. Growth of the black-lippearl oyster *Pinctada margaritifera*, in suspended culture under hydro-biological conditions of Takapoto lagoon (French Polynesia). Aquaculture. 2000; 184:133-154.
18. Blay CM, Sham-Koua V, Vonau R, Tetumu PC, Ky CL. Influence of nacre deposition rate on cultured pearl grade and colour in the black-lipped pearl oyster Pinctada

margaritifera using farmed donor families. Aquaculture International. 2014, 22:937–953.
19. Ram EJ, Morris C. Cleaning Regime for *Pinctada margaritifera* (Linneaus, 1758) in Savusavu Bay, Fiji. Journal of Aquatic Research Development. 2018; 9:542-546.
20. Von Bertalanffy L. A quantitative theory of organic growth (Inquiries on growth laws. II) Human Biology, 1938; 10:181-213.
21. Ford E. An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. Journal of Marine Biology Association. U.K. 1933; 19:305-384.
22. Walford, LA. A new graphic method of describing the growth of animals. Biological Bulletin of Marine Biology Laboratory. Woods Hole, 1946; 90:141-147.
23. Munro JL, Pauly D. A simple method for comparison of growth in fish and invertebrates, Fishbyte, The World Fish Center. 1983; 1(1):5-6.
24. Pauly D, Munro JL. Once more on the comparison of growth in fish and invertebrates, Fishbyte, The World Fish Center. 1984; 2(1):1-21.
25. Tranter DJ. Reproduction in Australian pearl oysters (Lamellibranchia). V. *Pinctada ficata* (Gould). Australian Journal of Marine and Freshwater Research**.** 1959; 10:45-66
26. Chellam A. Growth of pearl oyster *Pinctada fucata* in the pearl culture farm at Veppalodai. Indian Journal of Fisheries. 1978; 25(1-2):77-83.
27. Coeroli MD, De Gaillande J, Landret P, Coatanea D. Recent innovations in cultivation of Molluscs in 1985. Study of different factors having an influence upon the pearl production of the black-lip pearl oyster. Proc.5th Int. Coral Reef Symposium, Tahiti, 1985; 5:551-556.
28. Numaguchi K, Tanaka Y. Effects of salinity on mortality and growth of the spat of the pearl oyster *Pinctada fucata martensii*. Bulletin Natural Research Institute of Aquaculture. (Japan). 1986; 9:41-44.
29. Gervis MH, Sims NA. The biology and culture of pearl oysters (Bivalvia: Pteriidae). ICLARM Studies Review. 1992; 21:49.
30. Saucedo P, Monteforte M. *In situ* growth of pearl oysters *Pinctada mazatlanica* (Hanley 1856) and Pteria Sterna (Gould 1851) under repopulation conditions at Bahia de La Paz,
31. Yukihira H, Lucas JS, Khumpp DW. The pearl oysters, *Pinctada maxima* and *P. margaritifera*, respond in different ways to culture in dissimilar environments. Aquaculture. 2006; 252(2-4):208-224.
32. Pandya JA. Influence of temperature on growth ring formation in the pearl oyster, *Pinctada fucata* (Gauld), of the Gulf of Kutch. Indian Journal of Marine Science. 1976; 5(2):249-251.
33. Friedman KJ, Southgate PC. Grow out of blacklip pearl oyster *Pinctada margaritifera* collected as wild spat in Solomon Islands. Journal of Shellfish Research. 1999; 18(1):159-167.
34. Southgate PC, Beer AC. Hatchery and early nursery culture of the blacklip pearl oyster *Pinctada margaritifera*, L. Journal of Shellfish Research. 1997; 16(2):561-56.