The Biodiversity and Ecology of Aquatic Plants at Tasik Chini, Pahang, Malaysia

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Abstract: This study determines the distribution, abundance and relationships between *Nelumbo nucifera* and *Cabomba furcata* as well as to map out the distribution of the two most dominant aquatic plant species at Tasik Chini, Pahang, Malaysia. Ten sampling stations were selected and ten quadrats of 3×3 m were established at each sampling station on 2009 to July 2010. Data were analyzed to determine percentage cover of the two species, *Nelumbo nucifera* and *Cabomba furcata* in each quadrats and the biomass (dry weight) of each species was estimated. The water quality parameters using YSI multi probe in each station were also measured. Study on the mapping of distribution for *Lepironia articulata* and *Pandanus helicopus* includes all the twelve water bodies (namely Laut 1-12) in Tasik Chini. At every station, five coordinate sampling points for Global Positioning System (GPS) were recorded. At the same coordinate points recorded the depth of water were measured using a staff gauge with a maximum length of 5 m. The image of Tasik Chini dated 10 September, 2007 captured by spot-5 was obtained from Malaysia Centre for Remote Sensing (MACRES). Image processing was done in the laboratory using ERDAS Imagine 9.1 and ArcGis 9.2 software. The result indicates that a total of 73 from 100 quadrats showed the occurrence of *Cabomba furcata* whilst the *Nelumbo nucifera* occurred in only three quadrates. Estimation of percentage cover of *Cabomba furcata* revealed 95.1% cover whilst the *Nelumbo nucifera* indicated a 4.9% overall cover. The total dry weight of *Cabomba furcata* was 7892.5 g whereas the *Nelumbo nucifera* indicated a dry weight of 237 g. The relationship between the two species with the water quality parameters were analyzed using the Redundancy Analysis (RDA). The RDA indicated that the parameter of NH_4-N, PO_4^{2-}, TSS, BOD and COD influenced the distribution and abundance of *Cabomba furcata* however, the distribution and abundance of *Nelumbo nucifera* were influenced by parameters of namely $NH4$-N, SO_4^2, NO_3^-, temperature and DO. This study clearly shows that the water parameters influence the distribution and abundance of the two populations of *Cabomba furcata* and *Nelumbo nucifera*. From the image processing both species *Lepironia articulata* and *Pandanus helicopus* appear in the whole lake, except Laut 4 and 5. *Lepironia articulata* was found mostly at the shallow waters where as *Pandanus helicopus* was found at both shallow and deep areas.

Key words: Tasik Chini, biomass, water quality, redundancy analysis, aquatic plant, *Nelumbo nucifera*, *Cabomba furcate*, Malaysia

INTRODUCTION

Tasik Chini is known as the 2nd largest natural asfreshwater lake in Peninsular Malaysia, consist of twelve other smaller lakes which flow trough Sungai Chini to Sungai Pahang. The lake covers an area of 202 ha and is surrounded by a total of 4975 ha of tropical forests known as Tasik Chini forest reserves (Kutty *et al.*, 2005; Toriman *et al.*, 2010). The natural environment in Tasik Chini that includes rivers, lake, swamps, lowland and hill forests as well as the indigenous people form a unique ecosystem for eco-tourism purposes. Recent

situation, the decline population of *Nelumbo nucifera* (water-lily) seem reducing the eco-tourism factors and it is believe that was it caused by the rapid spread of a macrophyte called *Cabomba furcata*. The other most dominant macrophyte is the emergent macrophyte, *Lepironia articulata* and *Pandanus helicopus* (Hussin, 2005; Dan Ahmad Badri Mohamad, 1992) that are happened to be spread most to the lake. Since, the rapid growth of the *C. furcata* and the decline of population of *N. nucifera* as well as the most spread of *L. articulata* and *P. helicopus* is stillongoing, a study was conducted to determine the abundance of *C. furcata* and *N. nucifera*

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and to evaluate relationship and factors that influence the abundance of both population. The distribution of the two most dominant macrophyte species, *L. articulata* and *P. helicopus* were also mapped in relation to the water depth of the Tasik Chini.

MATERIALS AND METHODS

Study site and sampling procedure: A total of ten sampling stations were chosen at Tasik Chini, Pahang (Table 1 and Fig. 1). Ten quadrats of 3×3 m were establish along a line transect of 150 m with 15 m intervals for the *C. furcata* and *N. nucifera* study. Altogether, there were 100 quadrats established for this surveyed. Percentage coverage of both species was estimated in all quadrats using crude eye observation. Subsequently, the species that occurred in the quadrats was harvested for determination of its biomass. Harvesting was only conducted on those clumps or individuals that emerged above the water surface.

The harvested samples were kept in polythene bags and brought to the laboratory for drying. All samples were dried in the oven at 70°C until constant weights were obtained. Mapping of the distribution of Lepironia and Pandanus was conducted based on field observation and spot-5 image processing in the lab. All the twelve water bodies in Tasik Chini which are called Laut by the local are included in this research (each Laut one station). At every station, five coordinate of sampling points were recorded. The depth of water was mebbasured using a staff gauge with a maximum length of 5 m.

Water quality parameters: Data on water quality parameters were obtained from the Tasik Chini water quality group who conducted water quality survey at the similar sampling locations (Toriman *et al.*, 2010). Water quality parameters used in this study are temperature, pH, conductivity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), ammonium nitrogen (NH_4-N), Nitrate (NO_3^-), phosphate (PO_4^{2-}) and sulfate (SO_4^{2-}). Detailed methods on the water analysis can be referred in Shuhaimi-Othman *et al.* (2007).

Data analysis: Abundance analysis was based on biomass (dry weight) of both species in each quadrat at all sampling locations. Estimation of percentage cover for each sampling station was obtained by calculating average cover of ten quadrats at each sampling station. Relationships between species and water quality data were analyzed using multivariate techniques of

Table 1: Ten sampling stations and the coordinates of each station

| Station no.	Name	Coordinates
S1	Laut Gumum	N03°26.021' E102°55.745'
S2	Laut Pulau Balai	N03°25.951' E102°55.462'
S3	Laut Chenahan	N03°26.249' E102°55.092'
S4	Laut Gunung Jerating	N03°26.081' E102°54.677'
S5	Laut Tanjung Jerankung	N03°26.423' E102°54.828'
S6	Laut Mempitih	N03°25.833' E102°54.510'
S7	Laut Kenawar	N03°25.633' E102°54.119'
S8	Laut Seradong	N03°25.614' E102°54.636'
S9	Laut Batu Buruk	N03°24.803' E102°54.663'
S10	Laut Melai	N03°25.726' E102°55.082'
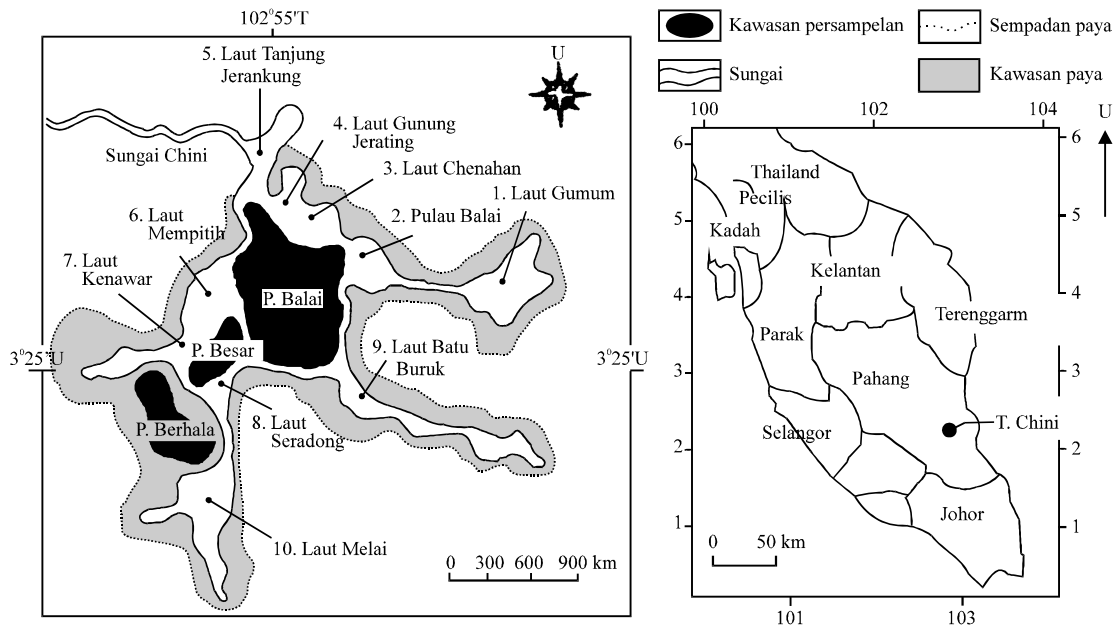
Fig. 1: Sampling location in Tasik Chini

Redundancy Analysis (RDA) in CANOCO program Version 4 (Ter Braak and Smilauer, 1998). Prior to conducting the RDA, Detrended Correspondence Analysis (DCA) was performed to verify the length of the species gradients extracted from the data for the purpose of deciding whether, a linear or unimodal analysis should be carried out. The DCA showed that the value of the species gradient length was <3 hence, a linear analysis was suitable. Given that the analysis was to determine relationships between species and environmental factors, a direct gradient analysis of RDA was appropriate. The RDA is a constrained linear method from canonical ordination which allows interpretation of relationship between species and environmental factors be carried out. The image of Tasik Chini dated 10. 9. 2007 captured by spot-5 is obtained from Malaysia Centre for Remote Sensing (MACRES). Image processing is done in the laboratory using ERDAS imagine 9.1 and ArcGIS 9.2 software.

RESULTS AND DISCUSSION

Distribution and coverage of *Nelumbo nucifera* and *Cabomba furcata*: Frequency of occurrence of both species in all quadrats at all sampling stations were used to describe distribution of the species at Tasik Chini. The study showed that *C. furcata* dominated most area of the lake compared to *N. nucifera* whereby the former occurred in 73 quadrats that reflects frequency of 73% whereas, the latter was recorded in only three quadrats (3%) out of 100 quadrats established (Table 2). Table 2 also shows that the *C. furcata* occurred at all sampling stations with various frequency of occurrence whilst the

N. nucifera was only observed at Laut Melai sampling station (station 10). Figure 2 shows estimation of percentage cover for both species at each sampling station. The coverage of *C. furcata* at the station 7 (Laut Kenawar) was the highest with percentage cover of 87.5% whilst the lowest coverage of this species was at station 9 (Laut Batu Buruk) of 6%.

In contrast, *N. nucifera* that was only found at station 10 (Laut Melai), showed only 19% coverage and no species cover was observed at the other nine sampling stations. In terms of average cover of the study quadrats, 95.1% of all the quadrat area was dominated by the *C. furcata* whereas only 4.9% of the area was populated by the *N. nucifera*.

It should be highlighted that the colony of *C. furcata* was never been observed in 1980's; a studied by DARA reported the *N. nucifera* as the most dominant aquatic macrophyte at Tasik Chini, coexisted
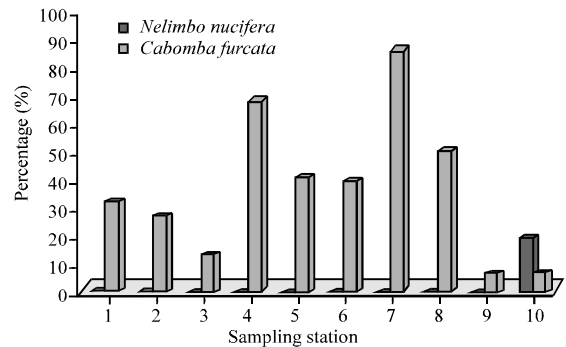

Fig. 2: Estimation of percentage species cover at each sampling station

Table 2: Frequency of occurrence of *C. furcata* and *N. nucifera* in all quadrats at selected sampling stations in Tasik Chini

Sampling stations	Species	Quadrats										Frequency (%)
		1	2	3	4	5	6	7	8	9	10	
S1	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	+	+	+	+	+	+	100
S2	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	-	-	-	-	-	-	40
S3	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	-	-	-	-	-	-	-	30
S4	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	+	+	+	+	+	+	100
S5	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	+	+	+	+	+	+	100
S6	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	+	+	+	+	+	+	100
S7	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	+	+	+	+	+	+	100
S8	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	+	+	+	+	+	+	80
S9	*N. nucifera*	-	-	-	-	-	-	-	-	-	-	0
	C. furcata	+	+	+	+	-	-	-	-	-	-	40
S10	*N. nucifera*	-	+	+	+	-	-	-	-	-	-	30
	C. furcata	+	+	+	+	-	-	-	-	-	-	40

with the 2nd most dominant species of *Pandanus helicopus*. However in 1990's, the presence of the colony *C. furcata* was noticed in several areas such as at Laut Batu Buruk, Laut Labuh and Laut Jemberau. Compared with the current study, the spread of this colony is tremendous whereby most lake areas of Tasik Chini are covered by this species.

Dry weight: The total dry weight of *C. furcata* at all sampling station was 7828.8 g in which the station 7 (Laut Kenawar) recorded the highest dry weight of 2480.5 g. On the other hand, the total dry weight of *N. nucifera* that was only found at station 10 was far lower with an estimation of 237 g. Table 3 shows the dry weight of both species at all sampling stations.

The results clearly show that besides the observation on species coverage, data on dry weight (biomass) have obviously indicated that the abundance of *C. furcata* is extremely high compared to *N. nucifera*. This phenomenon may partly due to the factor that the *C. furcata* is having high growth rate where the domination of the species could occur easily.

Water quality parameters: Water quality data were based on the study conducted by Shuhaimi-Othman *et al.* (2007) (Table 4). Table 4 shows that water pH values are in the

range of 6.06-6.67 where the station 9 (Laut Batu Buruk) had the highest pH value of 6.67 whilst the lowest was recorded at station 5 of 6.06. The station 9 was also recorded to have the highest water temperature and conductivity of 30.35°C and 29.98 µ Scm^{-1}, respectively. Further, the station 1 (Laut Gumum) recorded the highest Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) with values of 6.31, 1.95 and 19.37 mg L^{-1}, respectively. The highest Total Suspended Solid (TSS) was recorded at station 4 (Laut Gunung Jerating) of 21.71 mg L^{-1} whilst the station 10 (Laut Melai) showed the lowest TSS of 4.96 mg L^{-1}. Moreover, the station 4 had highest ammonia nitrogen (NH_3-N) value of 0.289 mg L^{-1} while the station 10 (Laut Melai) recorded the highest nitrate (NO_3^-) content of 0.24 mg L^{-1}. The highest phosphate concentration was recorded at the station 1 (Laut Gumum) of 0.082 mg L^{-1} and the highest sulphate content was recorded at the station 9 (Laut Batu Buruk) and station 10 (Laut Melai) with value of 1.181 mg L^{-1}.

Relationships between water quality parameters and the presence of *N. nucifera* and *C. furcata*: Redundancy Analysis (RDA) was conducted to observe relationships between water quality parameter and the presence of *N. nucifera* and *C. furcata* at Tasik Chini. Figure 3 shows the ordination diagram of RDA where the numbered points represent the sampling locations and the arrows represent the vectors of water quality parameters and the species of *N. nucifera* and *C. furcata*.

Figure 3 obviously indicates that the arrow vectors for both *N. nucifera* and *C. furcata* are pointing at different directions as well as distantly situated from each other. Based on the survey data, it is clear that both species do not occur together at all sampling locations except at the station 10 (Laut Melai) where *N. nucifera* was present in three sampling quadrats. From this analysis, it is apparent that the two species are located closely to different water parameter vectors which reflect

Table 3: Total dry weight of *C. furcata* and *N. nucifera* at sampling stations in Tasik Chini

Sampling stations	Total dry weight (g)	
	C. furcata	*N. nucifera*
1 (Laut Gumum)	600.4	0.0
2 (Laut Pulau Balai)	551.7	0.0
3 (Laut Chenahan)	145.2	0.0
4 (Laut Gunung Jerating)	1432.8	0.0
5 (Laut Tanjung Jerankung)	574.2	0.0
6 (Laut Mempitih)	683.2	0.0
7 (Laut Kenawar)	2480.5	0.0
8 (Laut Seradong)	992.0	0.0
9 (Laut Batu Buruk)	156.1	0.0
10 (Laut Melai)	212.7	237.0
Total	7828.8	237.0

Table 4: Water quality parameters at sampling stations based on Shuhaimi-Othman et al. (2007)

Parameters	Sampling stations									
	1	2	3	4	5	6	7	8	9	10
pH	6.530	6.380	6.480	6.320	6.060	6.620	6.630	6.650	6.670	6.540
Temperature	29.380	29.40	29.490	29.150	29.030	29.830	29.960	29.870	30.350	29.410
Conductivity	23.970	24.090	22.750	23.500	21.830	19.410	20.100	26.530	29.980	26.660
DO	6.310	5.650	5.980	5.130	4.090	5.920	5.880	5.860	6.120	5.740
BOD	1.950	1.680	1.690	1.610	1.440	1.590	1.700	1.380	1.080	1.770
COD	19.370	17.570	16.730	15.810	14.790	18.680	18.310	17.870	12.930	18.630
TSS	11.780	9.450	11.280	21.710	13.440	7.890	7.960	6.180	12.930	4.960
NH_3-N	0.217	0.176	0.196	0.289	0.212	0.153	0.148	0.165	0.084	0.143
NO_3^-	0.142	0.221	0.226	0.206	0.120	0.073	0.123	0.072	0.186	0.240
PO_4^{3-}	0.082	0.058	0.068	0.062	0.061	0.062	0.066	0.059	0.058	0.062
SO_4^{2-}	0.181	0.292	0.250	0.236	0.306	0.389	0.264	1.097	1.181	1.181

Temperature (°C); Conductivity (µ Scm^{-1}); DO: Dissolved Oxygen (mg L^{-1}); BOD: Biological Oxygen Demand (mg L^{-1}); COD: Chemical Oxygen Demand (mg L^{-1}); TSS: Total Suspended Solid (mg L^{-1}); NH_3-N (mg L^{-1}); NO_3^- (mg L^{-1}); PO_4^{3-} (mg L^{-1}); SO_4^{2-} (mg L^{-1})
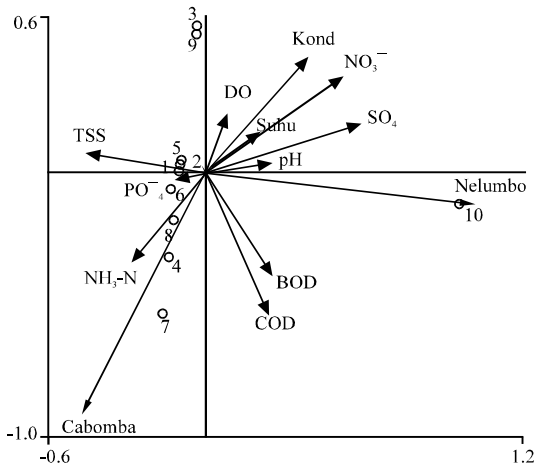
Fig. 3: RDA ordination diagram demonstrating the relationships between water quality parameters and the abundance of *N. nucifera* and *C. furcata* (No. 1-10: sampling stations)

the preference of water quality for both species at their habitats. Figure 3 shows that the ammonia nitrogen (NH_3-N) vector is closely situated next to the *C. furcata* vector. This shows that the occurrence of *C. furcata* at the study location is highly influenced by the presence of ammonia nitrogen. Based on this, *C. furcata* can be considered as in favour of high ammonia concentration for its survival while this is a different case for *N. nucifera* which distantly located from the ammonia vector, inferring the species favours to a habitat with a low nitrogen level. It has been suggested by Tilman and Wedin (1991) that a species that is adapted to a low nitrogen level habitat would finally be excluded by other species that has high nitrogen dependency. The scenario of present study at Tasik Chini seems in accordance with the suggestion of Tilman and Wedin (1991) where *N. nucifera* gradually being excluded by *C. furcata*.

In addition, Morecroft *et al.* (1994) and Aulio and Salin (1982) showed that the increase in ammonium content on semi-natural grassland communities in the United Kingdom had decreased the population of a moss species, *Rhytidiadelphus squarrosus* that favours low nitrogen content; the study clearly showed that the increase of nitrogen content in a vegetation community of the natural habitats would decline the population survival of certain species because of eutrophication.

Figure 3 also indicates that the other water quality parameters such as phosphate (PO_4^{2-}), Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) also influence the occurrence of *C. furcata*. The vector of *N. nucifera* positioned closely to the pH, sulphate (SO_4^{2-}), nitrate

(NO_3^-), temperature, conductivity and Dissolved Oxygen (DO) vectors. The closest pH vector to this species reflects the influence of water pH on the occurrence of the species at the study location. Nevertheless, since the pH values between sampling locations did not vary greatly thus, the influence of the pH parameter cannot be seen clearly. According to Chapeon (1992), suitable pH level for a lake ecosystem is between pH 4.5-6.5 and pH levels at sampling stations were within this range. It is apparent that the vector for *N. nucifera* is pointing at opposite direction of the vector Total Suspended Solid (TSS).

This scenario infers that the abundance of *N. nucifera* has a negative correlation with the total suspended solid present in the water body. Among main causes of the increase in total suspended solid are forest clearings for developments and agriculture (Toriman *et al.*, 2009). DARA reported the increase of TSS in the water body at Tasik Chini was due to forest exploitations by the locals for agricultural activities, rubber plantations and oil palm plantations.

As observed, all sampling stations that are positioned close to the TSS vector (stations 1, 2, 5, 6 and 8; Fig. 3) have turbid water and there was absolutely no trace of *N. nucifera* population. Moreover, the abundance of *N. nucifera* has a negative correlation with the amount of phosphate and ammonia nitrogen in the lake as the vectors for both water quality parameters are situated far from the *N. nucifera* vector.

The *C. furcata* dominated sampling stations such as stations 1-8 are influenced by the total suspended solid, phosphate and ammonia nitrogen parameters while the station 10 has obviously negative correlation with those parameters. Field observation also revealed that the water at the station 10 (Laut Melai) was clearer than other stations, of which *N. nucifera* population was recorded in three sampling quadrats at this station. This study clearly indicates that both *C. furcata* and *N. nucifera* have different environmental requirements and it is evident that the water quality factors play essential roles in influencing population distributions of both species at the study location. It can be concluded that the *N. nucifera* population is more suitable to develop in undisturbed surroundings where the water is clean while the *C. furcata* dominates environments of low water quality.

Distribution and coverage of *Lepironia articulata* dan *Pandanus helicopus*: Occurrence of both species in all quadrats at all sampling stations was used to describe distribution of *L. articulata* and *P. helicopus* at Tasik Chini. The study showed that *L. articulata* and *P. helicopus* dominated most area of the lake. Apparently,
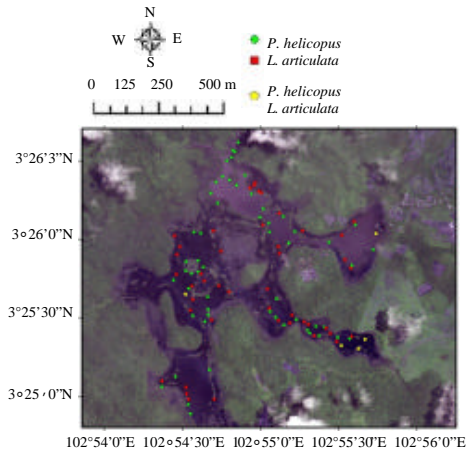
Fig. 4: Distribution of *Lepironia articulata* dan *Pandanus helicopus* in all quadrats at selected sampling stations in Tasik Chini
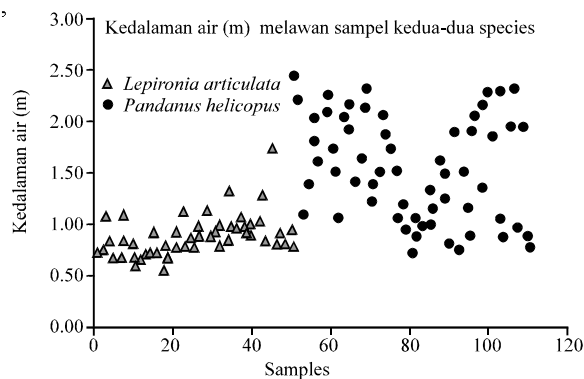

Fig. 5: Water depth against the sample of *Lepironia articulata* and *Pandanus helicopus*

there was no individual of *L. articulata* at station 4 and 5 but it was distributed dominantly at station 10 and 11. As for the *P. helicopus*, it was dominant at station 4, 5, 7 and also half of the station 6 (Fig. 4).

Influence of water depth towards distribution of *Lepironia articulata* dan *Pandanus helicopus*: From the data obtained both species *L. articulata* and *P. helicopus* were influenced by the water depth. Even though both species occurred at almost all station (except station 4 and 5 for *L. articulata*) but *L. articulata* was found at almost shallow area where as *P. helicopus* was found grew at both shallow and depth areas. Figure 5 shows the water depth against the sample collected.

CONCLUSION

In this study, it can be stated that Tasik Chini is still rich in biodiversity. Over the last 15 years, the relationship between biodiversity and ecosystem functioning in Tasik Chini has emerged as a central issue in lake conservation and restoration. Human environmental impacts include the destruction and fragmentation of natural habitats, pollution, climate change, over exploitation of biological resources, homogenization of biota and biodiversity loss (Bosserman, 1981; Chiras, 2001). These impacts affect species and ecosystems indistinctly in Tasik Chini.

In this regards, the present of *Nelumbo nucifera* and *Cabomba furcate* in which is considered as two most dominant aquatic plant species were mapped. General vegetation patterns as well as dry weight (biomass) have been identified as have the general interrelationships that exist between the water quality and plant distribution. In particular, the importance of the period of inundation as well as water depth has been identified influence the distribution and abundance of the two populations of *Cabomba furcata* and *Nelumbo nucifera*. Given the extent of change in these environments.

RECOMMENDATIONS

It is recommended that further specific investigations must be undertaken to identify the importance of such adaptations, especially in relation to management actions that may result in further change.

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