Advances in biology through agronomy, aquaculture, coastal and environmental sciences

Leandris Argentel Martínez
Ofelda Peñuelas Rubio
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Prologue

Advances in biology through agronomy, aquaculture, coastal and environmental sciences is an electronic book, edited by Pantanal Editora, based on the compilation of research papers where the authors of the different chapters have used highly current scientific methodologies and research equipment.

The biological sciences as the main object of research in agriculture, aquaculture, coastal and environmental sciences generate every day an understanding of knowledge that allows raising the scientific level of society as part of universal access to knowledge.

This book mainly addresses issues related to the use of plants extracts as sustainable alternatives for biocontrol of pests and bacterial diseases. It also brings together information on viruses and other diseases in aquatic organisms. In addition, studies of mangroves structure and their contribution to carbon sinks in experimental sites in northwestern Mexico are presented. Finally, an analysis on educational strategies for environmental education based on plant biology is carried out.

Editors appreciate the participation of the authors who have come from higher education institutions and research centers of great scientific prestige in Mexico. The majority of them are members of the National Research System of CONACyT, Mexico.

The authors

Summary

Chapter 8

Structure and carbon stock in relation to the biomass of *Nymphaea elegans* and *Sagittaria longiloba* in three temporary lagoons in the arid northwest of Mexico

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ABSTRACT

There are relatively few published studies on the effects of flood frequency and timing on wetland plants, representing under-researched areas in linking water regime to plant growth response. In the present study, the structural development and carbon stock in relation to the biomass production of *N. elegans* and *S. longiloba* were recorded under arid subtropical environmental conditions in three temporary lagoons in northwest Mexico. By means of sampling the plants in the field and processing in the laboratory, physical-chemical measurements of surface water and sediment were performed. Among the main results, it was identified in the study area that *N. elegans* and *S. longiloba* maintain a life period of ~2.5 months related to the presence of surface water (Flood pattern) and moisture content in the soil, with maximum stocks of biomass carbon of 165.5 g/C/plant in *N. elegans* and 75.5 g/C/plant for *S. longiloba*. That is why it is recommended to restore and maintain the natural hydrological regime that feeds the studied lagoons with water and allows the development of *N. elegans* and *S. longiloba* in a higher density and life period according to seasonal rainfall, which allows maintaining the environmental services they provide to the ecosystem.

Keywords: macrophytes, wetland, climate change

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INTRODUCTION

The increase in greenhouse gas emissions and the associated impacts on global warming (IPCC, 2013) have led to an urgent need to identify and protect ecosystems with high carbon storage capacity (Canadell; Raupach, 2008), such as freshwater wetlands. Wetlands represent 3% of the world's soils but account for approximately 21% of the global soil organic carbon stock (Scharlemann et al., 2014). In addition, they offer many ecosystem services to humankind, including water quality improvement, flood mitigation, coastal protection and wildlife protection (Mitsch et al., 2009). Within these ecosystems, CO_2 from the atmosphere is taken up via photosynthesis, most of which is temporarily stored in the plant foliage, whereas the remainder is sequestered for a long period in biomass and soils (Ahalya; Park, 2018). Among the various methods to quantify carbon, the observation and field sampling approach is the best and most accurate, although it is costly and time-consuming, as continuous sampling data are required (Lu, 2006). Various studies also report pH, soil texture, temperature, rainfall pattern, and hydrology as factors responsible for retaining sequestered carbon in wetland soils (Perera; Amarasinghe, 2019). An important limitation is that wetland field research has mainly focused on study sites located in humid regions in temperate and tropical latitudes (Alongi et al., 2020), with few studies in arid regions (Adame et al., 2018) such as northwestern Mexico, where differences in rainfall, evapotranspiration, and soil conditions could influence carbon capture and storage (Schile et al., 2017).

There are relatively few published accounts concerning the effects of flood frequency and timing on wetland plants, representing under-researched areas in linking water regime to plant growth response (Kenow et al., 2018). In recent decades, interest in the study of the plants *Nymphaea elegans* Hook and *Sagittaria longiloba* Engelm has increased since both species typically grow in a great diversity of aquatic and marshy habitats and predominate in freshwater swamps and marshes with little runoff (Zepeda-Gómez; Lot, 2005). In addition, since lentic ecosystems are being reduced by anthropogenic activities (droughts and water channeling, among other causes) (Zepeda-Gómez; Lot, 2005), the natural habitat of aquatic plants *N. elegans* and *S. longiloba* is highly threatened, and they are considered highly fragile. In this context, the present project studies the structural development and carbon stock in relation to the biomass production of *N. elegans* and *S. longiloba* under arid subtropical environmental conditions in three temporary lagoons in northwestern Mexico. Derived from the conditions of the arid region and the study site as a temporary lagoon, the following hypotheses were structured: (*i*) the species under study (*N. elegans* and *S. longiloba*) will increase their biomass progressively in response to the flood pattern above ground level, (*ii*) they will complete their life cycle until fructification before the water level is lower than ground level, and likewise, (*iii*) the *N. elegans* plant will have the highest carbon stock due to its structure with higher biomass production in leaves and stems in relation to *S. longiloba*.

MATERIALS AND METHODS

Study site

The proposed lagoon system is administratively located in the state of Sonora, Mexico (Fig. 1). This system has the RAMSAR (2007) designation that includes the entire area of the coastal zone of high importance for the hibernation of migratory waterfowl and shorebirds, in addition to some bodies of fresh water that fulfill their function in connectivity with the coast. It is an area of reproduction, breeding, feeding and refuge for aquatic invertebrates and birds of national and international importance.

The regional climate is dry and semidry and very dry with very low levels of rainfall throughout the year (BW(h')hw - BS0(h')hw) (García; CONABIO, 1998), with an average annual temperature of 24°C and average annual rainfall of 270.4 mm. The month of August is the warmest (38.6°C), and the month of January is the coldest (7.8°C), while the rainy season occurs during the months of July and October, with August and September being the months rainiest with 69.1 mm and 66.6 mm, respectively (SMN, 2021).

Figure 1. Study sites in basin delimitation (site = lagoon).

Plant material

In three temporary freshwater lagoons (sites 1, 2 and 3), three field monitoring campaigns were carried out (separated by 20 days between each monitoring event) for the collection of samples (Sept 11, Oct 01, and Oct 21, 2021). The first monitoring was performed twenty days after the presence of flooding in the study lagoons. Twenty days after the third monitoring event, the flood pattern was below ground level.

Physicochemical of water and sediment

In each monitoring, salinity (PSU), redox potential (mV), temperature (°C) and pH were measured in surface water (first 20 cm) using a Hanna HI9828 multiparameter. In addition, three sediment samples were collected at each site (n=27) in the first 20 cm of soil (n=18) with a nucleator (0.0033 m^2) to determine the texture according to the Bouyucos method (Klute, 1986), pH by electrometry in 1:2 relation to water, and organic matter (OM) content by ignition according to Heiri et al. (2001). In addition, three sediment samples with known volume were collected in each sample unit (n= 27) to determine the apparent density and moisture content of the soil according to Moreno-Casasola and Warner (2009). The moisture content of the soil is the percentage of water that is capable of storing one gram of soil; if the value was 100%, it would mean that 1 g of soil stores 1 g of water (Infante, 2011).

Biomass estimation

In each monitoring, 3 plants of each species (*N. elegans* and *S. longiloba*) were taken in each lagoon by means of botanical presses to transfer them to the laboratory. Leaf length and width and stem length were measured; subsequently, they were dried in each of its morphological components (leaf, stems, roots, rhizome, flower, and fruit) in an oven at 65°C to obtain biomass in dry weight.

Carbon stock

Derived from the lack of allometric equations to estimate carbon from the biomass of *N. elegans* and *S. longiloba*, mean carbon concentrations in the litter have been reported to be 38-49% (Kauffman et al., 1995). A conversion factor of approximately 0.45 is recommended.

Carbon (g•C_{org}•plant) = (Biomass * conversion factor (0.45))/plant (Kauffman; Donato, 2012).

Statistical analysis

Data were analyzed using the Kolmogorov–Smirnov test and Levene's homogeneity of variances. Differences in physicochemical data sets of water, sediment, plant structure, and carbon stock were identified at the 5% level of significance using Tukey's one-way ANOVA (Steel; Torrie, 1996).

Physical and chemical properties of water and sediment

The pH values showed significant differences between the monitoring periods, in a range of 9.1 to 9.7. In relation to the temperature values, a maximum of 32±0.15°C was identified in the first monitoring. In addition, the salinity showed values of freshwater systems with a slight increase in monitoring 3 with 0.61±0.03 UPS, and the values of ORP recorded more reductive conditions in monitoring 3 with -181±1.3 mV (Table 1). The physical chemicals of the sediment showed low variation during the study period. The bulk density of the soil registered average values of 1.03±0.02 g cm^{-3}, while the content of organic matter presented an average value of 6.22±0.32%. In addition, the pH registered an average value of 6.7±0.04. The texture values in the sediment did not show significant differences, with higher clay contents from 49.9±5.4 to 54.3±1.3% (Table 2).

Table 1. Physical chemical of surface water in each monitoring.

	Monitoring 1	Monitoring 2	Monitoring 3	F	p
pH	9.3±0.06	9.1±0.03	9.7±0.01	16	0.01
Temp (°C)	32±0.15	31±0.16	22±0.13	8.5	0.09
Sal (PSU)	0.14±0.01	0.33±0.02	0.61±0.03	12.3	0.4
ORP (mV)	-140±3.7	-145±2.5	-181±1.3	22	0.06

PSU= practical salinity units, mV=millivolts, $p<0.05$

Table 2. Physical chemical in sediment in each monitoring.

		Monitoring 1	Monitoring 2	Monitoring 3	F	p
	BD (g/cm^3)	1.1±0.011	1.1±0.019	0.9±0.024	12	0.4
	OM (%)	6.7±0.5	6.2±0.3	5.8±0.2	1.8	0.6
	pH	6.7±0.02	6.9±0.08	6.6±0.02	9.9	0.1
Texture (%)	Sand	37.4±3.8	36.3±5.3	26.8±2.3	2.1	0.18
	Silt	12.5±1.6	13.8±1.1	18.9±1.5	5.9	0.06
	Clay	50.1±2.3	49.9±5.4	54.3±1.3	1.4	0.7

BD: Bulk density, OM: Organic matter

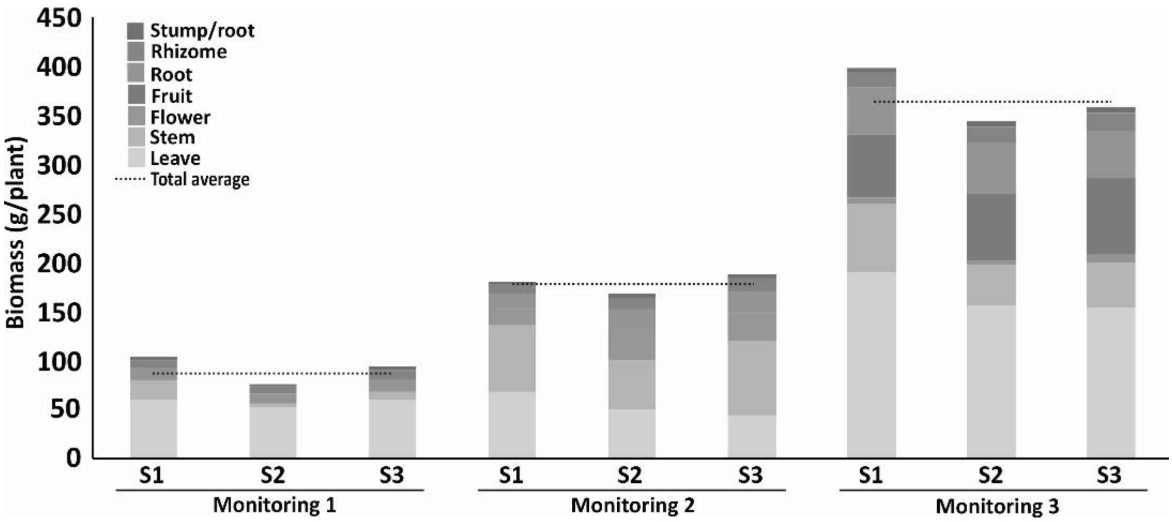

Figure 2. Biomass of the *N. elegans* plant by component (S=Site).

Biomass production

The structure of the N. elegans plant increased over time with a length of 12.7 cm and width of 13.5 cm on average in the first monitoring, up to 22.9 and 20.1 cm in the third monitoring with significant differences (N=381, F= 8.7, $p<0.05$ and N=381, F=9.9, $p<0.05$, respectively). The average length of the stem was 54.1 cm during the first monitoring up to a maximum of 85.2 cm during the third monitoring

(N=396, F=12.1, p<0.05). Biomass production in N. elegans temporarily showed a gradual increase, with 92 g/plant in the first monitoring, 179.8 g plant^{-1} in the second and 367.8 g-plan^{-1}t in the third. The component that contributed the most biomass was the leaf, with a maximum biomass of 168.1 g plant^{-1}. The plants presented low flowering from the first monitoring; however, the maximum occurred in the second monitoring with 25.2 g plant^{-1} of flowers in dry weight. In relation to the fruits, they only appeared in the third monitoring, with a maximum average of 71.3 g plant^{-1} (Fig. 2).

The structure of the *S. longiloba* plant increased over time with a length of 18.6 cm and width of 13.9 cm on average in the first monitoring, up to 26.1 and 18.5 cm in the third monitoring without significant differences (N=87, F= 9.6, p=0.4 and N=87, F=12.7, p=0.08, respectively). The average length of the stem registered at 38.7 cm during the first monitoring up to a maximum of 64.4 cm during the third monitoring (N=109, F=22, p=0.01). Biomass production in *S. longiloba* temporarily showed a gradual increase, with 8.19 g/plant in the first monitoring, 8.9 g/plant in the second and 33.2 g/plant in the third. The component that contributed the most biomass was the stems, with a maximum biomass of 21.2 g plant^{-1} on average. The plants showed low flowering from the first monitoring; however, the maximum occurred in the third monitoring with 0.72 g plant^{-1} of flowers in dry weight. In relation to the fruits, they only appeared in the third monitoring, with a maximum of 4.43 g plant^{-1} (Fig. 3).

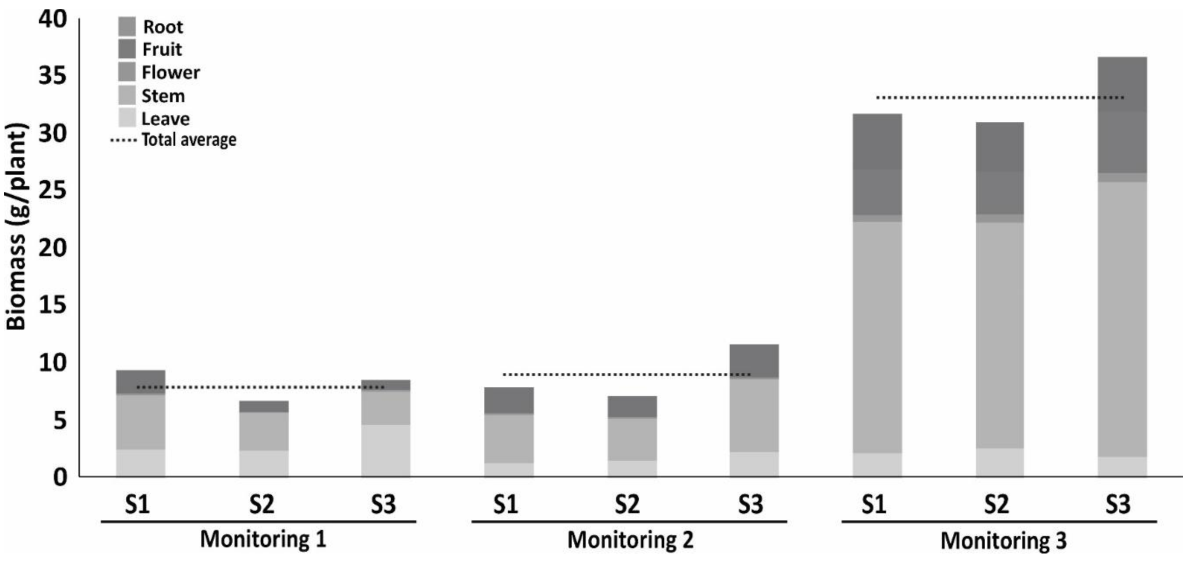

Figure 3. Biomass of the *S. longiloba* plant by component (S=site).

Carbon stock estimation

The carbon stock in relation to the biomass of the *N. elegans* plant registered maximum average values of 165.5 g/C/plant, where the leaf component had the highest concentration with 75.5 g/C/plant (Table 3 and Fig. 4). The carbon stock in relation to the biomass of the *S. longiloba* plant registered maximum average values of 14.9 g/C/plant, where the leaf component had the highest concentration with 9.55 g/C/plant (Table 4 and Fig. 4).

Table 3. Carbon stock (g) in the monitoring site of the *N. elegans* plant.

	Plant	Leave	Stem	Flower	Fruit	Root	Rhizome	Stump	Total
Monitoring 1	S1	27.8	8.2	0.9		5.2	3.3	1.6	46.9
	S2	23.5	1.9	0.8		4.2	3.7	1.0	35.0
	S3	27.5	3.9	1.0		4.4	4.1	1.4	42.3
Monitoring 2	S1	31.3	30.1	7.1		7.2	4.8	1.2	81.6
	S2	22.7	22.8	14.3		9.4	5.5	1.5	76.1
	S3	20.6	33.9	12.8		9.8	6.4	1.5	85.0
Monitoring 3	S1	85.8	31.7	2.8	28.9	21.3	7.3	2.1	179.9
	S2	70.6	18.7	1.8	30.9	23.7	7.3	2.2	155.3
	S3	70.0	20.5	3.4	34.9	22.0	8.1	2.4	161.4

S=site; Values presented in grams.

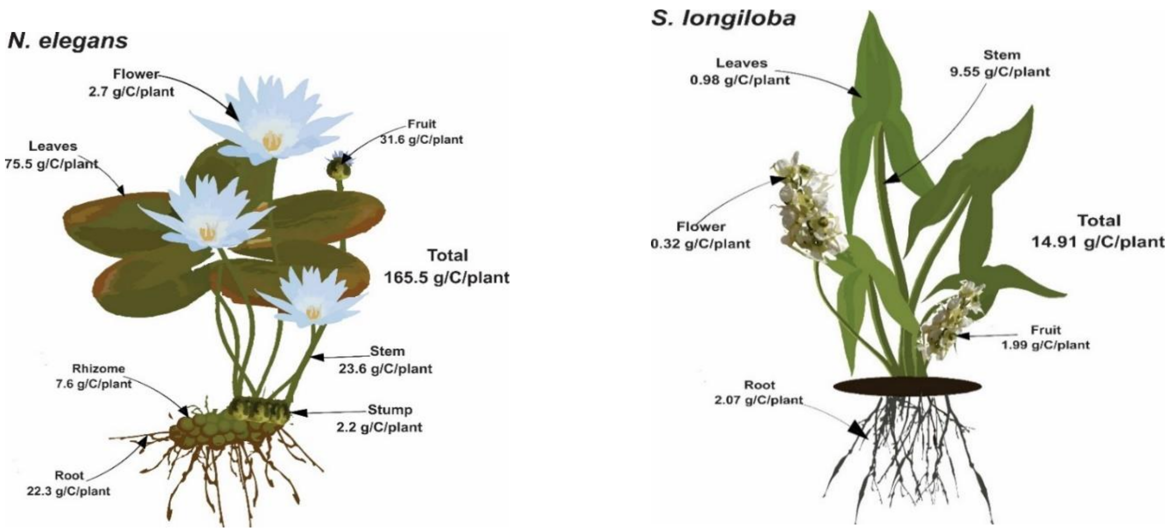

Figure 4. Carbon stock in relation to biomass by morphological component of *N. elegans* and *S. longiloba.*

Table 4. Carbon stock (g) in the monitoring site of the *S. longiloba* plant.

Monitoring	Plant	Leave	Stem	Flower	Fruit	Root	Total
Monitory 1	S1	1.10	2.12	0.10		0.90	4.22
	S2	1.03	1.49	0.08		0.40	3.01
	S3	2.08	1.26	0.12		0.37	3.83
Monitory 2	S1	0.57	1.87	0.10		1.03	3.58
	S2	0.67	1.64	0.08		0.82	3.20
	S3	0.98	2.87	0.08		1.31	5.23
Monitory 3	S1	0.97	9.06	0.26	1.80	2.18	14.27
	S2	1.15	8.82	0.37	1.69	1.93	13.96
	S3	0.81	10.77	0.33	2.50	2.09	16.49

S=site; Values presented in grams.

DISCUSSION

There are few published studies on the effects of aboveground flood pattern frequency and duration on wetland plants, representing underinvestigated areas, particularly the water regime with plant growth response (Webb et al., 2012). Hypothesis (i) that *N. elegans* and *S. longiloba* increase their biomass progressively in response to the flood pattern above ground level is confirmed, completing maturity, flowering and fructification (~2.5 months) earlier than the flood pattern decreases below ground level and the environmental temperature dries out the soil, which is why it is recommended to restore and maintain the natural hydrological regime that feeds the studied lagoons with water and allows the development of *N. elegans* and *S. longiloba* in higher density and life period according to the seasonal rainfall.

The two species under study (hypothesis ii) completed their life cycle to fructification before the water level decreased below ground level, although *N. elegans* requires flood levels above ground level to survive, *S. Longiloba* develops in environments with a low flood pattern but without desiccation, as recorded by Keddy and Ellis (1985) with the early establishment of *S. latifolia* seedlings along a water level gradient ranging from 10 cm above to 5 cm below the substrate surface, also Kenow and Lyon (2009) observed that *Sagittaria* species germinated and flowered when grown in substrates of moist, shallow (2–3 cm) and submerged (15 cm), but not on substrates that were allowed to dry.

Although the *Sagittaria* genus is considered a noxious weed in the Asian continent (Ozaki et al., 2018), since the plant has a broad ecological range in which it is able to survive and dominate (Ndlovu, 2020), for arid regions, its distribution decreases due to high temperature and low rainfall conditions, such as the study area of the present investigation with ~300 mm of rainfall per year with a life cycle duration of *N. elegans* and *S. longiloba* of ~ 2.5 months related to the duration of the flood pattern above ground (N. elegans) and the presence of moisture in the soil (*S. longiloba*).

In terms of promoting favorable conditions for the natural establishment of *Nymphaea* and *Sagittaria* in arid zone conditions, this work together with other studies (Keddy; Ellis, 1985; Marburger, 1993; Kenow; Lyon, 2009; Kenow et al., 2018) corroborates the importance of maintaining natural hydrological regimes that allow flood levels and substrates with a relatively high moisture content that allow the survival of these aquatic species that can have ecological benefits since they are plants pollinated by bees, hoverflies and other insects (Ozaki et al., 2018; Tanaka, 1985; Huang et al., 2006). The underground tissues of *N. elegans* and *S. longiloba* (roots, tubers and rhizomes) improve the permeability of the medium (Todunovics et al., 2005; Licata et al., 2019) and diffuse ions to drive microbial processes (Alufasi et al., 2017; Wang et al., 2018), fix and store carbon in wetland soils through roots (Qadiri et al., 2021), and serve as food for local herbivores.

The established hypothesis that mentions (iii) the *N. elegans* plant with the highest carbon stock is confirmed, since the biomass carbon contents were 14.5 times higher in the *N. elegans* plant than in *S. longiloba*. Carbon sequestration is one of the most important ecosystem services provided by wetlands, and it occurs in wetlands at a greater rate than in any other ecosystem on the planet (Mitsch; Gosselink, 2015). To provide an accurate estimate of the carbon storage and sequestration rates of wetlands, carbon sequestration and emissions from different wetland types should be thoroughly evaluated (Bernal; Mitsch, 2012; Craft et al., 2018); furthermore, it is an important factor in wetland restoration for mitigating global warming (Yeong et al., 2022).

The hydrology of the area is fundamentally influenced by the rainy season between July and September. However, it is important to mention that the river drainage system for these temporary lagoons is conditioned by the highway. In turn, the growth of the species of *N. elegans* and *S. longiloba* can be impacted by these anthropic aspects in addition to the adverse effects associated with climate variability and change in the area (e.g., prolonged drought events).

CONCLUSIONS

In the present study, it was recorded in a region of arid zones (Northwest Mexico) that the species of *N. elegans* and *S. longiloba* maintain a life span of ~2.5 months related to the presence of flooding (Flood pattern) and contents of soil moisture, with maximum biomass carbon stocks of 165.5 g/C/plant for *N. elegans* and 75.5 g/C/plant for *S. longiloba*. For this reason, it is important to determine the stock and stores of carbon as “baseline” information to know the potential of the ecosystems that they must capture and fix it in parts of the plant (biomass) and the soil, in this way justifying the conservation and restoration of this type of ecosystem that contributes to the mitigation of climate change. In addition, further research on carbon stores in dryland wetlands is recommended. Given the present limits on our ability to optimize wetland creation and restoration for specific carbon and greenhouse gas emission goals, it is wise to prioritize the conservation of existing wetland carbon stocks over restoration and management.

Unfortunately, for both species, the ecological factors that determine the growth and development of these plants in Mexican environments have not yet been sufficiently addressed, and management and conservation programs are required to rescue and simultaneously promote their biological importance among the population, cultural and economic characteristics of these plants.

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REFERENCES

Adame, M. F., Birdsey, R., Herrera-Silveira, J. (2018). Blue Carbon Opportunities for Mangroves of Mexico In: Windham-Myers, L., S. Crooks, and T. G. Troxler (eds.). A Blue Carbon Primer: The State of Coastal Wetland Carbon Science, Practice, and Policy (1st ed.). CRC Press. https://doi.org/10.1201/9780429435362

Ahalya, A., Park, J. S. (2018). Blue Carbon Stock of Mangrove Ecosystems. International Journal of Science and Research (IJSR) 8(12): 1371 – 1375.

Alongi, D. M. (2020). Global Significance of Mangrove Blue Carbon in Climate Change Mitigation. Sci 2(3): 67. https://doi.org/10.3390/sci2030067

Alufasi, R., Gere, J., Chakauya, E., Lebea, P., Parawira, W., Chingwaru, W. (2017). Mech- anisms of pathogen removal by macrophytes in constructed wetlands. Environ. Tech- nol. Rev. 6(1): 135–144.

Bernal, B., Mitsch, W. J. (2012). Comparing carbon sequestration in temperate freshwater wetland communities. Glob. Change Biol. 18(5): 1636–1647.

Canadell, J. G., Raupach, M. R. (2008). Managing Forests for Climate Change Mitigation. Science 320: 1456-1457. https://doi.org/10.1126/science.1155458

Craft, C., Vymazal, J., LenkaKröpfelová, L. (2018). Carbon sequestration and nutrient accumulation in floodplain and depressional wetlands. Ecological Engineering 114: 137–145.

García, E., CONABIO (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad). (1998). Catálogo de metadatos geográficos. http://geoportal.conabio.gob.mx/metadatos/doc/html/clima1mgw.html (Consulted Julio 2022).

Heiri, O., Lotter, A. F., Lemcke, G. (2001). Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. Journal of Paleolimnology 25(1): 101–110. https://doi.org/10.1023/A:1008119611481

Huang S. Q., Tang, L. L., Sun, J. F., Lu, Y. (2006). Pollinator response to female and male floral display in a monoecious species and its implications for the evolution of floral dimorphism. New Phytol. 171: 417–424.

Infante, M. D. (2011). Estructura y dinámica de las selvas inundables de la planicie costera central del Golfo de México. Doctoral thesis. Jalapa, Veracruz, Instituto Nacional de Ecología A. C.

IPCC (2013). Climate change 2013: the physical science basis. In: Stocker, T.F., D: Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley. (eds.). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press Cambridge, United Kingdom and New York, NY, USA 1535 pp.

Kauffman, J. B., Cummings, D. L., Ward, D. E., Babbitt, R. (1995). Fire in the Brazilian Amazon: 1. Biomass, nutrient pools, and losses in slashed primary forests. Oecologia 104: 397-408. https://doi.org/10.1007/BF00341336

Keddy, P. A., Ellis, T. H. (1985). Seedling recruitment of 11 wetland plant species along a water level gradient: Shared or distinct responses? Canadian Journal of Botany 63: 1876–1879. https://doi.org/10.1139/b85-263

Kenow, K. P., Lyon, J. E. (2009). Composition of the seed bank in drawdown areas of navigation pool 8 of the Upper Mississippi River. River Research and Applications 25: 194–207. https://doi.org/10.1002/rra.1118

Kenow, K. P., Gray, B. R., Lyon, J. E. (2018). Flooding tolerance of *Sagittaria latifolia* and *Sagittaria rigida* under controlled laboratory conditions. River Res Applic. 34: 1024–1031. https://doi.org/10.1002/rra.3337

Klute, A. (1986). Methods of soils analysis. Part 1. Physical and mineralogical methods (2nd ed.). Madison, Wisconsin, EUA, pp. 1188.

Licata, M., Gennaro, M. C., Tuttolomondo, T., Leto, C., La Bella S. (2019). Research focusing on plant performance in constructed wetlands and agronomic application of treated wastewater–A set of experimental studies in Sicily (Italy). PLoS ONE 14(7): e0219445.

Lu, D. (2006). The potential and challenge of remote sensing–based biomass estimation. Int J Remote Sens 27(7):1297–1328.

Marburger, J. E. (1993). Biology and management of Sagittaria latifolia Willd. (broad-leaf arrow-head) for wetland restoration and creation. Restoration Ecology, 1: 248–255. doi: https://doi.org/10.1111/j.1526-100X.1993.tb00034.x

Mitsch, W. J., Gosselink. J. G. (2015). Wetlands. John Wiley, Sons, New Jersey.

Mitsch, W. J., Gosselink, J. G., Zhang, L., Anderson, C. J. 2009. Wetland Ecosystems. John Wiley, Sons.

Moreno-Casasola, P., Warner, B. (2009). Breviario para describir, observar y manejar humedales. México: RAMSAR Instituto de Ecología A.C., CONANP, US Fish and Wildlife Service US State Department. Available online: http://www1.inecol.edu.mx/inecol/libros/Breviario_Humedales.pdf (Accessed on June 2022

Ndlovu, M.S., Coetzee, J. A., Nxumalo, M. M., Lalla, R., Shabalala, N., Martin, G. D. (2020). The Establishment and Rapid Spread of *Sagittaria Platyphylla* in South Africa. Water 12(5): 1472. https://doi.org/10.3390/w12051472

Ozaki, Y., Shimono, Y., Tominaga, T. (2018). Germination characteristics of *Sagittaria trifolia*. Weed Biol. Manag., 18: 160-166. https://doi.org/10.1111/wbm.12162

Perera, K. A., Amarasinghe, M. D. (2019). Carbon sequestration capacity of mangrove soils in micro tidal estuaries and lagoons: A case study from Sri Lanka. Geoderma, 347: 80–89. https://doi.org/10.1016/j.geoderma.2019.03.041

Qadiri, R. Z. Z., Gani, K. M., Zaid, A., Aalam, T., Kazmi, A. A., Khalil, N. (2021). Comparative evaluation of macrophytes in constructed wetlands for the treatment of combined wastewater (graywater and septic tank effluent) in a subtropical region. Environ. Challenges 5: 100265

RAMSAR (2007). Ficha informativa de los humedales de Ramsar, Complejo Lagunar Bahía Guásimas – Estero Lobos. https://rsis.ramsar.org/RISapp/files/RISrep/MX1790RIS.pdf (Consulted Julio 2022).

Scharlemann, J. P., Tanner, E. V., Hiederer, R., Kapos, V. (2014). Global soil carbón: Understanding and managing the largest terrestrial carbon pool. Carbon management, 5(1): 81-97.

Schile, L. M., Kauffman, J. B., Crooks, S., Fourqurean, J. W., Glavan, J., Megonigal, J. P. (2017). Limits on carbon sequestration in arid blue carbon ecosystems. Ecol Appl, 27: 859-874. https://doi.org/10.1002/eap.1489

SMN Servicio Meteorológico Nacional. (2021). Climograma [1981-2010]: Estación Guaymas 4-P-6, Sonora (27.55, -110.5). Clave 26292. https://smn.conagua.gob.mx/es/climatologia/informacion-climatologica/climogramas-1981-2010 (Consulted Julio 2022).

Steel, A., Torrie, M. (1996). Bioestadística: Principios y procedimientos. México D. F. México: Edit. McGrawHill.

Tanaka, H. (1985). Insect pollination of Sagittaria trifolia L. International Journal of Weed Science and Technology 30: 155–156.

Todorovics, C., Garay, T. M., Bratek, Z. (2005). The use of the reed (*Phragmites australis*) in wastewater treatment on constructed wetlands. Acta Biologica Szegediensis 49 (1–2): 81–83.

Wang, Q., Hu, Y., Xie, H., Yang, Z. (2018). Constructed wetlands: a review on the role of radial oxygen loss in the rhizosphere by macrophytes. Water (Basel) 10(6): 67.

Webb, J. A., Wallis, E. M., Stewardson, M. J. (2012). A systematic review of published evidence linking wetland plants to water regime components. Aquatic Botany 103: 1–14. https://doi.org/10.1016/j.aquabot.2012.06.003

Yeong, H. Y., Kim, S. H., Kim, J. G. (2022). Carbon sequestration potential in Montane wetlands of Korea. Global ecology and conservation 37: 02166. doi: 10.1016/j.gecco.2022.e02166

Zepeda-Gómez, C., Lot, A. (2005). Distribución y uso tradicional de *Sagittaria macrophylla* Zucc. y S. latifolia Willd. en el Estado de México. Ciencia Ergo. Sum. 12(3): 282-290.

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