**BIOTIK**
Jurnal Ilmiah Biologi Teknologi dan Kependidikan
P-ISSN: 2337-9812, E-ISSN: 2549-1768
Vol.14, No. 2, 2026. Page 275-290

# Floral Phenology of Lake Laut Tawar in the Gayo Highlands, Central Aceh Regency

[1]Nia Ananda Puspa, [2*]Djufri, [3]Zumaidar, [4]M. Ali S., [5]Hafnati Rahmatan, and [6]Vivera Ruselli Puspa

1. Biology Education Department, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
2. Biology Education Department, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia *
3. Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia
4. Biology Education Department, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
5. Biology Education Department, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
6. Biology Education Department, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia

*Correspondence email: djufri_bio@usk.ac.id

Accepted : April 6, 2026
Published: September 29, 2026

**Abstrak:** Danau Laut Tawar merupakan danau vulkanis yang memiliki nilai ekologis tinggi dan mendukung kehidupan masyarakat sekitar. Analisis fenologi merupakan suatu cara untuk mempelajari karakter reproduktif tumbuhan, seperti tipe bunga dan tipe buah, serta strategi penyebaran biji secara sistematis. Belum ada data komprehensif terkait karakter fenologi flora di kawasan Danau Laut Tawar. Penelitian ini bertujuan untuk mengetahui tipe bunga dan tipe buah serta keragaman strategi reproduksi tumbuhan di sekeliling Danau Laut Tawar, Kabupaten Aceh Tengah. Penelitian menggunakan pendekatan kuantitatif melalui observasi transek terhadap 48 familia tumbuhan, pendataan spesies serta tipe bunga dan buah. Hasil penelitian menunjukkan bahwa dominansi tipe bunga adalah simosa dan tipe buah kapsula, sedangkan tipe lain yang dijumpai adalah tipe rasemosa, tipe buah drupa, bakka, legum, akhene, kariopsis, dan polidrupa, yang menunjukkan variasi strategi reproduksi yang adaptif terhadap kondisi lingkungan dan interaksi sebagai agen penyerbuk maupun fauna penyebar biji. Variasi fenologi ini mendukung regenerasi vegetasi, stabilitas populasi fauna, serta meningkatkan nilai estetika kawasan, sehingga menjadi dasar ilmiah bagi strategi konservasi flora dan pengelolaan ekosistem Danau Laut Tawar di masa mendatang.
**Kata kunci**: Fenologi; Tipe bunga; Tipe buah; Vegetasi riparian; Danau Laut Tawar.

Copyright: © by the authors.
BIOTIK 2026
Open access article under the CC BY-SA Licence

**Abstract:** Lake Laut Tawar is a volcanic lake possessing high ecological significance and supporting the livelihoods of surrounding communities. Phenological analysis provides an essential framework for understanding plant reproductive characteristics, including inflorescence types, fruit morphology, and seed dispersal strategies. However, comprehensive information regarding the phenological traits of flora in the Lake Laut Tawar ecosystem remains limited. This study aimed to identify flower and fruit types and evaluate the diversity of plant reproductive strategies in the vegetation surrounding

Lake Laut Tawar, Central Aceh Regency, Indonesia. A quantitative field survey was conducted using transect-based observations covering 48 plant families, involving species identification and documentation of floral and fruit characteristics. The results revealed that cymose inflorescences and capsule fruits were the dominant reproductive forms, while additional inflorescence types included racemose structures, and fruit types comprised drupe, berry, legume, achene, caryopsis, and polydrupe. These findings indicate diverse adaptive reproductive strategies associated with environmental conditions, pollination mechanisms, and seed dispersal interactions. The observed phenological diversity contributes to vegetation regeneration, supports faunal population stability, and enhances ecosystem resilience and landscape aesthetics. This study provides baseline scientific data to support flora conservation planning and sustainable ecosystem management in the Lake Laut Tawar region.
**Keyword:** Phenology; Flower type; Fruit type; Riparian vegetation; Laut Tawar Lake.

## 1. Introduction

Lake Laut Tawar, located in Central Aceh Regency, Indonesia, is a volcanic lake situated in the Gayo Highlands at an elevation of approximately 1.230 m above sea level (masl), covering an area of about 5,247 hectares with an average depth of 51.31 m [1]. The lake holds significant ecological importance and plays a vital role in sustaining local livelihoods, serving as a primary resource for fisheries and agriculture, and as an increasingly prominent tourism destination. Recent data indicate a 25% increase in tourist visits compared to the previous year, reflecting intensified anthropogenic pressure associated with improved infrastructure, expanded tourism activities, and enhanced accessibility to information and services [2].

The rapid development around Lake Laut Tawar, including the construction of homestays, resorts, and cafés, has accelerated land-use transformation in riparian zones and catchment areas. Such changes represent significant environmental concerns, as the reduction of natural vegetation may disrupt ecological stability and ecosystem functioning. Vegetation communities perform complex ecological roles through plant–plant interactions and interactions with associated organisms, contributing to ecosystem structure and resilience [3]. In aquatic landscapes, riparian vegetation is particularly important for stabilizing riverbanks, controlling erosion, filtering pollutants, and maintaining water and soil quality [4]. Riparian vegetation also provides

multiple ecosystem services by reducing diffuse pollution, supporting biodiversity, and contributing organic matter and other resources to freshwater ecosystems. The effectiveness of these functions is influenced by vegetation structure, buffer width, and the spatial arrangement of riparian areas within the catchment [16].

Anthropogenic alterations in vegetation composition not only influence ecosystem functions but may also modify plant biological characteristics and reproductive dynamics. Phenological studies provide an important framework for evaluating these changes, particularly by examining reproductive traits such as inflorescence and fruit types. These phenological characteristics reflect plant reproductive strategies, including pollination mechanisms and seed dispersal processes, which are fundamental to species persistence, regeneration, and ecosystem sustainability.

Variation in flower and fruit types among plant species reflects adaptive responses to environmental conditions and ecological interactions. Floral morphology is closely associated with pollination strategies mediated by abiotic or biotic agents, whereas fruit characteristics influence seed dispersal mechanisms that determine plant distribution patterns and population dynamics within ecosystems. Consequently, phenological traits provide valuable indicators of natural regeneration processes and plant responses to environmental change. Changes in phenological timing can provide an important ecological signal of environmental change because flowering and other reproductive events respond to variations in climatic conditions. Consequently, shifts in flowering phenology may reflect changes in the environmental conditions experienced by plant communities [17].

Despite their ecological importance, scientific information regarding the phenological characteristics of flora, particularly inflorescence and fruit types, in the Lake Laut Tawar region remains limited. Such baseline data are essential for supporting ecology-based conservation and ecosystem management. Previous studies have demonstrated that riparian vegetation plays a critical role in maintaining aquatic ecosystem stability, while the loss or degradation of

DOI: 10.22373/biotik.v14i2.34501
Home page: www.jurnal.ar-raniry.ac.id/index.php/biotik/index

plant communities can accelerate sedimentation processes and alter microhabitat conditions [5]. Moreover, environmental challenges affecting Lake Laut Tawar, including land-cover transformation, reduction of water surface area, pollution, and sedimentation, have been identified as major threats to the sustainability of the lake ecosystem [6].

Despite their ecological importance, scientific information regarding the phenological characteristics of flora, particularly inflorescence and fruit types, in the Lake Laut Tawar region remains limited. Phenological traits provide important information on plant reproductive patterns, seasonal resource availability, and species responses to environmental changes. In riparian ecosystems, flowering and fruiting dynamics influence pollinator activity, seed dispersal processes, natural regeneration, and the maintenance of plant community structure. The timing of flowering is particularly important because temporal overlap among flowering plants can influence the structure of plant–pollinator interactions. Differences in flowering periods may therefore affect the availability of floral resources and the degree of interaction between plants and their pollinators [18]. Consequently, understanding the phenological characteristics of riparian flora is essential for evaluating ecosystem resilience and supporting effective conservation planning. Previous studies have demonstrated that riparian vegetation plays a critical role in maintaining aquatic ecosystem stability by reducing soil erosion, filtering pollutants, regulating nutrient cycling, and providing habitat and food resources for various organisms [5].

Changes in vegetation composition or disruptions to reproductive cycles may therefore affect ecosystem functions and biodiversity persistence. Alterations in flowering phenology may also influence the strength and timing of plant–pollinator interactions. Experimental evidence indicates that warming can advance flowering phenology while reducing the frequency of plant–pollinator interactions and ultimately affecting plant reproductive output [19]. Moreover, environmental challenges affecting Lake Laut Tawar, including land-cover transformation, reduction of water surface area, pollution, and sedimentation, have been identified as major threats to the sustainability of the

lake ecosystem [6]. These disturbances can alter habitat conditions and potentially influence the phenological patterns, regeneration capacity, and long-term survival of riparian plant species. Previous research has also demonstrated that reproductive phenology, including flowering and fruiting, can be influenced by climatic conditions, highlighting the importance of phenological information for understanding plant regeneration and developing conservation strategies [25].

Environmental disturbances may consequently influence not only the occurrence of plant species but also the temporal synchrony between plants and their ecological partners. Changes in flowering timing that are not matched by corresponding changes in pollinator activity may reduce the frequency of plant–pollinator interactions and potentially affect reproductive success [19]. Therefore, comprehensive information on the diversity, phenology, and conservation status of flora surrounding Lake Laut Tawar is needed to support sustainable ecosystem management and conservation strategies. Therefore, documenting flowering and fruiting characteristics is not only relevant for describing plant diversity but also provides information about reproductive processes that may support the maintenance and regeneration of plant populations. Understanding these characteristics is particularly important in ecosystems experiencing environmental pressures, where changes in plant–pollinator interactions and seed-dispersal processes may influence long-term vegetation dynamics [19][22]. Given these conditions, a comprehensive assessment of plant phenological characteristics in the Lake Laut Tawar area is required, with particular focus on identifying flower and fruit types across plant species. This study aims to provide insights into plant reproductive strategies and their potential for natural regeneration under increasing environmental pressures. The findings are expected to provide baseline scientific information to inform the formulation of effective and sustainable flora conservation strategies and to support the long-term ecological integrity of the Lake Laut Tawar ecosystem.

DOI: 10.22373/biotik.v14i2.34501
Home page: www.jurnal.ar-raniry.ac.id/index.php/biotik/index

## 2. Research Method

This study employed a qualitative, non-experimental observational survey design to document plant phenological characteristics in the study area.

### a. Time and Research Location

The research was conducted in the vicinity of Lake Laut Tawar, in the Gayo Highlands, Central Aceh Regency, Aceh Province, Indonesia. Field observations were carried out from August to November 2025.

### b. Data collection

Data were obtained through direct field observations using a transect survey method. Observation transects were established across representative vegetation areas surrounding the lake. All plant species encountered were recorded according to predetermined parameters, including species identity, occurrence at observation stations, and phenological condition, particularly flowering and fruiting stages (Figure 1). Species identification and documentation of reproductive characteristics were conducted systematically during each field survey.

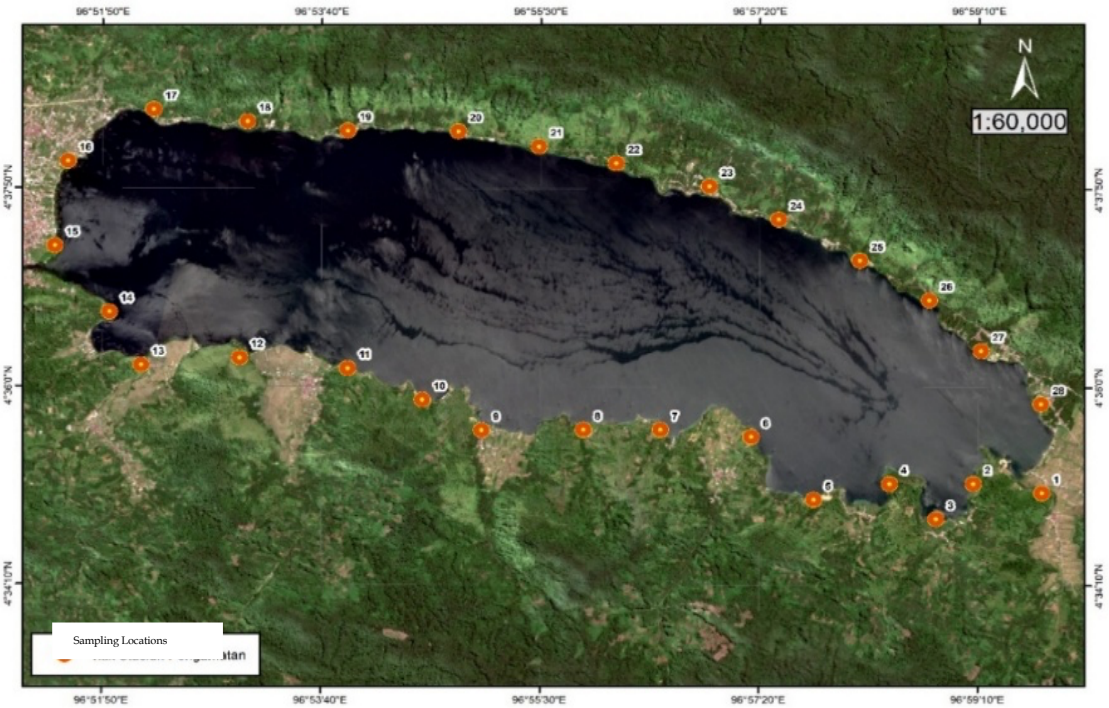



**Figure 1.** Map of the observation site

**c. Data Analysis**

Phenological data were analyzed using qualitative and quantitative descriptive approaches. Species composition was summarized using a floristic inventory, and the frequency of observed phenological stages, including flowering and fruiting, was calculated to identify dominant reproductive characteristics within the study area. Flower and fruit types were classified using standard botanical terminology to evaluate patterns in plant reproductive strategies.

Species identification was conducted using the Flora of Java, supported by the PlantNet application, and verified through the Plants of the World Online (https://powo.science.kew.org/) database to ensure the use of accepted scientific names and standardized taxonomic classifications in accordance with internationally recognized nomenclatural standards.

The relative occurrence of each inflorescence and fruit type was quantified to describe phenological variation among plant families and to assess ecological adaptations related to pollination mechanisms, seed dispersal strategies, and vegetation regeneration potential under environmental pressures around Lake Laut Tawar. The analyzed data were subsequently used as a scientific basis for developing flora conservation strategies and supporting sustainable ecosystem management in the Lake Laut Tawar region.

## 3. Results and Discussion

Based on the results of the study involving 48 plant families, a considerable diversity of floral and fruit types was documented (Table 1). The most dominant floral architectures were cymose and racemose inflorescences, including their variations such as spikes, panicles, capitula, spadices, and spikelets. The most frequently recorded fruit types were capsules, berries, and drupes, indicating diverse seed-dispersal strategies, both abiotic and animal-mediated.

Several plant families exhibited distinctive fruit morphologies that are taxonomically diagnostic, including legumes in Fabaceae and Mimosaceae,

caryopses in Poaceae, polydrupes in Pandanaceae, and syconia in Moraceae. These reproductive structures represent important characters for plant identification and classification. Illustrations of representative flowers and fruits observed at the study site are presented in Figures 2 and 3.

**Table 1.** Flower and Fruit Types of Plant Families at the Study Site

| Family | Flower Type | Fruit Type |
|---|---|---|
| Acanthaceae | Cymose or Racemose | Capsule |
| Amaranthaceae | Spike, Panicle, Raceme, or Cymose | Achene |
| Amaryllidaceae | Umbel | Capsule |
| Anacardiaceae | Cymose | Drupe |
| Apocynaceae | Cymose, Racemose, or Solitary | Follicle, Drupe, Berry, or Capsule |
| Arecaceae | Panicle or Spadix | Berry or Drupe |
| Asparagaceae | Panicle or Cluster | Berry |
| Asteraceae | Capitulum | Achene |
| Balsaminaceae | Umbel-like Cymose (Umbelliform Cyme) | Capsule (Impatiens-type capsule) |
| Cactaceae | Perianth Tube or Hypanthium | Berry |
| Cannaceae | Bisexual, Epigynous, Zygomorphic | Capsule with Exocarp |
| Caricaceae | Cymose forming a Tube | Large Fleshy Fruit |
| Casuarinaceae | Capitulum | Nut |
| Clusiaceae | Cymose | Berry, Drupe or Capsule |
| Combretaceae | Raceme, Spike or Capitulum | Capsule |
| Commelinaceae | Capitulum (Head) | Dry Fruit |
| Convulvulaceae | Dichasium or Solitary | Capsule |
| Cyatheaceae | - | - |
| Cyperaceae | Sessile forming a Spike or Spikelet | Achene |
| Dipterocarpaceae | Raceme or Panicle | Dry Fruit with Pericarp |
| Ericaceae | Raceme | Capsule, Berry, or Drupe |
| Euphorbiaceae | Actinomorphic | Skizhokarpium, Schizocarp, Drupe, Berry, or Samara |
| Fabaceae | Raceme, Spike or Capitulum | Legume |
| Lamiaceae | Cymose, Verticillaster, Spike, or Capitulum | Nut |
| Lauraceae | Raceme, Spike, Umbel, or Panicle | Berry or Drupe |
| Lecythidaceae | Axillary, or arranged in Racemes or Panicles | Capsule |
| Malvaceae | Cymose | Capsule |
| Melastomataceae | Cymose | Capsule or Berry |

| Family | Flower Type | Fruit Type |
|---|---|---|
| Meliaceae | Panicle | Capsule, Berry, or Drupe |
| Mimosaceae | Spike, Raceme or Capitulum | Legume |
| Molluginaceae | Actinomorphic | Capsule |
| Moraceae | Raceme, Spike, Umbel, or Capitulum | Drupe or Syconium |
| Musaceae | Cymose | Fleshy Fruit |
| Myrtaceae | Cymose or Racemose | Berry, Capsule, Drupe, or Nut |
| Nyctaginaceae | Cymose | Achene |
| Oxalidaceae | Cymose | Capsule or Berry |
| Pandanaceae | Spadix arranged in Racemes or Panicles | Polydrupe |
| Pinaceae | - | - |
| Poaceae | Spikelets are arranged in Spikes, Racemes, or Panicles | Caryopsis |
| Pontederiaceae | Raceme, Spike, Panicle, or Solitary | Capsule |
| Rhamnaceae | Umbel | Drupe |
| Rubiaceae | Cymose | Capsule, Berry, Drupe, or Schizocarp |
| Rutaceae | Cymose or Raceme | Capsule, Drupe, or Berry |
| Selaginellaceae | - | - |
| Solanaceae | Cymose | Berry, Capsule or Drupe |
| Theaceae | Panicle or Raceme | Capsule |
| Vebernaceae | Spike, Panicle, and Cymose | Drupe, Nut or Capsule |
| Zingiberaceae | Cymose | Capsule or Berry |

The results of the phenological identification revealed substantial variation in floral types within plant communities surrounding Lake Laut Tawar. The recorded inflorescence types included cymose, racemose, spike, spikelet, panicle, capitulum, spadix, umbel, dichasium, verticillaster, and solitary flowers. The duration and overlap of flowering periods can influence opportunities for interaction between flowering plants and pollinators. Consequently, differences in flowering phenology among plant species may contribute to differences in the degree of specialization within plant–pollinator networks [18][24]. Quantitative analysis indicated that the cymose inflorescence type was the most dominant, particularly among members of Acanthaceae, Malvaceae, Melastomataceae, Solanaceae, and Zingiberaceae.

This dominance is closely associated with a determinate inflorescence growth pattern, in which flowering occurs rapidly and synchronously as the terminal meristem ceases growth after floral initiation. Such a reproductive strategy promotes efficient resource allocation and increases reproductive success under the competitive conditions typical of tropical ecosystems [7].

In contrast, the racemose inflorescence type observed in Fabaceae and Lauraceae exhibited an indeterminate growth pattern characterized by sequential (acropetal) flowering, thereby prolonging the period of floral availability. This pattern provides ecological advantages by ensuring more evenly distributed pollination opportunities under fluctuating environmental conditions [8]. Meanwhile, spike and spikelet inflorescences, commonly found in Poaceae and Cyperaceae, represent adaptations to wind pollination (anemogamy), characterized by small, densely arranged flowers that enhance pollen dispersal efficiency.



**Figure 2.** Flower Types Found at the Study Site

The diversity of floral types reflects variation in plant reproductive strategies in response to environmental factors, including pollinator availability

and competition intensity. Floral traits are important components of plant reproduction because characteristics such as floral structures can influence interactions between plants and pollinators. Standardized assessment of floral traits can therefore provide useful information for understanding plant reproductive strategies and pollination interactions within plant communities [20]. Plant–pollinator interactions are also temporally dynamic, as plant species and pollinators may enter, change their interaction roles, and leave ecological networks at different times throughout the flowering season. Thus, variation in flowering phenology can contribute to temporal changes in the structure and composition of plant–pollinator communities [21]. Variation in floral architecture also promotes biotic interactions, particularly with pollinators such as insects and birds, which contribute to ecosystem stability [9]. Furthermore, differences in flower morphology and coloration enhance landscape aesthetic value, potentially supporting biodiversity-based ecotourism development in the Lake Laut Tawar area [10][11].

Overall, the dominance of cymose inflorescences indicates an efficient reproductive strategy, whereas the presence of racemose and other floral types demonstrates adaptive flexibility to maximize reproductive success. The coexistence of determinate and indeterminate flowering patterns suggests that phenological traits, especially inflorescence types, represent ecological adaptations of plant species to local environmental conditions surrounding Lake Laut Tawar.

Overall, the dominance of cymose inflorescences indicates an efficient reproductive strategy that enables synchronized flowering and effective resource allocation. This flowering type was commonly observed in several families, including Acanthaceae, Anacardiaceae, Malvaceae, Melastomataceae, Rubiaceae, Solanaceae, and Zingiberaceae. In contrast, racemose, spike, panicle, and capitulum inflorescences, which occurred in families such as Fabaceae, Mimosaceae, Poaceae, Cyperaceae, and Asteraceae, provide prolonged flowering periods that may increase pollination opportunities. The variation in inflorescence types likely reflects adaptive responses to local environmental

conditions, including light availability, soil moisture, water-level fluctuations, and habitat disturbance in the riparian zone of Lake Laut Tawar [23]. Therefore, the coexistence of determinate and indeterminate flowering patterns highlights the ecological flexibility of plant species in optimizing reproductive success under diverse environmental conditions.

Phenological identification also revealed considerable variation in fruit types within plant communities at Lake Laut Tawar. Similar variation in flowering and fruiting phenology has also been documented in tropical montane ecosystems, indicating that reproductive events may vary among plant species under highland environmental conditions [24]. Including capsules, drupes, berries, legumes, achenes, nuts, schizocarps, caryopses, and polydrupes. Quantitative analysis showed that capsules were the most dominant fruit type, particularly among members of Acanthaceae, Malvaceae, Solanaceae, and Zingiberaceae. This dominance is associated with efficient seed-dispersal mechanisms via fruit or organ dehiscence, enabling seed release by wind dispersal (anemochory) or autonomous dispersal (autochory). Such strategies provide adaptive advantages in competitive tropical environments, especially in open or disturbed habitats, by facilitating rapid and extensive seed dissemination.

In contrast, fleshy fruits such as drupes and berries, observed in Anacardiaceae, Meliaceae, Arecaceae, and Melastomataceae, indicate zoochorous dispersal strategies that rely on animals as seed dispersal agents. Fruit characteristics can influence the effectiveness of animal-mediated seed dispersal because differences in fruit traits may alter the visitation of frugivorous animals and consequently affect the quantity and composition of dispersed seeds. In tropical landscapes, fleshy-fruited pioneer trees have been shown to attract greater bird activity and seed dispersal than wind-dispersed species, highlighting the importance of fruit traits in vegetation regeneration [22]. These fruit types serve as important food resources for birds, mammals, and bats, thereby supporting wildlife population stability and promoting vegetation regeneration through seed dispersal [12]. Furthermore, the diversity of fruit morphology and coloration enhances the aesthetic value of the

landscape and may support biodiversity-based ecotourism development [10][11].



**Figure 3.** Fruit Types Found at the Study Site

DOI: 10.22373/biotik.v14i2.34501
Home page: www.jurnal.ar-raniry.ac.id/index.php/biotik/index

Other fruit types, including legumes in Fabaceae and achenes in Amaranthaceae and Asteraceae, also demonstrate efficient dispersal adaptations. Legumes exhibit dehiscent mechanisms that facilitate mechanical seed release and dispersal by environmental agents, whereas small, lightweight achenes enable long-distance dispersal with minimal energy investment. Meanwhile, caryopses in Poaceae represent a specialization for open habitats, utilizing effective dispersal strategies adapted to windy environmental conditions.

Overall, the variation in fruit types reflects the diversity of plant reproductive strategies in response to environmental conditions. Dry fruits, such as capsules and achenes, are better adapted to open and fluctuating environments because their dispersal does not depend on biotic agents. In contrast, fleshy fruits, including drupes and berries, rely on interactions with fauna for effective seed dispersal. The dominance of capsule-type fruits also indicates an efficient, synchronized reproductive strategy that maximizes seed dispersal under favorable environmental conditions. These findings demonstrate that fruit phenological traits play a critical role in determining regeneration success and shaping plant community dynamics within the Lake Laut Tawar ecosystem, Central Aceh Regency [13][15].

## 4. Conclusion

The plant communities surrounding Lake Laut Tawar exhibit high phenological diversity, particularly in flower and fruit types, reflecting adaptive reproductive strategies in tropical environments. The dominance of cymose inflorescences and capsule fruits indicates efficient reproduction and effective seed-dispersal mechanisms. Meanwhile, the presence of other flower and fruit types, including racemose inflorescences, drupes, berries, legumes, and achenes, demonstrates adaptive flexibility in response to environmental variation and ecological interactions with pollinators and seed-dispersing fauna. This phenological diversity plays an important role in supporting vegetation regeneration, maintaining wildlife population stability, and enhancing the aesthetic and ecotourism value of the lake area. Overall, these

findings provide a scientific foundation for developing flora conservation strategies and sustainable ecosystem management for Lake Laut Tawar.

## 5. Reference


[1]M. Setiawati, S. Kamal, and N. Amin, "Analisis faktor fisik-kimia habitat ikan depik (*Rasbora tawarensis*) di Danau Laut Tawar," in *Proc. Semin. Nas. Biologi, Teknologi dan Kependidikan*, vol. 8, no. 1, pp. 47–52, Jun. 2022.

[2]Hidayah, "Kunjungan wisatawan ke Danau Laut Tawar meningkat 25%," *Kantor Berita Radio Nasional (KBRN) Takengon*, Dec. 24, 2024.

[3]S. Agustina, Y. Maulana, and N. Zahara, "Analisis vegetasi jenis pohon di kawasan pegunungan Desa Iboih Kecamatan Sukakarya Kota Sabang," in *Proc. Semin. Nas. Biologi, Teknologi dan Kependidikan*, vol. 9, no. 1, pp. 97–105, 2021.

[4]F. B. P. Nurika, E. Wiryani, and J. Jumari, "Keanekaragaman vegetasi riparian Sungai Panjang bagian hilir di Kecamatan Ambarawa Kabupaten Semarang," *Jurnal Akademika Biologi*, vol. 8, no. 1, pp. 19–23, 2019.

[5]S. P. Kharisma, A. R. Fauzan, I. Permitasari, and T. Nurseha, "Diversitas vegetasi riparian: Upaya pelestarian ekosistem perairan Danau Buatan Air Batu Banyuasin, Sumatera Selatan," *Journal of Biotropical Research and Nature Technology*, vol. 2, no. 2, pp. 85–92, 2024.

[6]FPDLT, "Permasalahan lingkungan Danau Laut Tawar dan upaya konservasi," *Musyawarah Besar Forum Penyelamat Danau Laut Tawar*, Takengon, Indonesia, Mar. 31, 2022.

[7]V. Balanzà, P. M. Donnelly, D. F. Voytas, and J. M. Martínez Zapater, "Inflorescence meristem fate is dependent on seed development and FRUITFULL in *Arabidopsis thaliana*," *Frontiers in Plant Science*, vol. 10, Art. no. 1622, 2019.

[8]R. Masdar and H. Karim, "Kajian kekerabatan tumbuhan Magnoliopsida berdasarkan karakteristik morfologi tipe pembungaan racemosa di sekitar kampus UNM Parangtambung," in *Proc. Semin. Nas. Biologi: Inovasi Sains dan Pembelajarannya*, vol. 11, no. 1, pp. 1–10, 2023.

[9]Y. Han, H. Yang, and Y. Jiao, "Regulation of inflorescence architecture by cytokinins," *Frontiers in Plant Science*, vol. 5, Art. no. 669, 2014.

[10]F. A. Putra *et al.*, "Habitat heterogeneity and floral diversity in highland ecosystems," *Jurnal Ilmu Kebumian*, vol. 17, no. 4, pp. 211–224, 2019.

[11]S. Rosyidatun, S. Hadi, and P. Lestari, "Peran vegetasi riparian dalam menjaga kualitas air dan keanekaragaman hayati di danau lokal," *Jurnal Kauniyah*, vol. 14, no. 2, pp. 87–99, 2021.

[12]T. Van Andel and R. C. G. Mesquita, "Seed dispersal and forest regeneration in tropical landscapes," *Global Ecology and Conservation*, vol. 8, pp. 1–12, 2016.

[13]A. S. Darmayanti, Waluyo, B. Ariffin, and E. Arisoesilaningsih, "Study on the phenology of three fruit tree species in Purwodadi Botanical Gardens, East Java, and its relationship with mesoclimates," *Jurnal Manajemen Hutan Tropika*, vol. 29, no. 1, p. 88, 2023.

[14]R. Partasasmita, A. Mardiastuti, D. D. Solihin, R. Widjajakusumah, and S. N. Prijono, "Frugivorous bird characteristic of seed disperser in shrubland tropical forest West Java, Indonesia," *Biodiversitas Journal of Biological Diversity*, vol. 18, no. 1, pp. 263–268, 2016.

[15]V. R. Puspa, Zumaidar, Nurdin, and Fitmawati, "Ornamental plant potential of Asteraceae from the Gayo Highlands, Bener Meriah Regency," in IOP Conference Series: Earth and Environmental Science, Institute of Physics, 2024. doi: 10.1088/1755-1315/1297/1/012089.

[16]Cole, L. J., Stockan, J., & Helliwell, R. (2020). Managing riparian buffer strips to optimise ecosystem services: A review. *Agriculture, Ecosystems & Environment, 296*, 106891. https://doi.org/10.1016/j.agee.2020.106891

[17]Hassan, T., Gulzar, R., Hamid, M., Ahmad, R., Waza, S. A., & Khuroo, A. A. (2023). Plant phenology shifts under climate warming: A systematic review of recent scientific literature. *Environmental Monitoring and Assessment, 196*, 36. https://doi.org/10.1007/s10661-023-12190-w

[18]HaGlaum, P., Wood, T. J., Morris, J. R., & Valdovinos, F. S. (2021). Phenology and flowering overlap drive specialisation in plant–pollinator networks. *Ecology Letters*. https://doi.org/10.1111/ele.13884

[19]de Manincor, N., Fisogni, A., & Rafferty, N. E. (2023). Warming of experimental plant–pollinator communities advances phenologies, alters traits, reduces interactions and depresses reproduction. *Ecology Letters, 26*(2), 323–334. https://doi.org/10.1111/ele.14158

[20]Michelot-Antalik, A., et al. (2025). Handbook of protocols for standardized measurements of floral traits for pollinators in temperate communities. *Methods in Ecology and Evolution, 16*(5), 988–1001. https://doi.org/10.1111/2041-210X.70031

[21]Bramon Mora, B., Shin, E., CaraDonna, P. J., & Stouffer, D. B. (2020). Untangling the seasonal dynamics of plant-pollinator communities. *Nature Communications, 11*, 4086. https://doi.org/10.1038/s41467-020-17894-y

[22]Camargo, P. H. S. A., Pizo, M. A., Brancalion, P. H. S., & Carlo, T. A. (2020). Fruit traits of pioneer trees structure seed dispersal across distances on tropical deforested landscapes: Implications for restoration. *Journal of Applied Ecology, 57*(12), 2329–2339. https://doi.org/10.1111/1365-2664.13697

[23]Darmayanti, A. S., Ariffin, Waluyo, B., & Ariesoesilaningsih, E. (2024). Variation of phenology of *Flacourtia rukam* in two different habitats and their relation to rainfall, dry days, and the plant water status. *Jurnal Manajemen Hutan Tropika, 30*(1), 118–129. https://doi.org/10.7226/jtfm.30.1.118

[24]Ssali, F. (2023). Seasonality in the equatorial tropics: Flower, fruit, and leaf phenology of montane trees in the highlands of Southwest Uganda. *Biotropica, 55*(3), 753–765. https://doi.org/10.1111/btp.13219

[25]Chen, Y., et al. (2020). Reproductive phenology and its drivers in a tropical rainforest national park in China: Implications for Hainan gibbon (*Nomascus hainanus*) conservation. *Global Ecology and Conservation, 24*, e01317. https://doi.org/10.1016/j.gecco.2020.e01317