The impacts of monsoon and dry seasons on physical water quality changes and farmed Asian seabass *Lates calcarifer* (Bloch, 1790) mortality at Sri Tujuh lagoon, Tumpat, Kelantan, Malaysia

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Abstract. This study aimed to monitor the water quality in Sri Tujuh lagoon during monsoon and dry seasons, as well as the impact of the two seasons on the production of Asian seabass (*Lates calcarifer*). The water quality parameters such as temperature, pH, dissolved oxygen (DO), salinity, conductivity, turbidity and total dissolved solid of Sri Tujuh lagoon were assessed using water samples collected from 13 sampling points at 1ft, 4ft and 7ft water depth during dry season (March-August 2014) and monsoon (September-November 2014). Fish mortality was recorded from Asian seabass farmers in the lagoon. Water quality data during dry seasoon and monsoon was compared using T-Test and data from 3 different depths was analysed by using One Way Anova followed by Tukey test at $p < 0.05$. The water parameters in dry season, monsoon season, combination of dry and monsoon season were subjected to Pearson correlation analysis separately and a matrix was tabulated. Water parameters were also subjected to cluster analysis by using Ward's method with squared Euclidean distances as a measure of similarity. In the present study Ward's method was used ANOVA followed by Tukey post hoc in order to minimize the sum of squares. The result was represented by a dendrogram. The findings of the present study showed water parameters such as DO, salinity and turbidity were significantly different between dry and monsoon seasons. However no significant difference was found in term of fish mortality. The water parameters of Sri Tujuh lagoon during the study were as follow: temperature 29.4-33.3 ^{o}C; pH 7.0-9.3; DO 0.8-6.8 mg L^{-1}; salinity 10.7-31.3 ppt; conductivity 17.5-50.5 µs cm^{-1}; turbidity 5.4-59.8 NTU; TDS 23.3-32 ppt. The fish mortality was recorded ranging from 9.3 to 15.5% from March to November, 2014. The positive and significance ($p < 0.01$) correlation was recorded between temperature and pH (0.434), temperature and DO (0.472), DO and pH (0.315), salinity and pH (0.615), conductivity and pH (0.595), conductivity and salinity (0.992), TDS and pH (0.340), TDS and salinity (0.322) and TDS and conductivity (0.322). Fish mortality showed no correlation with all water parameters changing in the whole study at Sri Tujuh lagoon. Based on the water parameter records from 13 sampling stations, the sampling stations can be divided into 5 clusters. Cluster 1 possesses the greatest number of stations namely S3, S4, S6, S7, S8, S11 and S12 whereas Cluster 2 has S1, S10 and S13. Only one station was found in the Cluster 3 (S5), Cluster 4 (S2) and Cluster 5 (S9). Based on the findings of the present study, Sri Tujuh lagoon can be considered as one of the best places to conduct aquaculture activities in Kelantan.

Key Words: water quality, dry, monsoon, Asian seabass, lagoon.

Introduction. Malaysia is blessed with geographical location and plenty of water resources for aquaculture activities. In Malaysia, Perak and Selangor are the main producers of aquaculture products because there are plenty of water sources, suitable locations like ex-mining pond and a huge market demand of seafood. In Kelantan, Pasir Puteh, Bachok and Tumpat were identified as major aquaculture product producer districts (Department of Fisheries Kelantan State 2014). One of the famous locations for aquaculture activities is Sri Tujuh lagoon, located at Tumpat, Kelantan. Sri Tujuh lagoon is not only famous for its aquaculture and fisheries activities but also as a tourism spot. Sri Tujuh lagoon provided a platform to the nearby community to earn a living and improve their socio-economic status through aquaculture, fisheries and tourism. In present, both Semerak lagoon in Pasir Puteh and Sri Tujuh lagoon in Tumpat are the Kelantan's major fish producers, mainly for Asian seabass (*Lates calcarifer*) and tilapia (*Tilapi*a sp.). Both species are known for their tolerance to harsh environmental conditions and they can survive a wide temperature and salinities range thus make it possible to culture them in sea, brackish or fresh water using various farming systems such as ponds, sea cages and recirculating systems (Jensen et al 1998). Asian seabass and tilapia are tropical species requiring temperatures of 20-30°C, salinities of 0-30 ppt , DO ≥ 3.0 mg L^{-1} and pH 7.0-8.5 (DOF 2010; Athauda & Anderson 2014).

Seasonal variations during Northeast monsoon (November-March) in Kelantan cause survival rates of cage culture fish to decrease rapidly, stress-related mortalities and disease outbreaks are reported to frequently occur when water temperatures and salinity drop below optimum range during this monsoon period (Department of Fisheries Kelantan State 2014). Fish landing data by Kelantan's Department of Fisheries, shows that in 2009, more than 230 metric tonnes cultured fish were reportedly died during monsoon season which causes estimated losses around RM 1.9 million. Annually, farms at this lagoon are devastated by a massive loss of fish stock during monsoon and Department of Fisheries have rolled out appropriate initiatives (co-funding of fry restock and equipment) for affected farmers to resume operations as quickly as possible. Besides that, technical advice on the possible type of mitigation technique is also provided as a support for farmers to prepare for similar event in near future. However, in a long term there is a mound need for improvement of the current incentive. Intensive research in identifying the root cause of fish mortality during monsoon season is necessary so that sustainable and economical solution can be implemented to overcome this annual issue occurring at the Sri Tujuh lagoon cage culture. Hence, the present study was carried out to monitor the impact of monsoon and dry seasons on the water quality changing and Asian seabass production in Sri Tujuh lagoon, Tumpat, Kelantan. Aquaculture activities were introduced to lagoon since 1983. The main fish species are seabass, red tilapia and grouper (*Epinephelus* sp.), which are cultured using floating net cages. The local community carried out fish farming activities throughout the year and the production of fish, mainly Asian seabass, is promising. However, the fish production of lagoon is affected by season changing, especially during monsoon season. There is a record showing that huge farmed fish mortality was observed in monsoon season. It is also hypothesized that rapid changing of salinity, low oxygen level, high turbidity and ammonia are the factors contributing to fish mortality. However, till present no study was carried out to monitor water parameters changing during monsoon and dry season.

However, the production of Asian seabass is not consistent due to monsoon and dry seasons. Hence, the objectives of the present study are to monitor physical water quality of Sri Tujoh lagoon, Tumpat, Kelantan during monsoon and dry seasons and to study the effects of monsoon and dry seasons on farmed Asian seabass production in the same location.

Material and Method

Study area. Study area was located on the north east coast of Peninsular Malaysia, in the state of Kelantan. Total area of the lagoons is 24 hectare (Figure 1) and it is connected to the open sea by an opening in it bordering sand bar. This study area was selected because of the high landed value to the marine aquaculture production in Kelantan. Survey data from Kelantan's Department of Fisheries showed 20,154 m^2 was used as cultured area in the lagoons in 2013 (Department of Fisheries Kelantan State 2014). However there is limited information and scientific evidence to proof high mortality rate of cultured fish during monsoon season. In Sri Tujoh lagoon, the farmers used floated cages made of galvanised iron and PU buoy. The normal size of the cage was 8ft × 8ft with 4ft depth of the nets. Farmers started to farm fish in March to November. The size of Asian seabass fingerling was about 3 inches. Farmers used formulated feed and the fish were harvested from 500 g and above. This study involved a sampling period of 8 months beginning on April 2014 to November 2014 and thirteen

(13) stations were selected as the sampling points. Geographical coordinates of sampling sites were marked using a Global Positioning System (GPS) (Table 1).

Figure 1. Study area in Sri Tujoh Lagoon, Tumpat, Kelantan, Malaysia.

Table 1

GPS position for every sampling stations in study area

Station	*GPS position*
Station 1	N 06°12'56.8"; E 102°09'26.4"
Station 2	N 06°12'20.5"; E 102°09'45.3"
Station 3	N 06°12'30.7"; E 102°09'25"
Station 4	N 06°12'34"; E 102°09'11.8"
Station 5	N 06°12'41.6"; E 102°08'55.8"
Station 6	N 06°12'30.3"; E 102°08'43.9"
Station 7	N 06°12'43.7"; E 102°08'20.2"
Station 8	N 06°12'46.8"; E 102°08'13.4"
Station 9	N 06°12'50.3"; E 102°08'7.3"
Station 10	N 06°12'43.3"; E 102°08'0.25"
Station 11	N 06°12'48.2"; E 102°07'58.2"
Station 12	N 06°12'51.7"; E 102°07'52.6"
Station 13	N 06°12'52.9"; E 102°07'42.3"

Sampling stations were selected based on different water depths during tide as suggested by the local fishermen. Due to shallow water (below than three feet) sampling was impossible at certain locations of the lagoon and small boat was used for boating in water depth with below than two feet of draft (Figure 2) (Table 2).

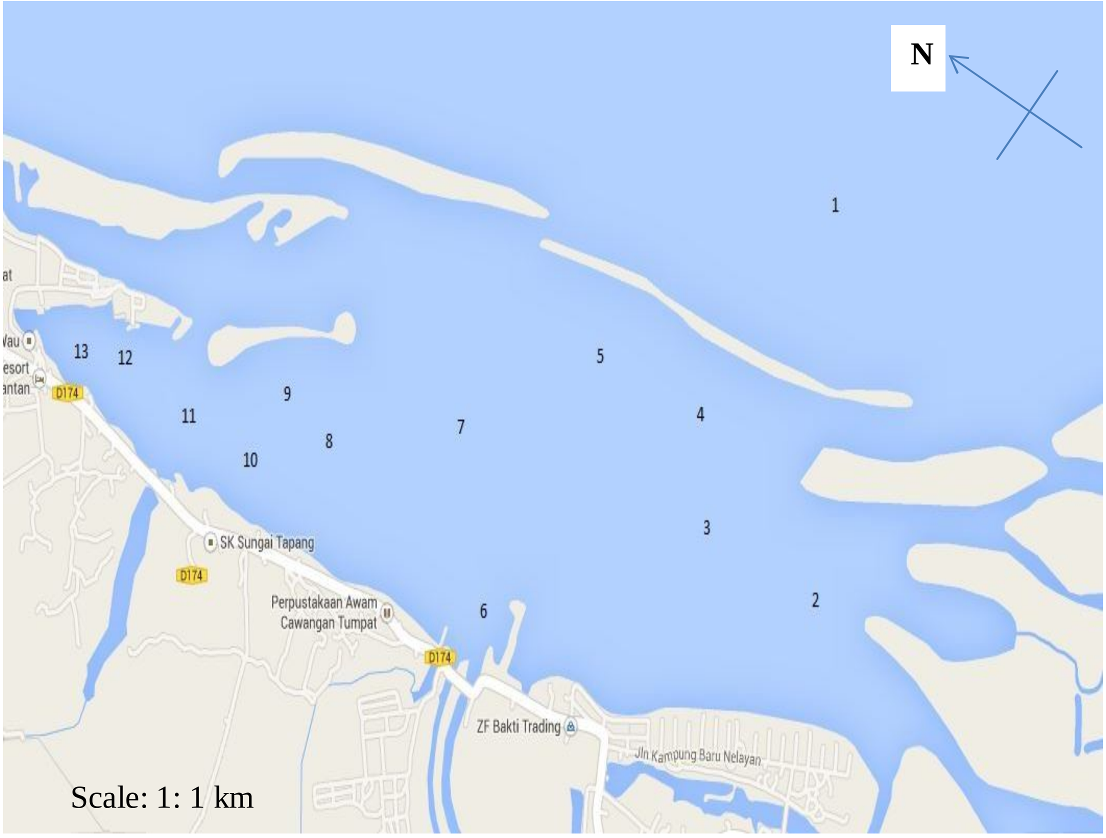

Figure 2. Thirteen (13) sampling stations in the study area.

Table 2

Thirteen (13) sampling stations description and sampling water depth

Station	*Sampling water depth*	*Description*
Station 1	1 ft, 4ft and 7 ft	Open sea; source of seawater to the lagoon during tide
Station 2	1 ft, 4ft and 7 ft	One of the main freshwater sources where upstream water discharged to the lagoon; the freshwater flows from Kelantan; river then dispersed into small rivers and flow to the South China Sea
Station 3	1 ft, 4ft and 7 ft	Sand dredger was located in this station; lateral mixing area with heavy water flow during tide
Station 4	1 ft, 4ft and 7 ft	Nature area for oyster seed in this lagoon; oyster seed is successful at this area due to transplanting initiative taken by the Department of Fisheries in 1986
Station 5	1 ft, 4ft and 7 ft	Nature area for oyster seed in this lagoon
Station 6	1 ft, 4ft and 7 ft	Source of freshwater from 2 flood gates manage by Department of Drainage and Irrigation Kelantan State and KADA; the source of freshwater from both of these gates came from agricultural activities discharge, flood discharge and urban settlement
Station 7	1 ft, 4ft and 7 ft	As the midstream between nature area for oyster seed and fish culture area
Station 8	1 ft, 4ft and 7 ft	Fish culture area
Station 9	1 ft , 4 ft and 7 ft	Fish culture area
Station 10	1 ft and 4ft	Fish cage
Station 11	1 ft, 4ft and 7 ft	Source of freshwater from water gate managed by and KADA; the source of freshwater from this gate came from agricultural activities discharge, flood discharge and urban settlement
Station 12	1 ft, 4ft and 7 ft	Source of water discharge from chalets, restaurants and stalls
Station 13	1 ft, and 4ft	Fish cage

Water sampling and analysis. In the present study, water parameters namely salinity, pH, water depth, dissolved oxygen (DO), turbidity, conductivity, total dissolved solid and temperature were monitored (Table 3). Water were sampled based on 1 ft, 4 ft and 7 ft depth which represent surface water, mid water and bottom water. In this study all the parameters except for turbidity were measured in-situ using multi parameter (YSI Multi Probe System Model YSI 556 MPS, USA) following manufacturer manual. This equipment was calibrated in the laboratory prior to sampling. The multisensory probe was immersed directly into sampling area at water depth 1 ft, 4 ft and 7 ft accordingly. For turbidity analysis, water samples were collected using vertical Van Dorn water sampler and immediately transferred into 1 L polyethylene bottle and labelled for each station. The samples were then measured using HACH Portable Turbiditimeter Model 2100P ISO following manufacturer instruction. The results of the water quality were compared to Malaysia water quality standards (DOE 2006) (Table 4).

Table 3

The water quality parameters and analytical methods in the present study

Parameters	*Analytical method*	*Unit*
Salinity	Salinity probe	ppt
pH	pH probe	
Dissolved oxygen	Oximeter	mg L^{-1}
Turbidity	Turbidimetry	NTU
Conductivity	Conductometry	µs cm^{-1}
Total dissolved solid	Gravimeter	mg L^{-1}
Temperature	Temperature probe	^{o}C

Table 4

Malaysia National Water Quality Standards (NWQS)

Parameter	*Unit*	*Class*					
		I	*IIA*	*IIB*	*III*	*IV*	*V*
Dissolved oxygen	mg L^{-1}	7	5-7	5-7	3-5	< 3	< 1
pH	-	6.5-8.5	6-9	6-9	5-9	5-9	-
Electrical conductivity	µs cm^{-1}	1000	1000	-	-	6000	-
Total dissolved solid	mg L^{-1}	500	1000	-	-	4000	-

Collection of fish mortality data. The fish mortality data collection was focused on Asian seabass because 95 % of fish production in Sri Tujuh Lagoon is Asian seabass. The total fish mortality was obtained and recorded from 72 Asian seabass fish farmers that use cage farming system. The data collection was carried out from March to November 2014.

Data analysis. Water quality data from 13 stations were recorded, summarised and analysed using SPSS version 23 to compare data during dry seasoon and monsoon (T-Test) and data from 3 different depths (One Way Anova followed by Tukey test) at $p < 0.05$. The water parameters pearson correlation matrix was analysed by SPSS version 23 and tabulated in Tables 5 and 6. Water parameters were subjected to hierarchical cluster analysis by using Ward's method with squared Euclidean distances as a measure of similarity. In the present study Ward's method was used ANOVA followed by Tukey post hoc in order to minimize the sum of squares. The result was represented by a dendrogram.

Results. This study showed Sri Tujuh Lagoon depth varies from 4 to 12 ft. The deepest recorded at S2 and S12. Shallow depth recorded at S3-S6 was expected to cause the incomplete marine flushing process as low depth because the efficiency of the marine flushing depend on the changes in water depth close to open sea. There are four main activities operating in the vicinity of the lagoon area: (i) recreation and tourism; (ii) paddy cultivation and tobacco planting; (iii) aquaculture and capture fisheries; and (iv) urban settlement.

Water parameters of the 13 stations were tabulated in the Tables 5 and 6. Based on Malaysia National Water Quality Standards (DOE 2006), Sri Tujuh Lagoon is suitable to carry out aquaculture activities. However, the water quality of the some sampling stations (S2, S6, S9, S10, S11, S12 and S13) were found deteriorated during monsoon seasoon in which fluctuation of DO, salinity, TDS and turbidity were detected where the values of the water parameters (DO and salinity) were under critical point.

The temperature of the sampling stations ranged from 29.4 to 31.0^{o}C and 30.2 to 33.3^{o}C during flood tide and ebb, respectively in dry season, whereas 29.2 to 30.9^{o}C and 30.0 to 33.1^{o}C during flood tide and ebb, respectively in monsoon season. There is no significant difference at $p < 0.05$ in temperature between ebb and flood tide, dry and monsoon seasons and among water levels.

The water pH of Sri Tujuh lagoon ranged from 8 to 9.3 and 8.3 to 9.2 during flood tide and ebb, respectively in dry season, at the mean time, pH values ranged from 7.0 to 9.0 and 7.3 to 9 during ebb and flood tide, respectively in monsoon seasoon. There is no significant difference at $p < 0.05$ in pH between ebb and flood tide, dry and monsoon seasons and among water levels.

The results of DO of the present study revealed that DO ranged from 1.4 to 6.8 mg L^{-1} and 2.3 to 5.7 mg L^{-1} during ebb and flood tide in dry season, whereas 1.5 to 6.7 mg L^{-1} (ebb) and 0.8 to 4.68 mg L^{-1} (flood tide) in monsson season. The values of DO were found significantly different between monsoon season in the sites namely S1, S2, S3, S4, S5, S7, S6, S9 and S12.

Salinity records in the Sri Tujuh lagoon showed no significant difference at $p < 0.05$ between ebb and flood tide, but salinity fluctuation has significant difference at $p < 0.05$ in all sampling stations except for S7 between monsoon and dry season. The salinity was ranging from 17.3 to 31.3 ppt and 10.7 to 28.4 ppt during flood tide and ebb, respectively in monsson season, whereas salinity changing was recorded 19.7 to 31.8 ppt and 22.0 to 31.9 ppt during flood tide and ebb, respectively during dry season.

The water conductivity from sampling stations ranged from 28.6 to 50.3 µs cm^{-1} and 17.5 to 46.2 µs cm^{-1} during flood tide and ebb, respectively in monsoon season. On the other hand, water conductivity in dry seasoon was ranging from 32.5 to 50.5 µs cm^{-1} and 36.4 to 48.8 µs cm^{-1} during flood tide and ebb, respectively. Water conductivity is significantly different in the sampling stations S1, S2, S3 and S12 between monsoon and dry seasons.

Turbidity of the water in Sri Tujuh lagoon revealed significant difference at $p < 0.05$ between dry and monsoon seasons in the sampling stations of S1, S2, S3, S5, S7, S9 and S13. The turbidity reading ranged from 5.4 to 59.8 NTU and 6.6 to 33.8 NTU for flood tide and ebb, respectively in monsoon season. Whereas turbidity reading were recorded from 5.1 to 52.1 NTU and 5.8 to 53.1 NTU for flood tide and ebb in dry season. Only sampling stations S1, S2, S3, S4 and S5 were showed significant difference in TDS reading between dry and monsoon seasons. The TDS reading recorded from 25.6 to 32 ppt and 23.3 to 30.9 ppt for flood tide and ebb, respectively in dry season. Whereas 18.6 to 30.8 ppt and 11.3 to 30.8 ppt for flood tide and ebb, respectively during monsoon season.

There is no significant diference at $p < 0.05$ in fish mortality between dry and monsoon seasons (Table 7). The fish mortality was recorded ranging from 9.3 to 15.5% from March to November, 2014.

Table 5

Mean ± SD of temperature, pH, dissolved oxygen from 13 stations (dry season March-August 2014 vs monsoon season September-November 2014)

Station	*Temperature (^oC)*		*pH*		*Dissolved oxygen (mg L^{-1})*	
	Dry season	*Monsoon season*	*Dry season*	*Monsoon season*	*Dry season*	*Monsoon season*
S1 1ft (flood tide)	31.0±0.46	29.3±0.97	9.0±0.26	7.8±2.02	5.7±0.54	3.2±1.75*
Ebb	32.9±0.53	31.0±0.43	8.9±0.21	8.0±1.41	5.1±1.66	3.2±1.68*
4 ft (flood tide)	31.0±0.39	30.0±0.29	9.0±0.26	8.0±1.78	5.6±0.47	3.2±1.81*
Ebb	33.1±0.86	33.1±0.86	8.9±0.22	8.9±0.22	4.8±1.51	4.8±1.51
7 ft (flood tide)	31.1±0.55	-	8.8±0.57	-	5.4±0.97	-
S2 1ft (flood tide)	31.0±0.39	29.5±0.87	8.9±0.31	7.8±1.99	4.9±0.28	3.5±2.19
Ebb	32.6±0.51	31.2±0.35	8.9±0.18	8.0±1.35	6.2±2.94	3.0±1.69*
4 ft (flood tide)	30.9±0.28	30.9±0.28	9.0±0.32	9.0±0.32	4.3±1.14	4.3±1.14
Ebb	31.5±0.46	30.0±0.61	8.9±0.20	8.1±1.41	5.0±1.98	2.9±1.78*@
7 ft (flood tide)	31.0±0.27	31.0±0.27	9.0±0.30	9.0±0.30	4.4±1.33	4.4±1.33
Ebb	31.3±0.34	29.8±0.27	8.9±0.22	8.2±1.18	4.4±1.49	2.8±1.12*@
S3 1ft (flood tide)	31.0±0.47	29.8±0.33	9.1±0.25	7.7±2.26	5.7±0.23	3.5±2.13*
Ebb	33.2±1.13	31.5±1.49	8.9±0.20	8.1±1.34	5.5±1.69	3.4±1.96*
4 ft (flood tide)	31.1±0.27	-	9.2±0.30	-	4.6±2.59	-
S4 1ft (flood tide)	31.1±0.43	29.8±0.34	9.1±0.27	8.0±1.89	5.4±0.46	3.0±1.94*
Ebb	33.3±0.76	31.7±0.52	8.9±0.25	8.2±1.38	5.1±1.52	3.8±2.64*
4 ft (flood tide)	31.1±0.40	29.63	9.3±0.14	8.02	4.8±0.61	4.68
S5 1ft (flood tide)	31.0±0.51	29.6±0.47	9.1±0.46	8.0±1.86	5.5±0.52	3.1±2.02*
Ebb	32.9±0.42	31.7±0.59	8.9±0.26	8.2±1.36	4.9±2.94	3.8±2.64*
4 ft (flood tide)	31.0±0.39	29.39	9.1±0.48	7.97	5.1±0.54	4.59
S6 1ft (flood tide)	30.9±0.39	29.5±0.29	9.1±0.26	7.7±1.99	4.4±1.30	2.7±1.60*@
Ebb	33.1±0.48	33.1±0.48	9.0±0.29	9.0±0.29	6.7±1.51	6.7±1.51
4 ft (flood tide)	31.0±0.56	30.9±0.56	9.1±0.26	9.1±0.26	4.9±0.54	4.9±0.54
S7 1ft (flood tide)	29.9±0.49	29.2±0.32	9.2±0.07	7.9±1.84	5.0±0.30	3.3±2.11*
Ebb	32.3±0.71	31.7±0.44	9.1±0.23	8.5±1.16	6.0±2.20	4.6±3.14
4 ft (flood tide)	29.9±0.16	28.86	9.3±0.19	7.93	4.4±0.72	4.56
S8 1ft (flood tide)	29.9±0.37	29.5±0.60	9.2±0.07	7.3±2.86	4.9±0.26	4.6±2.92
Ebb	32.3±0.58	31.8±0.35	9.1±0.24	8.6±1.00	6.4±2.72	5.6±4.18
4 ft (flood tide)	29.8±0.48	29.6±0.82	9.3±0.08	8.2±1.40	4.0±0.37	4.0±2.57
Ebb	-	31.51	-	8.69	-	4.42
S9 1ft (flood tide)	29.4±0.24	29.4±0.24	8.0±1.76	8.0±1.76	4.3±2.74	4.3±2.74
Ebb	32.0±0.59	31.6±0.17	9.1±0.24	8.5±0.88	6.8±2.64	5.4±3.79
4 ft (flood tide)	29.8±0.48	30.0±1.34	9.2±0.08	8.0±1.66	4.1±0.52	2.3±1.85*@
Ebb	30.6±0.25	30.0±0.57	9.1±0.23	8.3±1.07	3.7±1.48	2.0±1.24*@
7 ft (flood tide)	30.0±0.42	30.45	9.3±0.11	9.67	3.5±0.29	0.87*@
S10 1ft (flood tide)	31.2±0.14	30.6±0.48	9.3±0.13	7.9±1.77	4.3±0.34	2.7±2.07@
Ebb	32.3±0.51	32.0±1.34	9.2±0.18	8.6±0.96	6.6±2.32	4.2±2.66
4 ft (flood tide)	30.4±0.80	30.2±1.36	9.2±0.13	7.9±1.72	2.3±1.21@	1.4±0.55@
Ebb	31.3±0.30	31.3±0.30	9.0±0.11	9.0±0.11	1.5±0.30@	1.5±0.30@
S11 1ft (flood tide)	30.2±0.27	30.2±0.18	9.2±0.11	7.9±1.85	5.2±0.11	4.0±2.34
Ebb	32.4±0.51	31.9±0.35	9.1±0.25	8.5±0.94	5.6±2.76	5.4±3.91
4 ft (flood tide)	29.90.46	29.8±1.05	9.20.10	7.9±1.71	2.80.14	1.9±1.17
Ebb	30.5±0.54	30.0±0.81	9.1±0.24	8.4±1.02	3.7±0.34	2.6±1.53
S12 1ft (flood tide)	30.9±0.39	30.1±0.35	9.2±0.09	7.9±1.83	5.7±0.23	4.5±3.04
Ebb	32.4±0.57	32.1±1.27	9.1±0.25	8.6±0.88	5.7±3.64	4.7±3.35
4 ft (flood tide)	30.5±0.13	30.5±1.37	9.2±0.09	7.8±1.74	2.5±0.12@	1.4±0.16@
Ebb	30.6±0.25	30.1±0.96	9.1±0.25	7.0±3.23	3.6±0.75	4.4±3.39
7 ft (flood tide)	30.2±0.50	29.8±1.09	9.2±0.17	7.9±1.64	3.8±0.58	1.7±0.96*
Ebb	30.2±1.76	-	8.3±0.53	-	5.4±1.26	-
S13 1ft (flood tide)	30.4±0.24	30.3±0.29	9.2±0.10	7.6±1.74	2.5±0.15@	2.6±0.94@
Ebb	32.1±0.35	31.8±0.78	9.1±0.25	8.4±1.07	2.1±1.52@	3.4±2.33
4 ft (flood tide)	30.9±0.10	30.8±1.43	9.3±0.08	7.8±1.67	1.4±0.23@	1.6±0.36@
Ebb	30.9±0.22	30.4±1.26	9.1±0.24	8.3±1.10	1.5±0.27@	1.6±0.38@

*Data has significantly ($p < 0.05$) different compared to dry season vs monsson seasson;
@Critical point which is not suitable for aquaculture activity;
- No test.

Table 6

Mean ± SD of salinity, conductivity, turbidity & total dissolved solid from 13 stations (dry season March-August 2014 vs monsoon season September-November 2014)

Station	*Salinity (ppt)*	*Conductivity (µs cm^{-1})*	*Turbidity (NTU)*	*Total dissolved solid (ppt)*	*Salinity (ppt)*	*Conductivity (µs cm^{-1})*	*Turbidity (NTU)*	*Total dissolved solid (ppt)*
	Dry season	*Monsoon season*	*Dry season*	*Monsoon season*	*Dry season*	*Monsoon season*	*Dry season*	*Monsoon season*
S1 1ft (flood tide)	31.8±0.56	22.0±12.79[@]	48.6±1.54	34.6±18.81	7.5±5.25	59.8±79.21*[@]	32.0±0.58	22.5±12.26
Ebb	22.0±3.09	12.8±8.03*[@]	36.4±3.52	20.7±12.12*	19.7±3.08	21.8±9.65	23.2±2.53	13.5±8.02*
4 ft (flood tide)	31.9±0.59	29.3±2.38	49.6±1.57	45.5±3.31	7.2±4.73	19.5±12.48*[@]	32.2±0.70	29.6±2.15
Ebb	28.3±1.21	28.3±1.21	45.4±2.79	45.4±2.79	40.7±15.18[@]	40.7±15.18[@]	28.8±1.21	28.8±1.21
7 ft (flood tide)	32.0±0.47	-	50.5±1.02	-	8.5±2.76	-	32.4±0.30	-
S2 1ft (Flood tide)	26.2±2.52	17.8±10.10*[@]	43.4±4.86	28.6±15.07*	14.0±5.02	22.2±9.26*	27.1±2.38	18.6±10.08*
Ebb	23.7±3.16	10.3±7.18*[@]	39.8±6.55	17.7±11.57*	24.0±6.56	28.6±15.58[@]	24.6±3.02	11.3±7.57*
4 ft (flood tide)	30.4±1.30	30.4±1.30	48.8±3.57	48.8±3.57	15.1±4.64	15.1±4.64	30.8±1.26	30.8±1.26
Ebb	29.7±0.98	22.1±8.41[@]	47.6±3.61	35.7±11.29	20.7±3.41	23.9±10.21[@]	29.9±0.93	22.9±7.99
7 ft (flood tide)	31.3±0.78	31.3±0.78	50.3±2.99	50.3±2.99	14.2±5.70	14.2±5.70	31.6±0.81	31.6±0.81
Ebb	30.8±0.58	24.4±7.72[@]	48.8±3.09	38.9±9.46	52.9±42.77[@]	21.3±13.58*[@]	30.9±0.53	25.1±7.33
S3 1ft (flood tide)	31.2±1.12	20.7±13.72[@]	48.2±1.84	33.0±20.23	23.1±24.36[@]	13.7±4.96*	31.4±1.05	21.3±13.40
Ebb	29.2±1.85	10.7±12.19*[@]	46.3±3.55	17.5±19.06*	26.4±6.26	33.8±22.43[@]	29.5±1.63	11.4±12.42*
4 ft (flood tide)	31.6±0.66	-	49.9±3.37	-	13.9±6.36	-	31.6±0.61	-
S4 1ft (flood tide)	31.8±0.53	20.6±14.64[@]	49.2±1.57	32.4±21.75	12.3±9.39[@]	14.3±5.54	31.8±0.47	20.9±14.38
Ebb	28.0±1.68	16.6±10.40*[@]	45.4±3.47	27.2±15.45	26.2±11.34[@]	28.3±13.16[@]	28.5±1.52	17.5±10.41*
4 ft (flood tide)	31.9±0.26	29.09	49.2±0.36	45.16	12.7±11.19[@]	17.6	32.0±0.24	29.36
S5 1ft (flood tide)	30.3±1.90	21.2±12.18[@]	47.3±1.87	33.8±17.63	18.4±14.18[@]	19.8±6.86	30.5±1.70	21.8±11.88
Ebb	28.4±0.85	15.4±10.03*[@]	46.0±3.67	25.9±13.98	53.1±18.12[@]	33.5±8.18*	28.8±0.68	16.4±9.89*
4 ft (flood tide)	30.5±2.04	28.93	47.7±1.94	44.92	17.7±10.75[@]	22.3	30.7±1.90	29.2
S6 1ft (flood tide)	30.0±0.67	17.3±14.63*[@]	47.7±2.56	27.3±22.89	13.4±3.60	20.11±7.04	30.2±0.55	17.8±14.90*
Ebb	28.4±1.85	28.4±1.85	46.2±4.40	46.2±4.40	29.0±6.82	29.0±6.82	28.8±1.67	28.8±1.67
4 ft (flood tide)	31.4±0.42	31.4±0.42	48.7±0.96	48.7±0.96	23.1±8.67	23.1±8.67	31.5±0.37	31.5±0.37
S7 1ft (flood tide)	27.8±0.58	18.9±8.83*[@]	43.4±0.75	30.8±12.41	15.6±0.72	12.0±2.25	28.3±0.53	19.8±8.50
Ebb	26.8±0.65	19.6±8.13*[@]	42.5±0.27	32.9±9.85	10.1±2.85	16.1±5.32	27.4±0.56	20.4±8.12
4 ft (flood tide)	31.3±0.62	28.55	48.2±0.88	44.34	52.1±30.19[@]	22.1*	31.3±0.57	28.88
S8 1ft (flood tide)	27.2±0.22	19.5±9.00*[@]	42.9±0.56	31.5±12.73	17.9±7.56	18.9±15.93[@]	27.7±0.21	20.2±8.76
Ebb	26.6±0.91	19.4±8.10*[@]	42.2±0.92	31.8±11.02	10.4±3.95	9.0±2.05	26.9±1.35	20.3±7.85
4 ft (flood tide)	30.7±0.11	26.0±2.38	47.4±0.25	42.6±1.52	37.3±30.17	13.1±7.00*	30.8±0.13	26.4±2.26
Ebb	-	29.45	-	52.50	-	23.50	-	29.76
S9 1ft (flood tide)	19.7±6.95	19.7±6.95[@]	32.5±8.45	32.5±8.45	7.9±1.51	7.9±1.51	20.8±6.32	20.8±6.32
Ebb	27.7±0.39	20.0±7.24[@]	43.6±0.88	33.5±9.08	8.3±1.41	6.6±2.51	28.2±0.39	21.1±6.79

4 ft (flood tide)	30.5±0.16	26.8±1.75	47.2±0.12	43.2±0.77	22.6±7.51	12.9±7.42*@	30.7±0.18	27.2±1.64
Ebb	31.1±0.08	27.1±2.41	47.9±0.15	43.9±0.78	13.4±2.54	14.4±8.25@	31.2±0.09	27.7±2.06
7 ft (flood tide)	31.2±0.20	29.68	48.0±0.36	46.02	27.7±11.78@	8.25*	31.4±0.12	29.91
S10 1ft (flood tide)	26.2±0.59	20.0±7.32@	41.6±0.71	33.0±9.35	7.9±5.80	9.5±2.27	26.7±0.45	21.0±6.91
Ebb	26.9±1.85	18.8±10.62*	42.2±2.39	30.9±14.67	5.8±0.40	7.1±3.03	27.4±1.69	19.7±10.28
4 ft (flood tide)	29.4±0.66	26.4±1.69	46.2±1.00	42.7±1.12	8.5±3.59	5.4±0.80	29.6±0.75	26.9±1.60
Ebb	28.3±0.68	28.3±0.68	44.6±1.91	44.6±1.91	6.4±2.40	6.4±2.40	28.7±0.54	28.7±0.54
S11 1ft (flood tide)	25.0±2.10	20.5±5.58	40.6±1.27	33.9±6.60	7.6±3.55	7.7±0.34	25.6±1.89	21.4±5.36
Ebb	26.3±1.63	20.6±5.90	42.0±1.29	33.3±8.41	7.0±0.98	9.0±2.79	26.8±1.39	21.4±5.89
4 ft (flood tide)	29.10.11	26.0±1.34	45.50.28	42.3±1.29	14.3±0.92	11.8±3.14	29.50.18	26.6±1.21
Ebb	30.9±0.23	27.2±1.97	47.6±0.18	43.9±0.34	10.4±1.25	9.2±1.13	31.1±0.20	27.7±1.73
S12 1ft (flood tide)	26.0±0.66	20.2±5.48	41.5±0.11	33.4±6.57	5.8±2.06	6.9±1.80	26.7±0.48	21.1±5.27
Ebb	27.2±0.75	19.5±9.65*@	42.5±0.95	31.8±13.43*	6.2±0.63	7.5±3.30	27.7±0.59	20.3±9.28
4 ft (flood tide)	29.0±0.47	26.1±0.99	45.3±0.47	42.3±1.11	10.6±2.24	11.7±6.51@	29.3±0.42	26.6±0.94
Ebb	30.1±0.48	27.3±1.64	46.9±0.61	44.1±0.31	8.7±0.17	13.1±5.96	30.4±0.41	27.7±1.49
7 ft (flood tide)	30.2±1.50	27.7±1.23	47.6±0.72	44.6±0.88	14.5±1.01	13.8±2.17	30.4±1.35	28.1±1.14
Ebb	28.5±1.40	-	47.1±6.05	-	9.1±0.58	-	28.8±1.31	-
S13 1ft (flood tide)	24.9±1.53	20.4±5.99	40.2±1.07	33.6±7.20	5.1±2.05	12.2±4.18	25.6±1.29	21.0±6.10
Ebb	28.1±0.45	20.7±9.69@	44.0±0.57	33.6±13.30	8.8±4.34	9.4±6.15	28.6±0.30	21.3±9.38
4 ft (flood tide)	28.9±0.58	25.9±1.31	45.1±0.63	42.2±1.34	17.8±5.09	7.5±7.85*@	29.2±0.51	26.5±1.07
Ebb	30.1±0.70	27.3±1.28	46.7±0.86	44.2±0.78	13.5±1.10	6.6±6.04*@	30.3±0.64	27.8±1.15

*Data has significantly ($p < 0.05$) different compared to dry season vs monsson seasson;
@Critical point where has huge salinity and turbidity fluctuation.

Table 7

Number of total farmed and total of mortality of Asian seabass in March – August (dry season); September-November (monsoon season) 2014 at Sri Tujoh Lagoon, Tumpat Kelantan

Months	*Total of farmed fish*	*Total of dead fish*	*Percentage (%) of fish mortality*
March	343891	36467	10.6
April	307424	31050	10.1
May	276374	28845	10.4
June	247529	22985	9.3
July	224544	24949	11.1
August	194484	30060	15.5
Total in dry season	1250355	137889	11.0
September	175036	19448	11.1
October	157533	17503	11.1
November	141780	15753	11.1
Total in monsoon season	474349	52704	11.1

During the dry season in Sri Tujuh Lagoon showed there are strong correlation between the changing of DO and temperature (0.429), salinity and pH (0.378), conductivity and salinity (0.980), TDS and salinity (0.391) and conductivity and TDS (0.417) in which the correlations were significantly different at $p < 0.01$ (Table 8). Fish mortality showed no correlation with all water parameters changing in dry season at Sri Tujuh lagoon.

In the monsoon season, the highest and significant at $p < 0.01$ water parameters changing correlation was observed between TDS and salinity (1.0) (Table 9). This was followed by TDS and conductivity (0.993), conductivity and salinity (0.992), temperature and pH (0.588) and temperature and DO (0.384). Other significant correlations ($p < 0.05$) were observed between pH and salinity (0.347), pH and conductivity (0.353) and pH and TDS (0.349). Table 10 showed correlation of the changing of water parameters and Asian seabass mortality in dry and monsson seasons. The positive and significant ($p < 0.01$) correlation was recorded between temperature and pH (0.434), temperature and DO (0.472), DO and pH (0.315), salinity and pH (0.615), conductivity and pH (0.595), conductivity and salinity (0.992), TDS and pH (0.340), TDS and salinity (0.322) and TDS and conductivity (0.322). Fish mortality showed no correlation with all water parameters changing in the whole study at Sri Tujuh lagoon. Based on the water parameter records from the 13 sampling stations, the sampling stations can be divided into 5 clusters (Figure 3). Cluster 1 possesses the highest number of stations namely S3, S4, S6, S7, S8, S11 and S12, whereas cluster 2 has three stations (S1, S10 and S13). Only one station was found in each of the clusters 3 (S5), 4 (S2) and 5 (S9).

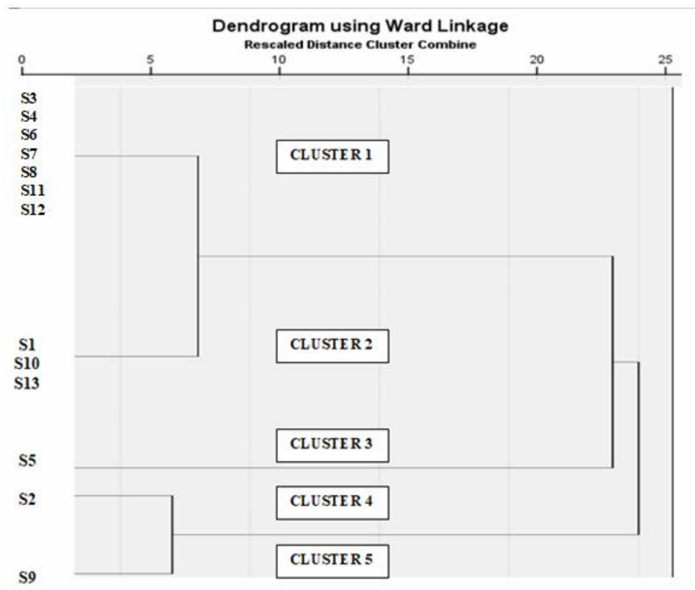

Figure 3. Dendrogram using Ward Linkage.

Table 8

Pearson correlation matrix for water parameters and mortality of Asian seabass in March-August (dry season)

Parameters	*Temperature*	*pH*	*Dissolved oxygen*	*Salinity*	*Conductivity*	*Turbidity*	*Total dissolved solid*	*Fish mortality*
Temperature	1							
pH	-0.109	1						
Dissolved oxygen	0.429**	-0.202	1					
Salinity	-0.213	0.378**	-0.133	1				
Conductivity	-0.146	0.287*	-0.086	0.980**	1			
Turbidity	0.171	0.006	0.057	0.211	0.252	1		
Total dissolved solid	-0.241	-0.161	-0.021	0.391**	0.417**	0.080	1	
Fish mortality	-0.528	-0.153	-0.255	-0.165	-0.077	-0.328	-0.149	1

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

Table 9

Pearson correlation matrix for water parameters and mortality of Asian seabass in September-November (monsoon season)

Parameters	*Temperature*	*pH*	*Dissolved oxygen*	*Salinity*	*Conductivity*	*Turbidity*	*Total dissolved solid*	*Fish mortality*
Temperature	1							
pH	0.588**	1						
Dissolved oxygen	0.384**	0.178	1					
Salinity	-0.130	0.347*	-0.077	1				
Conductivity	-0.087	0.353*	-0.060	0.992**	1			
Turbidity	0.077	-0.038	0.203	-0.151	-0.168	1		
Total dissolved solid	-0.125	0.349*	-0.072	1.000**	0.993**	-0.162	1	
Fish mortality	b	b	b	b	b	b	b	1

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); b. Cannot be computed because at least one of the variables is constant.

Table 10

Pearson correlation matrix for water parameters and mortality of Asian seabass in March-November 2014 (dry and monsoon seasons)

Parameters	*Temperature*	*pH*	*Dissolved oxygen*	*Salinity*	*Conductivity*	*Turbidity*	*Total dissolved solid*	*Fish mortality*
Temperature	1							
pH	0.434**	1						
Dissolved oxygen	0.472**	0.315**	1					
Salinity	0.047	0.615**	0.145	1				
Conductivity	0.079	0.595**	0.156	0.992**	1			
Turbidity	0.125	-0.007	0.115	-0.008	-0.014	1		
Total dissolved solid	-0.021	0.340**	0.110	0.322**	0.312**	0.068	1	
Fish mortality	-0.466	-0.139	-0.132	-0.140	-0.065	-0.319	-0.126	1

** Correlation is significant at the 0.01 level (2-tailed).

Discussion. In the present study, high standard deviation was observed in all water parameters between dry and monsoon seasons except for temperature and pH. This happened may be due to temporal variation caused by natural factors or pollution from human activities surrounding the lagoon (Barakat et al 2016). However, no high standard deviation was recorded between flood and ebb and among levels of water. Based on the findings of the present study and referred to National Water Quality Standards, Malaysia (NWQS), water quality of the lagoon is suitable to carry out fishery activities. The temperature of the 13 sampling stations showed higher value during dry season compared to monsoon season. Temperature reading in the present study is only recorded during day time in order to avoid fishery activities which are carried out during night by the local communities. Hence temperature reading basically is high in the present study where the records have been done in day time. According to Shuhaimi-Othman et al (2007), temperature reading is inffluenced by weather, sampling time and location. The temperature value will effect on DO, biological activities and other water parameters. Therefore, in the present study, temperature records has strong and significance correlation with pH and DO.

DO is an important factor in carrying fish farming activity in Sri Tujuh lagoon. Overall, the oxygen level in Sri Tujuh lagoon can sustain fish farming activity in which the farmed fish mortality in this lagoon was recorded as low as < 16%. Water movement during flood tide and air exchange on the water surface were the two main factors that contribute to maintain the level of DO in the lagoon. However, very low DO was observed during monsoon season. This finding was contrary to the finding in studiesof Gadhia et al (2012) and Islam et al (2015) in which both studies reported that DO level in monsson season increased and was higher than dry season because of water exchange and high wind velocity. On the other hand, similar finding with the present study was recorded in the study of Pejman et al (2009) where lower DO was found in Haraz River in Iran during monsoon season. According to Sharma & Rathore (2000) and Ravindra et al (2003), higher value of DO may due to the presence of photosynthetic phytoplankton in the water system. Low DO level in Sri Tujuh lagoon during monsoon season was observed may be due to the lacking of this photosynthetic phytoplankton community in the lagoon. Furthermore, degradation of organic matter in the water system led to the oxygen depletion in the lagoon (Astel et al 2006). Factors that contributing to the lacking of this phytoplankton in the Sri Tujuh lagoon were due to fluctuation of water salinity and limited of sunlight during monsoon season where effect the growth and bloom of the phytoplankton in the lagoon. Although, low DO was recorded in the lagoon, however, its seem do not affect the fish production in the lagoon.

Zweig et al (1999) recommend suitable pH for marine fish culture in the range of 6.5 to 9.0. FAO (1999) suggested 7.0 to 8.5, meanwhile the range of 6.7 to 8.6 was suggested by ANZECC/ARMCANZ (2000). Large range in pH changes will driven to physical damage to the gills, skin and eyes of fish. Subsequently it will increase the susceptibility of secondary infection of fish. If the pH value is 4 or below or 11 and above, most aquatic species will die (Zweig et al 1999). In the present study, pH has strong and significance correlation with temperature, salinity, TDS, DO and conductivity. Al-Badaii et al (2013) mentioned that pH value ranging from 6.5 to 9.0 is suitable to a variety of aquatic life in where the pH values of Sri Tujuh lagoon were fall into these ranges. Hence, Sri Tujuh lagoon is suitable to carry out aquaculture activities. The low pH value may be due to the presence of high organic matter in the water. Low pH value is always associated with high presence of ammonia which is harmful to all aquatic life. The presence of photosynthetic algae will lead to the consumption of the carbon dioxide dissolved in the water, further leading to the increasing of water pH (Gandaseca et al 2011). In order to maintain the pH at optimum level for aquatic life, oxygen level needs to be maintained in the water system to propagate ammonia NH_3 to nitrate NO_3 conversion to allow aquatic plants to absorb NO_3. In this case, flood tide is helping to flush out all organic matter in Sri Tujuh lagoon into open sea at the mean time maintained water quality in the lagoon.

Turbidity of Sri Tujuh Lagoon is moderate high with the lowest and highest values 5.1 NTU and 59.8 NTU, respectively. The value of turbidity frequently is associated with pollution from nearby human activities such as agricultural activities. Turbidity value is dependent on the presence of suspended particles such as silt, plankton, clay, organic matters etc. (Al-Badaii et al 2013). In this case, moderate turbidity in Sri Tujuh lagoon may be due to agricultural activities discharge, flood discharge, urban settlement, water discharge from chalets, restaurants and stalls. However, flood tide play an important role in diluting turbidity in Sri Tujuh lagoon into optimum level. Total dissolved solid or TDS is suspended matter that can be found in the water system mainly from source of anthropogenic activities (WHO/UNESCO/UNEP 2001). In the present study, data collection record revealed that TDS value of Sri Tujuh lagoon can be categorised as poor as the value as high as more than 30 ppt based on NWQS where recommended TDS value less than 4 ppt for aquaclture activity (DOE 2006). This finding clearly showed that the lagoon is extremely exposed to anthropogenic and land use activities. However, flood may help to ease the high concentration of TDS in the lagoon by flushing out TDS into open sea. Hence, high TDS in the lagoon does not affect the Asian seabass production from the lagoon. Furthermore, TDS value was significantly lower in the monsoon compared to dry season in which the rainfall is diluting TDS in the lagoon. Subsequently, in the monsoon season, fish production from the lagoon was slightly higher compared to dry season. Government agency should monitor anthropogenic and land use activities that take place in the surrounding of the lagoon in order to minimize the effluent discharge from these activities into lagoon.

In the present study, conductivity value of Sri Tujuh lagoon showed good and normal range for a healthy water system. Harun et al 2010 claimed that concentration of conductivity that exceeds 1000 µS cm^{-1} indicates that water ways are highly polluted. The value conductivity in water system is influenced by the presence of inorganic dissolved solids like calcium, chloride, iron, magnesium etc. Generally marine water has higher conductivity value compared to freshwater. However, in this study Sri Tujuh lagoon possesses a lower conductivity value compared to river as described in the study of Al-Badaii et al (2013) where it was revealed that the conductivity value ranged from 46 to 231 µS cm^{-1} in the studied river. The low conductivity value was observed in the lagoon may be due to the inorganic dissolved solids settled down and accumulated in the sediment of the lagoon. Furthermore, flood tide that daily take place in the lagoon may help to discharge the inorganic dissolved solids into open sea.

Asian seabass is a popular seafood in Malaysia. Sri Tujuh lagoon is identified as one of the main producer in Kelantan in which the fish produced from this lagoon is not only sold to fulfill the local market needs, but it is also exported to other states in Malaysia to meet the market demand. The uniqueness of the Asian seabass is it can grow in both freshwater, marine water and brackish water. The high tolerance to salinity allowed this fish to be farmed in the Sri Tujuh lagoon during monsoon season. Furthermore, the production of Asian seabass was recorded slightly higher during monsoon compared to dry season. This is because Asian seabass can grow better in freshwater or less salinity environment where the fish spends less energy in osmotic process in freshwater comparing to high salinity environment. Athauda & Anderson (2014) reported that the temperature and salinity can influence sex inversion of Asian seabass. Male fish can perform better growth rate than female as most energy of female fish will be focused on egg production. In the present study, phenomena of flood tide and water level do not have significant differences in term of salinity. However, there is a huge significant difference in salinity between monsoon and dry seasons. As Asian seabass is tolerant to high range of salinity, therefore, salinity is not a main factor in Asian seabass production in Sri Tujuh lagoon.

Hierarchical cluster analysis is a common analysis tool that is used in many studies related to water quality. In the present study, it is revealed that the 13 sampling stations can be divided into 5 clusters. DO and turbidity are two main factors that differentiate the 13 sampling stations in clustering analysis. Statistical analysis via One Way Anova followed by Tukey post hoc test revealed that water parameters from 13 sampling stations are almost the same except for DO and turbidity values. This is because the size of the lagoon is small. Therefore, most of water parameters from 13 sampling stations shared almost similar range. Thus, further study is needed to be carried out by monitoring more water parameters such as ammonia, nitrate, total sulfate, total phosporus, biological oxygen demand, chemical oxygen demand and fecal coliform in order to differentiate in detail the water quality in each sampling station.

The information of the present study will provide useful information to fish farmers. The outcomes of the present study will provide database information on the water quality changing during monsoon and dry seasons. The information can be referred by fish farmers in order to carry out the aquaculture activities in the lagoon. The information can be suggested to government in improving the lagoon infrastructure in maintaining good water quality environment for fish farming. Furthermore, the record on the production of Asian seabass which is the main aquaculture product from Sri Tujuh lagoon can provide a guideline to fish farmer on which season is the best time to have Asian seabass farming. The main aquaculture production of Sri Tujuh Lagoon is Asian seabass, in which annual production is reached 500 to 1000 tons by using cage farming system (DOF 2010).

Conclusions. This study was conducted to evaluate the impact of dry and monsoon season on the Asian seabass production in Sri Tujuh lagoon located at Tumpat, Kelantan, Malaysia. Based on Malaysia National Water Quality Standard (NWQS), the lagoon is suitable to carry out aquaculture activity. Therefore in the present study the documented farmed fish mortality rate does not exceed 16% throughout the study. Hence, we recommend that Sri Tujuh lagoon as one of the best places for aquaculture activity in Kelantan, Malaysia. However, at station 9, aquaculture activity should be avoided during monsoon season because the deterioration of water quality especially DO at critical level for fish farming. Furthermore, high turbidity was also observed in the water sample from the lagoon during monsoon season indicating high contamination of particles from human activities like agricultural activities discharge, flood discharge, urban settlement, water discharge from chalets, restaurants and stalls into the lagoon. In spites of the facts, fish production was not affected with the higher turbidity value during monsoon season. This means that the increasing of turbidity level during monsoon season is still accepted.

Hierarchical cluster analysis on the water parameters revealed that the sampling stations in the present study can be divided into 5 clusters based on the water quality data collection from March to November, 2014 in Sri Tujuh Lagoon. However, further study by using One way Anova on the water quality data collection indicating water quality among sampling stations were almost same except for DO and turbidity. Hence we may conclude that further study is needed to be carried out by monitoring more water parameters such as ammonia, nitrate, total sulfate, total phosporus, biological oxygen demand, chemical oxygen demand and fecal coliform in order to differentiate in detail the water quality in each sampling stations.

Acknowledgement. This project was funded by Ministry Education of Malaysia under scheme of Niche Research Grant Scheme (NRGS) vot no: R/NRGS/A0.700/00387A/006/2014/00152 and R/NRGS/A0.700/00303A/002/2014/00151.

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Received: 03 November 2017. Accepted: 15 January 2018. Published online: 10 February 2018.
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How to cite this article:
Abdullah H. H., Rak A. E, Wei L. S., 2018 The impacts of monsoon and dry seasons on physical water quality changes and farmed Asian seabass *Lates calcarifer* (Bloch, 1790) mortality at Sri Tujuh lagoon, Tumpat, Kelantan, Malaysia. AACL Bioflux 11(1):167-183.