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Relationship between Kai Algae and Aquatic Environmental Quality Using AARL-PC Score and Inverse Distance Weighting Interpolation

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Abstract

This study aimed to determine relationship between Kai algae and water quality using the Applied Algal Research Laboratory-Physical and Chemical Score (AARL-PC score) and inverse distance weighting (IDW) in the Mekong River. Kai algal habitats were discovered at three sampling sites during a survey of the Mekong River, Chiang Khong district, Chiang Rai Province, Thailand in January and February 2022. Kai algae were collected in the field and identified by microscope. Kai morphology and environmental factors including length, dry weight, water conductivity, DO, BOD, nitrate nitrogen, soluble reactive phosphorus and ammonium nitrogen were investigated. The results showed two Kai genera, *Cladophora* sp. and *Rhizoclonium* sp., were presented in the sampling sites. In January, BOD had a strong positive relationship with the length of Kai algae while ammonium nitrogen had a significant relationship with water conductivity ($p < 0.01$), and DO had a significant relationship with dry weight ($p < 0.05$). In February, BOD had a strong positive relationship with the length of Kai algae ($r = 0.9804$), while ammonium nitrogen had a significant relationship with water conductivity ($p < 0.05$). IDW derived from the AARL-PC-score revealed that clean-moderate water quality was directly related to environmental factors in January and February and can be used to determine Kai algal growth in the Mekong River.

Keywords: Kai algae; Environmental factors; Geostatistics; Mekong River; Lotic ecosystem

1. Introduction

Freshwater green macroalgae provide several health and therapeutic advantages, and are also vital water quality markers in the lotic ecosystem. Natural macroalgae known as "Kai" grow in the Mekong River in Northern and Northeastern Thailand and are a vital resource for the local people (Peerapornpisal *et al.,* 2006). Kai algae grow on cobbles and gravel substrata along the riverbank and belong to the genera *Aegagropila*, *Cladophora* and *Rhizoclonium.* Kai algal growth in the Mekong River only occurs during the dry season (November-March).

Anthropogenic activities such as the construction of reservoirs and dams across the Mekong River for electricity generation and water resources are rapidly altering the ecosystem by impacting the natural river flow, thereby affecting nutrient cycles and changing the physicochemical characteristics of the water (Thiamdao *et al.,* 2012a; Mungmai *et al.,* 2014; Wang *et al.,* 2017; Ruen-Pham *et al.,* 2021). Kai algal habitats are significantly impacted by these erratic environmental changes. Understanding the relationship between algae and their environmental

conditions is critical for algal management planning in the Mekong River.

The relationships between algae and the environmental parameters are complex. Algal habitats depend on dissolved oxygen (DO), water conductivity and essential nutrients (Wongsawad & Peerapornpisal, 2013; Hui *et al.,* 2022). Previous research into the management planning of algal habitats emphasized the importance of the water quality index (WQI) value (Ogbozige *et al.,* 2018; Sapna *et al.,* 2018; Delina *et al.,* 2019; Massinai *et al.,* 2021). The Applied Algal Research Laboratory-Physical and Chemical Score (AARL-PC score) is obtained by monitoring key environmental factors of lotic environments such as water conductivity, DO, biochemical oxygen demand (BOD), ammonium nitrogen, nitrate nitrogen and soluble reactive phosphorus. All these factors affect algal growth and determine both the water quality and the trophic status of the aquatic environment (Peerapornpisal *et al.,* 2004; Leelahakriengkrai & Peerapornpisal, 2011; Thiamdao *et al.,* 2012b; El-Adl, 2014).

Water quality assessment is important for algal growth and survival and is used for conservation and management (Liao *et al.,* 2021). The geostatistical inverse distance weighting (IDW) mapping approach is commonly used to anticipate spatiotemporal gradient changes in water quality which have an impact on the aquatic environment. IDW provides spatially continuous environmental data on aquatic environments (Al Naqeeb *et al.,* 2012; Khouni *et al.,* 2021;) such as water quality (Yang *et al.,* 2020), the aquatic plant community (Tapia-Silva *et al.,* 2015; Zarco-Perello & Simões, 2017), and suitable sites for aquaculture (Longdill *et al.,* 2008).

The inhabitants of Bann Had Krai, Chiang Khong district, Chiang Rai Province, Thailand have strong connections with the Mekong River which contains large numbers of edible aquatic plants and fishes. Kai algae are well-known in Bann Had Krai, and a Kai algae community enterprise has been established (Pokaew, 2018). This study used an integrated approach to assess spatial environmental changes in surface water quality as a quantitative trophic status score using the six environmental parameters (water conductivity, DO, BOD, nitrate nitrogen, soluble reactive phosphorus, and ammonium nitrogen). The IDW method, never previously applied in this area, was used to interpolate the spatial distribution of water quality affecting Kai algal growth based on the association between Kai algal growth and the AARL-PC water quality score. Our results can be used for determining water quality affecting Kai algal growth in the Mekong River.

2. Methodology

2.1 Study area and field survey

Kai algae sampling sites were located along the Mekong River at Bann Had Krai, Chiang Khong district, Chiang Rai Province, Thailand ($20^o15'4''$ to $20^o15'11''$ N, $100^o24'48''$ to $100^o24'52''$ E). Three sampling points (K1, K2 and K3) in which distance from a point-to-point is 70 m. intervals, based on the consideration of the presence of Kai algae, were selected along the Had Krai bank (Figure 1). Sampling of Kai algae and the physicochemical water properties was conducted in January and February 2022.

2.2 Collection and identification of Kai algae

Kai algae thalli were manually collected at each sampling site from substrate such as rocks and cobbles. The specimens were separated into two portions; one was used for identification using morphological features, while the other was investigated for species content using quadrants for both wet and dry weight determinations. The specimens were kept in plastic boxes at 5 - 7 °C and transferred to the laboratory. For the morphological study, Kai algae were measured based on relevant characteristics such as the width and length of apical cells, ultimate branches, and main axial cells. The examined qualitative characteristics included organization of branches, cell shape, characteristics of chloroplasts, and formation of branches. The morphological terminology followed freshwater algal flora and guide books including van den Hoek (1963), Whitford & Schumacher (1969), Prescott (1970) and Jonh *et al.* (2002). Photographs were taken using a digital microscope camera (Zeiss Primo Star).

2.3 Determination of physicochemical properties of water

The physicochemical properties of the water were determined at each sampling site. Water conductivity was measured using a multiparameter Eutech CyberScan CD 650, while dissolved oxygen was measured using the azide modification method (Eaton *et al.,* 2005). Water samples were collected at a depth of 30 cm from the surface of the water body using polyethylene bottles, which were then kept in a cool box at 5 - 7º C for later analysis in the laboratory. Biochemical oxygen demand was measured using the azide modification method. Nutrient contents, especially with regard to ammonium nitrogen, nitrate nitrogen, and soluble reactive phosphorus (P) were determined using the Nesslerization method, cadmium reduction method, and ascorbic method, respectively (Eaton *et al.,* 2005).

Due to the small sample sizes in this study, correlations between Kai algae and their environmental factors were tested using Regularized Canonical Correlation Analysis (RCCA) and Pearson's correlation in the R statistic program (Crawley, 2005; González *et al.,* 2008; R Core Team, 2022). The trophic status of water was evaluated from the main parameters (water conductivity, DO, BOD, ammonium nitrogen, nitrate nitrogen, and soluble reactive phosphorus) by AARL-PC score (Table 1 and Table 2) (Peerapornpisal *et al.,* 2004). Our results complemented the regular surveys conducted by the Pollution Control Department, Ministry of Natural Resources and Environment, Thailand that categorize water quality and assess the trophic status affecting freshwater macroalgae. Inverse distance weighting for water quality assessment was conducted following Peerapornpisal *et al.* (2004) and Leelahakriengkrai & Peerapornpisal (2011), based on Wetzel (2001) and Lorraine & Vollenweider (1981).
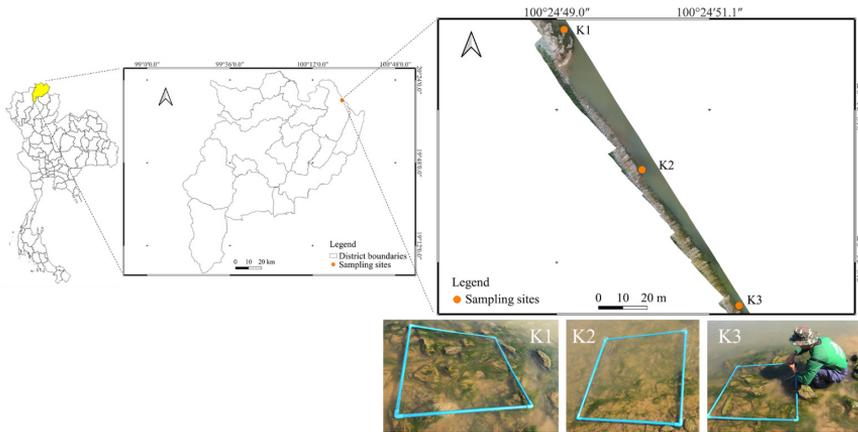
Source: GISTDA, 2012; DroneDeploy, 2022; QGIS Development Team, 2022.

Figure 1. Study area and Kai algae sampling sites

Table 1. AARL-PC scores for DO, BOD, water conductivity, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus

DO (mg/L)	BOD (mg/L)	Water conductivity (μS/cm)	Nitrate nitrogen (mg/L)	Ammonium nitrogen (mg/L)	Soluble reactive phosphorus (mg/L)	Score
> 9	> 0.3	> 10	> 0.05	> 0.01	> 0.05	0.1
8 - 9	0.3 - 0.8	10 - 30	0.05 - 0.1	0.01 - 0.05	0.05 - 0.10	0.2
7 - 8	0.8 - 1.5	30 - 60	0.1 - 0.3	0.05 - 0.1	0.1 - 0.2	0.3
6 - 7	1.5 - 3	60 - 100	0.3 - 0.8	0.1 - 0.2	0.2 - 0.4	0.4
5 - 6	3 - 5	100 - 200	0.8 - 1.5	0.2 - 0.5	0.4 - 1.0	0.5
4 - 5	5 - 10	200 - 350	1.5 - 3.0	0.5 - 1.0	1.0 - 2.0	0.6
3 - 4	10 - 20	350 - 600	3.0 - 10.0	1.0 - 2.0	2.0 - 3.5	0.7
2 - 3	20 - 40	600 - 1,000	10.0 - 20.0	2.0 - 4.5	3.5 - 7.0	0.8
1 - 2	40 - 80	1,000 - 2,000	20.0 - 40.0	4.5 - 10.0	7.0 - 15.0	0.9
< 1	< 80	< 2,000	< 40.0	< 10.0	< 15.0	1.0

Table 2. Classes of trophic status and water quality based on AARL-PC score

Score	Trophic status	Water quality
< 0.8	Ultraoligotrophic status	Very clean
0.9 - 1.6	Oligotrophic status	Clean
1.7 - 2.4	Oligotrophic-mesotrophic status	Clean-moderate
2.5 - 3.2	Mesotrophic status	Moderate
3.3 - 4.0	Mesotrophic-eutrophic status	Moderately-polluted
4.1 - 4.8	Eutrophic status	Polluted
> 4.8	Hypereutrophic status	Very polluted

3. Results and Discussion

3.1 Identifying Kai algae morphology

Two species of Kai algae including *Cladophora* sp. and *Rhizoclonium* sp. were identified based on their morphological differences. In January, K1 found *Cladophora* sp. while K2 and K3 found *Rhizoclonium* sp. In February, K1 found *Cladophora* sp. and *Rhizoclonium* sp. while K2 and K3 found only *Rhizoclonium* sp.

Cladophora sp.
Macroscopic filament, sparsely to profusely branched, or dichotomous branching, filaments of cylindrical cells, vegetative cells 40-80 μm in width, 80-200 μm in length, cell wall thickened, attached by a disc-like holdfast and/or rhizoids, cells may be multinucleate, chloroplast parietal, or net-like with bilenticular pyrenoid structure.
Ecology: Slow-flowing and fast-flowing water in the Mekong River 20 - 30 cm deep. The filamentous rhizoids were attached to stones by long strands growing toward the water surface.

Rhizoclonium sp.
Thallus unbranched or branched with 2 - 3 cells. Cell length about the same as cell width or many times longer, vegetative cells 40 - 50 μm in width, 50 - 100 μm in length, sometimes with walls thick and lamellate, each with a parietal, reticulate chloroplast and several pyrenoids and nuclei. Filaments are slender, may attach to substrate with basal cell or holdfast. Reproduction by fragmentation and fragment regeneration.
Ecology: Standing and slow-flowing water in the Mekong River 20 - 30 cm deep. The filamentous rhizoids were attached to stones by long strands growing toward the water surface.

Cladophora sp. and *Rhizoclonium* sp. frequently appear in the Mekong River (Figure 2). They are immobilized on cobbles and gravels in river and stream banks of lentic and lotic environments (Thiamdao *et al.,* 2012a). *Cladophora* sp. and *Rhizoclonium* sp. were not presented at all sample sites due to varied development stages or maturity, possibly related to the trophic status of the water (Wongsawad & Peerapornpisal, 2013). Findings revealed that *Rhizoclonium* sp. commonly grew with *Cladophora* sp. Peerapornpisal (2015) reported that *Rhizoclonium* sp. was often found growing with *Cladophora* sp.

### 3.2 Relationship between Kai algae and environmental factors

In January, average lengths of Kai algae in K1, K2 and K3 were 152.90, 54.40 and 136.50 cm, respectively. Dry weight of Kai algae in K1, K2 and K3 were 20.42, 8.08 and 83.81 g, respectively. K3 revealed high water conductivity, DO, and BOD while K1 showed higher concentrations of nitrate nitrogen and ammonium nitrogen than the other sites, possibly indicating increased nutrient load in the river induced by agricultural runoff containing nutrient-rich fertilizers. K2 recorded highly concentrated soluble reactive phosphorus which can contribute to eutrophication (Table 3). In February, average lengths of Kai algae at K1, K2 and K3 were 77.14, 50.30 and 42.20 cm, respectively. Dry weights of Kai algae in K1, K2 and K3 were 24.92, 2.98 and 4.91 g, respectively. K1 recorded high values of water conductivity, DO, BOD and ammonium nitrogen whereas K2 showed a higher concentration of nitrate nitrogen than the other sites. K3 gave highly concentrated soluble reactive phosphorus (Table 4). High concentrations of soluble

reactive phosphorus in K2 of January and K3 of February may cause concern for regulatory bodies in charge of monitoring and managing water quality. Nutrient management plans should be implemented to remove phosphates from agricultural runoff and improve agricultural practices to reduce nutrient runoff (Sharpley *et al.,* 2013).

In January, BOD had a strong positive relationship with length of Kai algae (Figure 3 and Table 5), while ammonium nitrogen had a significant relationship with water conductivity ($p < 0.01$), and DO had a significant relationship with dry weight of Kai algae ($p < 0.05$) (Table 6).

In February, BOD had a strong positive relationship with length of Kai algae ($r = 0.9804$) (Figure 4 and Table 7), while ammonium nitrogen had a significant relationship with water conductivity ($p < 0.05$) (Table 8).
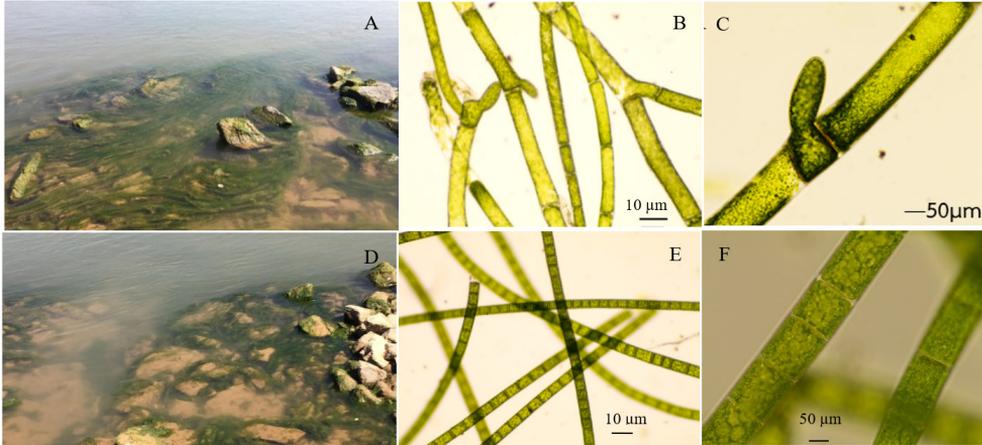

Figure 2. Kai algae; *Cladophora* sp. (A-C) and *Rhizoclonium* sp. (D-F)

Table 3. Length and dry weight of Kai algae and environmental factors in January

Environmental factor	Sampling sites		
	K1	K2	K3
Water conductivity (µS/cm)	270	282	289
Dissolved oxygen (mg/L)	7.8	7.6	8.6
BOD (mg/L)	0.6	0.2	1.4
Nitrate nitrogen (mg/L)	1.5	0.2	0.3
Soluble reactive phosphorus (mg/L)	0.14	0.5	0.12
Ammonium nitrogen (mg/L)	0.24	0.17	0.13
Average dry weight (g)	20.42	8.08	83.81
Average length (cm)	152.90	54.40	136.50

Table 4. Length and dry weight of Kai algae and environmental factors in February

Environmental factor	Sampling sites		
	K1	K2	K3
Water conductivity (µS/cm)	317	311	314
Dissolved oxygen (mg/L)	8.0	7.8	7.4
BOD (mg/L)	1.8	1.4	1.0
Nitrate nitrogen (mg/L)	0.7	1.1	0.5
Soluble reactive phosphorus (mg/L)	0.35	0.11	2.07
Ammonium nitrogen (mg/L)	0.39	0.09	0.23
Average dry weight (g)	24.92	2.98	4.91
Average length (cm)	77.14	50.30	42.20
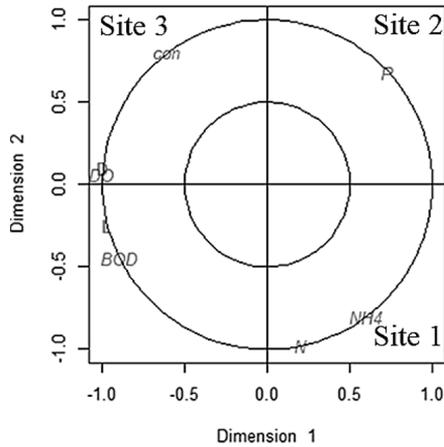
Figure 3. Relationship between environmental factors, length (L) and dry weight (D) of Kai algae using RCCA in January
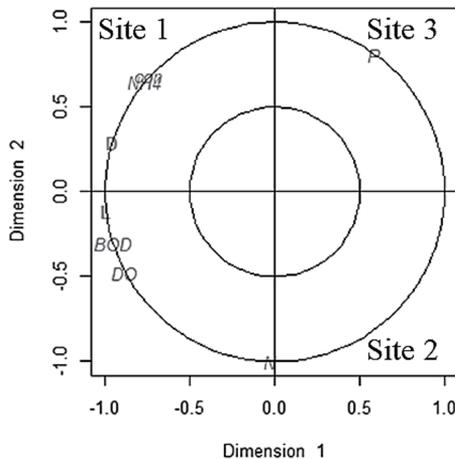
Table 5. Correlation coefficients of environmental factors affecting Kai algae in January

Environmental factors	Length	Dry weight
Water conductivity (μS/cm)	0.3903	0.6816
DO (mg/L)	0.9537	0.9990
BOD (mg/L)	0.9762	0.8433
Nitrate nitrogen (mg/L)	0.0409	-0.3031
Soluble reactive phosphorus (mg/L)	-0.8751	-0.6570
Ammonium nitrogen (mg/L)	-0.3853	-0.6776

Table 6. Pearson correlation analyses between Kai algae and environmental factors in January

	Length	Dry weight	Conductivity	DO	BOD	N	P	NH$_4$
Length	1							
Dry weight	0.2221	1						
Conductivity	0.7447	0.5226	1					
DO	0.1943	0.02779*	0.5504	1				
BOD	0.139	0.364	0.8837	0.3333	1			
N	0.9739	0.8039	0.2814	0.8317	0.8349	1		
P	0.3215	0.5436	0.9338	0.5158	0.1825	0.6524	1	
NH$_4$	0.7481	0.526	0.003435**	0.5538	0.8871	0.2779	0.9304	1

**Significance level of 0.01; *Significance level of 0.05

Figure 4. Relationship between environmental factors, length (L) and dry weight (D) of Kai algae using RCCA in February

Table 7. Correlation coefficients of environmental factors affecting Kai algae in February.

Environmental factors	Length	Dry weight
Water conductivity (µS/cm)	0.6606	0.9030
DO (mg/L)	0.9256	0.7015
BOD (mg/L)	0.9804	0.8235
Nitrate nitrogen (mg/L)	0.1350	- 0.2663
Soluble reactive phosphorus (mg/L)	- 0.6718	- 0.3255
Ammonium nitrogen (mg/L)	0.6889	0.9188

Table 8. Pearson correlation analyses between Kai algae and environmental factors in February

	Length	Dry weight	Conductivity	DO	BOD	N	P	NH$_4$
Length	1							
Dry weight	0.2579	1						
Conductivity	0.5406	0.2827	1					
DO	0.2471	0.505	0.7877	1				
BOD	0.1261	0.384	0.6667	0.121	1			
N	0.9138	0.8283	0.5456	0.6667	0.7877	1		
P	0.531	0.7889	0.9284	0.2839	0.4049	0.3828	1	
NH$_4$	0.5161	0.2582	0.02449*	0.7632	0.6422	0.5701	0.9529	1

*Significance level of 0.05

Results showed that in January and February, average water conductivity was 280.33 ± 9.61 and 314.00 ± 3.00 µS/cm, respectively. In February, water conductivity was higher compared to January, attributed to heavy rainfall and runoff occurring 3 - 4 days before sample collection in February (Chiang Rai Meteorological Station, 2023). This resulted in elevated water conductivity values for February. Water conductivity values were correlated with the dissolved organic matter content. High water conductivity values indicated the presence of dissolved organic compounds. In January, water conductivity was within the appropriate range, while in February it was higher. Good water quality typically falls within the conductivity range of 150 to 300 µS/cm. Values exceeding 300 µS/cm suggest higher contamination, which might not be conducive to the growth of aquatic life. Results from the study on dissolved oxygen levels in water are important for the growth of Kai algae. In January and February, the average DO values were 8.00 ± 0.53 and 7.73 ± 0.31 mg/L, respectively. Generally, an appropriate dissolved oxygen concentration for supporting aquatic life is between 5 and 7 mg/L. If the dissolved oxygen level falls below 3 mg/L, it is not suitable for sustaining aquatic life (Trichaiyaporn *et al.,* 2006; Srirat *et al.,* 2012). The study results of the amount of oxygen used by bacteria for organic matter degradation in January and February showed average values of 0.73 ± 0.61 and 1.40 ± 0.40 mg/L, respectively. These values fell within surface water quality Class 2. The specified oxygen quantity utilized by bacteria for organic matter degradation should not exceed 1.5 mg/L. Measuring the oxygen quantity utilized by bacteria for organic matter degradation serves as an indicator of water pollution. The measured values in both months suggested that the water sources were influenced by community activities and were not fit for consumption before proper treatment to eliminate pathogens and improve water quality. Furthermore, these water sources are also utilized for agricultural purposes (Srirat *et al.,* 2012). The study findings on nitrate nitrogen levels revealed that in January and February, the average values were 0.67 ± 0.72 and 0.77 ± 0.31 mg/L, respectively. These values exceeded surface water quality Class 3. The specified nitrate nitrogen quantity should not exceed 5.0 mg/L. Contamination by nitrate nitrogen in water originates from agricultural activities and domestic wastewater from communities. Algae utilize nitrate, ammonium, and organic nitrogen as significant sources for growth and development (Srirat *et al.,* 2012; Tuntoolavest, 2008). The study results on ammonium nitrogen levels showed that in

January and February, the average values were 0.18 ± 0.06 and 0.24 ± 0.15 mg/L, respectively. These values conformed to surface water quality Class 2. The specified ammonium-nitrogen quantity should not exceed 0.5 mg/L. Ammonium originates from the microbial degradation of nitrogenous organic compounds. In water sources, nitrogen compounds exist as nitrate, nitrite, and ammonium. Algae utilize ammonium by converting it after transformation from ammonium to various cellular components (Srirat *et al.,* 2012; Trichaiyaporn *et al.,* 2006). The study results on soluble reactive phosphorus levels revealed that in January and February, the average values were 0.25 ± 0.21 and 0.84 ± 1.07 mg/L, respectively. soluble reactive phosphorus exists in dissolved form in water and is commonly found in detergents as well as being a component of chemical fertilizers in agriculture, including areas where plant and animal remains are incorporated. The February values were higher compared to January, attributed to rainfall occurring 3 - 4 days before the sampling date (Chiang Rai Meteorological Station, 2023). This rainwater washed contaminants from communities and agricultural areas into the water sources, leading to elevated orthophosphate levels. Orthophosphate is an essential nutrient contributing to the growth of algae. An appropriate level for algal growth should not exceed 0.3 mg/L (Srirat *et al.,* 2012; Trichaiyaporn *et al.,* 2006).

From the analysis of the correlation between environmental factors influencing Kai algae, utilizing RCCA in January, specifically at K3, a significant positive correlation ($p < 0.05$) was observed between dry weight of Kai algae and dissolved oxygen levels. Kai algae in the Mekong River cannot grow in the summer season because of high temperatures and the southwest monsoon brings rain and heavy storms from April through to October (Thiamdao *et al.,* 2012a; Mungmai *et al.,* 2014; Wang *et al.,* 2017; Ruen-Pham *et al.,* 2021). Moreover, suitable light intensity for Kai algal growth is no more than 35,000 lux. This allows Kai algae to photosynthesize more effectively, resulting in higher oxygen levels, typically around 8 mg/L. The optimal orthophosphate

level is no more than 0.3 mg/L, promoting Kai algal growth. Ammonium nitrogen showed a significant correlation with water conductivity ($p < 0.05$). The ammonium nitrogen concentration was 0.13 mg/L, relating to surface water quality Class 2, which specifies that ammonium nitrogen levels should not exceed 0.5 mg/L. The water conductivity value was 289 µS/cm, and good water quality generally falls within the range of 150 to 300 µS/cm. A positive correlation was found between BOD and algal length. The BOD value was 1.4 mg/L, and within surface water quality Class 2, which recommends BOD levels not exceeding 1.5 mg/L. These environmental factors mentioned above contributed to Kai algal ability to bloom and grow well (Mala, 2018; Srirat *et al.,* 2012; Trichaiyaporn *et al.,* 2006).

Analysis results of the environmental factors influencing Kai algae using RCCA in February, specifically at K1, suggested a positive correlation between BOD and length of Kai algae when the BOD value was 1.8 mg/L. This value related to surface water quality Class 3, where the recommended BOD level should not exceed 2.0 mg/L. DO concentration was 8 mg/L, also within surface water quality Class 2. Ammonium nitrogen showed a significant correlation with water conductivity ($p < 0.05$) at a concentration of 0.35 mg/L. This concentration aligned with surface water quality Class 2, which specifies that ammonium nitrogen levels should not exceed 0.5 mg/L. The water conductivity value was 317 µS/cm. Kai algae bloomed well in February based on these environmental factors (Srirat *et al.,* 2012; Trichaiyaporn *et al.,* 2006).

During the sampling period (January and February), K1 had mesotrophic status, which caused Kai algae to have longer lengths than at the other sites. The dry weight of Kai algae in K3 (oligotrophic-mesotrophic status) in January was higher than the other samples but dry weight of Kai algae in K1 (mesotrophic status) in February was higher than the other sites (Table 9 and Table 10). Thus, Kai algae favored mesotrophic status with moderate water quality suitable for Kai algal growth (Moonsin *et al.,* 2013).
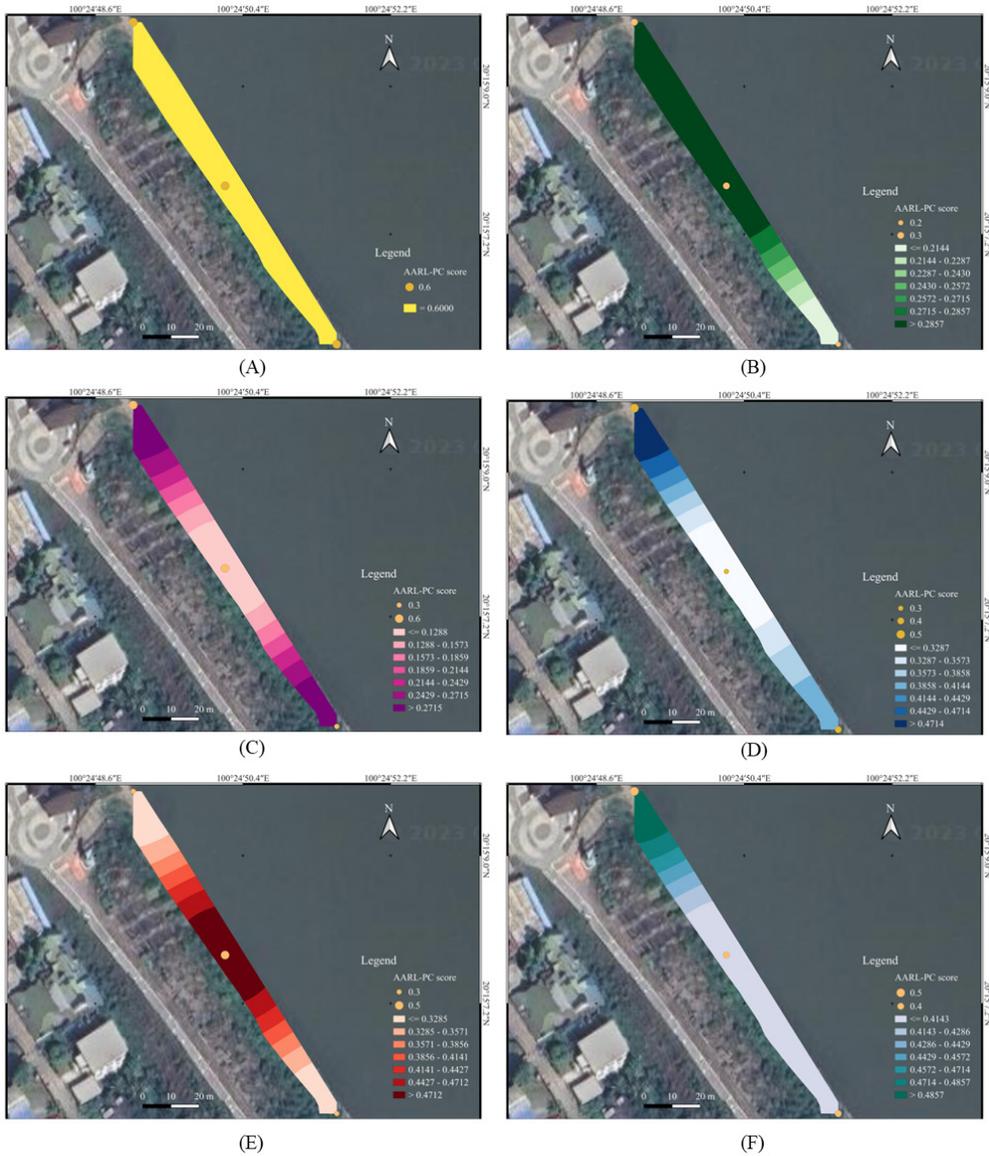
Table 9. AARL-PC scores in January

Sites	Water conductivity	DO	BOD	Nitrate nitrogen	Soluble reactive phosphorus	Ammonium nitrogen	Total score	Water quality
1	0.6	0.3	0.3	0.5	0.3	0.5	2.5 (Mesotrophic status)	Moderate
2	0.6	0.3	0.1	0.3	0.5	0.4	2.2 (Oligotrophic-mesotrophic status)	Clean-moderate
3	0.6	0.2	0.3	0.4	0.3	0.4	2.2 (Oligotrophic-mesotrophic status)	Clean-moderate

Table 10. AARL-PC scores in February

| Sites	Water conductivity	DO	BOD	Nitrate nitrogen	Soluble reactive phosphorus	Ammonium nitrogen	Total score	Water quality
1	0.6	0.2	0.4	0.4	0.4	0.5	2.5 (Mesotrophic status)	Moderate
2	0.6	0.3	0.3	0.5	0.3	0.3	2.3 (Oligotrophic-mesotrophic status)	Clean-moderate
3	0.6	0.3	0.3	0.4	0.7	0.5	2.8 (Mesotrophic status)	Moderate

However, the correlation between Kai algae and key environmental factors requires further consideration to fully understand their sensitivity to environmental conditions in the Mekong River (Ogbozige *et al.,* 2018).

The AARL-PC scores in January and February indicated oligotrophic-mesotrophic status and mesotrophic status, respectively. Using the AARL-PC score, Moonsin *et al.* (2013) found that macroalgae, *Spirogyra* sp.1, *Spirogyra* sp.2, *Cladophora glomerata, Microspora pachyderma*, and *Microspora* sp. could grow in mesotrophic status with low to moderate water quality. IDW generated from the AARL-PC score in January (Figure 5) and February (Figure 6) revealed clean-moderate and moderate water quality, respectively. As a result, IDW provided by the AARL-PC score (Figure 7) can be used for determining water quality affecting Kai algal growth in the Mekong River. Our findings provide an empirical approach to improve the management planning of Kai algal habitats along the Mekong River as a useful tool for sustainable development.

Figure 5. IDW derived from the AAPL-PC scores in January; water conductivity (A); DO (B); BOD (C); N (D); P (E) and NH₄ (F)
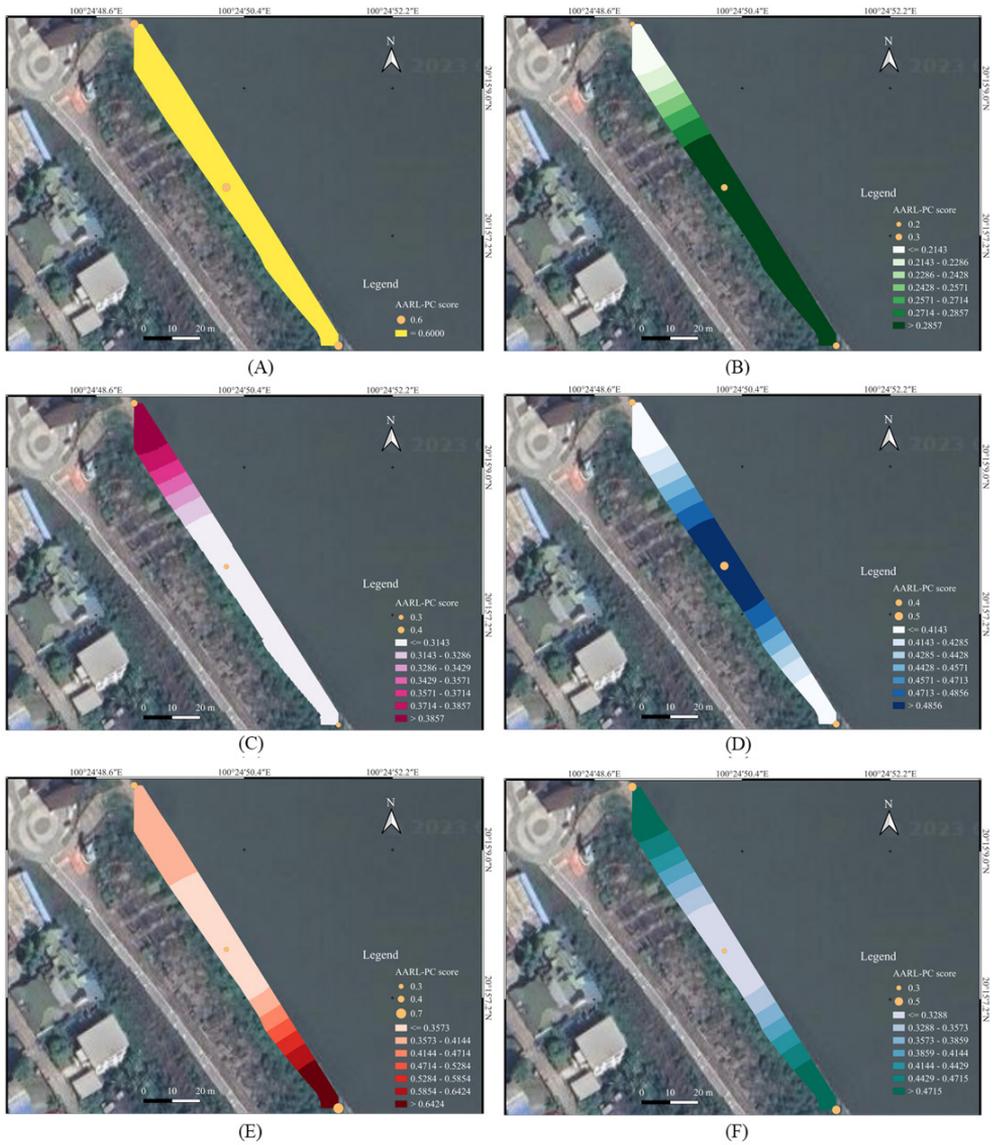
Figure 6. IDW derived from the AAPL-PC scores in February; water conductivity (A); DO (B); BOD (C); N (D); P (E) and NH_4 (F)
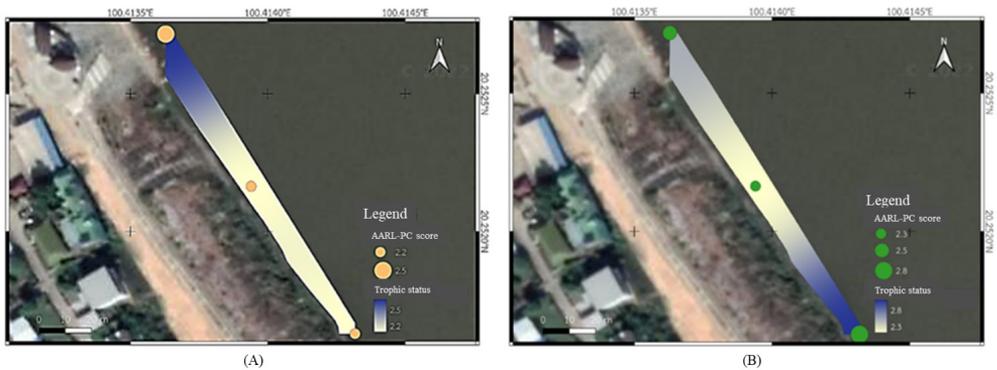
Figure 7. IDW derived from the AAPL-PC scores in January (A) and February (B)

4. Conclusion

In this study, two genera of Kai algae were found, namely *Cladophora* sp. and *Rhizoclonium* sp. Most environmental factors were optimized for Kai algal growth, except for water conductivity and soluble reactive phosphorus in February. An analysis of the correlation between environmental factors influencing Kai algae in January showed that ammonium nitrogen exhibited a significant correlation with water conductivity. The BOD value was significantly correlated with Kai algal length, while the dissolved oxygen levels showed significant correlation with algal dry weight. In February, BOD values were significantly correlated with Kai algal length, while ammonium nitrogen presented a significant correlation with water conductivity. IDW derived from the AARL-PC-scores revealed that clean-moderate water quality was directly related to environmental factors in January and February and can be used for determining water quality affecting Kai algal growth in the Mekong River.

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