Mangrove leaf litter production in the Iwahig River estuary ecosystem of Puerto Princesa Bay, Palawan, the Philippines

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ABSTRACT

This study aims to quantify mangrove leaf litter's contribution to the Iwahig River estuary ecosystem's primary productivity in Puerto Princesa Bay, Palawan, Philippines. There are several studies of this nature in the Indo-west Pacific and Malesian regions, but none, so far, in the island province of Palawan. A sampling protocol using the net traps was employed, and the dry leaf production in gram dry-weight per sq. m per day (g DW m^{-2} d^{-1}) was computed. The amount of calculated mangrove leaf litter was at 2.34 ± 0.42 g DW m^{-2} d^{-1} of which 49.6% was from the species *Lumnitzera littorea* (Jack) Voigt. The contribution of five other species, *Rhizophora mucronata* (Lamk.), *Rhizophora apiculata* Bl., *Xylocarpus granatum* König, *Bruguiera sexangula* (Lour.) Poir., and *Xylocarpus moluccensis* (Lamk.) Roem came in varying quantities. The seasonal variability was evident, but this did not differ significantly between the rainy (1.48 ± 0.3 g DW m^{-2} d^{-1}) and the dry (2.12 ± 1.0 g DW m^{-2} d^{-1}) seasons with a P-value of 0.432 (α = 0.99). None of the four environmental parameters (temperature, rainfall, wind speed and day lengths) correlated well with the average monthly leaf litter production. Nonetheless, the computed value for this is high and can be associated with the Iwahig River estuary ecosystem's high biodiversity. A year-round assessment, with the inclusion of relevant variables such as tides, nutrients, species density, and diameter-at-breast-height (DBH), should be done. Understanding the inter-annual variability in mangrove leaf litter production and its contribution to the Iwahig River estuary ecosystem in Palawan, the Philippines, are imperative.

Keywords: dry weight, litterfall, productivity, species, variability

INTRODUCTION

The mangrove forest of the Iwahig River estuary in Puerto Princesa Bay, Palawan, south-western Philippines, is a bio-diverse ecosystem with 19 mangrove species scattered at nearly 280 ha of forest cover (Dangan-Galon et al. 2016). It harbors 91 mangrove-associated terrestrial vertebrates, consisting of 20 herpetofauna, 63 birds, and eight mammals (Dangan-Galon et al. 2015). It is also home to nearly 15 bivalves and 50 gastropod species from 25 families and 45 genera (Dolorosa and Dangan-Galon 2014).

The high biodiversity of this forest can be associated with its productivity. Mangroves are among the most productive ecosystems on earth with an average productivity of 2,500 mg C m^{-2} d^{-1} (Bunt 1995). Nutrient input from land and sea and the internal recycling of organic matter determined the mangrove's productivity (Holquin et al. 2001). Between the two processes, the latter is a more efficient way of meeting the high mangrove demand for nutrients to sustain the forests' productivity (Alongi et al. 1989; Ovalle et al. 1990; Bunt 1995; Jennerjahn and Ittekkot 2002).

The internal recycling of organic matter in mangrove forest begins with the leaching of soluble organic and inorganic compounds from vegetative and reproductive plant parts due to senescence, mechanical factors, stress, death, weathering of the whole plant, or a combination of these factors in a given time (Kozslowski 1973). Colonization of microorganisms that initiate fragmentation of plant materials will then follow (Hossain and Hoque 2008). Organic matter production, in this case, can reach up to 12 t ha^{-1} y^{-1} (Amarasinghe and Balasubramaniam 1992), and in general, 50-85% of such production is from littered leaves (Saenger and Snedaker1993; Navarrete and Rivera 2002; Imbragen and Dittman 2008; Bernini and Rezende 2010).

Mangrove litter production varies widely with species, forest type, stand age, geographical locations, tidal inundation, and environmental parameters such as temperature, rainfall, and wind (Twilley 1995; Twilley and Day 1999; Bernini and Rezende 2010). Litter production tends to be higher in old, dense, mixed stands and riverine forests at lower latitudes (e.g. tropical regions) during the dry season because of increased soil, water salinity, and evapotranspiration rate (Hossain and Hoque 2008). This correlation trend, although evident, is not uniform and varies across regions.

In the Philippines, quantification of mangrove leaf litter production is limited to the works of De Leon et al. (1992), Calumpong and Cadiz (2012), and Rafael and Calumpong (2018) in the central Philippines. In most parts of the country, including the Iwahig River estuary mangrove forest of Palawan in the south-western Philippines, a similar study has never been conducted. Given the recent findings on its rich biodiversity, it is equally interesting to determine the forest contribution to the primary productivity of the Iwahig

River estuary and to account for variability in mangrove leaf litter production as influenced by environmental factors and seasons.

METHODS

Study Site

Mangrove forests adjacent to the Iwahig River estuary located off the mid-eastern portion of Palawan Island, between 9.7359°N and 118.6969°E with a river stretch of 9.1 km was the site of this study (Figure 1). Three permanent stations (Station 1: 9.4408°N and 118.4150°E; Station 2: 9.4403°N and 118.4101°E; Station 3: 9.4434°N and 118.4926°E) were established along this riverbank, representing the upper, mid, and lower portion of the river estuary. These stations harbored a mixed mangrove species with relatively excellent forest cover.

Sampling Procedure

The littered leaves were collected from mangrove forests along the riverbank for nine months, June-October 2013, December 2013, January-February 2014, and April 2014. By installing the net traps, measuring 1 x 1 m tied on mangrove trunks or branches at 0.5-1.5 m high from the sediment to prevent losses by flooding (De Leon 1992; Sukarjo 2010; Calumpong and Cadiz 2012) and with three replications per site, a weekly collection of trapped leaves had materialized (Figure 2). The collected leaves were then sorted per species in the laboratory, air-dried for 48 h, weighed using the top loading balance, wrapped in aluminum foil, and oven-dried at 60°C until reaching a constant dry weight.

The dry leaf litter production, expressed in g DW m^{-2} d^{-1}, was obtained by dividing the mean weekly dry weight of collected leaves from the net traps by seven days. The 2013-2014 environmental data indicated that the dry season in Palawan, Philippines, extends from December to May while the rainy season, June to November. The mean temperature was at 28°C whereas, the mean precipitation or rainfall, 151 mm, with the highest (274.3 mm) recorded in June 2013. These data were from the Philippine Atmospheric, Geophysical, Astronomical Services Administration, Department of Science and Technology (PAGASA, DOST), Puerto Princesa station.

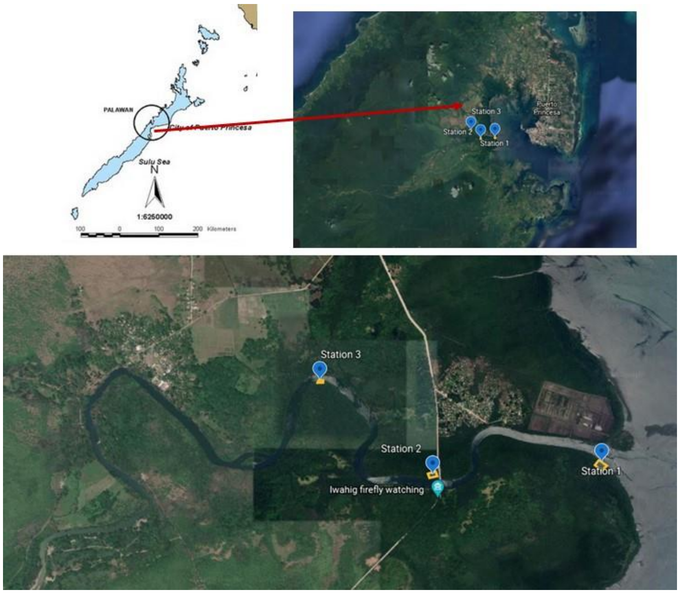

Figure 1. The map of Palawan (top-left) indicating the location of Puerto Princesa City and an aerial view of Puerto Princesa Bay (top-right), where the Iwahig River estuary is situated. The zoomed-in aerial view of the study site shows the three collection stations (bottom).

Figure 2. The leaf litter net traps established in the mangrove forests of the Iwahig River estuary in Puerto Princesa Bay, Palawan, the Philippines.

Statistical Analyses

This study used nonparametric tests such as the Wilcoxon Signed-Rank and Kendall Rank correlation tests of the RStudio 4.0.3 statistical software (R Core Team 2020). These nonparametric tests applied only for data sets that did not satisfy bivariate normality assumptions.

Particularly, Wilcoxon Sign-Rank test was used to determine the mean differences in mangrove leaf litter production between the rainy and the dry seasons. On the other hand, the Kendall Rank correlation test determined the relationship between the average monthly mangrove leaf litter production (as a dependent variable) and a particular physicochemical parameter such as the air temperature, rainfall, wind speed, and day-length (as the independent variables).

RESULTS

Mangrove Leaf Litter Production

Quantified mangrove leaf litter production in the Iwahig River estuary, Puerto Princesa Bay, Palawan, was at 2.34 ± 0.42 g DW m^{-2} d^{-1}. Out of the 19 mangrove species present in the area, only six had a high contribution to mangrove litter production. These included *Lumnitzera littorea* (Jack) Voigt, *Rhizophora mucronata* (Lamk.), *Rhizophora apiculata* Bl., *Xylocarpus granatum* König, *Bruguiera sexangula* (Lour.) Poir., and *Xylocarpus moluccensis* (Lamk.) Roem. Of these species, the *L. littorea* had the highest production, 0.87 ± 0.54 g DW m^{-2} d^{-1}, constituting 49% of total leaf litter weighed for the six species. The *R. mucronata*, *R. apiculata* and *X. granatum* followed with productivity values of 0.43 ± 0.38 (25%), 0.22 ± 0.12 (12%), and 0.164 ± 0.13 (9%) g DW m^{-2} d^{-1}, respectively. The remaining 5% was for *B. sexangula* with litter production of 0.043 g DW m^{-2} d^{-1} and *X. moluccensis* with 0.037±0.03 g DW m^{-2} d^{-1} (Figure 3).

Seasonal Variability

Seasonal variability in mangrove leaf litter production at the river estuary was evident. The monthly yield of these species ranged from 0.72 to 2.87 g DW m^{-2} d^{-1}. The month of January 2014 had the highest, followed by 2.83 g DW m^{-2} d^{-1} in the preceding month of December 2013, while February 2014 had the lowest production value (Figure 4). The result of the Wilcoxon Signed-Rank test had indicated no significant difference in mean monthly leaf litter production between the rainy (1.48 ± 0.3 g DW m^{-2} d^{-1}) and the dry (2.12 ± 1.0 g DW m^{-2} d^{-1}) seasons with a *P*-value of 0.432 (α = 0.99).

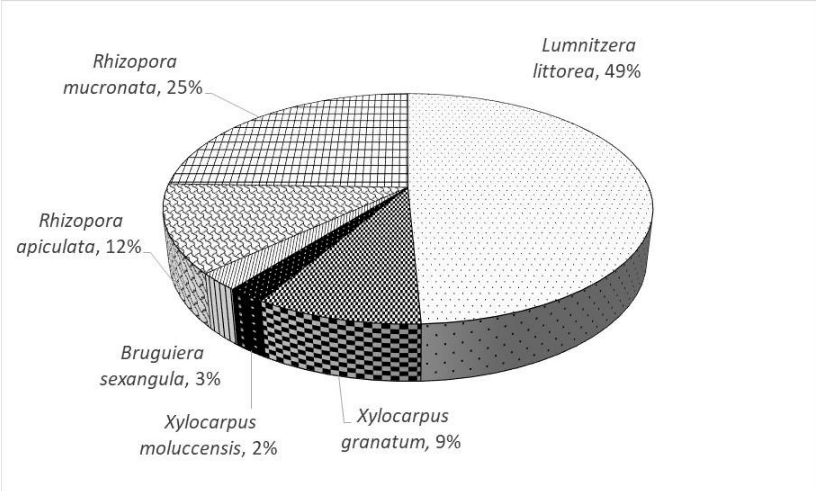

Figure 3. The leaf litter production (g DW m^{-2} d^{-1}) and percent leaf litter contribution of the six predominating mangrove species in the Iwahig River estuary, Puerto Princesa Bay, Palawan, the Philippines.

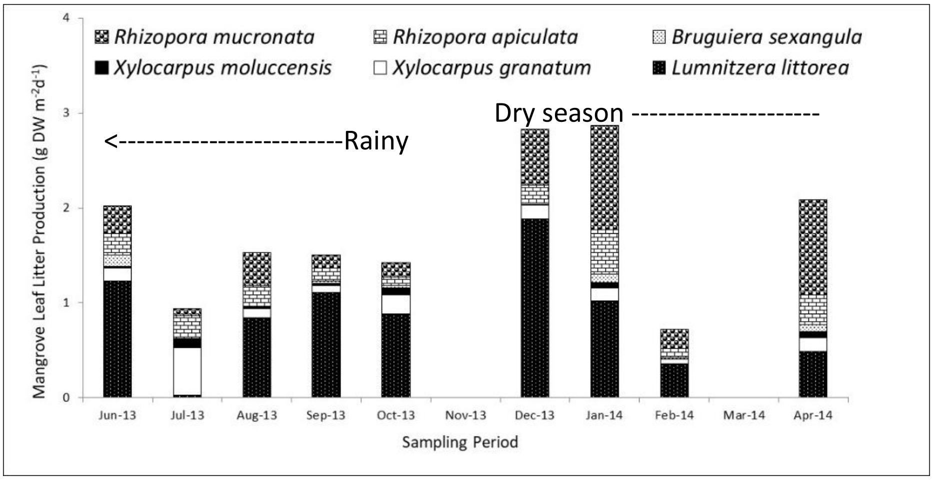

Figure 4. The seasonal variability in mangrove leaf litter production in the Iwahig River estuary, Puerto Princes Bay, Palawan, the Philippines.

Leaf Litter Production and Environmental Factors

None of the four measured physicochemical parameters, the temperature, rainfall, wind speed, and day-length, correlated well with the mean monthly mangrove leaf litter production (Figure 5). However, the highest leaf litterfall was recorded in December 2013 and January 2014 when the temperature and day length was relatively high, and the wind speed and rainfall were low (Figures 6 and 7).

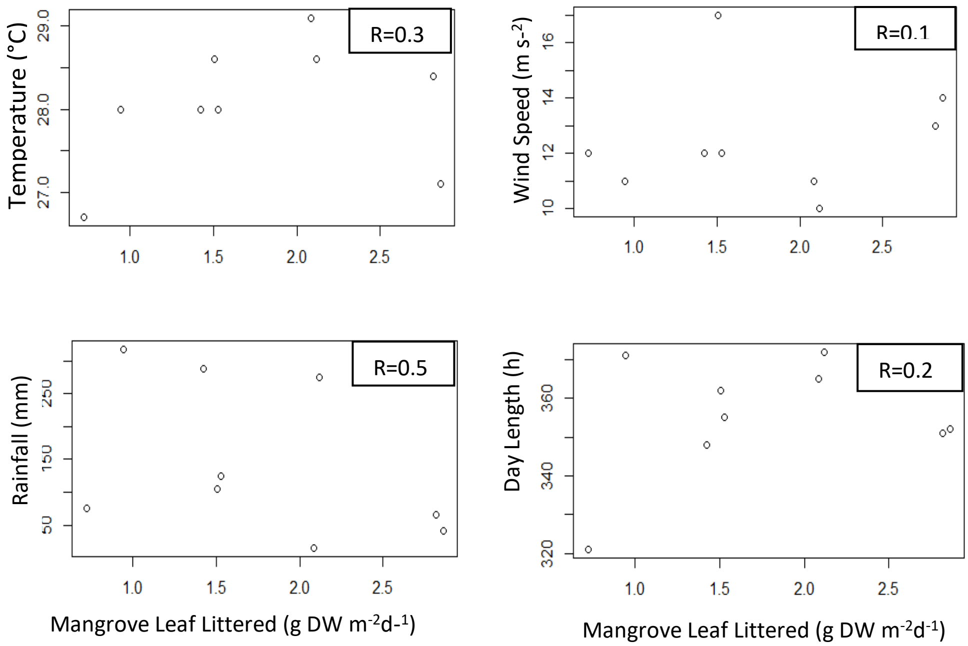

Figure 5. The scatter graphs between the mean monthly mangrove leaf litter production and the temperature, rainfall, wind speed, and day-length values from June 2013 to April 2014 in the Iwahig River estuary, Puerto Princesa Bay, Palawan, the Philippines.

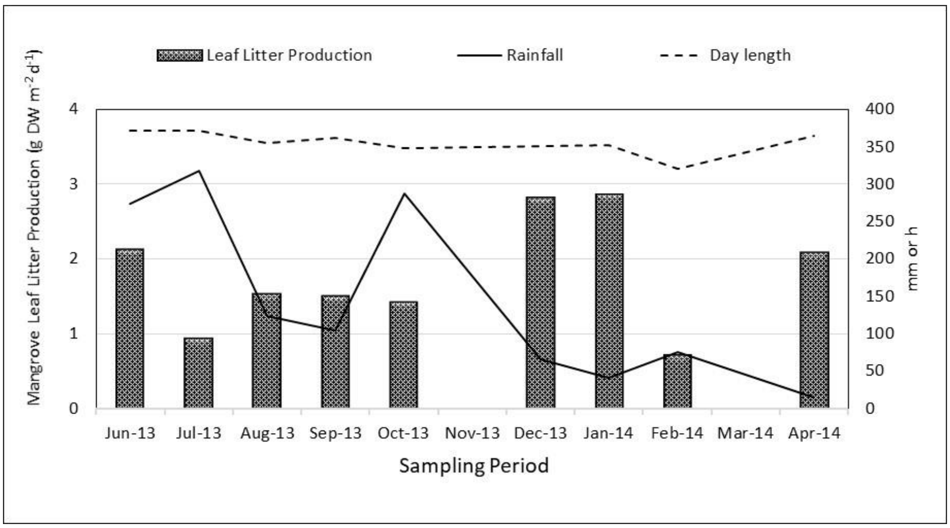

Figure 6. The profile of rainfall, and day length, from June 2013 to April 2014 in the Iwahig River estuary, Puerto Princesa Bay, Palawan, the Philippines.

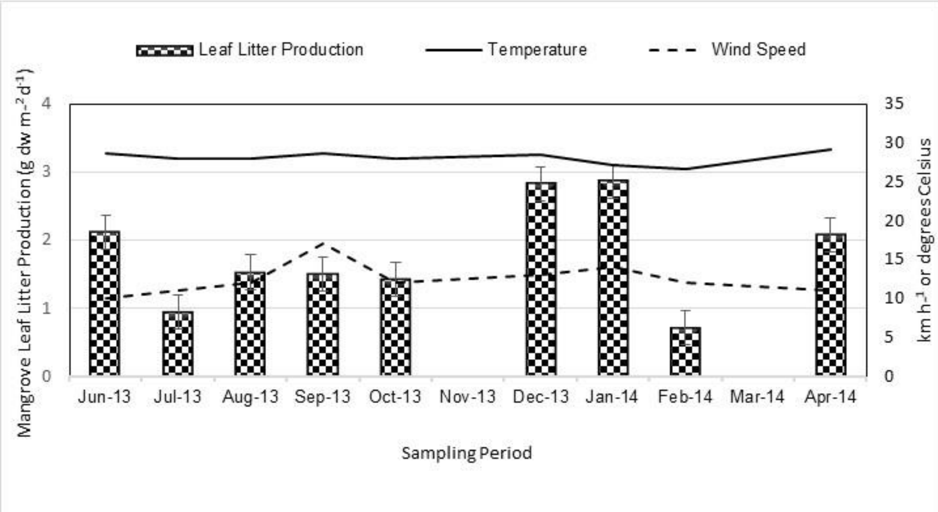

Figure 7. The profile of temperature and wind speed, from June 2013 to April 2014 in the Iwahig River estuary, Puerto Princesa Bay, Palawan, the Philippines.

DISCUSSION

Mangrove Leaf Litter Production

Mangrove leaf litter production in the Iwahig River estuary, Puerto Princesa, Palawan differs among species. The most dominant, *L. littorea* has the highest contribution, almost 50% of the total value from the five other prominent species, *R. mucronata, X. granatum*, *R. apiculata*, *B. sexangula*, and *X. moluccensis*. The entire litter production, 2.34 ± 0.42 g DW m^{-2} d^{-1}, contributed by these species is relatively low compared to natural mangrove forests in the central Philippines (Bais Bay, Negros Oriental; Bohol; and Cebu) with an average litter production of 6.04 ± 1.9; 7.06 ± 3.9; 7.43 ± 4.33; g DW m^{-2} d^{-1}, respectively (Rafael and Calumpong 2018). It is important to note that litter production from the central Philippines included mangrove-littered leaves and twigs, flowers, and fruits. On per species basis, leaf litter production of *R. apiculata*, 0.43 ± 0.38 g DW m^{-2} d^{-1} and *R. mucronata*, 0.22 ± 0.12 g DW m^{-2} d^{-1} in the study site were relatively high compared to data obtained by De Leon et al. (1992) from Bais Bay, Negros Oriental, with only 0.17 and 0.29 g DW m^{-2} d^{-1}, respectively. Species could influence the variations in mangrove litter production, sampling stations, stand density, and DBH (Rafael and Calumpong 2018), phenology (Nazim et al. 2013), and other physiological characteristics (Twilley et al. 1997). Nevertheless, the amount of mangrove leaf litter production in the Iwahig River estuary was almost five times higher than that of Tiris mangrove forest in West Java, Indonesia

(Sukardjo 2010). It is, therefore, a high value compared to the mangrove forest in the Indo-West Pacific and Malesian regions. This high leaf litter production contributes mainly to the overall productivity of the mangrove forest and river estuary system. When comprehensively studied, this can help explain the presence of diverse organisms in the area. Several studies had documented the positive relationships between productivity and biodiversity in forest ecosystems (Waide et al. 1999; Costanza et al. 2007; Liang et al. 2016; Brun et al. 2019).

Seasonal Variability

There was no seasonal trend observed on mangrove leaf litter production in the Iwahig River estuary ecosystem. An immense mangrove leaf shedding associated with seed maturation (Nazim et al. 2013), which generally transpired during the dry season in Asian countries, like Vietnam (Clough et al. 2000) and South Australia (Imgraben and Dittman 2008) and the rainy season in Brazil (Bernini and Rezende 2010) were not evident in the study site.

Leaf Litter Production and Environmental Factors

None of the tested Physicochemical parameters (temperature, rainfall, wind speed, and day-length) correlated well with the mean monthly mangrove leaf litter production. This finding conformed to the study of Bernini and Rezende (2010) in Brazil, which is also a tropical country where fluctuations of environmental parameters are minimal. Even in the warm-temperate region of Mgazana, South Africa, mangrove leaf litter production showed no seasonal trends (Emmerson and McGwynne 1992). A similar study in the central Philippines by Rafael and Calumpong (2018) showed no significant correlation between the average monthly leaf litter and rainfall. The factors that showed a positive correlation with mangrove leaf litter included solar radiation, pH, nutrients, tides, and salinity (Twilley 1995; Twilley and Day 1999). Accordingly, the low salinity of interstitial water favors nutrient enrichment (Bernini and Rezende 2010), enhancing mangrove productivity. Unfortunately, this study could not elucidate such an effect of salinity. Lumping of data sets obtained from the sampling stations was inevitable due to varying net-traps retrieved every collection period.

Therefore, conducting a year-round assessment of mangrove litter production, including the effects of several other variables such as the tides, nutrients, species density, and DBH, is essential. Considering that environmental factors may differ from year-to-year, a series of annual litterfall cycles could be done to understand further the inter-annual variability on mangrove leaf litter production in Iwahig River estuary, Palawan, the Philippines.

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