Allometric relations for *Typha domingensis* natural populations

Relações alométricas de populações naturais de *Typha domingensis*

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Abstract: Allometric determinations are usually utilized to examine populations on field. This technique is highly recommended for plants that perform vegetative reproduction within wetlands, such as *Typha domingensis* Pers. This study evaluates several *T. domingensis* allometric relations. Morphologic characteristics such as leaf area, weight, leaf water content and nitrogen present relevant positive relation with an increase of leaf length. However, these relations with carbon concentration were not significant ($p > 0.8$), since carbon content maintain relatively stable values along ontogenic development. Random samples showed that 73% of *T. domingensis* leaves from Norte Fluminense present leaf length between 50 and 250 cm. Allometric relations were utilized in order to check isometry, which indicates morphologic characteristics relations concerning size. However, most variables not presented isometry in *T. domingensis* leaves. This study also indicates how development of forecast models of aerial plant biomass obtained from allometric variables may turn process evaluation, such as primary production, faster and not so laborious with non-destructive measuring, easily obtained on field.

Keywords: aquatic macrophyte, *Typha domingensis*, allometric analysis, biomass.

Resumo: Determinações alométricas são comumente utilizadas para examinar as populações no campo. Esta técnica muito bem recomendada para plantas que realizam reprodução vegetativa, como *Typha domingensis* Pers., em áreas alagáveis. Nesta pesquisa foram avaliadas várias relações alométricas de *T. domingensis*. As características morfológicas entre área foliar, peso fresco, seco, teor de água e nitrogênio apresentaram relação significativa positiva com o aumento do comprimento foliar. Entretanto, estas relações com as concentrações de carbono não foram significativas ($p > 0{,}8$), já que os valores desta variável se mantêm relativamente estáveis ao longo do desenvolvimento ontogenético. Coletas aleatórias mostraram que 73% das folhas de *T. domingensis* da região Norte Fluminense encontram-se entre 50 a 250 cm de comprimento foliar. As relações alométricas foram utilizadas para verificar a isometria, que indica relações das características morfológicas com o tamanho. Entretanto, a maioria das variáveis não apresentou isometria nas folhas de *T. domingensis*. Este estudo também evidencia como o desenvolvimento de modelos de previsão de biomassa vegetal aérea obtida a partir de variáveis alométricas pode tornar a avaliação de processos como, produção primária muito rápida e menos laboriosa a partir de medições não-destrutivas que são facilmente obtidas no campo.

Palavras-chave: macrófita aquática, *Typha domingensis*, análise alométrica, biomassa.

1. Introduction

Typha is often found close to water, in lakes, lagoons and riverine areas of several regions of the world, America, Europe and Asia (Mitch, 2000). This genus includes about eleven species that may tolerate fluctuations in water level, reduced conditions in soil and moderate salinity. Depending on nutrients availability, *Typha* individuals may be aggressive invaders in flooded areas of fresh and brackish waters (Miao et al., 2000; Miao, 2004).

These plants show relevant structural and metabolic importance in lentic ecosystems (Neue et al., 1997). It also stands out for its capacity to provide substratum to periphytic and bacterial communities, as well as shelter for insects and fish egg laying. Besides, such organisms have demonstrated enormous energy and nutrient storage capacity (Daoust and Childers, 1998), and they may be widely used in minimizing current issues, such as carbon sequestration and phytoremediation of domestic and industrial sewage, when properly managed.

In Brazil, *Typha domingensis* Pers. is well distributed and abundant in flooded areas. It may be found in almost all aquatic systems of Norte Fluminense region, where lagoons and wetlands are common. It is a rhizomatous perennial aquatic macrophyte, capable of forming monospecific meadrows (Miao, 2004). Flexibility for self fecundation of this plant is considerably high; however, gathering young individuals by means of clonal expansion is more effective, limited only by environmental conditions (Miao, 2004). Increase of this species meadrow depends on rhizomes expansion in sediment and aerial growth of new ramets. Balance between mortality and gathering causes population to decline or to expand (Kuehn et al., 1999).

Within such wetlands and lagoons areas high rates of carbon storage are found, resulting from important conditions like constant water availability, low decompositions rates due to frequent anaerobiosis in sediment and increased primary production (Wetzel, 2001). Carbon incorporation in plant biomass may be expressive in the littoral zone of aquatic environments, especially in sites where plant mortality is high, resulting in a more frequent return to initial successional stages with higher productivity (Neue et al., 1997). Temperature low decrease during winter, differently that it occurs in temperate areas, may favor carbon incorporation by aquatic macrophytes during all year round in tropical wetlands (Neue et al., 1997).

Allometric comparisons are utilized to relate growth of different parts of an organism due to its metabolic performance (Enquist and Niklas, 2002). Such approach is utilized to search for modifications in biomass allocation due to environmental changes, such as: fire, hydrological changes and stress due to ions excess (Barrett-Lennard et al., 2003; Demirezen and Aksoy, 2004; Watt et al., 2006). Macrophytes present strategies to translocate resources between aerial and underground parts, and such relations vary depending on the ontogeny and phenotypical plasticity of organisms (McConnaughay and Coleman, 1999). Utilization of allometric determinations may be very useful in changing environments. Besides, relations between different morphologic characteristics and macrophytes size may be applied for a population of plants that perform clonal expansion and with different individual stages (Kuehn et al., 1999).

Allometric data such as, length, area and leaf biomass are essential parameters for evaluating aspects, such as: reproduction, nutritional requirements, effects of several stresses and primary production. The last aspect has been recognized, for some time now, as main role in carbon cycle and energy flow between systems (Dickerman et al., 1986; Robertson et al., 2001). Methods have been developed in order to calculate aerial primary production based on leaf length or biomass, for a period of time (Edwards and Mills, 2005; Darby and Turner, 2008). Many computational methods have been devised to evaluate primary production based on some measurement of changes in standing live and dead biomass over a year. Of these several methods, those presented by Smalley (1959), Wiegert and Evans (1964), Milner and Hughes (1968) and Valiela et al. (1975) are mainly employed in coastal, estuarine and wetland systems.

The advantages of non destructive or partially destructive methods consist in frequent follow up of leaf length and expansion of the same plant until the end of cycle or experiment, which makes it possible to note issues of spatial heterogeneity, estimate mortality more precisely. Non destructive techniques tend to be very laborious, being usually applied with few samples and simplified census. Utilization of dimensional variables may create equations among leaf length and other linear dimensional parameters of leaves.

The present work aims to investigate relations among morphologic characteristics such as, biomass and size in populations of *T. domingensis*. Another evaluated aspect was the possibility to utilize leaf length as principal variable in order to determine a relation or equation proper to variables, weight, water content, leaf area, carbon, nitrogen and C:N ratios from *T. domingensis*.

2. Material and Methods

T. domingensis leaves were sampled (963 leaves), collected from two lagoons found at north of Rio de Janeiro state, Açu and Campelo. All leaves utilized in this study did not present visible deformations proceeding from external factors, such as diseases and herbivory. Two excursions were performed on field in July, 2006, one in each lagoon. In the littoral zone of each lagoon, *T. domingensis* leaves were sampled with a cut right above sediment and organized in classes of 20 to 300 cm length, in 10 cm intervals. In lab, material was washed under running water to remove any inorganic or organic material adhered. After measure leaf area (3100 Area Meter Li-Cor) and fresh weight (FW), material were conditioned in paper bags. Dry weight (DW) was determined after desiccation at 80 °C for 72 hours. Leaf water content (WC, $mL.g^{-1}$ DW) was estimated using the Equation 1:

$$WC = (FW - DW) / DW \tag{1}$$

Specific leaf weight (SLW; $g.cm^{-2}$) for leaves was calculated dividing dry weight by leaf area. Posteriorly, leaves were crushed and stored in recipients hermetically closed. Seventy eight leaves were separated for determining C and N using elemental analyser Perkin Elmer 2400 (CHNS/O).

Leaf length allometric relations and other morphologic traits were transformed in log (base 10) so to attend normality and linear regressions were obtained. Leaf length (x) and other morphological characteristics (y) were then incorporated in the typical allometric Equation 2:

$$y = \alpha x^{\beta} \quad (2)$$

where the allometric coefficient, α is the intercept and the allometric exponent, β is the slope. Allometric relations were considered isometric when increase was equally proportional for relative rates to dimensional exponents utilized in each comparison. If the comparison specific slope needed for isometry fell within the 95% confidence intervals of the allometric exponents (slopes), the association was considered isometric. Significance level adopted for statistics tests in this study was 0.05.

3. Results

Nine hundred, sixty three *T. domingensis* leaves were sampled and medium, minimum and maximum values of variables obtained in this study are shown in Table 1. Allometric relations depending on *T. domingensis* leaves size are presented in Figure 1. Results of the regression performed, relating different morphologic characteristics, such as leaf length, weight and leaf areas, are represented in Table 2. Values contained in this table allow to estimate weight, leaf area, carbon content, nitrogen and ratios of these elements to *T. domingensis.*

Carbon content ranged between 367 to 449 mg $DW.g^{-1}$. Leaves showed little variation between different lengths, presenting coefficient of variation of 55.14% (Figure 2). But, carbon content tended to increasing values with length.

Total nitrogen concentrations in different *T. domingensis* leaves varied between 6 and 28 mg $DW.g^{-1}$, when it was also noted decline of lower leaf lengths to higher ones (Figure 2). Due to decrease in total nitrogen concentration and steadiness in carbon contents, C:N ratios presented increase with length.

All parameters to elaborate equations in order to estimate *T. domingensis* morphologic characteristics were log-transformed so to improve data normal distribution. Allometric information obtained involving leaf length presented a coefficient of determination above 0.9 for fresh weight, dry and leaf area, indicating that variations noted in these variables were justified due to leaf length and so, they were used for creating some equations (Tables 2 and 3).

Table 1. Minimum, maximum, mean values, standard deviations and coefficients of variation (CV %) of 963 *T. domingensis* leaves obtained from Norte Fluminense lagoons.

Characteristics	Minimum	Maximum	Mean	S.D.	C.V. (%)
Leaf length (cm)	20	339	147.8	81.5	55.14
Fresh weight (g)	0.7	137.7	29.5	27.2	92.20
Dry weight (g)	0.1	21.1	4.4	3.6	81.82
Water content ($mL.g^{-1}DW$)	2.77	18.83	7.45	2.61	35.03
Leaf area (cm^2)	8.5	1045.6	261.9	215.1	82.13
C ($mg.g^{-1}$ DW)	367.4	449.3	401.83	14.44	3.59
N ($mg.g^{-1}$ DW)	5.9	28.2	16.75	5.61	33.49
C (g)	0.03	7.69	1.28	1.86	145.31
N (g)	0.002	0.17	0.03	0.04	133.33
C:N ratio	15.63	80.6	32.47	14.87	45.80

Table 2. Log versus log (base 10) leaf-level allometric relations for T. domingensis leaves and related statistics. S.E. is standard error of α and β. The 95% confidence intervals is of β.

Allometric comparison	α	S.E (α)	β	S.E (β)	R^2	p	Isometry	95% confidence intervals
Length versus fresh weight	–2.4	0.025	1.7	0.012	0.96	<0.0001	0.58	1.7 to 1.8
Length versus leaf area	–1.0	0.023	1.5	0.011	0.95	<0.0001	0.65	1.5 to 1.6
Length versus dry weight	–4.0	0.026	2.1	0.013	0.97	<0.0001	0.49	2.0 to 2.1
Length versus water content	1.6	0.024	–0.36	0.011	0.52	<0.0001	–2.76	–0.3847 to –0.3406
Length versus SLW	–3.0	0.026	0.51	0.012	0.63	<0.0001	2.0	0.48 to 0.53
Fresh weight versus leaf area	1.1	0.0071	0.88	0.0054	0.97	<0.0001	1.1	0.87 to 0.89
Dry weight versus leaf area	2.0	0.0036	0.74	0.0052	0.96	<0.0001	1.4	0.73 to 0.75
Dry weight versus SLW	–2.0	0.0036	0.26	0.0052	0.72	<0.0001	3.8	0.25 to 0.27
Length versus C ($mg.g^{-1}DW$)	2.6	0.0079	–0.00058	0.004	0.00028	0.8843	–1700	–0.0086 - 0.0074
Length versus N ($mg.g^{-1}DW$)	2.1	0.074	–0.44	0.031	0.73	<0.0001	–2.3	–0.50 - –0.38
Length versus C:N	0.57	0.089	0.47	0.032	0.74	<0.0001	2.1	0.40 to 0.53
Length versus C (g)	–4.1	0.06	2.00	0.037	0.97	<0.0001	0.51	1.9 to 2.0
Length versus N (g)	–4.6	0.063	1.5	0.045	0.93	<0.0001	0.67	1.4 to 1.6
C (mg g^{-1}DW) versus N (mg g^{-1}DW)	1.3	4.4	–0.026	1.7	0.0000031	0.9878	–39	–3.4 to 3.4
C (g) versus N (g)	–1.5	0.012	0.76	0.017	0.96	<0.0001	1.3	0.73 to 0.79

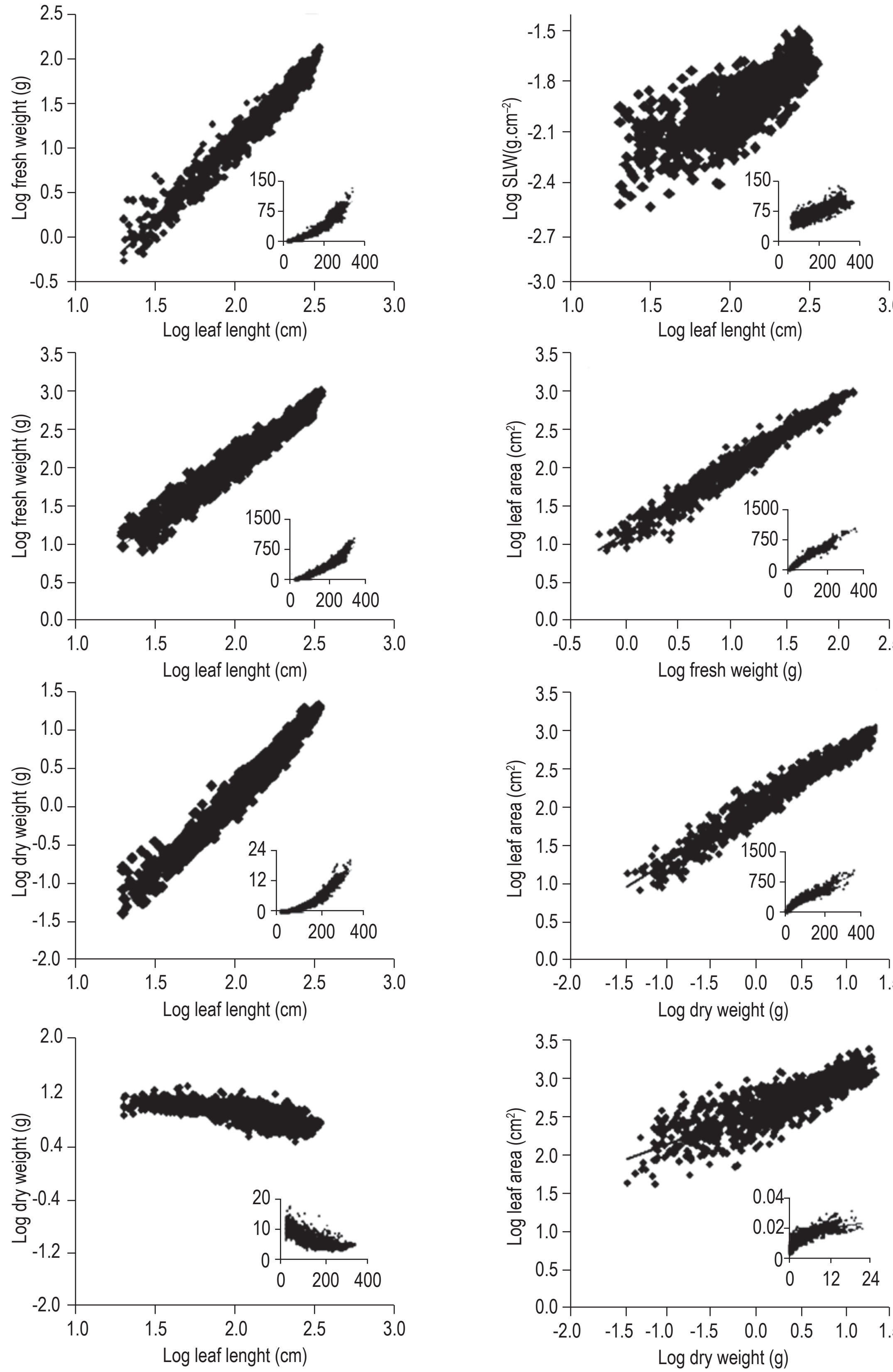

Figure 1. Log–log (base 10) plot of *T. domingensis* relationships between a) leaf length and leaf fresh weight; b) leaf length and leaf area; c) leaf length and leaf dry weight; d) leaf length and leaf water content; e) leaf length and SLW; f) leaf fresh weight and leaf area; g) leaf dry weight and leaf area; h) leaf dry weight and SLW. Solid line is the regression for *T. domingensis*. Inserted plots show un-transformed data.

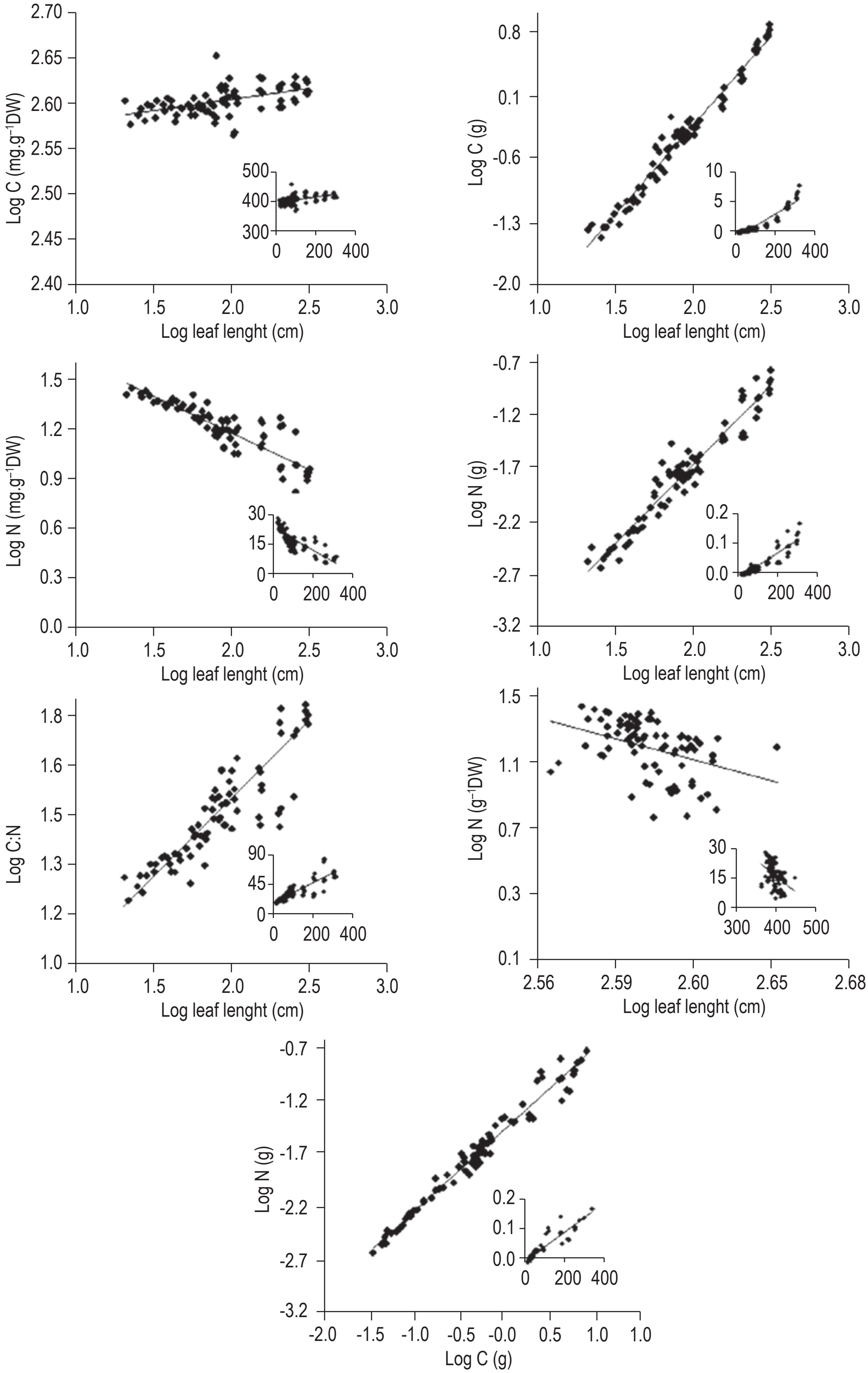

Figure 2. Log–log (base 10) plot of *T. domingensis* relationships between a) leaf length and C (mg.g^{-1}DW); b) leaf length and N (mg.g^{-1}DW); c) leaf length and total quantity of C by leaf (g); d) leaf length and total quantity of N by leaf (g); e) leaf length and C:N ratio; f) C (mg.g^{-1}DW) and N (mg.g^{-1}DW); g) total quantity of C by leaf (g) and total quantity of N by leaf (g). Solid line is the regression for *T. domingensis*. Inserted plots show un-transformed data.

Table 3. The regression equations estimated for *T. domingensis*, using the leaf length, fresh weight, dry weight and total quantity of carbon in leaves. These variables showed $R^2 > 0.9$.

Allometric comparison	Equation
Leaf length versus fresh weight	log(FW) = log (–2,4) + 1,7 log (length)
Leaf length versus leaf area	log(LA) = log (–1,0) + 1,5 log (length)
Leaf length versus dry weight	log(DW) = log (–4,0) + 2,1 log (length)
Fresh weight versus leaf area	log(LA) = log (1,1) + 0,88 log (FW)
Dry weight versus leaf area	log(LA) = log (2,0) + 0,74 log (DW)
Leaf length versus C (g)	log(C) = log (–4,1) + 2,0 log (length)
Leaf length versus N (g)	log(N) = log (–4,6) + 1,5 log (length)
C (g) versus N (g)	log(N) = log (–1,5) + 0,76 log (C)

Remaining coefficients of determination were above 0.7. Relations with carbon concentration were an exception, since correlations were insignificant and presented a $R^2 < 0.001$.

4. Discussion

Resource allocation in plants is an issue widely discussed in contemporary ecology, indicating their different survival strategies. This process is important to check nutritional need of plant structures in different stages of life cycle (Wright and McConnaughay, 2002). Allocation is better comprehended in terms of growth and size of plant due to its life time period (Ryan et al., 1997). Allometric evaluations are determinate depending on size, which allows quantification between growth and resources allocation due to numerous environmental pressures, which interferes in plants populations' development (Bonser and Aarssen, 2001). However, some allocation patterns were relatively stable, present little variation among different environments (Bianco et al., 2003; Sultan, 2004).

Allometric relations herein presented were originated from individual macrophytes of different sizes sampled from field population from two lagoons and, therefore, does not follow ontogenetic development of macrophytes with high clonal expansion (McConnaughay and Coleman, 1999; Wright and McConnaughay, 2002). This fact usually generates data variance. Nonetheless, relations found in this research were significant and allometric patterns were evident. However, leaf length would not be connected only to its chronology, but to environmental effects, such as temperature, disturbs or resources availability (Miao et al., 2000; Salter et al., 2007).

Considering field data as leaf length, fresh weight, dry, water content and leaf area, it was possible to develop predictive mathematical models (Table 3). These models may contribute to better understand of aquatic macrophytes population dynamics showed possibly helps understanding different development stages. Morphologic characteristics of *Typha* were consistent when opposing to isometry, being similar to results obtained by Miao et al. (2008). Some characteristics, such as leaf area of *T. domingensis* were similar when compared with other studies (Bianco et al., 2003; Miao et al., 2008).

Significant relation between *T. domingensis* weight and leaf length in lagoons from Norte Fluminense may facilitate, in measure of aerial primary production of these emergent aquatic macrophytes. Considering leaf length measure direct from the field and a defined sampling area, it is possible to estimate primary production.

Models that relate leaf length and nutrients content, make possible to estimate energy used and lost by the leaves and, to evaluate their production and resources translocation. Variations on the carbon and nitrogen contents were similar as the ones found in other studies with *T. domingensis* (Ennabili et al., 1998; Samecka-Cymerman and Kempers, 2001; Corstanje et al., 2006; Steinbachová-Vojtísková et al., 2006). Older aerial structures present higher carbon contents than younger structures, with lower development of sustentation structural components (lignifies components). Decrease of nitrogen concentrations are expected during more advanced development stages, possibly due to higher translocation to parts of intense metabolic activity (Asaeda and Siong, 2008).

Predictive models were developed so to estimate *T. domingensis* allometric variables, which growth in natural conditions. These models were based on individuals sampling from field populations utilizing morphologic characteristics in order to facilitate non destructive measures in the field. Only aerial parts prediction was performed due to difficulty in obtaining measures of other structures, such as roots. Model was developed in order to estimate plant biomass, reducing drastically strength used for destructive methods, allowing increasing number of samples and offering more precise data.

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