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The Effect of Water Depth on the Structure and Allocation of Waterlily (*Nymphaea pubescens* Willd) Biomass in *Lebak* Swampland in Kalimantan Selatan

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Abstract:

Nymphaea pubescens is found in the swamplands of Kalimantan Selatan, where it lives in the shape of a basin with divergent levels of water. From February to June 2019, the environment and its development were studied in four zones, with depth differences ranging from 28 to 95 meters in the zone I, 28 to 99 meters in zone II, 54 to 112 meters in zone III, and 55 to 124 meters in zone IV. A transect system is used to zone the area, with fluctuating degrees of water depth reflected in each zone as one moves closer to a basin. Geomorphology in a basin has an essential relief, causing different levels of water surface depth in *lebak* swampland. The GPS was used to determine the distance traveled.

The purposive sampling technique determines the number of observation stations in each zone. In zone I, waterlily growth generated smaller and more frequent leaves than plants in zone II, which produced smaller and fewer leaves than plants in zone III, which produced smaller and fewer leaves than plants in zone IV. However, the area of the leaves expanded greatly with the depth of water, although the number of leaves fell dramatically with water depth. The organization of the percentage of biomass for the development of shoots and roots was different, even though the total biomass was not statistically different. Waterlily growing in shallower water depths had larger biomass allocations for seeds and lower biomass allocations for roots. Root biomass increased significantly as the depth of the water body increased.

This experiment showed that the deeper the water, the lesser the nutrients and the greater the extent the roots must spread to meet their nutritional requirements. Even though the relationship between leaf area and bloom number weakened as water depth increased, the relationship between leaf number and root number was significantly positive concerning biomass and water depth. Groundwater depth has a significant effect on the allocation of underground biomass (A), with the biomass proportion decreasing as water depth increases from 28 to 95 cm in zone I = 53.1 percent to 28–99 cm in zone II = 53.7 percent to 55–124 cm in zone III = 48.6 percent in zone IV = 42.4 percent. Because water depth has a considerable effect on the average aboveground biomass–to–underground biomass ratio, the average root crown ratio decreases as water depth increases. Among the lowest average ratios found are those found at a water depth of 55–124 cm in zone IV (ratio of 0.54 ± 0.2), while the highest average percentage found is that found at a water depth of 28–95 cm in the zone I (ratio of 1.25 ± 0.61).

Keywords: biomass allocation; water depth; *Nymphaea pubescens*; *lebak* swampland; biomass structure.

JEL Classification: Q10; Q15; Q56; Q57.

Introduction

Aquatic plants such as *Nymphaea pubescens* are usually hydrophobic to avoid decay (Yang and Guo 2015), specific air canals are arranged in the midrib and petiole (Ismuhajarah *et al.* 2022), the roots to the sediments (Cronk and Fennessy 2001; Chen *et al.* 2017; Li *et al.* 2020) in muddy ponds (Lacoul and Freedman 2006; Yang and Guo 2015). Rooted plants can absorb large amounts of inorganic carbon while also collecting nitrogen, phosphorus, calcium, and other nutrients from the surrounding sediment (Barko and Smart 1981; Lacoul and Fredman 2006; Zhu *et al.* 2017). For gas exchange, particularly with the atmosphere, floating aquatic plants have an easy-to-maintain canopy structure that is positioned on the air surface, while the abaxial section of the plant is in contact with water (Tsuchiya 1991) and has a trichome or hydropot (Kordyum *et al.* 2021). In the case of buoyant waterlily leaves, Ritchie (2012) observed the limits on photosynthesis imposed by transpirational water loss do not apply, nor does the assumption that primary production by vascular plants is typically constrained by water rather than light, CO₂, or nutrients.

A wetland is a habitat where water levels vary regularly; the ecology relies on local hydrological fluctuations (Zhu *et al.* 2017; Ismuhajarah *et al.* 2022), climate, and its variations (Fossey and Rousseau 2016; Liu and Kumar 2016; Zhu *et al.* 2017). The water level fluctuates and changes during specific periods (Deegan *et al.* 2012) throughout several decades (van der Valk 2005; White *et al.* 2008), in addition to seasonal to daily (Ismuhajarah *et al.* 2022). Fluctuating water levels are hydrological regime components relating to water depth, velocity, amplitude, and the timing of floods or low tides, among other factors (Raulings *et al.* 2010; Jian *et al.* 2018). The distance from the ocean's edge to the water body influences the water regime at different depths, which has a significant impact on the ecosystem and species composition (Torres–Fernández del Campo *et al.* 2018; Solórzano *et al.* 2020), diversity (Casanova and Brock 2000; Kleindl and Steinman 2021), distribution in the community (Kennedy *et al.* 2003; Boar 2006; Wang *et al.* 2016), can have an impact on the growth and development of aquatic plants (Raulings *et al.* 2010; Jian *et al.* 2018; Kleindl and Steinman 2021).

The availability of light in the water, as well as the availability of oxygen in the sediment, are both directly affected by oscillations in water level (Casanova and Brock 2000; Raulings *et al.* 2010), sediment composition (Maurer and Zedler 2002), sedimentation (Baldwin and Mitchell 2000), nutrient concentration (Lu *et al.* 2018; Zhang *et al.* 2019), nutrition cycle (Coops and Hosper 2002; Pinay *et al.* 2002), nutrient availability (Kornijów *et al.* 2016), acidity level, as well as alkalinity (Bini *et al.* 1999; Magee *et al.* 1999) therefore, affect aquatic plant growth (van der Valk 2005; Baastrup–Spohr *et al.* 2015). According to Riis and Hawes (2002); van Geest *et al.* (2005), the duration and frequency of fluctuations in water level impact the germination, growth, and survival of aquatic plants.

In contrast, the frequency and depth of changes affect reproduction. One of the primary variables influencing changes in the temperature of the marine environment is sunlight (Barko and Smart 1981; Maurer and Zedler 2002; Yu *et al.* 2014; Bando *et al.* 2015). The temperature and light range influence the physiological variations in growth defined by photosynthesis the affected ration and CO₂ compensation points (Barko and Smart 1981). The increase in temperature and light that occurs in the growing environment affects the capacity or aptitude of plants to photosynthesize (Yu *et al.* 2014). Tsuchiya (1991) elaborated that the adequate supply of light, carbon, and water in the environment caused the net photosynthetic rate per unit area to be higher in floating aquatic plants than in terrestrial plants. Aquatic plants with floating leaves can sustain a high net photosynthesis rate to constantly grow new leaves (Yamamoto *et al.* 1999). The shape of their development somewhat determines the capacity of aquatic plants to thrive in various light situations. As a general rule, low light conditions in the shallow littoral zone support the dominance of helophytes (emergent species).

At the same time, deeper water tends to favor free-floating and leaf-floating species rather than submerged species. Even though aquatic plants such as *Nelumbo* spp., *Nymphaea* spp., and *Trapa* spp. may grow in water with low transparency; the seasonal clarity may be crucial in producing new seedlings (Gopal and Sharma 1990). Even though water depth can significantly impact the light intensity (Bai *et al.* 2015), waterlily seeds can still germinate and grow to 90 cm in depth (Richard and Cao 2012). Aquatic plants that grow or leave floating at depths of 0.5 m to 2.0 m and that rarely grow in water deeper than 3 m (Richards and Cao 2012; Klok and van der Velde 2017; Les 2018) and clay (Lacoul and Fredman, 2006), while at specific depths, sandy loam and clay soils can be found and clay (Bai *et al.* 2015). The biomass allocation in plants may characterize the reaction to changes in environmental parameters due to variations in water depth. These changes can include changes in pH and light levels, particle solids, temperature, and light intensity, among other aspects.

Adaptation of plants to environmental changes is the responsibility of aquatic plants, which is necessary for their continued existence (Yang and Guo 2015). Plants may evolve adaptation mechanisms even when

variations in water level or frequency amplitude are minor. Still, the changes that occur are nevertheless reflected in the response of aquatic plants due to these changes (van der Valk and Mushet 2016). Plants' reactions to their environments may change the biomass allocation pattern, influencing their ability to collect available resources (Müller *et al.* 2000; Poorter and Nagel 2000; Poorter *et al.* 2012). In 2003, van Wijk *et al.* developed a method to maximize growth rate or optimize plant performance (Bloom *et al.* 1985). Adaptation is accomplished by balancing the allocation of resources to the leaves, stems, and roots by the physiological activities and functions performed by each organ in question (Poorter *et al.* 2012). The teleonomic model, which is a theory of functional balance, may be used to determine the pattern of biomass allocation (van Wijk *et al.* 2003) as it states that plants respond to a decrease in aboveground resources by increasing their share to shoots, while a decrease in underground resources increases root allocation (Poorter and Nagel 2000; Shipley and Maziane 2002; Poorter *et al.* 2012).

In research done in lowland swampland, the structure and allocation of biomass for the response of *N. pubescens* to varied water depths were revealed. This research aimed to discover how various water depths impact the growth environment in terms of pH, sunshine, water solids particles, and temperature, affecting the structure and biomass allocation of all plant components above and below ground. Additionally, this research will analyze how the link between the leaf surface area utilized for photosynthesis and the total weight of biomass influences the total weight of biomass. The association between the number of leaves, flowers, and roots and the importance of the biomass in each section was also investigated to find the appropriate depth level for *N. pubescens* growth.

1. Literature Review

Chernova (2015) evaluated the dynamics of *Nuphar lutea* L. production characteristics at the soil surface, as well as the contribution of different organs of each plant portion to total biomass and plant production. The dynamics of changing seasons must take into account the biomass of *Nuphar lutea*. The buildup of biomass in soil surface organs is greatest in the spring and early summer, as well as during the concurrent blooming and early fruiting seasons. *Nuphar lutea*'s yearly net production at ground level is twice as great as its highest productivity. Müller *et al.* (2000) investigated the impact of nutrient availability on the pattern of biomass allocation in 27 herbaceous plant species. In general, the total organ biomass above the soil surface rises.

Paillisson and Marion (2011) investigated the effect of water level fluctuation (WFL) on the biomass of three aquatic plant species (*Nymphaea alba*, *Nymphaea lutea*, and *Nymphaea peltata*). The purpose of this study was to discover when in the plant life cycle a high water regime influences plant biomass. The results revealed that there was a little rise in the shallow lake water regime in the long-term research, which might severely affect the biomass of some Nymphaeid species that were still tolerant to minor changes in water level. Richards *et al.* (2011) evaluated the influence of water depth on *Nymphaea odorata* growth, morphological allocation, and biomass. Deeper water plants have more biomass assigned to the leaves and roots, whereas shallower water plants have more biomass devoted to the rhizome. *Nymphaea odorata* growth is approaching to maximum in summer with a water depth of 75 cm.

2. Materials and Methods

2.1. Time and Location of Research

The research area is in Desa Teluk Sinar, Kecamatan Sungai Pandan, Kabupaten Hulu Sungai Utara, Kalimantan Selatan, Indonesia. The research was carried out over five months, from February to June 2019. Geomorphology in a basin has an essential relief, causing different levels of water surface depth in *lebak* swampland. The swampland has the characteristics of being a water catchment area for overflowing rivers in the surrounding area and a wetland. The swamp zone where the study was located was divided into four water depth zones, namely in location I with a depth of 28–95 cm at 2°30'5.7"S, 115°10'23.5"E, zone II at 2°30'4.3"S, 115°10'18.6"E, zone III at 2°30'4.3"S, 115°10'15.3"E, and zone IV at 2°29'4.3"S, 115°10'10.5"E. In Indonesia, which has a tropical climate, *lebak* swampland was an area where the water surface was influenced by two seasons known as the wet and dry seasons. The two seasons are the rainy season and the dry season. It was a fact of life that as soon as the rainy season arrives, the *lebak* swampland was filled with water from the river, which causes the water level to rise in tandem with an increase in rainfall. Rainfall in 2019 in Kecamatan Sungai Pandan was recorded at 1,846 mm with a height of 6 m above sea level and a slope of 0–2° (BPS–HSU, 2020).

2.2. Procedures

Preliminary determination of observation sites in four different water depth zones

This study's observation sites are chosen in each zone by drawing a line from the beach base towards the basin and continuing the line as far as 150 meters for each area, resulting in an observation site that was 0.6 kilometers from the baseline. The GPS was used to determine the distance traveled. The purposive sampling technique determines the number of observation stations in each zone. It was necessary to take as many as six replications of the observation sites of *N. pubescens* plants for each zone for 24 observation points. Each observation site was marked by the placement of four *Galam* wood (*Melaleuca leucadendron*) as a plugged barrier into the swamp's bottom. The wood was then connected with a rope to make a quadrant frame measuring 5 meters by 5 meters. To select a representative sample of the observed plants, three plants were picked at random from each observation location for a total of 72 sample plants. Sample plants are marked with a wooden slat plugged near the plant sample and then labeled with mica plastic manufactured from water-repellent ink, announced near the plant sample again.

Environmental Factor Observation

The pH of water and soil was measured in the laboratory with the help of a pH electrode (Wetzel and Likens 2000). Water samples were collected using a plastic bottle with a capacity of 150 mL. In contrast, soil sediment samples were collected by diving to the swamp's bottom with a PVC core diameter of 0.15 m and a length of 0.12 m. The sediment collected was placed in a plastic bag for further analysis. All samples were taken at random from three points near the sample plants marked with wooden slats on each quadrant frame in each zone: zone I, zone II, zone III, and zone IV. Water and sediment samples were taken at three points near the sample plants marked with wooden slats on each quadrant frame in each zone: zone I, zone II, zone III, and zone IV.

A Secchi-disk disc (Cazzanelli *et al.* 2008) may be used to measure the depth of light entering water or the transparency of water. The disc was lowered into the water until it was no longer detectable. To make measurements, it was necessary to record the date and location of each sample and carefully read the Secchi-disk. The observation of water depth was measured using a scaled metal plate affixed to the wood to serve as a location to hold the measuring device (Rossenberry and Hayashi 2013). Both the depth of light entering the water and the depth of the water was measured concurrently throughout the day when the sun was shining brightly, and the water was completely submerged. Measurements may be taken at a single location for each selected quadrant as well as for all zones, including zones I, II, III, and IV, at the same time. Total dissolved solids (TDS) measurements were taken at each quadrant frame and three locations near the sample plants. The digital TDS-meter should be dipped into a body of water at a depth of 5 cm, allowed to sit in the water for a few minutes, and then the dissolved solids number was shown on the TDS-meter should be read.

Air and water temperature measurements were carried out at three places near the sample plants in each redefined quadrant and for all zones, zone I, zone III, and IV. Air temperature measurement was carried out using a digital thermometer elevated above the water level by as high as 50 cm (Nohara and Tsuchiya 1990). Water temperature experiments are conducted using a thermometer dipped in water to a depth of 5 cm below the water's surface and then recorded (Klok and van der Velde 2017) and in the vicinity of waterlily plants (Pip 1989). A Lux meter (Digital Lux Meter LX-1330B) was used to determine the intensity of light or lighting. The measurement was carried out during the day, when the sun was entirely shining, by raising the Lux meter above the marsh area to a height of roughly 10 cm.

Structure and Determination of Biomass

The biomass of *N. pubescens* was measured in each growth zone of the observation plot using the harvest technique, which was used to collect the samples. There are 24 observation plots in all, each measuring 5 m x 5 m and marked with *Galam* wood. There are six observation plots in each growth zone, for 24 observations throughout all the zones. The sediment tops and bottoms were collected with a surface area of 1 m² for each sample. The harvesting focused on expressing the biomass per unit surface area of the sediment (Brock *et al.* 1983). Canoes or *jukung* are the modes of transportation employed throughout the harvesting process. Plants are sampled by diving to the swamp's bottom and removing all of the plant's components, including roots, by scratching its root system.

The collected plants are first scrubbed of mud with swamp water, then rinsed with running water until completely clean before being placed in a plastic bag with a label and delivered to the lab. Plants are divided into organs, which include leaves, seeds, rhizome, and roots, among other things. Each section contains an

examination of the organs that have been divided. The Leaf Area Meter DELTA T Devices Ltd, UK was used to measure leaf area. The number of leaves on the organs of the leaf, flower, and root was counted on each organ. While it was true that not all the seeds can be dug, depending on the root markings on the rhizome allows for a more accurate root count than just digging up the rhizome and separating them from them. When splitting the organ into its constituent pieces, it was possible to count the leaf and flower organs directly. Aquatic plants are made from organs that have been separated and tagged, which are then dried in the sun for one day to lessen their excessive water content. Following that, the sun-dried plants are individually wrapped in aluminum foil and labeled. This was followed by baking the sample package at 105°C for 12 hours and weighing the package to ensure that it had maintained its consistency throughout the drying process (Brock *et al.* 1983). The data on all biomass was expressed as grams of dry weight per square meter of surface area (g DW m⁻²).

2.3. Data Analysis

With the help of SAS 9.4 analysis, we compared morphological data (including leaf area, number of leaves, number of flowers, and number of roots) and harvested biomass at various water depths (SAS Institute, Inc., Cary, NC). Tukey's HSD was used for post-hoc comparisons, and differences were considered significant when $P \leq 0.05$ was achieved. The ANOVA test for normal distribution was used to determine whether there were any differences in water depth between treatments. The linear regression method was used to investigate the relationship between the parameters of leaf area, number of flowers, and number of roots with biomass at various depths of water infiltration.

3. Results and Discussion

3.1. *N. pubescens* Growing Environment in Fluctuating Water Depth

Acidity level

The chemical properties of the soil in swamplands are influenced by the type of soil present in the area. *Lebak* swampland was mineral soil (river sediment) with a clay texture ranging from dusty clay to clay with a clay texture ranging from clay to dusty clay, which receives silt from upstream regions every year. Generally speaking, water pH at a water depth of 28–95 cm in the zone I was between 6.9 and 7.3, while 28–99 cm in area II was between 7.0 and 7.5, 54–112 cm in zone III was between 7.0 and 7.3, and 55–124 cm in zone IV was between 7.0 and 7.4 (Table 1). When measured at a water level of 28–95 cm in the zone I, the soil pH ranges between 4.1 and 4.7, while 28–99 cm in zone II, pH 4.4 to 4.8, 54–112 cm in zone III, pH 3.8 to 4.8, and 55–124 cm in zone IV, pH 4.1 to 4.5 (Table 1). This situation demonstrates that the pH of the water in the *Lebak* swampland usually was in the neutral range, but the pH of the soil was in the highly acidic to the acidic content, as seen in the graph.

Table 1. For the period February to June 2019, differences in water and soil pH were observed in the *Lebak* swampland in Hulu Sungai Utara, with water depths ranging from 28 to 95 cm (zone I), 28 to 99 cm (zone II), 54 to 112 cm (zone III), and 55 to 124 cm (zone IV)

Variable	Water depth in each growth zone			
	28–95 cm (zone I)	28–99 cm (zone II)	54–112 cm (zone III)	55–124 cm (zone IV)
pH:				
Water	6.9–7.3 n	7.0–7.5 n	7.0–7.3 n	7.0–7.4 n
Soil	4.1–4.7 ea–vsa	4.4–4.8 ea–vsa	3.8–4.8 ea–vsa	4.1–4.5 ea–vsa

Description: BP Tanah Bogor (2009) defined the following soil and water reactions as follows: ea = extremely acidic (pH < 4.5); vsa = very strongly acidic (pH 4.5–5.5); sa = slightly acidic (pH 5.6–6.6); n = netral (pH 6.6–7.5); sla = slightly alkaline (pH 7.6–8.5); sta = strongly alkaline (pH > 8.5).

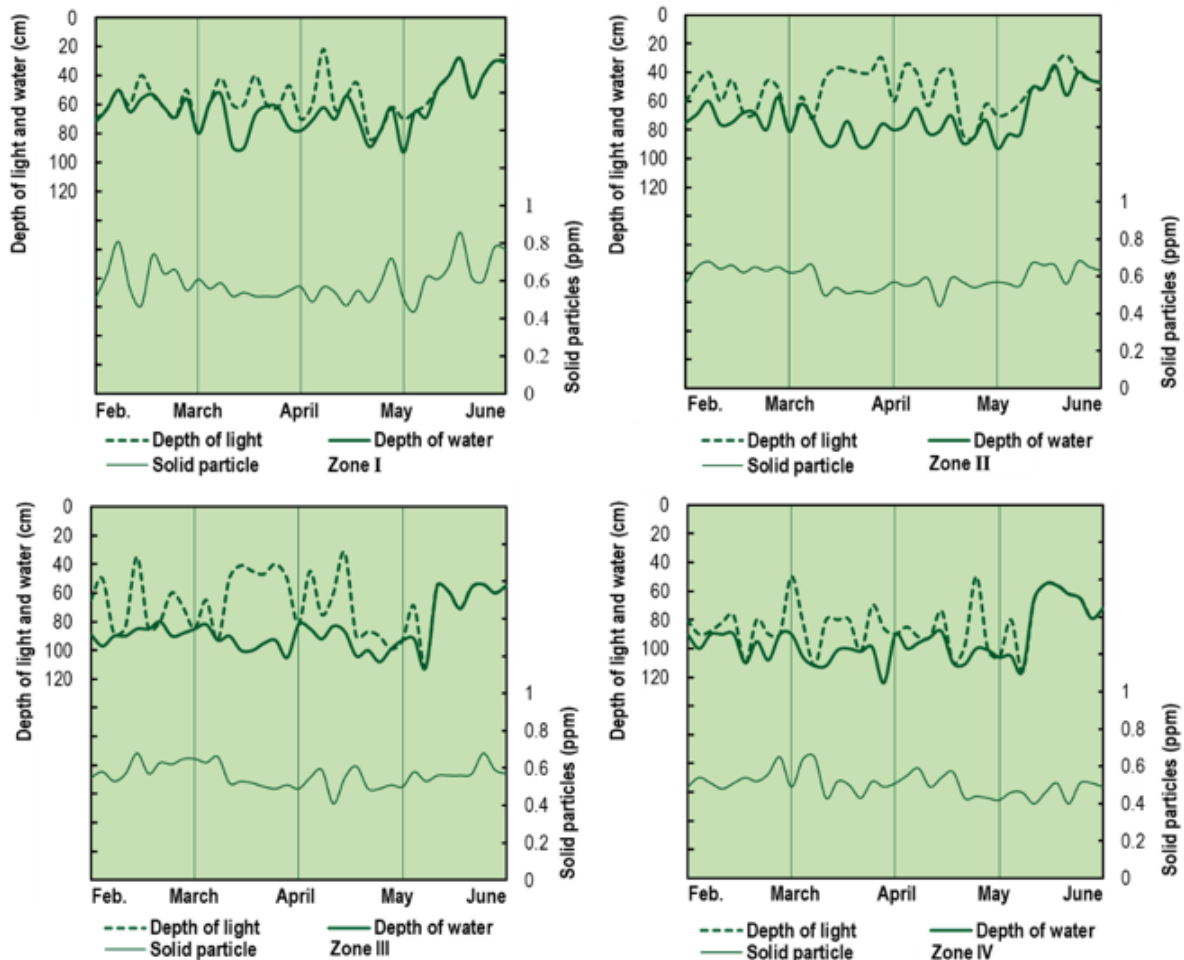
The acidity of water and soil has an impact on the availability of nutrients (Sudiarto *et al.* 2019), their distribution, and the development of aquatic plants air (Webb *et al.* 2012; Kutschker *et al.* 2014; Dong *et al.* 2017; Klok and van der Velde 2017), as well as on a variety of activities occurring inside plant cells (Felle 2005). Specifically, according to Les (2018), a waterlily was an aquatic plant that can thrive in water that ranges from acidic to neutral. The acidity of the water in the lowlands for all zones was classified as neutral water pH, with a pH range in all pH zones ranging from 6.9 to 7.5. These parameters imply that *N. pubescens* can grow in all depth zones in the lowlands. According to the statistics, the acidity of the waterfalls into the neutral was greater than the pH of the soil (Table 1). The water pH was affected by productive aquatic plants in a swamp

environment. Plants photosynthesize by absorbing CO₂ from their surroundings and releasing H⁺ elements from their roots, thus raising the pH of the water by around 3–4 units (Cronk and Fennessy 2001).

Depth, light, and solids of water particles

Hydrology significantly impacts the environment; important aspects include evapotranspiration, rainfall volume (Lacoul and Fredman 2006; Zhu *et al.* 2017), geomorphology, vegetation cover, and season (Lacoul and Fredman 2006). The edge zone was a transition zone between land and water where the depth fluctuates considerably (Yu *et al.* 2014). In swampland, the water regime was a significant determinant of plant community development and zoning patterns (Casanova and Brock 2000). Throughout the depths of swampland water, the water's height fluctuates, resulting in a constantly fluctuating depth. According to Lu *et al.* (2018), natural oscillations in water levels may be caused by rainfall and runoff in the environment. From February to June 2019, the maximum and lowest retentions of water varied depending on the depth of the water. It takes 28–95 cm to retain swamp water in zone I, 28–99 cm in zone II, 54–112 cm in zone III, and 55–124 cm in zone IV to retain swampland water in zone IV. Because the depth of swampland water varies from one zone to another, so does the depth of light that penetrates the water. The average depth of light penetrating the water increases from zone I to zone IV, with an average depth of 53.73 cm in the zone I, 54.11 cm in zone II, 66.97 cm in zone III, and 83.19 cm in zone IV. The average depth of light penetrating the water increases from zone I to zone IV, with an average depth of 53.73 cm in zone I, 54.11 cm in zone II, 66.97 cm in zone III, and 83.19. Observations for solid particle data at a water depth of 28–95 cm in the zone I and a depth of 28–99 cm in zone II yielded 0.59 parts per million (ppm), which was higher than the 0.56 parts per million (ppm) obtained at a depth of 54–112 cm in zone III and the 0.50 parts per million obtained at a depth of 55–124 cm in zone IV (Figure 1).

Figure 1. Top position left scale: In this study, we looked at results from measurements made of how far light penetrates the water and how much the water surface fluctuates in a swampland. Position at the bottom of the right scale: The findings of the solid particle measurement Data was collected between February and June 2019 at water depths ranging from 28 to 95 cm (zone I), 28 to 99 cm (zone II), 54 to 112 cm (zone III), and 55 to 124 cm (zone IV) (zone IV)



As a water catchment region, water fluctuations occur in swampland impacted by rainfall, evaporation, and variability. According to Smith and Brock (2007) and Wang *et al.* (2014), variations occur due to various variables, including the length of flooding or drought, the frequency of flooding or drought, and the intensity of the fluctuations. According to Duarte and Kalff (1986), the slope of the water base impacts water fluctuations as well. The occurrence of modest variations in water surface depth (less than 10 cm) may influence the structure of a wetland and the operation of the ecosystem it supports (Webb and Leake 2006). It was evident from the statistics that water fluctuations vary depending on the swampland zone, with a depth range of 28–95 cm in zone I, 28–99 cm in zone II, 54–112 cm in zone III, and 55–124 cm in zone IV (Figure 1). The hydrological regime, which includes changes in water depth and clarity across time and space and sediment properties, has the most significant impact on the development of aquatic plants (Barko and Smart 1983; Neill 1990; Phillips *et al.* 2016). The adaptation of the waterlily was carried out in response to variations in the water level in its surrounding habitat. The adaptability of the waterlily was accomplished by the modification of both physiological and anatomical alterations (Lyn and Waldren 2003; Mommer *et al.* 2005; Sasidharan *et al.* 2018; Ford and Champion 2019).

When the petiole of the waterlily was elongated in response to water depth (Wu *et al.* 2017), the leaves can maintain contact with carbon dioxide in the surrounding atmosphere (Casanova and Brock 2000), and the plant can photosynthesize (Voeselek *et al.* 2003; Deegan *et al.* 2012), it was considered a successful bloom. It was closely related to the net assimilation outcomes (Scheffer 2004), while Les (2018) stated that the depth limit for waterlilies that may still photosynthesize was between 0.5 and 2.9 meters (feet). In the *lebak* swampland, waterlily can tolerate a wide range of water depths, including 28–95 cm in the zone I, 28–99 cm in zone II, 54–112 cm in zone III, and 55–124 cm in zone IV. Because waterlily can tolerate a wide range of water depths in the *lebak* swampland as its habitat, it can be found in all zones of the *lebak* swampland.

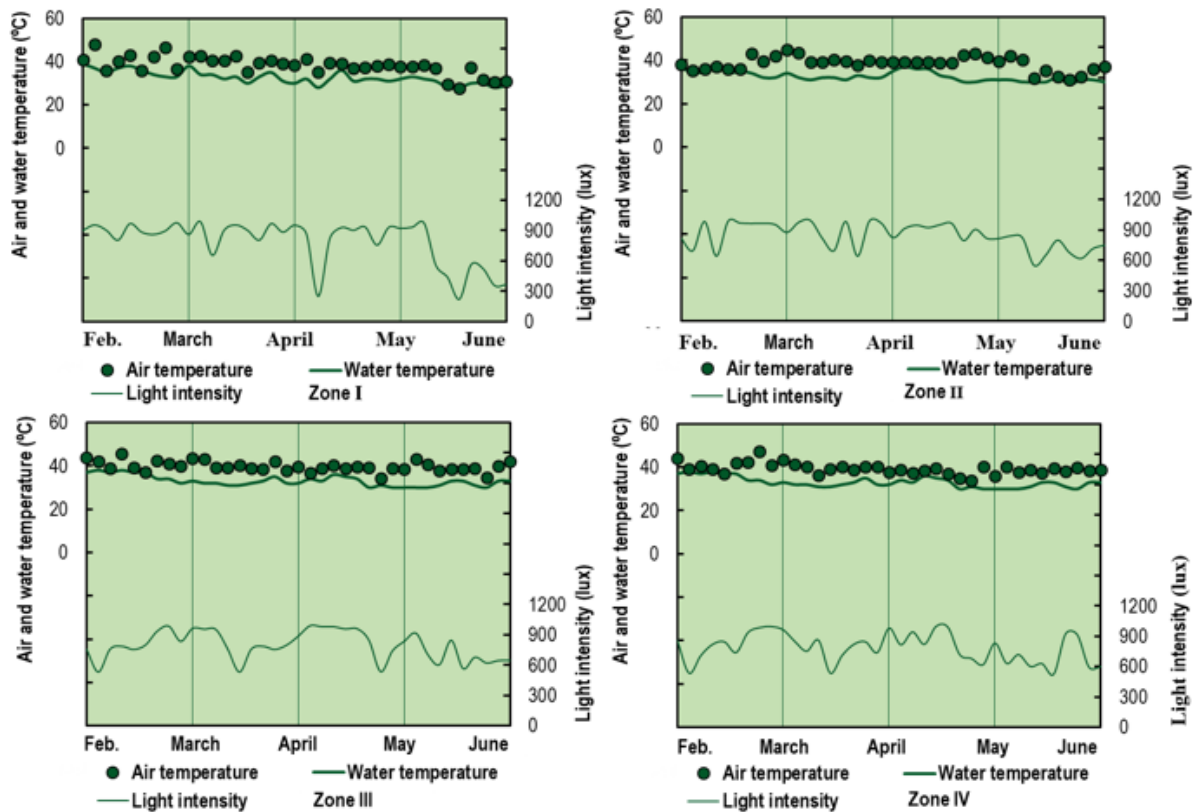
The presence of solid particles causes turbidity in water. The amount of turbidity in swamp water was affected by the presence of *Lebak* swampland in the shape of a basin with varying levels of water depth. It was shown in this study that the average turbidity was 0.59 parts per million higher at a depth of 29–95 cm in zone I and 28–99 cm in zone II than at a depth of 54–114 cm in zone III and a depth of 55–124 cm in zone IV, where the average turbidity was 0.56 parts per million higher and 0.50 parts per million lower, respectively (Figure 1). The turbidity of the water decreases in direct proportion to the depth of the water. According to Scheffer *et al.* (1993), the amount of turbidity was influenced by the water level, with lower water levels resulting in greater turbidity levels. The turbidity of the waterlily has an impact on the amount of light that the leaves can use as they grow towards the surface of the water, which inhibits the photosynthesis of floating leaves that have not yet reached the surface of the water, as well as on the overall health of the waterlily (Chernova 2015). According to Coops and Hosper (2002), turbidity was caused by the redeposition of swampland sediment, which was impacted by the high frequency of changes in the depth of swampland water. The depth of swampland water that fluctuates was also essential in producing turbidity. Because of the existence of aquatic vegetation, the degree of water turbidity may be reduced. According to Scheffer *et al.* (1993), vegetation enhances water clarity, increasing the amount of light available to support the growth process.

Air temperature, water, and sunlight intensity

According to Barko and Smart (1981), the temperature was a critical component in the growth and development of aquatic plants since it influences various physiological processes, including the rate of photosynthesis. The temperature may fluctuate due to variations in the height of the sun and changes in the seasons as a result of the sun's declination (Madsen and Brix 1997). A sinusoidal curve was formed in the *lebak* swampland's temperature, both in terms of air temperature and water temperature, resulting from variations in fluctuations in water depth between various levels of water depth (Figure 2).

According to the statistics, the average air temperature at a water level of 28–95 cm in zone I and 28–99 cm in zone II was 38°C, while the average air temperature at a water depth of 54–122 cm in zone III and 55–124 cm in zone IV was 39°C and 40°C, respectively. The average change in air temperature at each depth level varies. For example, a depth of 29–95 cm in zone I in the temperature range of 28°C–45°C, a depth of 28–99 cm in zone II in the temperature range of 31°C–46°C, a depth of 54–112 cm in zone III in the temperature range of 34°C–47°C, and a depth of 55–124 cm in zone IV in the temperature range of 34°C–48°C (Figure 2).

Figure 2. The results of the air and water temperature measurements are shown at the top of the left scale. The measurement of light intensity was shown at the bottom of the right scale. Data were collected between February and June 2019 at water depths ranging from 28 to 95 cm (zone I), 28 to 99 cm (zone II), 54 to 112 cm (zone III), and 55 to 124 cm (zone IV) (zone IV)



The greater the depth of the water, the higher the temperature of the air. In contrast to the water temperature, which demonstrates various variations at different degrees of water depth, the average water temperature at all depth levels was 33.0°C, which was the same temperature throughout all depth levels. When it comes to changing temperatures, the intensity of light impacts both water and air temperature changes. If you look at the light intensity data at a depth of 28–95 cm in zone I, you will see that it fluctuates more than data at a depth of 28–99 cm in zone II, 54–122 cm in zone III, and 55–124 cm in zone IV. The average light intensity reveals that the greater the distance between the basin and the open marsh, the greater the average light intensity. In zone I, the average light intensity was 775 lux at a depth of 29–95 cm; in zone II, it was 843 lux at a depth of 28–99 cm, in zone III, it was 858 lux at a depth of 54–114 cm, and in zone IV, the average light intensity was 861 lux at a depth of 55–124 cm (Figure 2).

Adaptability to changes in their environment is essential for aquatic plants, which are particularly sensitive to variations in ambient temperature (Fares *et al.* 2020). In the swampland waters, temperature fluctuations may be seen in the air and the water. Figure 2 illustrates that the deeper a swampland's water level is, the smaller and more stable the fluctuation pattern becomes. According to Klok and van der Velde (2017), water depth impacts water to and air temperatures, with deeper water resulting in more stable temperatures. In general, the average air temperature increases as water depth increases, with the lowest average air temperature of 38°C occurring at a depth of 28–95 cm in zone I and 28–99 cm in zone II, and the maximum average air temperature of 40°C occurring at a depth of 55–124 cm in zone IV. According to Madsen and Brix (1997), the temperature of the water is influenced by the water level, which, in turn, influences the depth limit and species composition.

Photosynthesis may be managed when there is enough enzyme activity in the waterlily. Enzyme activity is influenced by temperature (Long *et al.* 1995). Temperature is a critical factor in determining the pace of metabolic processes in plants (Larcher 1995) and the stimulation of growth and the compression of the growth cycle, among other things (Barko and Smart 1981; Pip 1989). Compression and temperature (within the tolerance range) often boost biomass output throughout the growth cycle. According to the statistics, water has an average temperature lower than the air. Zone I has an average air temperature of 38°C, while zone II has an average air temperature of 39°C, and zone IV has an average air temperature of 40°C. Water depths of 28–95 cm in the zone I and 28–99

cm in zone II have an average air temperature of 38°C, while water depths of 54–122 cm in zone II have an average air temperature of 40°C. The presence of aquatic vegetation is one of the elements that contribute to the low water temperatures that are experienced. According to Pip (1989), the water temperature does not exist in and of itself influence development; rather, the effect of water temperature may be seen via the pH variable and other chemical variables.

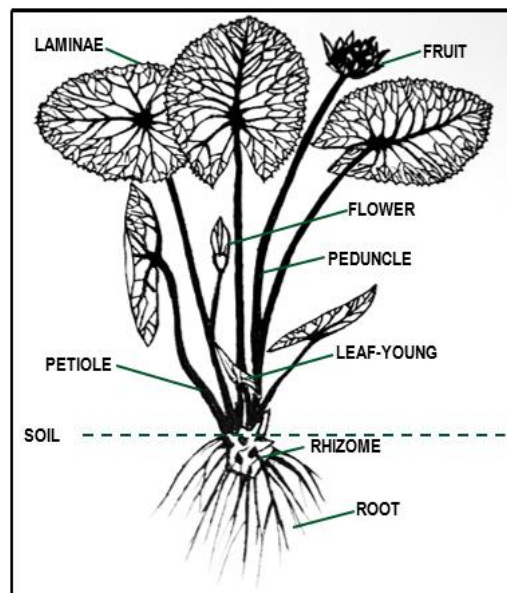
For aquatic plants, temperature and light availability are critical elements in their leaves and stems (Lacoul and Fredman 2006). In zone I, the average light intensity is 775 lux at a depth of 29–95 cm; in zone II, it is 843 lux at a depth of 28–99 cm; in zone III, it is 858 lux at a depth of 54–112 cm; and in zone IV, it is 861 lux at a depth of 55–124 cm (Figure 2). The average light intensity reveals that the greater the distance between the basin and the scattered swampland, the greater the average light intensity. Compared to the other zones, the light intensity in the zone I is lower. This is because the zone I region is still exposed to the shadows cast by the trees that grow along the border of the *lebak* swampland. Light intensity in the *lebak* swampland is vital at all depths, with an average of 775–861 lux over the whole swamp. Because waterlilies are plants that need a lot of sunshine in their habitat, such circumstances are ideal for lotus plants to grow in a flourishing setting (Lu and Chen 2012). In addition to being capable of photosynthesis in full sun ($\approx 2110 \mu \text{mol m}^{-2} \text{s}^{-1}$ PAR; Snir *et al.* 2006), *Nymphaea* has a high tolerance for high solar radiation, which is similar to that found in C4 plants (Atwell *et al.* 2003). It is possible to increase the use of sunshine to satisfy the development requirements of *N. pubescens*. As a result of having leaves that float above the water surface and the leaves not being darkened by light and water reducing components (Brock *et al.* 1983; Zhonghua *et al.* 2007) have a significant competitive impact on light (Brock *et al.* 1983).

3.2. Variations in the Structure and Allocation of *N. Pubescens* Biomass in Response to Changing Water Depths

Structure of *N. pubescens*

The root, rhizome, petiole, leaf–young, peduncle, flowers, fruit, and laminae of *N. pubescens* are all built by the plant's morphology throughout its differentiation (Figure 3). The structural qualities of this plant decide how well the overall system will perform in coping with the growing environment. It is a plant that has leaves that float above the water's surface and some juvenile leaves that are below the water's surface, which is known as *Nymphaea pubescens*.

Figure 3. Structure of the plant *N. pubescens*



Oval in form with serrated leaf edges, long petioles, and blooms, the leaves of this plant are very fragrant. In the silt, rhizome and roots sprout from the stem, which then grows through the sediment, while the leaves and blossoms float to the surface of the water, indicating that the plants are thriving. Because of the robust petiole and lengthy peduncle, the leaves and flowers can remain above the water's surface, but the fertilized flowers are instantly immersed. After digging up the developing rhizome, a lengthy, white, sponge-like root system was

discovered. The diameter of the roots ranged between three and six centimeters in diameter and might extend up to one meter in length. The waterlily flower can adapt to changes in its habitat environment, such as fluctuations in the level of swampland water in the surrounding area.

The results revealed that the outcome of the leaf area computation varied greatly depending on the depth of the water ($P < .0001$, ANOVA). At a water depth of 28–95 cm in zone I, the leaf surface area covering the soil surface per soil area is $1.3 \pm 0.6 \text{ m}^2\text{m}^{-2}$, which is significantly smaller than the leaf surface area covering the soil surface per soil area at a water depth of 28–99 cm in zone II, which is $1.8 \pm 0.7 \text{ m}^2\text{m}^{-2}$, 54–112 cm in zone III, which is $2.1 \pm 0.5 \text{ m}^2\text{m}^{-2}$, and 55–124 cm in zone IV, which is 2.8. As the depth of the water surface area is increased, the more the amount of leaf surface area that covers the soil surface is increased (Table 2A). There were also statistically significant differences in all counts of the number of leaves, blooms, and roots depending on the water depth (leaves: $P < .0001$; flowers: $P < .0001$; and roots: $P < .0012$, ANOVA). When planted at a depth of 28–95 cm in zone I and 28–99 cm in zone II, the waterlily produced more leaves and blooms than when planted at a depth of 54–112 cm in zone III and 55–124 cm in zone IV, respectively (Table 2A). The number of leaves and blossoms dropped as the depth of the water increased, but the number of roots grew as the depth of the water increased.

Adaptations may occur in every component of aquatic plants in response to changes in their environment, such as changes in water level, pH, light intensity, temperature, and turbidity level, among other things. For the most part, plants maintain their structure and physiology throughout time, allowing them to adjust to changing environmental circumstances. Plants may thus modify their adaptability to environmental changes associated with morphological alterations or physiological processes (Molles and Sher 2019). Researchers discovered a significant association between the leaf area of *N. pubescens* and the rise in water depth in their study. The leaf area of *N. pubescens* rises with the increasing water level, with a range of leaf surface area per soil surface area of 1.3 ± 0.6 – 2.7 m^2m^{-2} in water depth, with ranges of 28–95 cm in the zone I to 55–124 cm in zone II (zone IV, Table 2A).

In their research, Kunii and Aramaki (1992) discovered that the leaves of *N. tetragona* exhibited an increase in leaf area from May to June when the water level exceeded 100 cm and a decrease in leaf area when the water depth approached 30–40 cm, which occurred in June and October, respectively. Changing circumstances in the plant environment as a result of fluctuations in the water level impact these conditions. Increases in air temperature and light intensity are caused by increasing water depth, whereas the water temperature at all depth levels is on average 33°C. The water temperature at all depth levels has an average temperature of 33°C (Figures 1, 2). In addition, as water depth grows, the intensity of the light and the temperature of the water rise, increasing leaf temperature (Givnish 1987), which enhances the efficacy of pressured ventilation, while lowering leaf number results in more directed leaf flow (Richards *et al.* 2011).

Nymphaea pubescens Biomass Allocation

A plant's biomass represents the result of all metabolic processes that occur during a plant's growth (Poorter *et al.* 2012; Kornijów *et al.* 2016). Plants are composed of several parts, which, according to Vymazal and Kröpfelová (2008), can be divided into two categories: aboveground (which includes all vegetative and reproductive parts above the soil surface) and underground (which includes all vegetative and reproductive parts below the soil surface) (roots, rhizomes, tubers, and others). The results showed that seed and root biomass allocation in *N. pubescens* differed depending on water depth. Still, a leaf, rhizome, and total plant biomass were not significantly different depending on water depth (Table 2B).

The results of the calculation of the biomass of *N. pubescens* seeds were influenced by the depth of the water table ($P < .0001$, ANOVA), with the lower the weight of the biomass is obtained, the deeper the water table was. Zone I had the highest seed biomass, $221.8 \pm 35.1 \text{ g DW m}^{-2}$, while Zone IV had the lowest, $126.0 \pm 13.8 \text{ g DW m}^{-2}$ (Table 2B). The highest seed biomass occurred at a 28–95 cm depth, and the lowest at 55–124 cm. Both were in zone I (Table 2B.) Additionally, root biomass weight is impacted by water level ($P < .0001$, ANOVA), with the deeper water table resulting in greater root biomass weight. When measured at a depth of 28–95 cm in the zone I, the root biomass was found to be $76.8 \pm 23.0 \text{ g DW m}^{-2}$, but when measured at a depth of 55–124 cm in zone IV, the root biomass was found to be $147.3 \pm 41.4 \text{ g DW m}^{-2}$, the lowest root biomass ever recorded (Table 2B). When comparing water depth levels, the root: leaf ratio did not change substantially, but the leaf: seed ratio and the root: rhizome biomass ratio did ($P < .0001$, ANOVA), with the ratio of both rising as water depth increased (Table 2C).

A response of *N. pubescens* to variations in water depth is shown by changes in leaf morphology, which results in leaf biomass having no meaningful impact on environmental changes (Tables 2A, 2B). Increases in the

length and area of the leaf lamina, as well as a reduction in the number of leaves, are indicative of morphological adaptation in waterlily when the water depth varies (Richards *et al.* 2011). Aquatic plants elongate their shoots or young leaves in response to increased water depth and reestablish touch with the surrounding environment (Wang *et al.* 2014). When growing near the water's surface, plants need to acquire enough light, oxygen, and CO₂ to exchange gases with the surrounding environment live and thrive (Vartapetian and Jackson, 1997). Plants are more capable of changing their morphology to adapt to their environment than they are of changing the allocation of plant components to adapt (Poorter *et al.* 2012).

Table 2. (A) The area and quantity of leaves (leaves, flowers, and roots); (B) the biomass of leaves, seeds, roots, tubers, and total biomass; and (C) the leaf: seed and root: tuber biomass ratios of plants. *N. pubescens* is found in *lebak* swampland with water depths ranging from 28 to 95 cm (zone I), 28 to 99 cm (zone II), 54–112 cm (zone III), and 55–124 cm (zone IV). The *P*-value is the probability χ^2 of the GLM test, *df* = 3; a significant difference occurred when data were followed by letters in the same row (*P* < 0.05)

Variable	Water depth in each growth zone				<i>P</i>
	28–95 cm (zone I)	28–99 cm (zone II)	54–112 cm (zone III)	55–124 cm (zone IV)	
(A) Leaf area (m ² m ⁻²)	1.3 ± 0.6 ^c	1.8 ± 0.7 ^{bc}	2.1 ± 0.5 ^b	2.7 ± 0.5 ^a	<.0001
Quantity (m⁻²):					
Leaf	27.9 ± 7.6 ^a	23.6 ± 6.7 ^{ab}	18.1 ± 6.4 ^b	18.0 ± 5.5 ^b	0.0001
Flower	20.4 ± 6.9 ^a	21.1 ± 8.4 ^a	18.9 ± 6.5 ^{ab}	13.2 ± 5.0 ^b	<.0001
Root	871 ± 335 ^b	827 ± 289 ^b	896 ± 333 ^{ab}	925 ± 367 ^a	0.0012
(B) Biomass (g DW m⁻²):					
Leaf	104.2 ± 44.6 ^a	114.1 ± 45.4 ^a	117.4 ± 45.4 ^a	112.2 ± 33.0 ^a	0.7154
Seed	221.8 ± 35.1 ^a	193.4 ± 35.1 ^b	168.1 ± 31.0 ^b	126.0 ± 13.8 ^c	<.0001
Rhizome	211.9 ± 62.3 ^a	185.3 ± 46.2 ^a	188.0 ± 69.2 ^a	176.4 ± 61.6 ^a	0.3370
Root	76.8 ± 23.0 ^c	79.8 ± 35.2 ^{bc}	114.5 ± 43.9 ^{ab}	147.3 ± 41.4 ^a	<.0001
Total biomass	614.7 ± 81.2 ^a	572.5 ± 93.3 ^a	588.0 ± 80.2 ^a	561.9 ± 72.2 ^a	0.2203
(C) Biomass Ratio:					
Root:Leaf	0.90 ± 0.51 ^a	0.83 ± 0.63 ^a	1.13 ± 0.57 ^a	1.41 ± 0.50 ^a	0.1345
Leaf:Seed	0.48 ± 0.19 ^c	0.60 ± 0.27 ^{bc}	0.71 ± 0.25 ^b	0.90 ± 0.28 ^a	<.0001
Root:Rhizome	0.39 ± 0.15 ^b	0.49 ± 0.34 ^b	0.66 ± 0.29 ^{ab}	0.97 ± 0.49 ^a	<.0001

Seed biomass weight in *N. pubescens* decreases due to increasing water depth; the deeper the water surface is, the less seed biomass weight is produced by this species (Table 2B). Plants in their development need more energy to carry out morphological changes as a type of adaptation to changes in their environment when growing in water circumstances that experience a rise in water depth with significant volatility (Baastrup–Spohr *et al.* 2016). Furthermore, fluctuations in water level have been shown to directly affect the availability of light in water and the availability of oxygen in sediments (Raulings *et al.* 2010), which can, in turn, reduce nutrient concentrations (Lu *et al.* 2018; Zhang *et al.* 2019) and, consequently, have a direct influence on generative growth. The root biomass responded in various ways to the rise in water depth; the deeper the water surface, the heavier the root biomass, and the deeper the water surface, the more significant the increase in water depth (Table 2B).

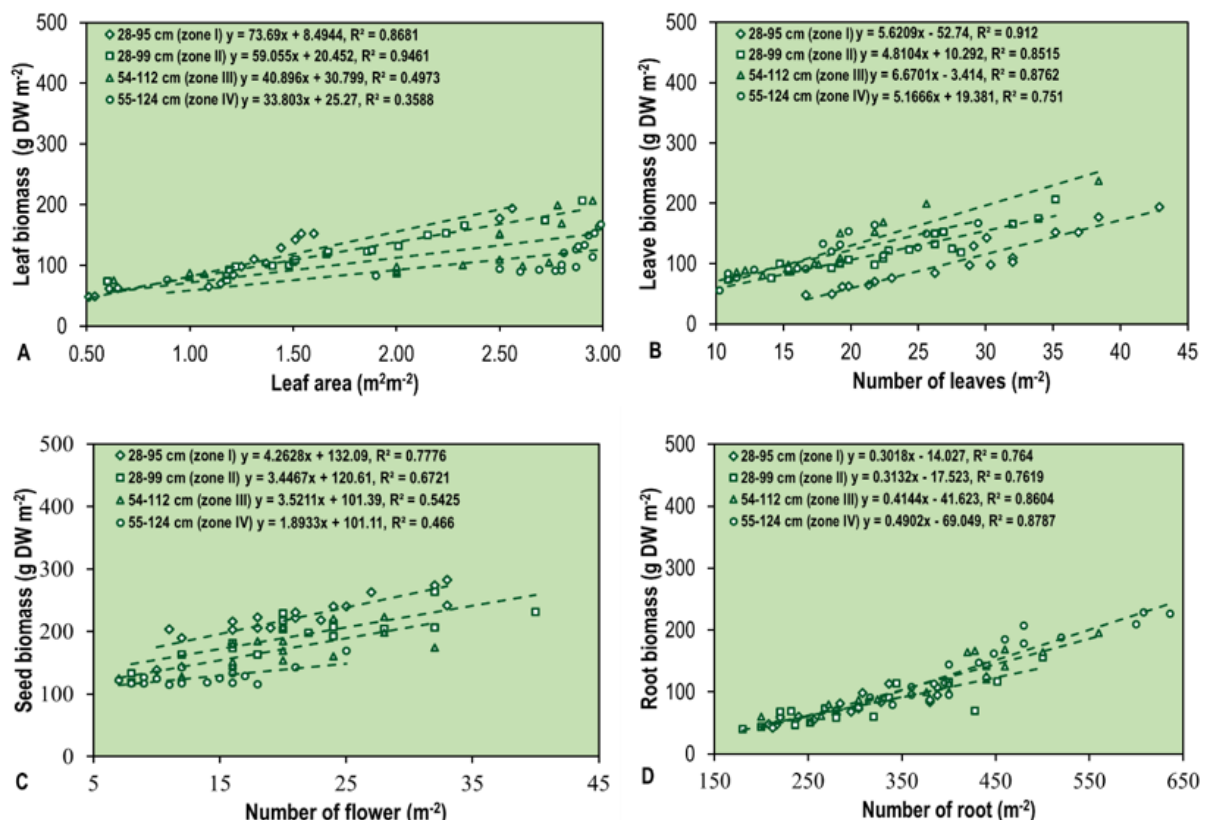
The water depth is the most critical ecological component that influences root development (Bai *et al.* 2015). When the waterlily has a robust and healthy root system, it may grow and flourish even at greater depths below the water's surface. Roots adapt to environmental changes, particularly variations in the number of nutrients in the sediment, by changing their structure and function (Huang *et al.* 2018). Adaptation to root growth may alter the allocation of biomass; the largest plant biomass is seen in well-drained situations, particularly for the roots, perhaps as a result of increased sediment oxygenation and leaf transpiration in these circumstances (Baastrup–Spohr *et al.* 2016). Increased biomass allocation to organs that exploit the most limited resources (Poorter and Nagel 2000) is another example of plant responses. This is particularly true for low nutrient concentrations, which drop with deeper water depths (Lu *et al.* 2018; Zhang *et al.* 2019). When it comes to growth, the waterlily is constrained by environmental conditions that influence the distribution of root and leaf biomass. For a plant to develop balanced, more biomass must be allocated to plant organs responsible for collecting scarce resources (Shingley and Meziane 2002; van Wijk *et al.* 2003). Carbon is captured by leaf organs,

whereas water and mineral nutrients are captured by roots (Shipley and Meziane 2002). The amount of biomass allocated to leaves and roots was unaffected by environmental variations caused by variances in water depth fluctuations (Table 2B), as did the root:leaf ratio (Table 2C). However, the allocation of root and leaf biomass is balanced at all depths of water, though. However, environmental variables affect the development of each of these organs; the waterlily can adapt effectively to changes in its habitat throughout its maturation. The leaf seed and root:rhizome ratios demonstrated the responsiveness of the biomass ratio to variations in water depth (Table 2C).

The ratio of organs on the water's surface, namely the ratio of leaves to seeds, and organs beneath the sediment, specifically the ratio of roots to rhizome, rises with increasing water depth. Leaves are photosynthetic organs that provide energy for survival, and part of that energy is transformed into seeds. The growing leaf biomass:seed ratio suggests that the environment promotes leaf development, but the allocation of floral organ synthesis diminishes as water depth increases (Tables 2B, 2C). As the depth of the water grows, the amount of energy needed for development increases as well, resulting in an automatic reduction in the amount of energy transformed into seeds. The root-to-rhizome ratio grew when the depth of the water was raised (Table 2C).

As Chen (2007) points out, the most active root zone in a swampland, where physicochemical and biological activities occur. In a nutrient-limited environment, biomass allocation is preferred to the allocation of biomass to leaf organs, which serve as carbon fixing organs (Shipley and Meziane 2000; van Wijk *et al.* 2003). In response to rising water depth, the more active roots grew larger. They produced more biomass (Table 2B), but biomass allocation to rhizome reduced as the water surface depth increased. Plants in a more complex environment need more energy to maintain a healthy balance between growth and the environment. It is possible to receive energy from food reserves in the form of rhizome; however, the deeper the water level is, the greater the number of food reserves that will be used (Table 2B).

Figure 4. A. Interrelations of leaf area, B. Number of leaves, C. number of flowers, and D. number of roots and weight of biomass on *N. pubescens* growing from February to June 2019 in *lebak* swampland at a water depth of 28–95 cm (zone I), 28–99 cm (zone II), 54–112 cm (zone III), and 55–124 cm (zone IV)



Calculations of leaf area, leaf number, blossom number, and root number at various water depths revealed a favorable association with the weight of the biomass (Figure 4, Table 2). Each of these data for calculating leaf area was linked with varying leaf biomass and water level, albeit the connection deteriorated as water depth increased ($R^2 < 0.70$, Figure 4A). Similarly, when seed weight is calculated about the number of blooms at various water levels, a slight association with increasing water depth is seen. At a 28–95 cm water level in zone I,

the connection between seed weight and flower number was quite good ($R^2 = 0.71$), but it was weaker at a depth of 55–124 cm in zone IV ($R^2 = 0.47$, Figure 4C). Calculations of leaf weight and the number of leaves revealed a perfect association at all various levels of water depth. Therefore a significantly positive correlation between root weight and the number of roots was discovered ($R^2 > 0.70$, Figure 4B, Figure 4D).

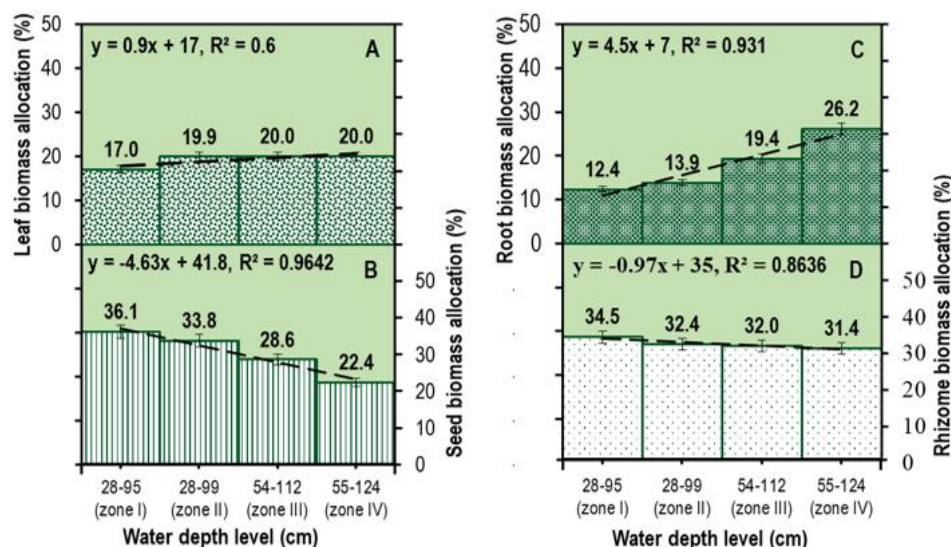
The water level is critical for *N. pubescens*, which has leaves that float above the water’s surface. Numerous activities occur at the water’s surface, including photosynthesis, gas exchange, and other chemical accumulations (Tsuchiya 1991; Ritchie 2012; Ribaudo *et al.* 2012). Using a simple linear model, the allometric calculation data showed that leaf biomass was positively linked with leaf area but less correlated with increasing water depth ($R^2 < 0.70$, Figure 4A). The increased leaf area can cause the water table to close (Table 2A). According to Ritchie (2012), a waterlily leaf in association with water can cover the water’s surface and fix one-third of the maximum amount of carbon, even in the presence of limited nutritional resources. Even if the leaves that float on the water’s surface have a better photosynthetic capacity than land herbaceous plants, the leaves that float on the water’s surface have considerably lower biomass since their leaf area index is less than $3 \text{ m}^2\text{m}^{-2}$ (Tsuchiya 1991). High photosynthetic capacity supported by high availability of resources such as sunlight, water, and carbon in floating leafy plants (Lacoul and Fredman 2006; Ritchie 2012) is not followed by the amount of biomass.

It is determined by the availability of resources in the environment, which is connected to the depth of the water and how aquatic plant biomass is distributed between the aboveground and subsurface sections. According to Bloom *et al.* (1985), an ideal pattern of biomass allocation occurs when the growth limiting variables in the aboveground and subterranean parts are balanced, or what is sometimes referred to as the optimal partition theory (Pooter and Nagel 2000; van Wijk *et al.* 2003; Shipley and Maziane 2002; Pooter *et al.* 2012). It is generally accepted that the percentage of total biomass in the aboveground region decreases as water depth increases. Still, the total biomass in the subterranean area tends to rise as water depth decreases (Table 3, Figure 5A).

Table 3. The ratio between aboveground (A) of leaf and seed biomass and underground (U) of root and tuber biomass of *N. pubescens* growing in *lebak* swampland in zones with water table depths between 28–95 cm (zone I), 28–99 cm (zone II), 54–112 cm (zone III), and 55–124 cm (zone IV). The *P*-value is the probability $> \chi^2$ of the GLM test, *df* = 3; data followed by letters in the same row is a significant difference ($P < 0.05$)

Variabel	Water depth in each growth zone				P
	28–95 cm (zone I)	28–99 cm (zone II)	54–112 cm (zone III)	55–124 cm (zone IV)	
A (g DW m ⁻²)	297.6 ± 42.9 ^a	240.8 ± 48.6 ^b	190.5 ± 62.0 ^c	143.2 ± 33.9 ^d	<.0001
U (g DW m ⁻²)	288.8 ± 137.3 ^a	265.0 ± 90.7 ^a	296.9 ± 185.9 ^a	323.6 ± 141.6 ^a	0.7749
Ratio A:U	1.25 ± 0.61 ^a	1.02 ± 0.41 ^{ab}	0.85 ± 0.51 ^{ab}	0.54 ± 0.27 ^b	0.0032

Figure 5. The proportion of biomass from each plant component in the total biomass of *N. pubescens* growing in *lebak* swampland with water depth zones ranging from 28–95 cm (zone I) through 28–99 cm (zone II), 54–112 cm (zone III), and 55–124 cm (zone IV) (zone IV). The precision of data samples aboveground (leaf and seed biomass) and underground (rhizome and root biomass). A = average value; B = average relative allocation of each plant portion in each data set for all plant biomass m⁻²

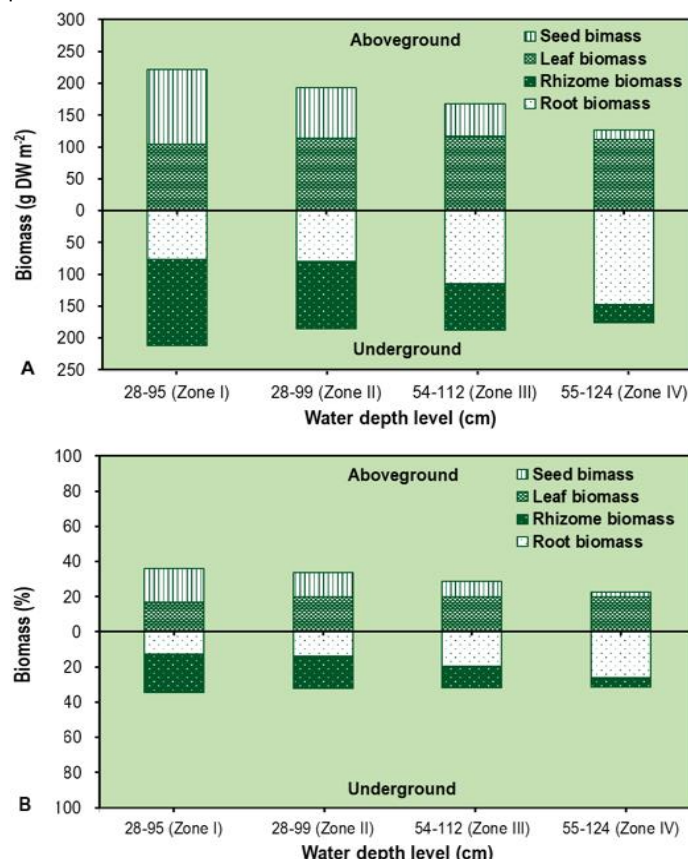


The observed percentage of biomass in the aboveground segment (leaves and seeds) was significantly different from the water depth level ($P < .0001$, ANOVA). In contrast, the proportion of biomass in the subterranean section did not vary substantially from the water depth level ($P > 0.77$, ANOVA) (Table 3). The biomass proportion in the aboveground section (28–95 cm in zone I, 28–99 cm in zone II, 54–112 cm in zone III, and 55–124 cm in zone IV) is 53.1 percent, 53.7 percent, 48.6 percent, and 42.4 percent, respectively; in the underground section, the biomass proportion is 46.9 percent, 46.3 percent, 51.4 percent, and 57.6 percent (Table 3, Figure 5B). The aboveground and underground biomass ratios were dramatically varied (Table 3). The A:U biomass ratio decreases with increasing water depth (28–95 cm in zone I = 1.25 ± 0.61 , 38–99 cm in zone II = 1.02 ± 0.41 , 54–112 cm in zone III = 0.85 ± 0.51 and 55–124 cm in zone IV = 0.54 ± 0.27).

Although the allocation of leaf biomass from total biomass is positively linked with water depth ($y = 0.9x + 17$, $R^2 = 0.60$, Figure 6A), the greater the water level, the more biomass assigned to the leaf; similarly, root biomass allocation increased as water depth rose, and the correlation between biomass and water depth was quite strong ($y = 4.5 + 7$, $R^2 = 0.93$, Figure 6C). Biomass assigned to seeds and rhizome were significantly linked with water depth, with seed correlation ($y = -4.63x + 41.8$, $R^2 = 0.96$, Figure 6B) and tuber correlation ($y = -0.97x + 35$, $R^2 = 0.83$, Figure 6D), indicating that as water depth rises, biomass allocated to seeds and rhizome declines (Figures 6B, 6D).

Each plant component's response *N. pubescens* has a unique response to its environment, which is reflected in the total biomass contribution. A high biomass contribution indicates that the organ is highly metabolically active, while a low biomass contribution indicates that the organ is hypotonic (Kornijów *et al.* 2016). Aboveground leaves and seeds respond differently to their environment. Although the correlation was weak, the greater the water depth, the greater the leaf biomass (Figure 5, 6A).

Figure 6. The correlation between the biomass of each plant part of *N. pubescens* with the depth of *lebak* swamp water between 28–95 cm (zone I), 28–99 cm (zone II), 54–112 cm (zone III), and 55–124 cm (zone III) zone IV). The accuracy of the data sample is the ratio of biomass, A = leaves, B = seeds, C = roots, and D = rhizome



The rise in biomass allocation with increasing water depth was accompanied by an increase in leaf area seven though the leaves dropped with increasing water depth (Table 2A). The rapid production of new leaves and the fall of old leaves almost certainly contributed considerably to the rapid cycle of floating leaf plant biomass (Tsuchiya 1991). A similar contribution to the proportion of seeds is a productive component that contributes to

the total biomass up to 36.1% at a depth of 28–95 cm in the zone I, and the biomass declines as the depth of the water increases (Figure 5B, 6B).

The production of flowers and fruits in the presence of high–water depth, according to Brock *et al.* (1983), influences biomass re–allocation, even if it only contributes around 3% of the total biomass. Water levels are increasing, which has an impact on the amount of biomass available, as well as the availability of resources in general, and carbon from the atmosphere in particular (Čížková–Končalová *et al.* 1992; Blanch *et al.* 1999; Huber *et al.* 2012), oxygen (Crawford 1992; Casanova and Brock 2000), nutrition (Kornijów *et al.* 2016). Because of the restricted availability of resources, plants devote higher or proportionately more significant quantities of resources to structures that collect limited resources to maximize waterlily productivity.

Nymphaea pubescens rhizomes are a component of the plant that contribute to the provision of energy for vegetative development and propagation (Twilley *et al.* 1985), as well as the acceleration of shoot growth (Miao *et al.* 2000; Maceka *et al.* 2006). A strong favorable relationship exists between biomass allocation in the rhizome and increases in water depth, since *N. pubescens* demands more energy at deeper water surfaces, which ultimately leads to a greater consumption of carbohydrates (Figure 6D). In accordance with Deegan *et al.* (2007), as water depth increases, the oxygen supply to the bottom decreases, causing plants to extend the length of the diffusion flow channel by using more carbohydrate reserves stored inside their rhizomes. Adaptations in biomass allocation arise as a result of plants' natural inclination to allocate carbohydrates to more active tissues in the process of photosynthesis (Barko *et al.* 1991) and continue to grow new leaves in order to reach the surface of the water (Čížková–Končalová *et al.* 1992). Plant anchoring capability is reduced due to reduced biomass allocation to rhizomes as a result of increased water depth (Coops *et al.* 1996) and have less biomass at deeper water levels (Richards *et al.* 2011). The rhizome of *N. pubescens* are densely packed with roots, making them ideal for rooting. The portion of the plant that may boost growth and decide plant survival is the root system.

The allocation of biomass to roots is regulated by the depth of the water; the greater the depth of the water, the considerably greater the root biomass allocation (Table 2B, Figure 6C). In the study by Wei *et al.* (2019), the researchers discovered that when there is a change in water availability, the roots are the component at lesser risk of being damaged than the allocation to the shoots. Plants may store carbohydrates more safely and establish a more secure anchor when there is a more significant accumulation of biomass in the roots due to the higher accumulation of biomass in the roots under often disturbing situations (Puijalón *et al.* 2008; Poorter *et al.* 2012). For the maintenance, healing, and development of new shoots and shoots once they have sprouted, more resource storage and more excellent anchoring would be desirable. Compared to deeper water levels, *lebak* swampland has a greater fertility rate at lower water depths. According to Alwi and Tapakkrisnanto (2017), shallower swampland soils are comprised of river deposits (fluvialite) that do not include sulfidic/pyrite materials. Still, deeper swampland soils are composed of a sulfidic layer composed of marine deposits (sulfidic layer). Plants often grow more extensive root systems as a means of coping with nutrient–deficient situations (Chapin 1980).

According to Brouwer (1963), in plants that receive insufficient nutrition, an increase in the allocation of resources to roots occurs. The water depth also impacts the amount of sunlight reaching the roots, which affects their shape and biomass (Riis *et al.* 2012). Low light levels deplete the soil's biomass. The shallow water regime exerts substantial influence over some Nymphaeid species that are thought to be tolerant of a particular range of water level fluctuations (Paillisson and Marion 2011).

The ratio of aboveground to underground biomass varies significantly according to water surface depth (Table 3); the deeper the water level, the lower the resultant ratio. The A:U biomass ratio of *N. pubescens* was between $(0.54 \pm 0.27) - (1.25 \pm 0.61)$, which was within the range established by Brock *et al.* (1983) for *N. peltate*, which is 0.3–2.85. Plants alter their resource allocation to the network aboveground and underground due to environmental gradients resulting from disturbance and resource availability in the environment (Nohara and Tsuchiya 1990).

Conclusion

Nymphaea pubescens have prominent leaves on the water's surface where photosynthesis takes place, distinguishing it from other species. Plants growing in shall more significantly have more leaves, but they are narrower than plants growing in deeper waters. Plants allocate the most significant amount of biomass and produce many blooms when the water level is shallow. In zone I, the ideal water depth for seed–producing plants is 28–95 cm, while in zone II, the optimal water level is 28–99 cm. The organization of the percentage of biomass for the development of shoots and roots was different, even though the total biomass was not statistically

different. Waterlily growing in shallower water depths had larger biomass allocations for seeds and lower biomass allocations for roots. Root biomass increased significantly as the depth of the water body increased.

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References

- [1] Alwi, M., and Tapakrisnanto C., 2017. Potensi dan karakteristik lahan rawa lebak in: Fatah, L., Noor, M., Masganti, H., Subagio, Alwi, M., Simatupang, S., Ar–Riza I., 2017. *Lahan rawa lebak: Sistem pertanian dan pengembangannya*. IAARD Press 160 pp. (in Indonesian)
- [2] Atwell, B.J., Kreidermann, P.E., and Turnbull, C.G.N., 2003. *Plants in action: Adaptation in nature, performance in cultivation*. Macmillan, South Yarra, Australia.
- [3] Baastrup–Spohr, L., Møller, C.L., and Sand–Jensen, K., 2016. Water–level fluctuations affect sediment properties, carbon flux and growth of the isoetid littorella uniflo rain oligotrophic lakes. *Freshw. Biol.* 61, 301–315. DOI: <https://doi.org/10.1111/fwb.127044>
- [4] Baastrup–Spohr, L., Sand–Jensen, K., Nicolajsen, S.V., and Bruun, H.H., 2015. From soaking wet to bone dry: Predicting plant community composition along a steep hydrological gradient. *J. Veg. Sci.* 26, 619–630. DOI: <https://doi.org/10.1111/jvs.12280>
- [5] Badan Pusat Statistik Kabupaten Hulu Sungai Utara (BPS–HSU), 2020. Kecamatan Sungai Pandan dalam angka. Available at: <https://hulusungaiutara.bps.go.id/publication.html>. (in Indonesian)
- [6] Bai, X., Chen, K., Zhao, H., and Chen, X., 2015. Impact of water depth and sediment type on root morphology of the submerged plant *Vallisneria natans*. *J. Freshw. Ecol.* 30: 75–84. DOI:<http://dx.doi.org/10.1080/02705060.2014.970672>
- [7] Balai Penelitian Tanah (BPT–Bogor), 2009. *Petunjuk teknis: Analisis kimia tanah, tanaman, air, dan pupuk*. Balai Penelitian Tanah, Bogor, Jawa Barat, Indonesia. (in Indonesian)
- [8] Baldwin, D.S, and Mitchell, A.M. 2000. The effects of drying and re–flooding on the sediment and soil nutrient dynamics of lowland river–floodplain systems: A synthesis. *River Research and Applications: an international journal devoted to river research and management*, 16: 457–467.
- [9] Bando, F.M., Michelan, T.S., Cunha, E.R., Figueiredo, B.R.S., and Thomaz, S.M., 2015. Macrophyte species richness and composition are correlated with canopy openness and water depth in tropical floodplain lakes. *Rev. Bras. Bot.* 38: 289–294. DOI: <https://doi.org/10.1007/s40415-015-0137-y>
- [10] Barko, J.W., Gunnison D., and Carpenter S.R. 1991. Sediment interacters with submerged macrophyte growth and community dynamics. *Aquat. Bot.* 41. DOI: [https://doi.org/10.1016/0304-3770\(91\)90038-7](https://doi.org/10.1016/0304-3770(91)90038-7)
- [11] Barko, J.W. and Smart, R.M. 1981. Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes. *Ecol. Monogr.* 51: 219–236. DOI: <https://doi.org/10.2307/2937264>
- [12] Barko, J.W., and Smart, R.M. 1983. Effects of organic matter additions to sediment on the growth of aquatic plants. *J. Ecol.* 71: 161–175. DOI: <https://doi.org/10.2307/2259969>

- [13] Bini, L.M., Thomaz, S.M., Murphy, K.J. and Camargo, A.F.M. 1999. Aquatic macrophyte distribution in relation to water and sediment conditions in the Itaipu Reservoir, Brazil. *Hydrobiologia*, 415: 147–154. Available at: <https://repositorio.unesp.br/handle/11449/20426>
- [14] Blanch, S.J., Ganf, G.G., and Walker, K.F. 1999. Growth and resource allocation in response to flooding in the emergent sedge *Bolboschoenus medianus*. *Aquat. Bot.* 63: 145–160. DOI:<https://dx.doi.org/10.1007/s10452-010-9334-8>
- [15] Bloom, A.J., Chapin, F.S. and Mooney, H.A., 1985. Resource limitation in plants an economic analogue. *Annu. Rev. Ecol. Syst.* 16: 363–392. DOI: <https://doi.org/10.1146/annurev.es.16.110185.002051>
- [16] Boar, R. 2006. Responses of a fringing *Cyperus papyrus* L. swamp to changes in water level. *Aquat. Bot.*, 84: 85–92. DOI: <https://dx.doi.org/10.1016/j.aquabot.2005.07.008>
- [17] Brock, Th.C.M., Arts, G.H.P., Goossen, L.L.M. Rutenfrans, A.H.M., 1983. Structure and annual biomass production of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae). *Aquat. Bot.* 17: 167–188. DOI:[https://doi.org/10.1016/0304-3770\(83\)90056-6](https://doi.org/10.1016/0304-3770(83)90056-6)
- [18] Brouwer, R. 1963. Some aspects of the equilibrium between overground and underground plant parts. *Jaarboek van het instituut voor biologisch en scheikundig onderzoek van landbouwgewassen*, Wageningen 31–39. Available at: <https://edepot.wur.nl/361707>
- [19] Casanova, M.T., and Brock, M.A., 2000. How do depth, duration and frequency of flooding influence the establishment of wetland plant communities?. *Plant Ecol.* 147: 237–250. DOI: <https://doi.org/10.1023/>
- [20] Cazzanelli, M., Warming, T.P., and Christoffersen, K.S., 2008. Emergent and floating-leaved macrophytes as refuge for zooplankton in a eutrophic temperate lake without submerged vegetation. *Hydrobiologia* 605: 113–122. DOI: <https://doi.org/10.1007/s10750-008-9324-1>
- [21] Chapin, F.S. 1980. The mineral nutrition of wild plants. *Ann. Rev. Ecol. Syst.* 11: 233–260. DOI:<https://doi.org/10.1146/annurev.es.11.110180.001313>
- [22] Chen, F., et al. 2017. Water lilies as emerging models for Darwin's abominable mystery. *Hortic. Res.* 4. DOI:[10.1038/hortres.2017.51](https://doi.org/10.1038/hortres.2017.51)
- [23] Chen, W., et al. 2007. Root growth of wetland plants with different root types. *Acta Ecol. Sinica*, 27: 450–457. DOI: [https://doi.org/10.1016/s1872-2032\(07\)60017](https://doi.org/10.1016/s1872-2032(07)60017)
- [24] Chernova, A.M., 2015. Seasonal dynamics of yellow water lily *Nuphur lutea* (L.) Smith (Nymphaeaceae) in the small Ild River (Yaroslavl oblast). *Inland Water Biol.*, 8: 157–165. DOI: <https://doi.org/10.1134/S1995082915020042>.
- [25] Čížková–Končalová, H., Květ, J., and Thompson, K., 1992. Carbon starvation: A key to reed decline in eutrophic lakes. *Aquat. Bot.* 43: 105–113. DOI: [https://doi.org/10.1016/0304-3770\(92\)90036-1](https://doi.org/10.1016/0304-3770(92)90036-1)
- [26] Coops, H., and Hosper, S.H. 2002. Water–Level management as a tool for the restoration of shallow lakes in the Netherlands. *Lake Reserv. Manage.*, 18: 293–298. DOI: <https://doi.org/10.1080/07438140209353935>
- [27] Coops, H., van den Brink, F.W.B., and van der Velde, G., 1996. Growth and morphological responses of four Helophytes species in an experimental water–depth gradient. *Aquat. Bot.*, 54: 11–24. DOI:[https://doi.org/10.1016/0304-3770\(96\)01025-X](https://doi.org/10.1016/0304-3770(96)01025-X)
- [28] Crawford, R.M.M. 1992. Oxygen availability as an ecological limit to plant distribution. *Adv. Ecol. Res.*, 23: 93–185. DOI: [https://doi.org/10.1016/S0065-2504\(08\)60147-6](https://doi.org/10.1016/S0065-2504(08)60147-6)
- [29] Cronk, J.K., and Fennessy, M.S. 2001. *Wetland plants: Biology and ecology*. Washington, New York. Lewis Publishers 462 p.
- [30] Deegan, B.M., White, S.D., and Ganf, G.G. 2007. The influence of water level fluctuations on the growth four emergent macrophyte species. *Aquat. Bot.* 86: 309–315. DOI: <https://doi.org/10.1016/j.aquabot.2006.11.006>
- [31] Deegan, B.M., White, S.D., and Ganf, G.G. 2012. Nutrients and water level fluctuations: A study of three aquatic plants. *River Res. Appl.* 28: 359–368. DOI: <https://doi.org/10.1002/rra.14611>

- [32] Dong, B., Qin, B., Li, W., and Gao, G., 2017. Growth and community composition of submerged macrophytes in Lake Taihu (China): Assessment of changes in response to sediment characteristics. *Wetlands*. 37: 233–243. DOI: [10.1007/s13157-016-0861-5](https://doi.org/10.1007/s13157-016-0861-5)
- [33] Duarte, C.M., and Kalff, J., 1986. Littoral slope as a predictor of the maximum biomass of submerged microphyte communities. *Limnol. Oceanogr.*, 31: 1072–1080. DOI: <https://doi.org/10.4319/lo.1986.31.5.1072>
- [34] Fares, A.L.B., et al. 2020. Environmental factors affect macrophyte diversity on Amazonian aquatic ecosystems inserted in an anthropogenic landscape. *Ecol. Indic.*, 113: 106–231. DOI:<https://doi.org/10.1016/j.ecolind.2020.106231>.
- [35] Felle, H.H. 2005. pH regulation in anoxic plants. *Ann. Bot.* 96: 519–532. DOI: [10.1093/aob/mci207](https://doi.org/10.1093/aob/mci207).
- [36] Ford, K.A., and Champion, P.D. 2019. *Flora of New Zealand: Seed plants Nymphaeales*. Manaaki Whenua Press. DOI: <http://dx.doi.org/10.7931/b1jh-cp50>
- [37] Fossey, M. and Rousseau, A.N. 2016. Can isolated and riparian wetlands mitigate the impact of climate change on watershed hydrology? A case study approach. *J. Environ. Manage.*, 184: 327–339. DOI:<http://dx.doi.org/10.1016/j.jenvman.2016.09.043>
- [38] Givnish, T.J. 1987. Comparative studies of leaf form: Assessing the relative roles of selective pressures and phylogenetic constraints. *New Phytol.*, 106: 131–160. DOI: <https://doi.org/10.1111/j.1469-8137.1987.tb04687.x>
- [39] Gopal, B. and Harma, K.P. 1990. *Ecology of plant populations. In: Ecology and management of aquatic vegetation in the Indian subcontinent*. Edited by B. Gopal. Kluwer Academic Publishers, Dordrecht 79–106 pp.
- [40] Huang, X. et al. 2018. The root structures of 21 aquatic plants in a macrophyte-dominated lake in China. *J. Plant Ecol.*, 11: 39–46. DOI: <https://doi.org/10.1093/jpe/rtx018>
- [41] Huber, H., et al. 2012. Plasticity as a plastic response: how submergence-induced leaf elongation in *Rumex palustris* depends on light and nutrient availability in its early life stage. *New Phytol.* 194: 572–582. DOI:<https://doi.org/10.1111/j.1469-8137.2012.04075.x>
- [42] Ismuhajarah, B.N., Indradewa, D., Kurniasih, B., and Utami, S.N.H., 2022. Interrelationships of Air Canal Adaptation in the Leaves of Water Lilies and Water Depth of Lebak Swampland in Kalimantan Selatan. *JEMT*, 1(57): 197-210.
- [43] Jian, Z., Ma, F., Guo, Q., Qin, A., and Xiao, W., 2018. Long-term responses of riparian plant's composition to water level fluctuation in China's three gorges reservoir. *PLoS ONE*. 13: e0207689. DOI:<https://doi.org/10.1371/journal.pone.0207689>
- [44] Kennedy, M.P., Milne, J.M., and Murphy, K.J., 2003. Experimental growth responses to groundwater level variation and competition in five British wetland plant species. *Wetl. Ecol. Manage.* 11: 383–396. DOI:[10.1023/b:wetl.0000007194.01073.6b](https://doi.org/10.1023/b:wetl.0000007194.01073.6b)
- [45] Kleindl, P.M., and Steinman, A.D. 2021. Contrasting trajectories in macrophyte community development after shoreline restoration: water level obscures trends. *Aquat. Bot.* 169, 103327. DOI: <https://doi.org/10.1016/j.aquabot.2020.103327>
- [46] Klok, P.F., and van der Velde, G., 2017. Plant traits and environment: Floating leaf blade production and turnover of waterlilies. *PeerJ.*, DOI:[10.7717/peerj.3212](https://doi.org/10.7717/peerj.3212)
- [47] Kordyum, E., Mosyakin, S., Ivanenko, G., Ovcharenko, Y., and Brykov, V., 2021. Hydropotes of young and mature leaves in *Nuphar lutea* and *Nymphaea alba* (Nymphaeaceae): Formation, functions and phylogeny. *Aquat. Bot.* 169, 103342. DOI: <https://doi.org/10.1016/j.aquabot.2020.103342>
- [48] Kornijów, R., Measey, G.J., and Moss, B., 2016. The structure of the littoral: Effects of waterlily density and perch predation on sediment and plant-associated macroinvertebrate communities. *Freshw. Biol.* 61: 32–50. DOI: <https://doi.org/10.1111/fwb.12674>

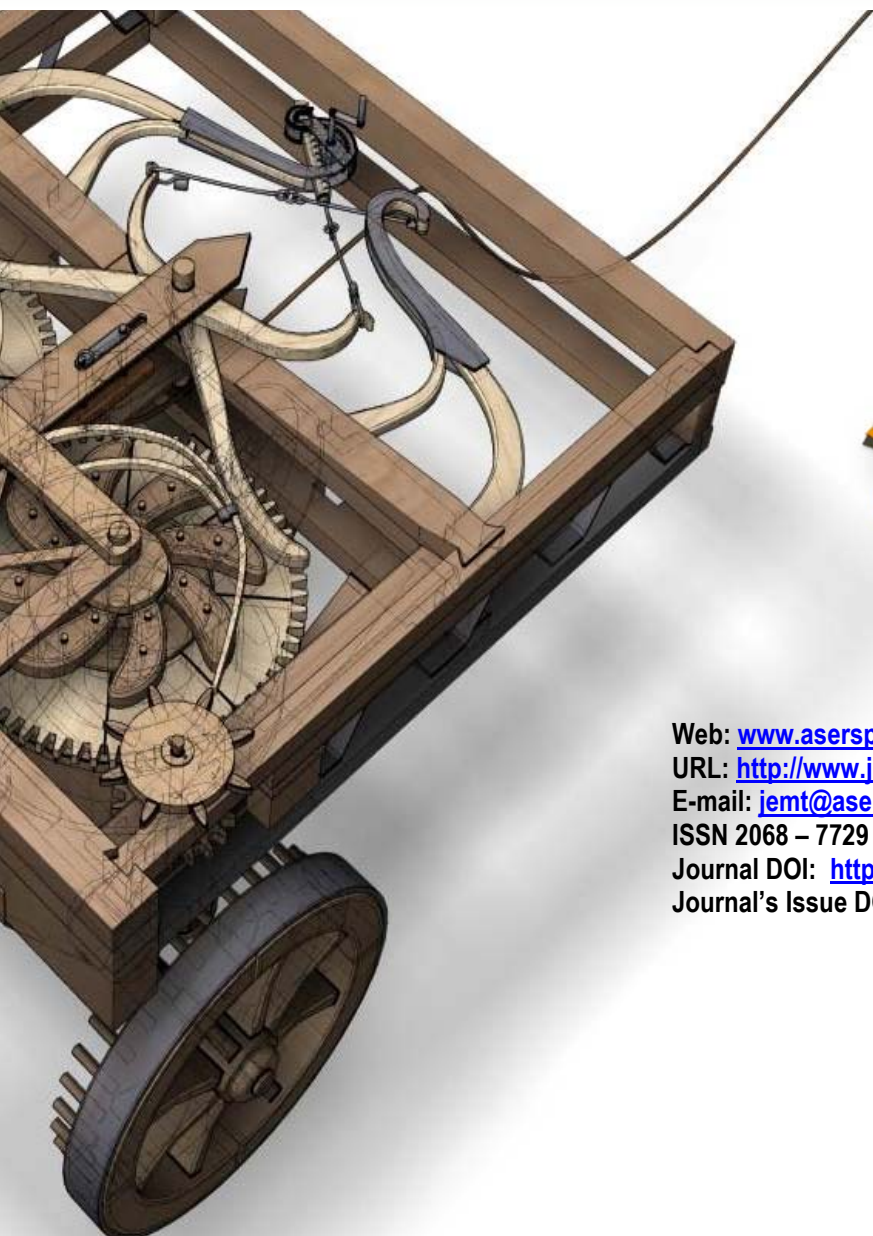
- [49] Kunii, H. and Aramaki, M., 1992. Annual net production and life span of floating leaves in *Nymphaea tetragona* Georgi: a comparison with other floating-leaved macrophytes. *Hydrobiologia*, 242: 185–193. DOI:<https://doi.org/10.1007/BF00019967>
- [50] Kutschker, A.M., Epele, L.B., and Miserendino M.L., 2014. Aquatic plant composition and environmental relationships in grazed Northwest Patagonian wetlands, Argentina. *Ecol. Eng.* 64: 37–48. DOI:<https://doi.org/10.1016/j.ecoleng.2013.12.007>
- [51] Lacoul, P. and Fredman, B., 2006. Environmental influences on aquatic plants in freshwater ecosystems. *Environ. Rev.* 14: 89–136. DOI:[10.1139/a06-001](https://doi.org/10.1139/a06-001)
- [52] Larcher, W. 1995. *Photosynthesis as a tool for indicating temperature stress events* In: Schulze, E.D., Caldwell, M.M., *Ecophysiology of photosynthesis*. Springer, Berlin Heidelberg New York, 261–277 pp.
- [53] Les, D.H. 2018. *Aquatic Dicotyledons of North America: Ecology, life history and systematics*, CRC Press. 1351p.
- [54] Li, Q., Zeng, Y., and Zha, W. 2020. Velocity distribution and turbulence structure of open channel flow with floating-leaved vegetation. *J. Hydrol.* 590, 125298. DOI: <https://doi.org/10.1016/j.jhydrol.2020.125298>
- [55] Liu, Y.L., and Kumar, M. 2016. Role of meteorological controls on interannual variations in wet-period characteristics of wetlands. *Water Resour. Res.* 52: 5056–5074. DOI:<https://doi.org/10.1002/2015WR018493>
- [56] Long, S.P., Farage, P.K., Nie, G.Y., and Osborne, C.P. 1995. *Photosynthesis and rising CO₂ concentration*. In: Mathis P. *Photosynthesis: from light to biosphere*. Kluwer Amsterdam V, 729–736.
- [57] Lu, J., Bunn, S.E. and Burford, M.A. 2018. Nutrient release and uptake by littoral macrophytes during water level fluctuations. *Sci. Total Environ.*, 622: 29–40. DOI: <https://doi.org/10.1016/j.scitotenv.2017.11.199>
- [58] Lu, X.M., and Chen, J.J., 2012. Effects of the diurnal variation of sunlight on water quality and the physiology of *Nymphaea tetragona*. *Environ. Toxicol. Chem.*, 94: 294–309. DOI:<https://doi.org/10.1080/02772248.2011.648939>
- [59] Lynn, D.E. and Waldren, S. 2003. Survival of *Ranunculus repens* L. (Creeping Buttercup) in an amphibious habitat. *Ann. Bot.* 91: 75–84. DOI: <https://doi.org/10.1093/aob/mcq011>
- [60] Macek, P., Rejmánková, E. and Houdková, K. 2006. The effect of long-term submergence on functional properties of *Eleocharis cellulosa* Torr. *Aquat. Bot.* 84: 251–258. DOI:<http://dx.doi.org/10.1016/j.aquabot.2005.11.003>
- [61] Madsen, T., and Brix, H. 1997. Growth, photosynthesis and acclimation by two submerged macrophytes in relation to temperature. *Oecologia*, 110: 320–327. DOI: <https://doi.org/10.1007/s004420050165>
- [62] Magee, T.K., Ernst, T.L., Kentula, M.E., and Dwire, K.A. 1999. Floristic comparison of freshwater wetlands in an urbanizing environment. *Wetlands*, 19: 477–489. DOI: <http://dx.doi.org/10.1007/BF03161690>
- [63] Maurer, D.A., and Zedler, J.B. 2002. Differential invasion of a wetland grass explained by tests of nutrients and light availability on the establishment and clonal growth. *Oecologia*, 131: 279–288. DOI:<https://doi.org/10.1007/s00442-002-0886-8>
- [64] Miao, S.L., Newman, S., and Sklar, F.H., 2000. Effects of habitat nutrients and seed sources on growth and expansion of *Typha domingensis*. *Aquat. Bot.* 68: 297–311. DOI: [https://doi.org/10.1016/S0304-3770\(00\)00127-3](https://doi.org/10.1016/S0304-3770(00)00127-3)
- [65] Molles, M.C.Jr., and Sher, A.A. 2019. *Ecology: Concepts and applications*. 8th Edition. Mc. Grow Hill.
- [66] Mommer, L. *et al.* 2005. Submergence-induced morphological, anatomical, and biochemical responses in a terrestrial species affect gas diffusion resistance and photosynthetic performance. *Plant Physiol.* 139: 497–508. DOI: <https://doi.org/10.1104/pp.105.064725>
- [67] Müller, I., Schmid, B., and Weiner, J. 2000. The effect of nutrient availability on biomass allocation patterns in 27 species of herbaceous plants. *Perspect. Plant Ecol. Evol. Syst.*, 3: 115–127. DOI:<https://doi.org/10.1078/1433-8319-00007>

- [68] Neill, C. 1990. Effects of nutrient and water levels on emergent macrophyte biomass in a prairie marsh. *Can. J. Bot.* 68: 1007–1014.
- [69] Nohara, S. and Tsuchiya, T. 1990. Effects of water level fluctuation on the growth of *Nelumbo nucifera* Gaertn. In lake Kasmigaura, Japan. *Ecol. Res.* 5: 237–252. DOI: <https://doi.org/10.1139/b90-127>
- [70] Paillisson, J.M. and Marion, L. 2011. Water level fluctuations for managing excessive plant biomass in shallow lakes. *Ecol. Eng.* 37: 241–247. DOI: <https://doi.org/10.1016/j.ecoleng.2010.11.017>
- [71] Phillips, G., Willby, N. and Moss, B. 2016. Submerged macrophyte decline in shallow lakes: What have we learnt in the last forty years?. *Aquat. Bot.* 135: 37–45. DOI: <https://doi.org/10.1016/j.aquabot.2016.04.004>
- [72] Pinay, G., Clément, J.C., and Naiman, R.J., 2002. Basic principles and ecological consequences of changing water regimes on nitrogen cycling in fluvial systems. *Environ. Manage.* 30: 481–491. DOI: [10.1007/s00267-002-2736-1](https://doi.org/10.1007/s00267-002-2736-1)
- [73] Pip, E. 1989. Water temperature and freshwater macrophyte distribution. *Aquat. Bot.* 34: 367–373. DOI: [https://doi.org/10.1016/0304-3770\(89\)90079-X](https://doi.org/10.1016/0304-3770(89)90079-X)
- [74] Poorter, H., and Nagel, O. 2000. The role of biomass allocation in the growth response of plants to different levels of light, CO₂, nutrients and water: A quantitative review. *Aust. J. Plant Physiol.*, 27: 595–607. DOI: http://dx.doi.org/10.1071/pp99173_co
- [75] Poorter, H., et al. 2012. Biomass allocation to leaves, stems and roots: Meta-analyses of interspecific variation and environmental control. *New Phytol.* 193: 30–50. DOI: <https://doi.org/10.1111/j.1469-8137.2011.03952.x>
- [76] Puijalon, S., et al. 2008. Phenotypic plasticity in response to mechanical stress: hydrodynamic performance and fitness of four aquatic plant species. *New Phytol.*, 177: 907–917. DOI: <https://doi.org/10.1111/j.1469-8137.2007.02314.x>
- [77] Raulings, E.J., Morris, K., Roache, M.C. and Boon, P.I. 2010. The importance of water regimes operating at small spatial scales for the diversity and structure of wetland vegetation. *Freshwater Biol.*, 55: 701–715. DOI: <https://doi.org/10.1111/j.1365-2427.2009.02311.x>
- [78] Ribaudo, C., et al. 2012. CO₂ and CH₄ fluxes across *Nuphar lutea* (L.) Sm. stand. *J. Limnol.*, 71: 200–210. DOI: <https://doi.org/10.4081/mnol.2012.e21>
- [79] Richards, J.F., Troxler, T.G., Lee, D.W., and Zimmerman, M.S. 2011. Experimental determination of effects of water depth on *Nymphaea odorata* growth, morphology and biomass allocation. *Aqua. Bot.*, 95: 9–16. DOI: [10.1016/j.aquabot.2011.03.002](https://doi.org/10.1016/j.aquabot.2011.03.002)
- [80] Richards, J.H., and Cao, C., 2012. Germination and early growth of *Nymphaea odorata* at different water depths. *Aquat. Bot.*, 98: 12–19. DOI: [10.1016/j.aquabot.2011.12.003](https://doi.org/10.1016/j.aquabot.2011.12.003)
- [81] Riis, T., and Hawes, I. 2002. Relationships between water level fluctuations and vegetation diversity in shallow water of New Zealand lakes. *Aquat. Bot.*, 74: 133–148. DOI: [https://doi.org/10.1016/S0304-3770\(02\)00074-8](https://doi.org/10.1016/S0304-3770(02)00074-8)
- [82] Riis, T., et al. 2012. Growth and morphology in relation to temperature and light availability during the establishment of three invasive aquatic plant species. *Aquat. Bot.*, 102: 56–64. DOI: <https://doi.org/10.1016/j.aquabot.2012.05.002>
- [83] Ritchie, R.J. 2012. Photosynthesis in the blue waterlily (*Nymphaea caerulea* Saligny) using pulse amplitude modulation fluorometry. *Int. J. Plant Sci.*, 173: 124–136. DOI: [10.1086/663168](https://doi.org/10.1086/663168)
- [84] Rossenberry, D.O., and Hayashi, M., 2013. Assessing and measuring wetland hydrology in: Anderson, J.T., Davis, C.A., Wetland techniques: Volume I: Foundations. DOI: [10.1007/978-94-007-6860-4_3](https://doi.org/10.1007/978-94-007-6860-4_3)
- [85] Sasidharan, R., et al. 2018. Signal dynamics and interactions during flooding stress. *Plant Physiol.*, 176: 1106–1117. DOI: <http://dx.doi.org/10.1104/pp.17.01232>
- [86] Scheffer, M. 2004. *Ecology of shallow lakes, Population and community biology series*. Chapman and Hall. London. 378p.

- [87] Scheffer, M., Hosper, S.H., Meijer, M.L., Moss, B., and Jeppesen, E. 1993. Alternative equilibria in shallow lakes. *Trends Ecol. Evol.*, 8: 275–279. DOI: [https://doi.org/10.1016/0169-5347\(93\)90254-M](https://doi.org/10.1016/0169-5347(93)90254-M)
- [88] Shipley, B., and Meziane, D. 2002. The balanced-growth hypothesis and the allometry of leaf and root biomass allocation. *Funct. Ecol.*, 16: 326–331. DOI: <https://doi.org/10.1046/j.1365-2435.2002.00626.x>
- [89] Smith, R.G.B., and Brock, M.A. 2007. The ups and downs of life on the edge: The influence of water level fluctuation on biomass allocation in two contrasting aquatic plants. *Plant Ecol.*, 188: 103–116. DOI: [10.1007/s1258-006-9151-2](https://doi.org/10.1007/s1258-006-9151-2)
- [90] Snir, A., Gurevitz, M., and Marcus, Y. 2006 Alterations in Rubisco activity and in stomatal behavior induce a daily rhythm in photosynthesis of aerial leaves in the amphibious-plant *Nuphar lutea*. *Photosynth. Res.*, 90: 233–242. DOI: [10.1007/s1120-007-9142-8](https://doi.org/10.1007/s1120-007-9142-8)
- [91] Solórzano, J.V., Gallardo-Cruz, J.A., Peralta-Carreta, C., Martínez-Camilo, R., and de Oca, A.F.M. 2020. Plant community composition patterns in relation to microtopography and distance to water bodies in a tropical forested wetland. *Aquat. Bot.* 167: 103295. DOI: <https://doi.org/10.1016/j.aquabot.2020.103295>
- [92] Sudiarto, S.I.A., Renggaman, A., and Choi, H.L. 2019. Floating aquatic plants for total nitrogen and phosphorus removal from treated swine wastewater and their biomass characteristics. *J. Environ. Manage.*, 231: 763–769. DOI: [10.1016/j.jenvman.2018.10.070](https://doi.org/10.1016/j.jenvman.2018.10.070)
- [93] Torres-Fernández del Campo, J., Olvera-Vargas, M., Figueroa-Rangel, B.L., Cuevas-Guzmán, R., and Iñiguez-Dávalos, L.I., 2018. *Patterns of spatial diversity and structure of mangrove vegetation in pacific West-Central Mexico*. *Wetlands*. DOI: <https://doi.org/10.1007/s13157-018-1041-6>
- [94] Tsuchiya, T. 1991. *Leaf life span of floating-leaved plants*. Kluwer Academic Publishers, Belgium. *Vegetation* 97: 149–160. DOI: [10.1007/BF00035388](https://doi.org/10.1007/BF00035388)
- [95] Twilley, R.R., Blanton, L.R., Brinson, M.M., and Davis, G.J. 1985. Biomass production and nutrient cycling in aquatic macrophyte communities of the Chowan River, North Carolina. *Aquat. Bot.*, 22: 231–252. DOI: [https://doi.org/10.1016/0304-3770\(85\)90002-6](https://doi.org/10.1016/0304-3770(85)90002-6)
- [96] van der Valk, A., and Mushet, D.M. 2016. Interannual water-level fluctuations and the vegetation of Prairie Potholes: Potential impacts of climate change. *Wetlands*, 36: 397–406. DOI: <https://doi.org/10.1007/s13157-016-0850-8>
- [97] van der Valk, A.G. 2005. Water-level fluctuations in North American prairie wetlands. *Hydrobiologia*, 539: 171–188. DOI: [10.1007/s10750-004-4866-3](https://doi.org/10.1007/s10750-004-4866-3)
- [98] van Geest, G.J., et al. 2005. Water-level fluctuations affect macrophyte richness in floodplain lakes. *Hydrobiologia*, 539: 239–248. DOI: [10.1007/s10750-004-4879-y](https://doi.org/10.1007/s10750-004-4879-y)
- [99] van Wijk, M.T., Williams, M., Gough, L., Hobbie, S.E., and Shaver, G.R., 2003. Luxury consumption of soil nutrients: A possible competitive strategy in above-ground and below-ground biomass allocation and root morphology for slow-growing arctic vegetation?. *J. Ecol.*, 91: 664–676. DOI: <https://doi.org/10.1046/j.1365-2745.2003.00788.x>
- [100] Vartapetian, B.B., and Jackson, M.B. 1997. Plant adaptations to anaerobic stress. *Ann. Bot.*, 79: 3–20. DOI: <https://doi.org/10.1093/oxfordjournals.aob.a010303>
- [101] Voesenek, E.J.W., et al. 2003. Interaction between plant hormones regulate submergence-induced shoot elongation in the flooding-tolerant dicot *Rumex palustris*. *Ann. Bot.*, 91: 205–211.
- [102] Vymazal, J., and Kröpfelová, L. 2008. Wastewater treatment in constructed wetlands with horizontal sub-surface flow. *Springer*. 579p.
- [103] Wang, P., Zhang, Q., Xu, Y.S., and Yu, F.H., 2016. Effects of water level fluctuation on the growth of submerged macrophyte communities. *Flora-Morphol. Distrib. Funct. Ecol. Plants.*, 223: 83–89. DOI: <http://dx.doi.org/10.1016/j.flora.2016.05.005>
- [104] Wang, Q., Chen, I., Liu, F., and Li, W., 2014. Morphological changes and resource allocation of *Zizania latifolia* (Griseb.) Stapf in response to different submergence depth and duration. *Flora*, 209: 279–284. DOI: [10.1016/j.flora.2014.03.006](https://doi.org/10.1016/j.flora.2014.03.006)

- [105] Webb, M.A., Ott, R.A.Jr., and Bonds, C.C. 2012. *Propagation and establishment of native aquatic plants in reservoirs*. Management data series, No. 273. Inland fisheries division, Austin, Texas 78744. Available at: https://tpwd.texas.gov/publications/pwdpubs/media/pwd_rp_t3200_1770.pdf
- [106] Webb, R.H., and Leake, S.A. 2006. Ground–watersurface–waterinteractions and long–term change in riverine riparian vegetation in the southwestern United States. *J. Hydrol.*, 320: 302–323. DOI:<https://doi.org/10.1016/j.jhydrol.2005.07.022>
- [107] Wei, G.W., *et al.* 2019. Growth responses of eight wetland species to water level fluctuation with different ranges and frequencies. *PLOS ONE.*, 14, e0220231. DOI:<https://doi.org/10.1371/journal.pone.0220231>
- [108] Wetzel, R.G., and Likens, G.E. 2000. *Limnological analyses*. San Diego, California. Academic Press 3rd Edition.
- [109] White, M.S., *et al.* 2008. Natural lake level fluctuation and associated concordance with water quality and aquatic communities within small lakes of the Laurentian Great Lakes region. *Hydrobiologia*, 613: 21 –31. DOI:[10.1007/s10750-008-9469-y](https://doi.org/10.1007/s10750-008-9469-y)
- [110] Wu, J., Zhao, H–B., Yu, D. and Xu, X., 2017. Transcriptome profiling of the floating leaved aquatic plant *Nymphoides peltata* in response to flooding stress. *BMC Genom.* 18. DOI:[10.1186/s12864-017-3515-y](https://doi.org/10.1186/s12864-017-3515-y)
- [111] Yamamoto, I., Tsuchiya, T., and Ikusima, I. 1999. Relationship between net photosynthetic rate and leaf life span of six submerged plants in experimental ponds. *Japanese J. Limnology*, 60: 257–263. DOI:<https://doi.org/10.3739/rikusui.60.257>
- [112] Yang, F., and Guo, Z. 2015. Characterization of micro–morphology and wettability of lotus leaf, waterlily leaf and biomimetic ZnO surface. *J. Bionic Eng.*, 12: 88–97. DOI: [https://doi.org/10.1016/S1672-6529\(14\)60103-7](https://doi.org/10.1016/S1672-6529(14)60103-7)
- [113] Yu, H., Niu, Y., Hu, Y., and Du, D. 2014. Photosynthetic response of the floating–leaved macrophyte *Nymphoides peltata* to a temporary terrestrial habitat and its implications for ecological recovery of lake side zones. *Knowl. Managt. Aquatic Ecosyst.* 412, 08. DOI: <https://doi.org/10.1051/kmae/2013090>
- [114] Zhang, A.Y., *et al.* 2019. Dam effect on soil nutrients and potentially toxic metals in a reservoir riparian zone. *Clean–Soil Air Water.* 47, 1700497. DOI: <https://doi.org/10.1002/clen.201700497>
- [115] Zhonghua, W., Dan, Y., Manghui, T., Qiang, W., and Wen, X. 2007. Interference between two floating–leaved aquatic plants: *Nymphoides peltata* and *Trapa bispinosa*. *Aquat. Bot.*, 86: 316–320. DOI:<https://doi.org/10.1016/j.aquabot.2006.11.008>
- [116] Zhu, J., *et al.* 2017. Modeling the potential impacts of climate change on the water table level of selected forested wetlands in the southeastern United States. *Hydrol. Earth Syst. Sci.*, 21: 6289–6305. DOI:<https://doi.org/10.5194/hess-21-6289-2017>

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