Ⅶ-269 Growth Dynamics of *Phragmites*, The Common Reed; A Modeling Approach

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1. Introduction

Common reed *Phragmites* is a major component of fresh water bodies in temperate regions throughout the world. Recently much attention has been drawn on this particular species to be used as a tool in removing nutrients from domestic and agricultural waste. There are many experimental analysis done on growth dynamics of *Phragmites*, but very few has attempted to analyze the phenomena using numerical simulation models. The dynamic growth model in discussion was developed with the objective to simulate the seasonal variation of above and below ground biomass of a mono specific stand of *Phragmites*. This is an initial step towards to investigate the potential of this species to be used as a tool in removing nutrients such as nitrogen and phosphorous from eutrophic shallow lakes.

2. Materials and methods

2.1 Model formulation

Five state variables were selected depending on their importance and competence to illustrate the plant growth. Hence, plant biomass (B) in grams per square meter was divided into five major plant organs such as shoots (including leaves and stems), panicles, roots, rhizomes and new rhizomes, which were the state variables. Plant growth was described mathematically using 1st order partial differential equations, and solved simultaneously. Net growth of the plant stand was described as the integral effect of photosynthesis (Ph), respiration (Res), mortality (De), reallocation of material from dead biomass and assimilates translocation between shoots and below ground organs. Plant height was stratified into 0.4m horizontal layers and all biomass variations per day were evaluated in grams per square meter by ash free dry weight for each layer.

2.1.1 Governing equations to describe the growth of different plant organs

$$\frac{\partial B_{sht}(i)}{\partial t} = Ph(i) - \mathrm{Res}_{sht}(i) - De^{p}_{sht}(i) + C_d.De^{p}_{sht}(i) + (1\text{-}x).Rhif.(Bb_{sht}(i)/B_{sht})$$
$$- B_{sht-Trans}(i) - Ph_{Trans}(i) - B_{sht-pTrans}(i) - Ph_{p-Trans}(i) - G_{rt}(i)$$

$$\frac{\partial B_{rhi}}{\partial t} = -\mathrm{Res}_{rhi} - De^{p}_{rhi} + C_d.De^{p}_{rhi} - Rhif + B_{sht-Trans}y + Ph_{Trans}y$$

$$\frac{\partial B_{nrhi}}{\partial t} = -\mathrm{Res}_{nrhi} - De^{p}_{nrhi} + nRhif + B_{sht-Trans}(1-y) + Ph_{Trans}(1-y) + C_d.De^{p}_{nrhi}$$

$$\frac{\partial B_{rt}}{\partial t} = G_{rt} - \mathrm{Res}_{rt} - De^{p}_{rt} + C_d.De^{p}_{rt} - nRhif + x.Rhif$$

$$\frac{\partial B_{pani}}{\partial t} = Ph_{p-Trans} + B_{sht-pTrans}$$

Where, $Ph(i) = P_m.\theta^{T-a}.\dfrac{I_{PAR}}{K_{PAR}+I_{PAR}}.\dfrac{K_{agesht}}{K_{agesht}+AGE_{sht}}.B_{sht}(i)$

$$G_{rt} = g_m.\frac{K_{rt}}{K_{rt}+AGE_{rt}}.B_{rt}$$

$\mathrm{Res} = \gamma_m.\theta^{T-a}.B$; $De = \beta.B$; $Rhif = \alpha_{rhi}.B_{rhi}$; $nRhif = \gamma_{down}.B_{rt}$

Notation;
x- fraction of rhizome biomass for root formation
y- fraction of shoot biomass for remobilization of rhizomes
$Bb_{sht}(i)$ -Shoot biomass in i^{th} layer
$B_{sht-Trans}$, $B_{sht-pTrans}$ -translocated shoot biomass for rhizomes and panicles respectively
Ph_{Trans}, Ph_{pTrans} -translocated photosynthesized material for rhizomes and panicles respectively
$Rhif$ -rhizome flow for formation of shoots
P_m -maximum photosynthesis rate
I_{par} -photosynthetically active radiation
K_{par} -half saturation constant of PAR
K_{agesht} -half saturation constant of age for shoots
C_d -fraction of dead biomass used for growth
G_{rt} -Growth of roots
Superscript p- quantity of previous day

Subscripts sht, rhi, nrhi, rt and pani denote the relevant quantities of shoots, rhizomes, new rhizomes, roots and panicles respectively. It is well established that plant phenology depends on the mean air temperature of the selected location. Hence, time scale for growing season is defined in sum of degree-days, which is referred as biological time.

$$\text{Biological time} = \sum_{i=\text{The day, where mean air temperature is more than } 5^{\circ}c}^{i=\text{ending day of growing season}} \text{Daily mean air temperature } (^{\circ}c)$$

2.1.2 Photosynthetically active radiation regime in the plant stand

Many researches proposed, that photosynthetically active radiation (PAR) is about 40%~50% of daily total global radiation (i.e. I_{PAR} =0.45*total global radiation).

Following Lambert-Bear law, light extinction in any layer i of the plant stand is given as;

$$I_{iPAR} = I_{PAR}.e^{k.F_i}$$

Where I_{iPAR} is the PAR in the stand at a level above which there is a cumulative leaf area index, F_i ($F_i = \sum_{i=1}^{i=i} LAI(i)$).

Key words: Biomass, Seasonal variation, Numerical simulation, Emergent macrophytes

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Day of growth commencement depends on physical (soil temperature, water availability) and biological factors (nature and status of rhizome reserves). Lack of availability of detailed studies in this area forced the growth commencement day to be considered as a forcing variable in the model and selected according to observed data. All other processes such as cessation of leaf area expansion, onset of flowering, translocation of dry matter from shoots to below ground organs etc. were taken as temperature dependent only and fixed by the sum of degree-days. Given the initial rhizome biomass prier to emergence, together with daily total global radiation (μE/m2/d) and daily mean air temperature (^{0}c) for the intended simulation period, the model calculates daily biomass of shoot (including stems and leaves), panicles root, rhizome and new rhizome. It also calculates daily variation of LAI, shoot height distribution and vertical distribution of LAI and shoot biomass.

2.2 Model calibration

The model was calibrated by using a set of measured data at Nesyt fishpond in Southern Moravia near Ledenice village (48^0 48' N, 34^0 21' E) in Czech Republic (Kev^t J., Svoboda J. and Fiala K., 1966). Several sets of parameters were tested by calibration and various model outputs of state variables were compared with measured values of the same state variables.

2.3 Model validation

To test the parameters found by calibration, represent the real values in a system, validation of the model was required with independent sets of data. It was preferable to validate the model by using data obtained from a period, in which other conditions prevail than from the period of data collection used for calibration. Hence, two sets of data were selected from two different countries, New south Wales- Australia and Japan. Simulation for each case was carried out using the same model parameters.

3. Results and discussion

Fig. 1 shows measured and simulated output results of seasonal variation of shoots, stems, leaves, panicle biomass and Leaf area index for the growing season 1966 in Southern Moravia. All apparent trends such as high initial growth phase followed by a slow growth phase, time of peak biomass attained, ceasing of growth and declining of biomass due to senescence were successfully reproduced. Fig. 3 illustrates measured and simulated results of seasonal variation of shoot, rhizome and root biomass for the growing season 1979/1980 in New South Wales, Australia. In this case rhizome biomass refers to the sum of both new and old rhizomes because, observed data were available in that form. It can be seen that all apparent trends such as decline of rhizome biomass during the early growing season due to remobilization of accumulated material for shoot growth and gaining of biomass during the later part of the growing season due to translocation of material from current photosynthesis and shoots, were well maintained. Fig. 2 and Fig. 4 show measured and simulated results of seasonal variation of shoot height and vertical distribution of shoot biomass (including leaves, stems with sheaths and panicles) in 0.4m thick horizontal layers on 24th August 1966 in Southern Moravia respectively.

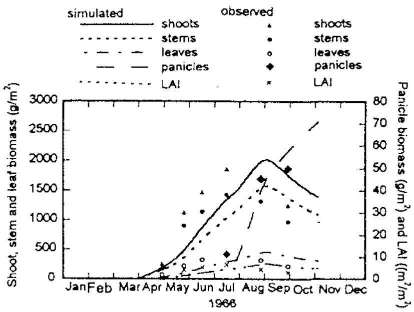

Fig.1 Seasonal variation of above ground biomass of Phragmites (Nesyt fishpond, Southern Moravia)

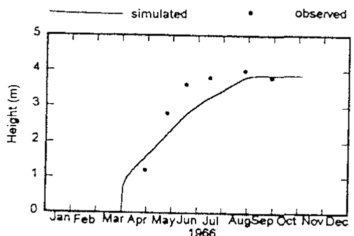

Fig.2 Seasonal variation of shoot height of Phragmites (Nesyt fishpond, Southern Moravia)

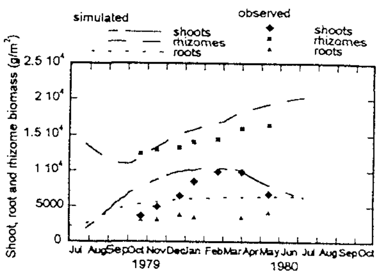

Fig.3 Seasonal variation of below ground biomass of Phragmites (New South Wales, Australia)

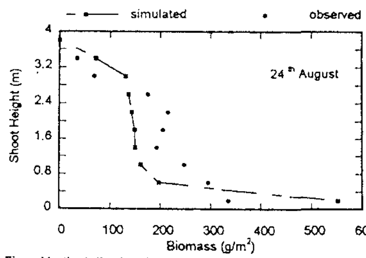

Fig.4 Vertical distribusion of shoot biomass by 0.4m horizontal layers (Nesyt fishpond, Southern Moravia)

4. References

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