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Identifying Potential Culture Areas for Angelwing Clams (*Pholasorientalis*) In Malaysia

Mohd Fadzil Shuhaimi bin Ramli and Hartinabt Mohd Yusop
School of Biological Sciences, Quest International University Perak, Malaysia.

Abstract *The success of breeding angel wing clams, Pholasorientalis, in captivity throughout the stages of embryonic, larvae and juveniles offers the potential of aquaculture on the commercial scale. However, as with other aquaculture systems, the clam culture is also facing the cardinal problem, that is, finding the suitable areas. The usual practice is to look for common criteria in parameters between areas known to harbour the clams and those that do not. This can be achieved by studying its life-cycle, the population dispersion in known natural beds of the species and determining the optimum environmental parameters that allow its growth and enhancing its abundance. Periodical samples were collected throughout the year of the study to determine its life-cycle and dispersion. Soil property such as total N (%) was analysed using Leco CNS-2000 automated dry combustion instrument while extractable P (ug/g) and extractable K (ug/g) were analysed using Bray-2 and ammonium acetate extraction method respectively. The YSI Pro Plus probes were used to determine pH, DO, temperature, salinity and TDS. Habitat study showed that the clams dwelled well in compact muddy sand covered with a thin layer of silt. Areas that fit the criteria may be chosen as culture grounds for the clams .In this study, it is found that the potential areas for clam culture will be in Sg Buluh, Selangor and Kuala Sepetang, Perak where the water's physico-chemical characteristics and nutrients composition both water and soil resemble the criteria suitable for the growth of the clams. Transplantation of clam seeds is suggested where knowledge of its life-cycle will be advantageous.*

Keywords: *aquaculture, distribution study, habitat, life-cycle, Pholasorientalis*

I. INTRODUCTION

Pholasorientalis(Gmelin, 1791), the angel-wing clam or locally known as SiputMentarang is a potential food resource from the sea [1] [2] [3] but also been considered endangered species [4] [5]. In Malaysia, angel-wing clam is not common seafood to many people and normally is available between January to June especially during low tide in limited areas in Malaysia such as SimpangEmpat, Perlis and PantaiSabak, PantaiRemisup to TanjungKarang, Selangor [6]. In the Philippines, the bivalves are considered as delicacy and because of its succulent texture, sweet and juicy taste and unique flavour, it has become a major source of livelihood for numbers of coastal fishermen and has become a tourist food attraction in major cities and towns in the region [7][8]. *P.orientalis* is edible and marketed either fresh or dried in Hong Kong, Malaysia, Thailand and Philippines[9][10][11][12][13][14]. Due to its juicy, sweetly and tenderly meat, it become one of the highly sought bivalves in Central Philippines[15][16].However, in Malaysia, the production of the bivalves is not well documented and absence in the statisticsproduced by the Department of Fisheries (DOF) although certain aspect of its biological importance [17][18], diversity [19] and economics significance [20]had been researched.

The success of breeding in captivity throughout the stages of embryonic, larvae and juveniles offers the potential of aquaculture on the commercial scale[8]. However, as with other aquaculture systems, the clam culture is also facing the cardinal problem, that is, finding the suitable culture areas [21].One method is to perform an experimental culture where a selected area is stocked with the seeds collected elsewhere[22].However the success can be more achievable by studying its life-cycle, the population dispersion in known natural beds of the species and determining the optimum environmental parameters that allow its growth and enhancing its abundance.

In State of Selangor, Perak and Kedah, *P. orientalis*is mostly found along the intertidal mudflats [23] [24]. The abundance of the species is not well documented as no landings data are recorded by the authority (DOF). However, in Selangor, it is observed that the clams are being sold as fresh to consumers along the roadside in Sekinchan area. There are about 7-10 stalls selling the clams whereby each stall is estimated to sell 25 kg of per day. The clams are collected by local inhabitants using bare hands usually during spring tide. Since the collection method does not include the use of sampan, fishers are confined to areas near the shore for safe return during the rising of the tide.Elsewhere, *P. orientalis* is found in the tidal flats and subtidal areas of Southeast Asia and Australia [24]. There were also reported abundance of *P. orientalis* in India, notably in the nearshore coastal system of Mumbai [25], coastal zone of Goa [26], estuaries of South Kerala [27], arid zone

mangroves of gulf of Kachchh in Gujarat, western India [28] and little abundance in the coastal area of Tamil Nadu [29]. In Southeast Asia, *P. orientalis* is found in Prachuap Khiri Khan, Upper Western Gulf of Thailand [14], Padang Pariaman, West Sumatera [30] and Bone Batang Waters in Spermonde archipelago, South Sulawesi [31].

P. orientalis is a deep burrowing bivalve molluscs found mostly in the intertidal flats of Southeast Asia [23] and were distributed and abundance in the lower intertidal zone, where the clams burrowed in compact muddy substrate to a depth of about 0.3m [18]. The danger of the population to become extinct is predictable as in the case of the Philippines due to overexploitation and unregulated collecting activities. The problem had initiated researchers in the Philippines to successfully breed the mussels in captivity throughout the stages of embryonic, larvae and juveniles. For the first time, [8] had successfully spawned the clams in captivity and reared through early embryonic, larval, and juvenile stages. Postlarvae of *P. orientalis* were successfully introduced in the muddy cove of San Dionisio, Panay Island, Philippines (11°13′N, 123°04′E) and have produced successive generations that successfully colonized the area This indicates a very promising future for the culture of the mussels where hopefully the juveniles are readily available from the hatcheries .In the meantime, there is an urgent need to understand the complete life cycle of the clams including the spawning season , availability of larvae and juveniles and areas favourable for the clams to grow. It is hoped that the successful development of seed production technologies would lead to the rehabilitation of depleted stocks in the wild. [32].

The need for new species for aquaculture production will be imminent. Recent failures in cockle culture due to excessive ammonia level had resulted severe decline in its production [32]. The increasing deterioration of coastal water quality resulting from the discharge of domestic, agricultural and industrial wastes into coastal waters has affected aquaculture production and profitability [34].Thus, new areas away from pollution should be identified taking the advantage of the 2014's DOF announcement of a 0-1 nm conservation zone meant for aquaculture, cockles farming and community-based fisheries management zone [35]. States such as Selangor, Perak and Kedah are involved in this new fishing regime that prohibits any fishing activity within the stipulated areas. Thus, creating safe haven for the development and expansion of marine aquaculture.

In the absence of credible data to support its economic significance and abundance makes future planning of the resource difficult, thus, as precautionary measure, aquaculture is a way of supplementing the production from the wild or relieves the pressure of overfishing on the population. New areas suitable for the culture have to be identified by studying its biological life cycle, distribution and habitats suitability to provide knowledge for further enhancing the production of the clams through aquaculture.Thus, the objectives of this study are as follows:

i. To determine the *P. orientalis's* distribution, life-cycle and habitat in relation to some important environmental parameters, and

ii. To identify two suitable areas for the culture of *P. orientalis*.

II MATERIALS AND METHOD

2.1 Study site

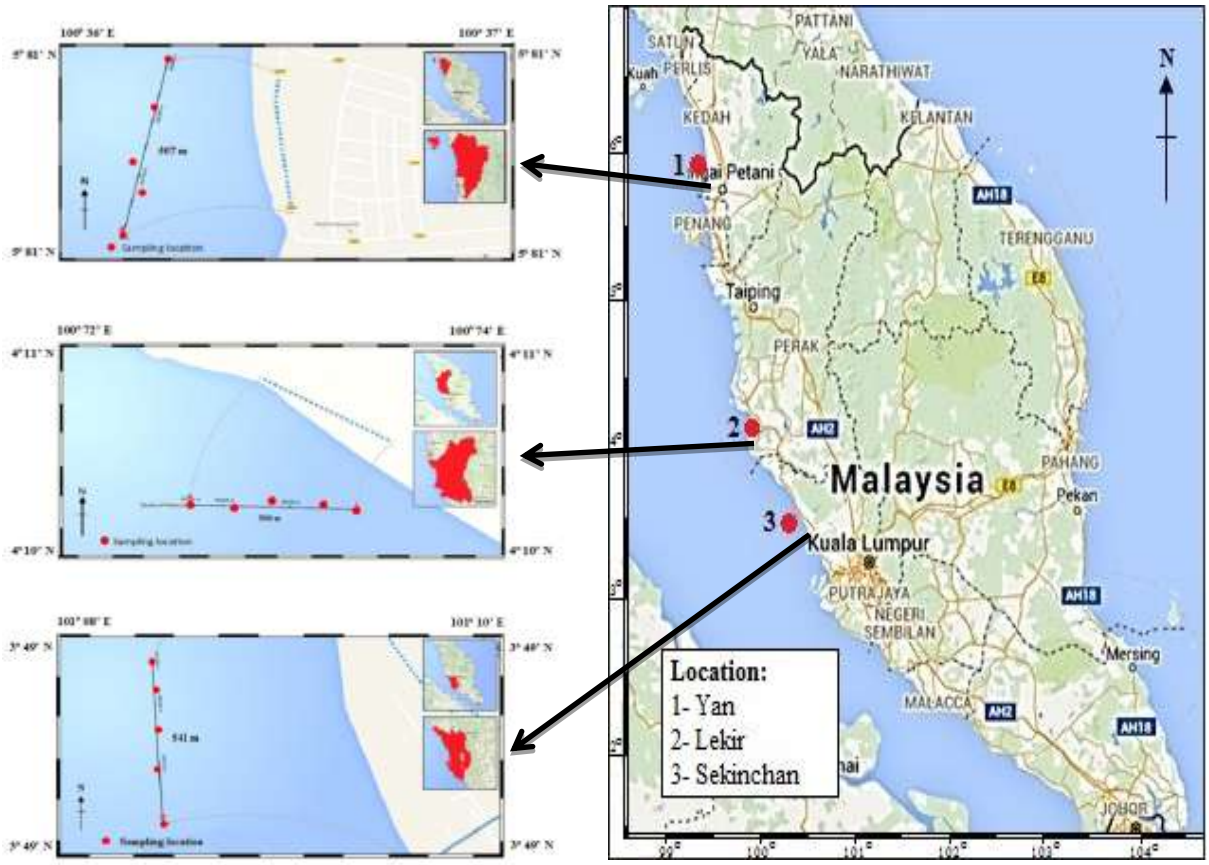
Three states;Kedah, Perak and Selangor were selected for this study for reason that most of the clams were found in these regions as recorded by[20][23][24]. In Kedah, the identified area was in Yan, while Lekirin Perak and Sekinchan in Selangorand denoted as Location 1, Location 2 and Location 3 respectively (Look Map 1.0).Potential areas for clams aquaculture to be studied were selected based on the various factors such as easy access, presence of other bivalves (mainly cockles, *Anadaragranosa*) and have been designated by the authority as aquaculture areas. Therefore, the chosen areas were Kuala Sepetang, Perak (Location 4) and Sg Buluh, Selangor (Location 5). Portable GPS was used to locateand fix all study sites. Table 1 illustrates the GPS locations and description of sampling areas along the coast of the Straits of Malacca at Peninsular Malaysia.All sampling at each location was carried out throughout the year fromMarch 2015 – April 2016 during the high tide.

2.2 Samples collection

In the distribution study samples collection was based on the information provided by the local clam collectors and carried out by simple random sampling [36] [37]. Samples collection was carried out for only three months where in each month, 45 samplings were collected. The location where it exhibited presence of the clams was noted down. For soil and water sampling, one transect line was selected within each location. Five sampling points were sampled along the transect line. Soil samples each approximately weighing 500 gm were collected using a scoop at 0.5 m depth and placed into a clear labelled sampling bag. Bottle used for storage of seawater samples were rinsed three times with the seawater. It was then submerged to a depth of 1m – 1.5m below the water level and allowed to fill completely to the top. The lid was then screwed on tightly to prevent leakage. Samples were kept out of direct sunlight. All these samples were kept into the ice box to prevent detrimental impact on biological indicator measurements during the transportation to the laboratory. The

samples were then stored at 4°C as soon as possible upon returning from the field until the analysis. However, physico-chemical parameters such as temperature, salinity, pH, DO and TDS were measured in-situ using the multisensory probes YSI Pro Plus. Soil property such as total N (%) was analysed using Leco CNS-2000 automated dry combustion instrument [38], extractable P (ug/g) and K (ug/g) were analysed using Bray-2 and ammonium acetate extraction method respectively [39]. Soil analysis was done at the laboratory of Centre of Tropical Soil Studies, University Putra Malaysia.

In life-cycle study, only planktonic animals were sampled using plankton net since the sessile animals were already sampled during the distribution study. The sampling used the systematic sampling [40] where it was done once a month at five points on one transect line (see Map 1).



Map 1: Locations of the study.

Table 1: GPS location and description of sampling areas along the coast of the Straits of Malacca, Peninsular Malaysia.

Sampling Area	GPS location	Description
Location 1 (Yan, Kedah)	Lat: 5.81°, Long: 100.36°	Several antrophogenic activities (urban, agriculture and aquaculture in river mouth areas)
Location 2 (Lekir, Perak)	Lat: 4.11°, Long: 100.73°	River mouth near to the agriculture area where the polluted effluent were discharged directly into the sea.
Location 3 (Sekinchan, Selangor)	Lat: 3.49°, Long: 101.09°	Closed to the river mouth where the effluent from industries and housing were discharged directly into the sea
Location 4 (Kuala Sepetang, Perak)	Lat: 4.86^{o} , Long: 100.54^{o}	Cockle culture areas, close to river mouth
Location 5 (Sungai Buluh, Selangor)	Lat: 3.19^{o} , Long: 101.31^{o}	Cockle culture areas, close to river mouth

III RESULTS AND DISCUSSION

3.1 Distribution and life-cycle of the *P. orientalis*

The distribution of *P.orientalis*in each site is shown in Fig. 1, Fig.2 and Fig. 3. For each site, a total of 135present-only data were collected for the period of three months. Most of the clams were discovered in area enclosed by the Latitudes A and B with distanceof about 200-700 m from the shorelines. The clams were almost absent outsidethe bounded area surveyed.

Figure1 : The presence of *P.orientalis* in Yan, Kedah.
A1= Lat. 5º 49' 25.33''N , B1=Lat. 5º 48' 28.09''N,
A2= Lat. 5º 47' 43.56''N, B2= Lat. 5º 47' 19.50'' N.

Figure 2 : The presence of P.orientalis in Lekir, Perak
A= Lat. 4º 06' 59.37''N , B= Lat. 4º 06' 32.88'' N.

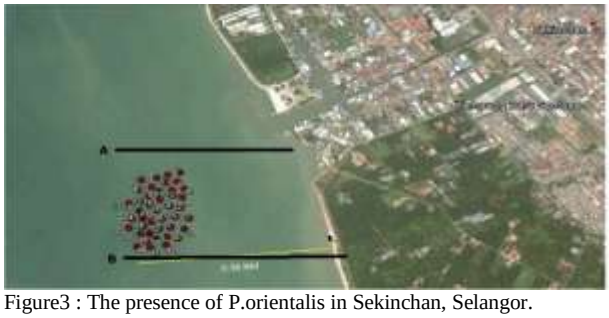


Figure3 : The presence of P.orientalis in Sekinchan, Selangor.
A= Lat. 3º 30' 03.06''N , B=Lat. 3º 29' 47.19''N.

Three developmental stages were easily identified, they are; adult stage, eggs and juvenile. In Yan, the adult stage was between October 2015 –March 2016, eggs released between July 2015-December 2015 and juvenile stage between August 2015-January 2016. In Lekir, the adult stage was between July 2015 –November 2015, eggs released between March 2015-July 2015 and juvenile stage between April 2015-August 2015.In Sekinchan, the adult stage was between March 2016 –May 2016, eggs released between December 2015-January 2016 and juvenile stage between January 2016-February 2016. Based on the studies by [8] and [17], the life-cycle of the *P. orientalis* at each location is thus proposed and shown in Fig. 4, 5 and 6.

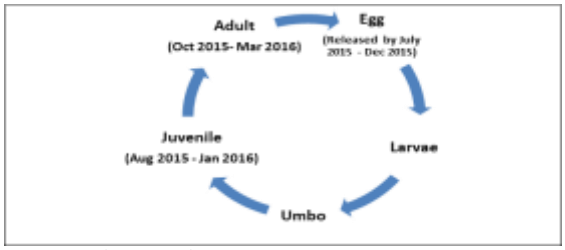


Figure 4:Life-cycle of *P. orientalis* in Yan

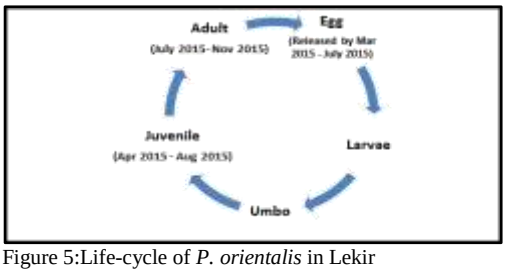


Figure 5:Life-cycle of *P. orientalis* in Lekir

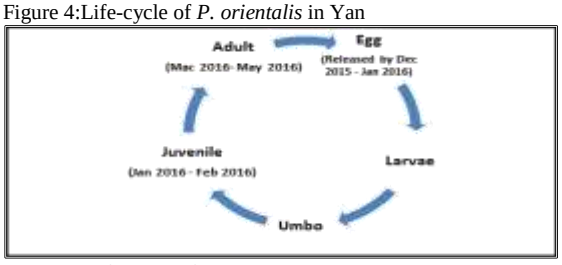


Figure 6 :Life-cycle of *P. orientalis* in Sekinchan

3.2 Habitats of *P. orientalis*

The characteristics of the natural beds studied in this research were habitat type, substrate type, vegetation found in or near the sampling area and species of mollusk found during or after the season of *P. orientalis* in the sampling areas. All these natural beds characteristics are shown in Table 2. *P. orientalis* were found in littoral locations of Yan, Lekir and Sekinchan (YLS). At Yan and Sekinchan, *P.orientalis*were found to burrow in a compact muddy sand covered with a thin layer of silt. A group of dead sponge was found near to the habitat of *P.orientalis* in these two areas. It was found about 50 m and 30 m respectively from the habitat area of *P.orientalis* at Yan and Sekinchan. At Lekir area, the bed was blackish compact muddy sand. No vegetation was found in this area. *P.orientalis* were found to burrow to a depth of about 0.3 m in a substrate in these three sampling locations.Others species of mollusk were found at the sampling location after the season of *P.orientalis*. They were *Paphia textile*, *Pernaviridis* and *Anadaragranosa*. *P.textile*, and *A.granosa* were found at all these three sampling locations while *P.viridis* were only found at Lekir and Sekinchan. Close to cockle culture areas, at the river mouth, both Kuala Sepetang (KS) and Sungai Buluh (SB)seabeds were characterised by blackish compact muddy sand with no vegetation found, however dominated by *A. granosa.* According to [5], muddy beds are suitable for the habitat of the clams.

Table 2: The characteristics of the natural bed of *P.orientalis* in study sites

Study site	Habitat type	Substrate type	Vegetation	Other mollusk species
Yan	Littoral area	Compact muddy sand covered with a thin layer of silt	None A group of dead sponge found about 50m from *P.orientalis* habitat.	*P. textile and A.granosa*were foundafter the season of p.orientalis
Lekir	Littoral area	Blackish compact muddy sand	None	*P. textile, P.viridis and A.granosa*were foundafter the season of p.orientalis
Sekinchan	Littoral area	Compact muddy sand covered with a thin layer of silt	None A group of dead sponge found about 30m from *P.orientalis* habitat	*P. textile, P.viridis and A.granosa*were foundafter the season of *P*orientalis
Kuala Sepetang	Littoral area	Blackish compact muddy sand	None	Dominated by*A.granosa*
Sungai Buluh	Littoral area	Blackish compact muddy sand	None	Dominated by*A.granosa*

3.3 Physico-chemical characteristics of water

The physico-chemical characteristics of water for YLSare shown in Table 3. The temperature range where*P. orientalis*was found, as recorded by this study,was between 30.3°C – 34.4°C. Both of the highest and the lowest temperature was recorded in Lekir at sites P9 and P7 respectively. Yan recorded the highest salinity ranged between 29.09 mg/l – 29.53 mg/l followed with Sekinchan with the range of 24.71mg/l- 26.23 mg/l. The salinity in Lekir was 20.08 mg/l - 21.33 mg/lwhich was slightly lower compared to other sampling locations. The pH values recorded in YLSranged from7.76 to 8.43. Dissolved oxygen (DO)vary greatly from the lowest value of 4.32 mg/l to the highest 9.93 mg/l both recorded in Lekir. The total dissolved solids (TDS) recorded for all sites ranged from 20858.50 mg/l to 29900 mg/l. Fig. 7 (temperature), Fig. 8 (salinity), Fig. 9 (pH), Fig. 10 (DO) and Fig. 11 (TDS) display graphically (by radar chart) the water parameters of SB and KS (KS) that fall within the ranges of the *P. orientalis* limits except in TDS where SB recorded the highest value of 38,700 mg/l. For the record, *P. orientalis* kept in captivity survived the following parameters; temperature at 27^{o} C – 29^{o} C, salinity at 36-38mg/l,DO at 4.05-6.42 mg/l and pH at 6.6-8.20 [23].Other studies informed that *P.orientalis* is generally found at salinities ranged from 30 mg/l to 35 mg/l[24] but in Malaysia, this marine bivalve species can be found at salinity ranged between 28 mg/l - 30 mg/l [18]. According to [24],*P.orientalis* can tolerate the pH about 7.8 -8.2, whereas, [16] stating that the optimum level of dissolved oxygen for the*P.orientalis*broodstock ranged from 4.05 mg/l – 6.42 mg/l. The ambient water temperature for *P.orientalis* ranged from 28°C to 30°C[24], where the optimal feeding activity of mature clams was obtained at temperature 27°C and salinity 35mg/l[41].

Table3 Thephysico-chemical parameters for the natural bed of *P.orientalis* in study sites..

Area	No.ofSites	temperature	Salinity	pH	DO Mg/L	TDS
K4	3	32.1	29.35	8.11	6.02	28393
K5		33.7	29.09	8.25	8.66	29510
K6		32.3	29.10	8.12	6.28	29900
P7	3	30.3	20.08	7.76	4.32	20858.5
P8		33.5	21.68	8.48	9.93	22653
P9		34.4	21.33	8.32	8.64	22204
S1	3	33.3	26.23	8.42	6.27	25928.5
S2		33.4	25.46	7.96	6.35	26156
S3		31.9	24.71	7.93	5.9	24628
Sg. Buluh	6	29-31	27-30	6.3-9.8	4.5-	28400-38700
K.Sepetang	6	29-33	26-28	8-9	8.33	23000-24556

Notes: Yan, Kedah – K4, K5 and K6, Lekir, Perak- P7,P8 and P9, Sekinchan, Selangor- S1, S2 and S3.

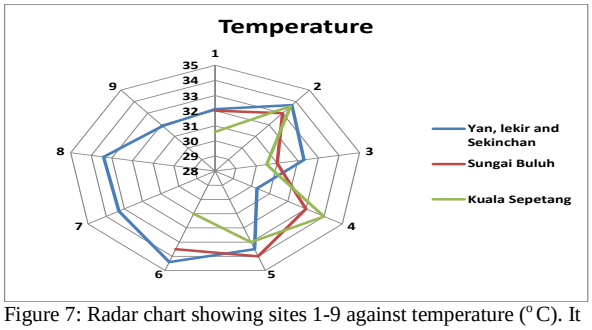


Figure 7: Radar chart showing sites 1-9 against temperature (^{o}C). It displays temperatures in both SB and KS are well within the range of YLS.

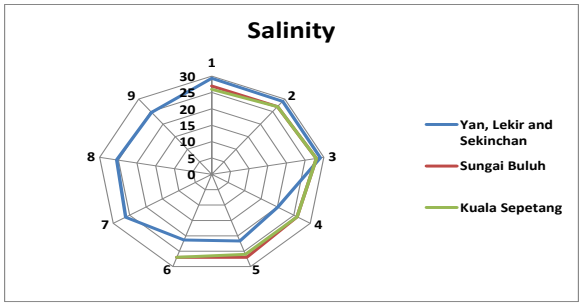


Figure 8:Radar chart showing sites 1-9 against salinity (mg/l). It displays salinity in both SB and KS are well within the range of YLS

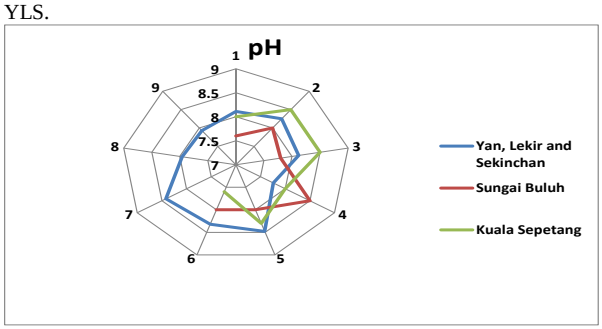


Figure 9:Radar chart showing sites 1-9 against pH. It displays pH in both SB and KS are well within the range of YLS

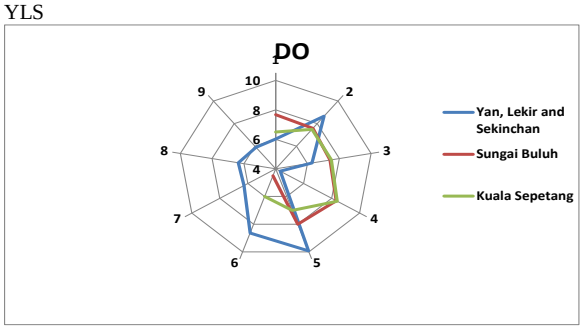


Figure 10:Radar chart showing sites 1-9 against dissolved oxygen (mg/l). It displays DO in both SB and KS are well within the range of YLS

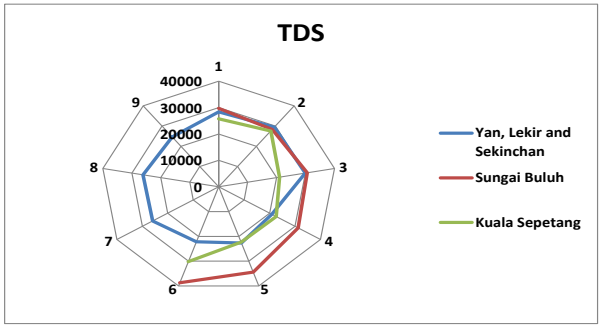


Figure 11:Radar chart showing sites 1-9 against total dissolved solid (mg/l).It displays higher TDS in SB than the rest of the sites.

3.4 Nutrient compositions of soil and the physico-chemical parameters for algal growth

The fertility of the soil[42]is very much influenced by the presence of the major nutrients; Nitrogen (N), Phosphorous (P) and Potassium (K). It was suggested by [43] that the fertilizer ratio of 7:7:7 may keep the algae at a healthy amount for marine life.These nutrients promote the growth of planktonic algae population that serves as food for primary consumers [42] including the clams. In study by [44], the clams kept in captivity survived highlyon algae such as *Chaetoceroscalcitrans* and *Tetraselmissuecica*at a rate of about 294 million cells per brood stock per day.Other molluscs such as *Congerialeucophaeate* (false mussel), *Brachidontesexustus*

(scorched mussel) and *Crassostreavirginica* (eastern oxyster) were found to feed on microalgae and detritus [45]. FAO suggested the following physico-chemicals parameters needed for optimum algal growth; salinity: 20-24 mg/l, temperature: 16^{o} C -35^{o} C, and pH : 8.2-8.7 [46] which are compatible with parameters obtained in SB and KS except in salinity where both locations showed slightly higher salinity range (26-30 mg/l). However, [47] found that ten strains belonging to six *Skeletonema* species grew well between salinities of 10 mg/l and 35 mg/l. The optimum pH for phytoplankton growth in laboratory is between pH 6.3 and 10 [48]. Table 4 shows the values of N (%), extractable P and K at YLS, SB and KS and displayed graphically (by radar chart) in Fig.12, 13 and 14. Higher N (%) and extractable P are observed in SB and KS compared to YLS. However, extractable K is higher at YLS compared to both SB and KS.

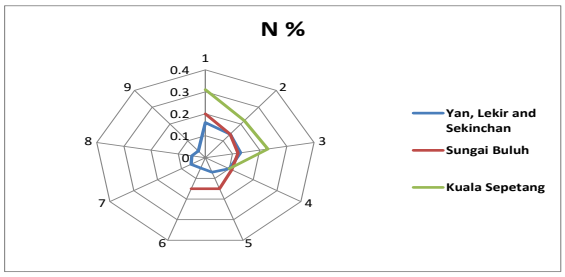


Figure 12: Radar chart showing sites 1-9 against Nitrogen %$.It displays higher N% at SB and KS compared to YLS.

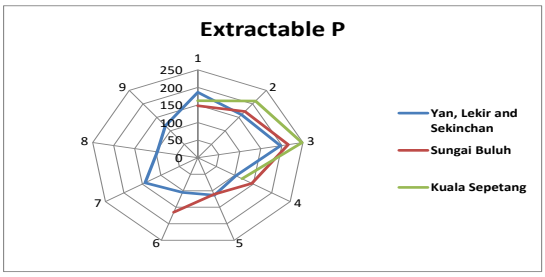


Figure 13:Radar chart showing sites 1-9 against extractable P. It displays higher extractable P at SB and KS compared to YLS.

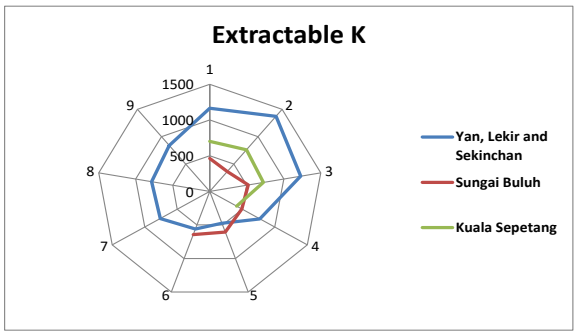


Figure 14 : Radar chart showing sites 1-9 against extractable K
It displays lower extractable K at SB and KS compared to YLS.

Table 4: N,P,K at three locations

Locations	Total N %	Extractable P(µg/g)	Extractable K(µg/g)
Yan, Lekir and Sekinchan	0.04-0.16	96.6-196.7	475.0-1374.0
Sungai Buluh	0.11-0.2	111.0-215.0	363.0-643.0
Kuala Sepetang	0.1-0.31	119.7-247.8	414.5-760.0

IV CONCLUSION

The proposed cultivation of *P. orientalis* must at the moment obtain the supply of seeds from the wild. The success of induced seed-production in the laboratory has been reported [20][21] but commercially-scaled aquaculture of the species currently is still absent although [7] had achieved between 0%-25% survival rate in their transplantation project in Western Visayas, Philippines. The potential of aquaculture of the clams is encouraging based on its high demand and reasonably good market value [18]. In addition, Malaysia's cockle production has been declining over the years [33] mainly due to pollution [49], therefore, a replacement species should be in the mind of the farmers as it happened in shrimps culture, where *Penaeus monodon* was replaced with a more resilient white shrimp, *Penaues* (*Litopenaues)vannamei*[50] after the former species was attacked by viral diseases and the production failed to recover [51]. It is therefore, proposed, that the new location for *P. orientalis* cultivation to be away from polluted areas.

Two locations have been identified by this study to be suitable for *P. orientalis* culture based on the resemblance in habitat, physico-chemicals and nutrients content compared to the areas known to harbour the clams. The first location is the inter-tidal areas of KS and the second location is at SB where both are dominated by cockles of species *A.granosa.*Obviously, *P. orientalis* is able to survive in a wide range of environmental parameters. In general, the physico-chemical parameters suitable for *P. orientalis*are as follow; temperature: 30^{o}C-34^{o}C, salinity, salinity: 20-29 mg/l, pH: 7.8-8.5, DO: 4.3 -9.9 and TDS: 20,858-29,510 mg/L. The nutrient levels needed for the growth of the phytoplankton are; Total N%: 0.0.4-0.16, extractable P:97-197µg/g and extractable K: 475-1374 µg/g.

Constant supply of seeds is most important for the success of clam culture. The usual practice is to collect juvenile clams from the natural beds and transfer it to the selected culture areas. Following the life-cycle study, the supply of seeds can be obtained in the months of August-Jan in Yan, April –August in Lekir, and Jan-February in Sekinchan. Since the production of seeds occurs almost year-round, farmer will have no problem in getting the seeds. This is quite promising for the success of *P. orientalis* culture in Malaysia.

Future study on *P.orientalis* should be in its mobility as during first few stages of its life-cycle, they are planktonic which may provide the answer for its non-existence in certain areas although the habitats are favourable for its growth. Growth-rate study is another scope which is important to determine the most optimal condition for the *P. orientalis* to survive. For aquaculture, *per se*, the study on its feeding to achieve optimum size using detritus balls [52] should also be carried out.

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