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Species composition, habitat structure and sedimentation in a *Sonneratia caseolaris* stand at the Lam River estuary, Vietnam

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ABSTRACT

This study aims to provide some information for development of silvofishery systems with a mangrove (*S. caseolaris* stand) for shrimp-culture ponds at the Lam River estuary, Vietnam. To achieve this objective, species composition, habitat structure and sedimentation effect in the *S. caseolaris* stand distributing along the canal for shrimp culture were surveyed. The study reveals that the stand contains four species or more under the canopy; dominant understory species are *Aegiceras corniculatum*, *Cyperus malaccensis* and *Acanthus* spp. (*A. ilicifolius* and *A. ebracteatus*). *A. corniculatum* was observed expanding its distribution area toward the low tidal zone. As a result, the habitat for seedlings/saplings of this species becomes significantly lower in land height than that of *Acanthus* spp. (ANOVA; $p<0.05$), but not different from that of *S. caseolaris*. Sedimentation rates of *A. corniculatum* and *Acanthus* sp. recorded were 13.2, 2.9 g m^{-2} h^{-1} and 13.0 4.4 g m^{-2} h^{-1}, respectively. *S. caseolaris* sparsely grows with less developing of pneumatophore, which effectively traps sediment, at the early stage of succession. Considering reinforcement of sedimentation effect, especially right after restoration of the mangrove in the silvofishery systems, *A. corniculatum* and *Acanthus* spp. with *S. caseolaris* are recommendable to be introduced to the systems.

Keywords: *Aegiceras corniculatum*, *Acanthus*, understory species, low tidal zone, shrimp-culture pond

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1 Introduction

Loss of mangroves due to mainly conversion to shrimp-culture ponds has been continued in Vietnam despite of increasing awareness of the value of mangrove ecosystems in the world (De Graaf and Xuan, 1998; Thu and Populus, 2007; FAO, 2008). Hung Hoa commune Vinh city Nghe An province located at the Lam River estuary is no exception. Right after the dike road was constructed, providing convenient transport infrastructure to this region in 2005, shrimp-culture pond area had been drastically increased according to Hung Hoa Commune People's Committee. Approximately 1,000 ha of shrimp-culture ponds exist in Nghe An province, accounting for 0.4% of total shrimp-culture ponds in Vietnam (Phuong, 2014a). Considering the situation of mangroves mentioned above, efforts for mangrove restoration had been implemented in Nghe An province, however, it had been conducted on the coastal line, but not in the inland area due to aiming of disaster prevention from high flood tide damages (IFRRCS, 2011). Thus, Takahashi et al. (2019) recommended introducing silvofishery systems with mangrove forests in this region, especially inland area. Silvofishery systems i.e. mixture of silviculture and aquaculture ponds nowadays have been widely adopted in Asian tropical countries (Fitzgerald, 2002; Clough et al., 2002; Ahmed et al., 2018). It was firstly developed in Myanmar and was introduced to Indonesia in 1978 (Takashima, 2000).

Benefits from this system is not only re-existence of mangrove forests but also feeding naturally shrimps by organic matters from mangroves (Ashton, 2008), and prevention from pond water contamination (Hastuti and Budihastuti, 2017). Therefore, it contributes to keep good water condition of pond water for longer time comparing to ordinary shrimp-culture ponds abandoned for three to four years in general after operation due to infected by diseases (Khoon et al., 2004).

Mangroves for silvofishery systems, in many cases, consist of only the species forming canopy such as *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicennia marina* (Clough et al., 2002; Hastuti and Budihastuti, 2017), but not contain species under canopies. *Sonneratia caseolaris* forest, which is a typical mangrove in the study area Phuong (2014b), however, involves some species under canopies, *Aegiceras corniculatum* (shrub) and *Acanthus* spp.; *A. ilicifolius* and *A. ebracteatus* (herb) (Takahashi et al., 2019). Mangrove forest accompanied with under canopy species could totally provide ecological services (Chen et al., 2016; Wei et al., 2020). In order to introduce under canopy species such as *A. corniculatum* and *Acanthus* spp. to silvofishery systems, their habitats especially relation to land height and their ecological functions are required to be understood for designing and determination of water operation framework. In terms of the habitats there have been a lot of qualitative descriptions, for *A. corniculatum* habitat is lower edge of the river estuary (Clarke, 1995), for *Acanthus* spp. distributes along the tidal creek or higher edge of the mangrove forest (Duke, 2006), however, not so many quantitative descriptions of habitats (Takahashi et al., 2019).

Sedimentation effect is one of the important functions for water purification to be considered for designing silvofishery systems. There have been many previous studies of sedimentation effect in different mangrove stands, trapped in *Ceriops* sp. stand and *Rhizophora* sp. stand (Furukawa and Wolanski, 1996), in *Avicennia* sp. stand and mixture stand of *Avicennia* sp. and *Rhizophora* sp. (Kathiresan, 2003). Bird and Barson (1977) reported *Avicennia* sp. with pneumatophore is considered to be more effective in trapping sediments than stilt rooted mangroves such as *Rhizophora* spp. or buttressed mangroves such as *Bruguiera* spp. Focusing on *A. corniculatum* and *Acanthus* spp. Santen et al. (2007) reported sedimentation rate of mixture of *A. corniculatum* (75%) and *Acanthus ilicifolius* (20%), but not separately evaluated. With background mentioned above, this study aims to elucidate species composition, habitat structure and sedimentation rate in the *S. caseolaris* stands, to provide some information for development of silvofishery systems with multi-layered mangrove stands for shrimp culture.

2 Materials and Methods

2.1 Study site

The present study was conducted at the mangrove stands of which the highest layer is formed by *S. caseolaris* in the canal network system connected to the estuary of the Lam River (Fig. 1(a)). The mangroves in the study site, thus, are inundated regularly by brackish water except for the water gate for irrigation to the shrimp-culture ponds being operated. The Lam River originates from Nam Can area in Laos, flowing for 556 km mainly through Nghe An province, discharging into Tonkin Bay (WVS, 2011; WB, 2012). Nghe An province is affected by South West monsoon from May to October; it is rainy and temperature reaches 30 – 35 °C, and affected by North East monsoon from November to April; it is dry and temperature lows of 14 – 16 °C. Annual average rainfall is 1,968 mm yr^{-1} (Vinh city; 18°40′ N, 105°40′ E) (Averyanov et al., 2003; Giang et al., 2014). The present study consists of two components; one is a vegetation survey (R1 – R4 on Fig. 1(b); 18°41′24″ N, 105°45′38″ E nearby shrimp-culture ponds (Fig. 1(c)), and another one is an evaluation of sedimentation effect of *A. corniculatum* and *Acanthus* sp. populations (St.1 and St.2 on Fig. 1(c); 18°41′23″ N, 105°45′38″ E).

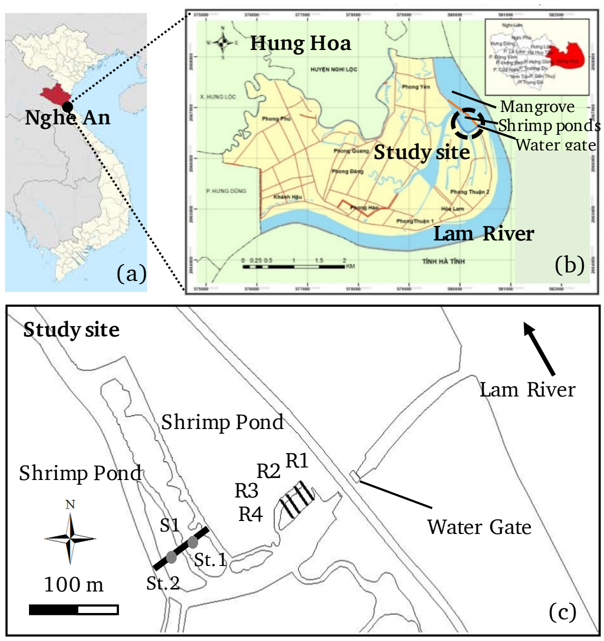

Figure 1. Location of the study site. (a) Red shaded area is Nghe An province, black dot is Vinh city; (b) Modified cadastral map of Hung Hoa commune (2018), dotted circle indicates the study site; and (c) Study site, R1 – R4 are transects for vegetation survey, sediment traps were set up in St.1 and St.2 on the transect S1.

2.2 Habitat structure

2.2.1 Cross section of the lands

Transects were set up, extending from the shoreline (at 7:00 am, on July 15th, 2019; Fig. 2) to the landward end of the vegetation. Their width is four meters; two meters for both sides from the center line. Above the center line the tape measure was set up horizontally and perpendicular to the shoreline kept by a level and a compass, and height from the land surface to the tape measure was recorded every meter. After cross section survey in the field, the measurements were converted into land height from datum line (LH) based on the tide fluctuation chart in Cua Hoi; 18°48′ N, 105°46′ E (OC, 2019). Cross section survey was conducted in four transects (R1 – R4) on July 15th and 16th, 2019.

2.2.2 Vegetation

Every plant individual occurring in the transects was recorded with species name, its position and LH, growth stage, plant height and diameter. For woody species, position was described with two parameters; distance from the shoreline and distance from the center line. For herbaceous species, distribution range in the direction of the center line was recorded. LH of each individual plant was represented by that on the center line. For woody species (*S. caseolaris* and *A. corniculatum*) it was divided into three age classifications; seedlings (height $\leq$ 30 cm), saplings (height > 30 cm, diameter < 10.2 cm) and trees (diameter $\geq$ 10.2 cm) (Good and Good, 1972). Both *S. caseolaris* and *A. corniculatum* at tree growth stage have reproductive ability based on observation in the study site. Diameter was measured at intermediate point of tree height (tree height < 2.6 m), except for two *S. caseolaris* individuals of which breast height diameter (at 1.3 m, tree height $\geq$ 2.6 m) can be measured (Batcheler and Craib, 1985). If trees are branched, diameter of all the branches were measured. Tree height and diameter were not measured for the tree individuals of which height is less than 30 cm and diameter is less than 1 cm. Vegetation survey was conducted at the same time as cross sections were measured.

2.3 Sedimentation effect

Sediment traps were set up at two different places covered by *A. corniculatum* at 1.20 m in LH (St. 1) and *Acanthus* sp. at 1.30 m in LH (St. 2) in the same transect (S1) dominated by *S. caseolaris* at the highest layer (Takahashi et al., 2019) (Fig. 1(c), Fig. 2(a, b). Plants cover the land by 80% for both St. 1 and St. 2 (Fig. 2(c)), they are not completely submerged even at high tide.

2.3.1 Sediment traps

The sediment trap is made of seven cylindrical plastic bottles gathered (3 cm in diameter $\times$ 9.5 cm in height for each bottle), one bottle is surrounded by six bottles (Fig. 2(c)). It is anchored (connected to the weight with strings which can stretch) and is floated up and down corresponding to water level fluctuation, i.e. if the land is not submerged by brackish water it is on the land, but if it is being submerged it will be floated up gradually and suspended in the water. Maximum height from the land to the top end of the trap is 0.2 m, thus water with sediments enters the traps at the 1.40 m $\leq$ water level for St. 1 and at the 1.50 m $\leq$ water level for St. 2. Cross-sectional area of the trap was 49.455 cm^2 $[\pi(3/2)2 \times 7]$.

2.3.2 Sediment and water collection

Sediment collection by the sediment traps was conducted at rising tide and ebb tide, separately for eight times at rising tide and seven times at ebb tide from August 18th to November 30th, 2019, mainly in rainy season (May to October). Sedimentation rate (SR) was calculated by the equation as follows:

$$SR = \frac{\Delta S}{A \Delta ti} \quad (1)$$

SR = sedimentation rate (g m^{-2} h^{-1}); ΔS = amount of sediment trapped (g); A = cross-sectional area of sediment trap (m^2); Δti = inundated time (h); inundated time was estimated by the tide fluctuation chart (OC, 2019).

Water samples were collected as well when sediment traps were set up at high tide. Sediments and water samples were immediately brought to the laboratory and measured total quantity of sediments trapped and analyzed total suspended sediment (TSS) of water samples with protocol of ISO 11923: 1997. Water salinity was measured in the study site immediately after samples were collected by 'TS-391 Thermo Salinity Meter' (As One Co., Ltd, Japan).

3 Results

3.1 Cross section of the lands

Fig. 3 displays the cross sections; R1 – R4. LH of the transects are gradually upward to inland with average gradients; 3.6% - 4.1%. *S. caseolaris* stand grows intertidal zone (between mean high-water level (MHWL) and mean low-water level (MLWL)) and LHs are close to mean water level (MWL) or slightly higher than MWL.

3.2 Species composition

Table 1is a summary of mangrove species occurring in four transects except for herbaceous species; *Acan-*

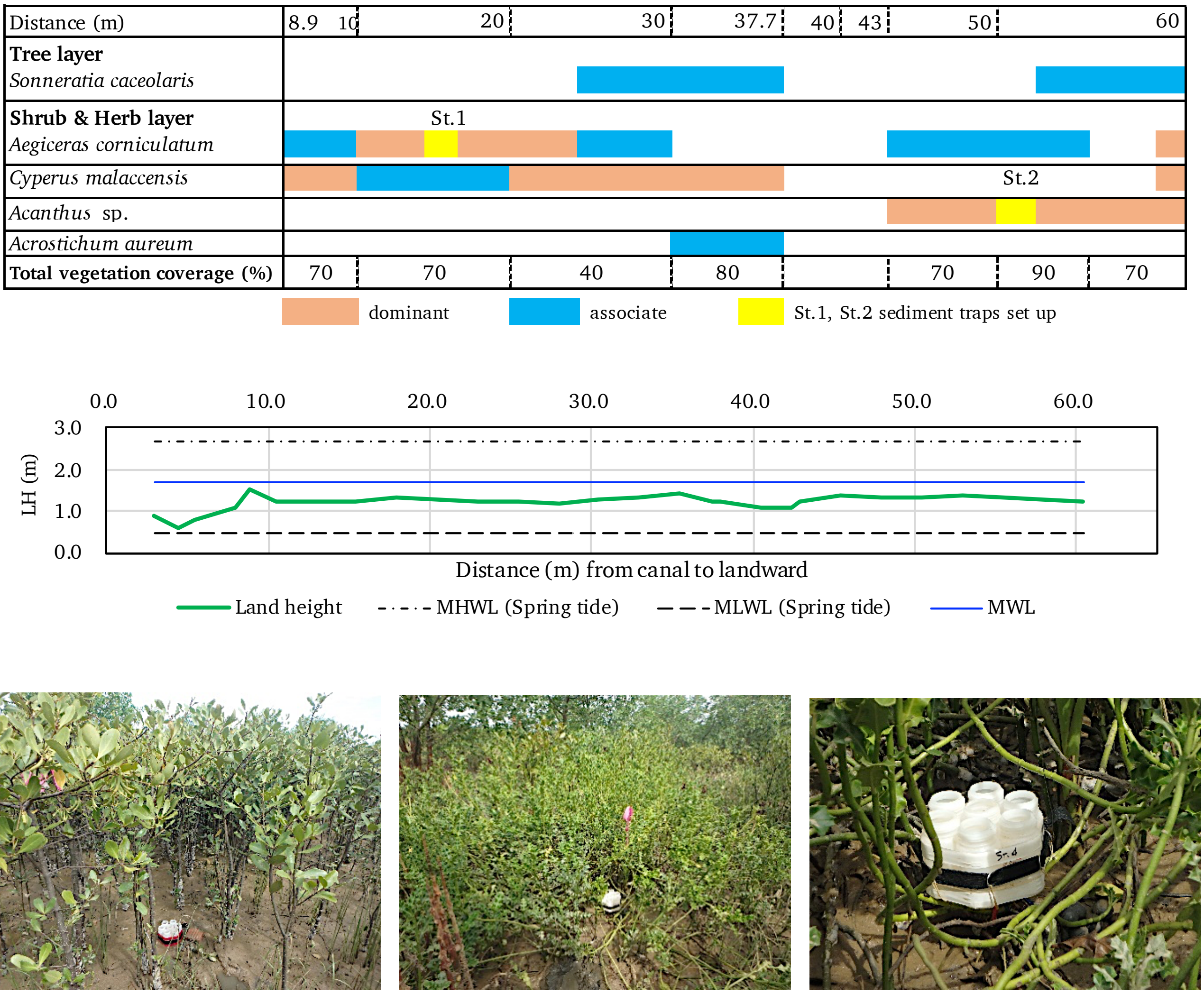

Figure 2. Location of the sediment traps, species distribution and cross section of the transect S1. (a) Species distribution in the transect S1 and location of the sediment traps (top); (b) Cross section of the transect S1 (middle); and (c) St.1 (bottom-left), St.2 (bottom-middle), and a close view of a sediment trap (bottom-right).

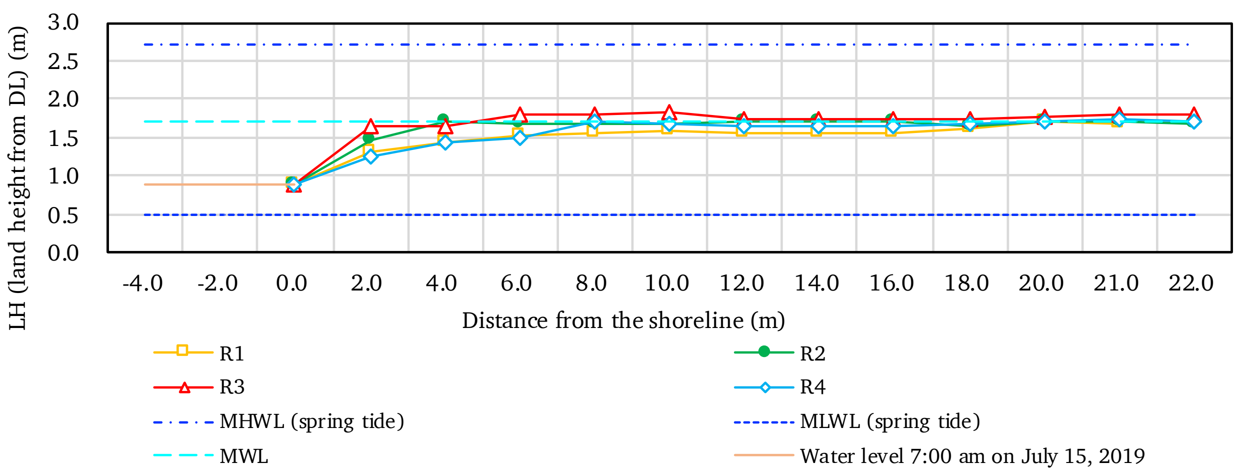

Figure 3. Cross section of R1 – R4. MHWL, MLWL and MWL stand for mean high water level, mean low water level and mean water level, respectively.

thus spp. and *Cyperus malaccensis*. Beside *S. caseolaris* woody species are *A. corniculatum* and *Derris trifoliata* growing in the transects. The *S. caseolaris* stand in the study site has two stories in structure, *S. caseolaris* is occupied at high layer (1.62 ± 0.13 m $\sim$ 3.88 ± 1.03 m in tree height), and low layer involves *A. corniculatum* (0.86 ± 0.06 m $\sim$ 1.41 ± 0.09 m in tree height), *D. trifoliata*, *Acanthus* spp. and *C. malaccensis*.

3.3 Habitats related to LH

Fig. 4(a) displays LH distribution of woody species involved in the *S. caseolaris* stand. *S. caseolaris* and *A. corniculatum* are distributed widely in LH except for *S. caseolaris* (trees), ranging approximately from 1.55 m to 1.85 m in LH, *A. corniculatum* (seedlings/saplings) is densely distributed from 1.67 m to 1.70 m in LH (slightly lower than MWL) and from 1.55 m to 1.60 m in LH. On the other hand, *S. caseolaris* (seedlings/saplings) is densely distributed from 1.66 m to 1.73 m (above/below MWL) in LH (Fig. 4(c)). Fig. 4(b) displays distribution range of herbaceous species; *C. malaccensis* and *Acanthus* spp. Former is distributed widely in LH; from 1.52 m to 1.81m, while latter are distributed narrowly in LH; from 1.70 m to 1.84 m. Focusing on average LH, *Acanthus* spp. distribute on significantly higher LH than *A. corniculatum* (seedlings/saplings) (ANOVA; $p < 0.05$). Average LH for *A. corniculatum* (seedlings/saplings) is below MWL (1.71 m in LH), but that for *Acanthus* spp. is above MWL and difference in LH of these two is 0.11 m in average. However, seedlings/saplings and trees for *A. corniculatum* are not significantly different in LH. For other species, *S. caseolaris* and *C. malaccensis* distribute as the same LH as *A. corniculatum* (seedlings/saplings and trees) and *Acanthus* spp. (Fig. 5).

3.4 Sedimentation effect

SR ranges widely in both *A. corniculatum* and *Acanthus* sp. populations from 3.6 g m^{-2} h^{-1} to 43.7 g m^{-2} h^{-1}, from 3.7 g m^{-2} h^{-1} to 41.2 g m^{-2} h^{-1}, respectively depending on water conditions (Fig. 6). However, concentrations of TSS are not significantly different in the same tide fluctuation. Average SRs both in *A. corniculatum* and *Acanthus* sp. populations at rising tide are not significantly different; 15.8 ± 5.2 g m^{-2} h^{-1} and 17.9 ± 6.4 g m^{-2} h^{-1}, respectively (Fig. 7(a)), and at ebb tide they are not significantly different, either; 8.6 ± 1.2 g m^{-2} h^{-1} and 7.8 ± 2.5 g m^{-2} h^{-1}, respectively Fig. 7(b)). SRs per one tide fluctuation are 13.2 ± 2.9 g m^{-2} h^{-1} in *A. corniculatum* population and 13.0 ± 4.4 g m^{-2} h^{-1} in *Acanthus* sp. population (Fig. 7(c)). In terms of tide fluctuation in the study site, tide goes up more rapidly and goes down more slowly, especially in August and September (Fig. 6(b)), however, it does not affect SRs for both populations (paired -test; p = 0.12 for *A. corniculatum*, p = 0.14 for *Acanthus* sp.). TSS and salinity in *A. corniculatum* and *Acanthus* sp. populations are 81.0 ± 35.6 mg L^{-1}, 77.5 ± 30.6 mg L^{-1} and 0.9 ± 0.2%, 0.8 ± 0.2%, respectively (Fig. 8).

4 Discussion

4.1 Habitats of *S. caseolaris* stand

S. caselorais stand in the study site involves four species or more at the low layer, of which *A. corniculatum* and *Acanthus* spp. are mangrove species (Phuong, 2014b). Those component species are distributed on the same LH in the stand, but focusing on the growth stage *A. corniculatum* (seedlings/saplings) distributes on the lower LH than *Acanthus* spp. Since *S. caseolaris* (trees) accounts for 13% to the total number (seedlings/saplings; n = 13, tress; n = 2), the stand is on the earlier stage of secondary succession. *A. corniclatum* (seedlings/saplings) grows on the lower land, implying *A. corniculatum* expands to the lower edge of the stand (Clarke, 1995) considering LH is descending toward shoreline. As a result, distribution zone of *Acanthus* spp. becomes relatively higher than that of *A. corniculatum* (seedlings/saplings); $p < 0.05$ (Duke, 2006). *A. corniculatum* propagates by crypto-viviparous seedlings whereas others are non-viviparous (Tomlinson, 1986), it could be an advantage for *A. corniculatum* to remain on the lower edge affected more by tide fluctuation (Jiang et al., 2019). In the case that *S. caseolaris* stand with *A. corniculatum* and *Acanthus* spp. is introduced to silvofishery systems, a mound for mangroves to grow should be a slope, gradually descending to the shrimp-culture pond with gradient of 3 -4%. Since *S. caseolaris* stand ranges from approximately 1.55 m to 1.85 m in LH (Fig. 4(a)), relative height from the regular water surface to the top of mound is recommended around 0.2 - 0.3 m and it should be submerged regularly. This geomorphological feature of the mound and water operation systems would enable *A. corniculatum* to propagate and expand its distribution area by itself and *Acanthus* spp. to be recruited on the higher land. Therefore, mixture of plantation approach and ecological restoration approach; planting minimum number of *S. caseolaris* and *A. corniculatum* and ecological restoration to form mangrove habitat is proposed (Lewis, 1999).

4.2 Sedimentation effects

SRs in *A. corniculatum* and *Acanthus* sp. populations per one tide fluctuation are 13.2 ± 2.9 g m^{-2} h^{-1} and 13.0 ± 4.4 g m^{-2} h^{-1}, respectively. The previous study (Santen et al., 2007) at Ba Lat estuary of the Red River, Vietnam reported the amount of sediments collected by the traps in the *A. corniculatum* pioneer

Table 1. Species occurring in the transects: number, density, height and diameter

Species	Growth stage	n	Density (m^{-2})	Height (m)†	Diameter (m)§
S. caseolaris	Seedlings/saplings	13	0.04	1.62 ± 0.13	0.04 ± 0.01
	Trees	2	0.01	3.88 ± 1.03	0.32 ± 0.08
	Total	15	0.04	–	–
A. corniculatum	Seedlings/saplings	22	0.06	0.86 ± 0.06	0.07 ± 0.03
	Trees	3	0.01	1.41 ± 0.09	0.17 ± 0.08
	Total	25	0.07	–	–
Derris trifoliata	Seedlings/saplings	1	0.00	1.11	–

† Height was measured except for 30 cm > height; § Diameter was measured except for 1 cm > diameter

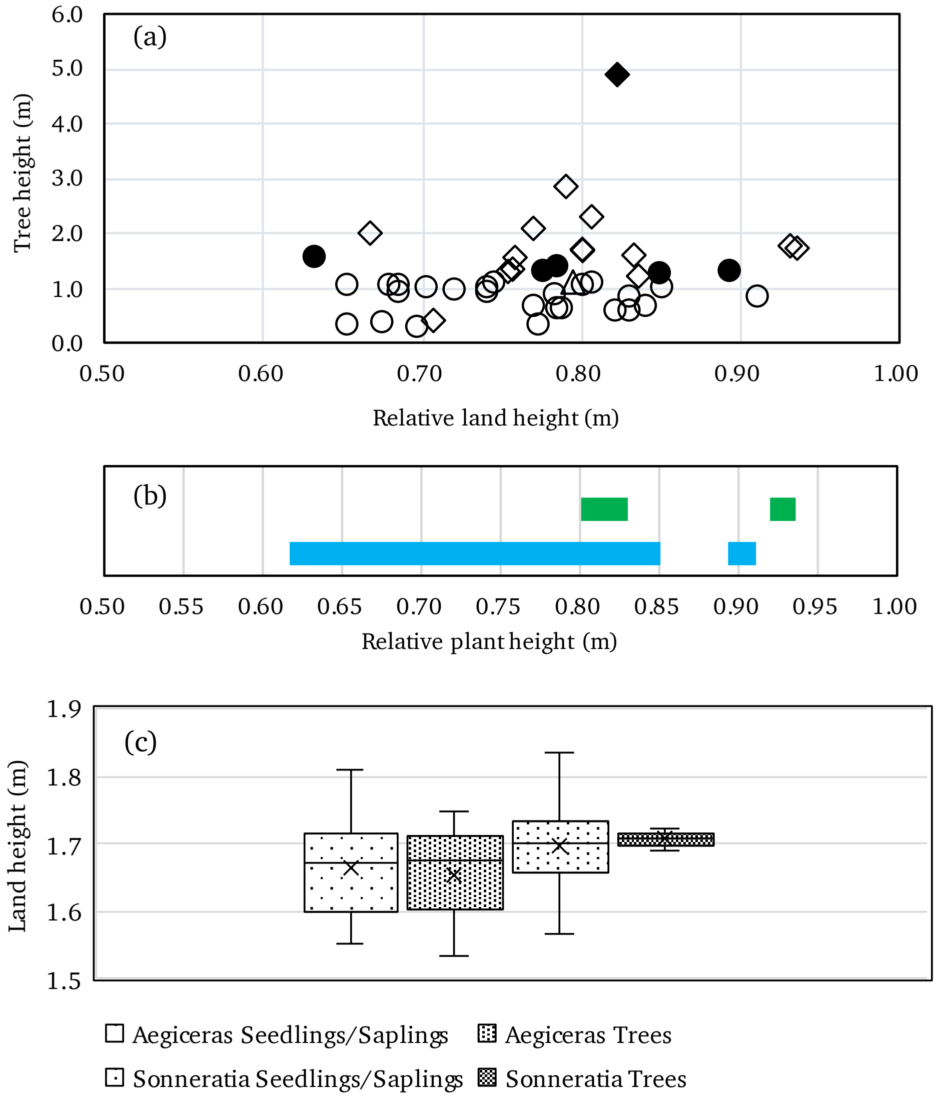

Figure 4. Land height distribution of component species of the *S. caseolaris* stand. (a) Tree height vs. LH, diamond, circle and triangle indicate *S. caseolaris*, *A. corniculatum* and *D. trifolinata*, respectively, white and black indicate seedlings/saplings and trees, respectively. (b) Distribution range of *Acanthus* spp. (green bar) and *C. malaccensis* (blue bar); and (c) Box plot on LH for *S. caseolaris* and *A. corniculatum*.

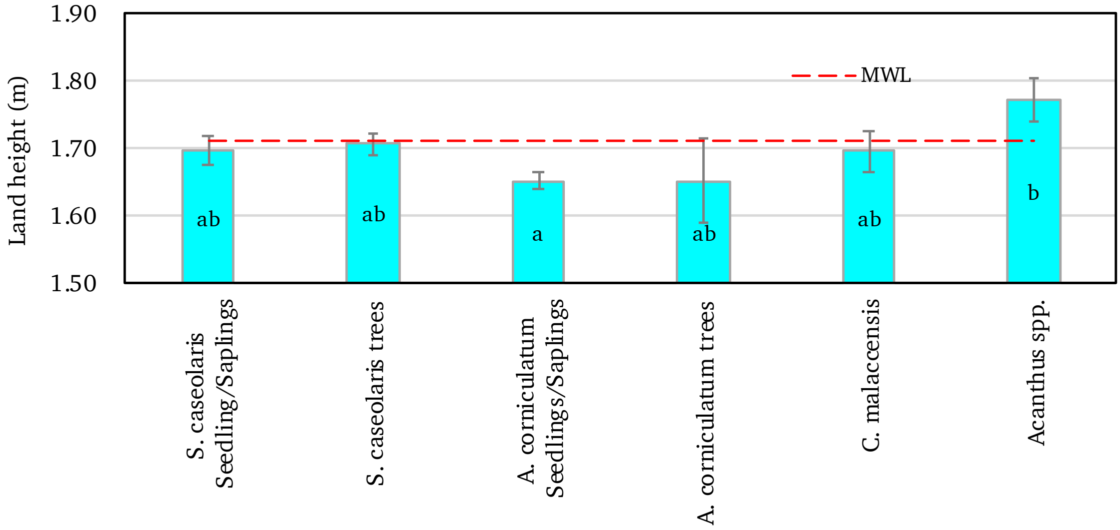

Figure 5. Comparison of species in land height (average ± SE). Alphabets denoted above SE bars indicate differences. *Acanthus* spp. in LH is significantly higher than *A. corniculatum* (seedlings/saplings) ($p < 0.05$). Red dotted line indicates MWL

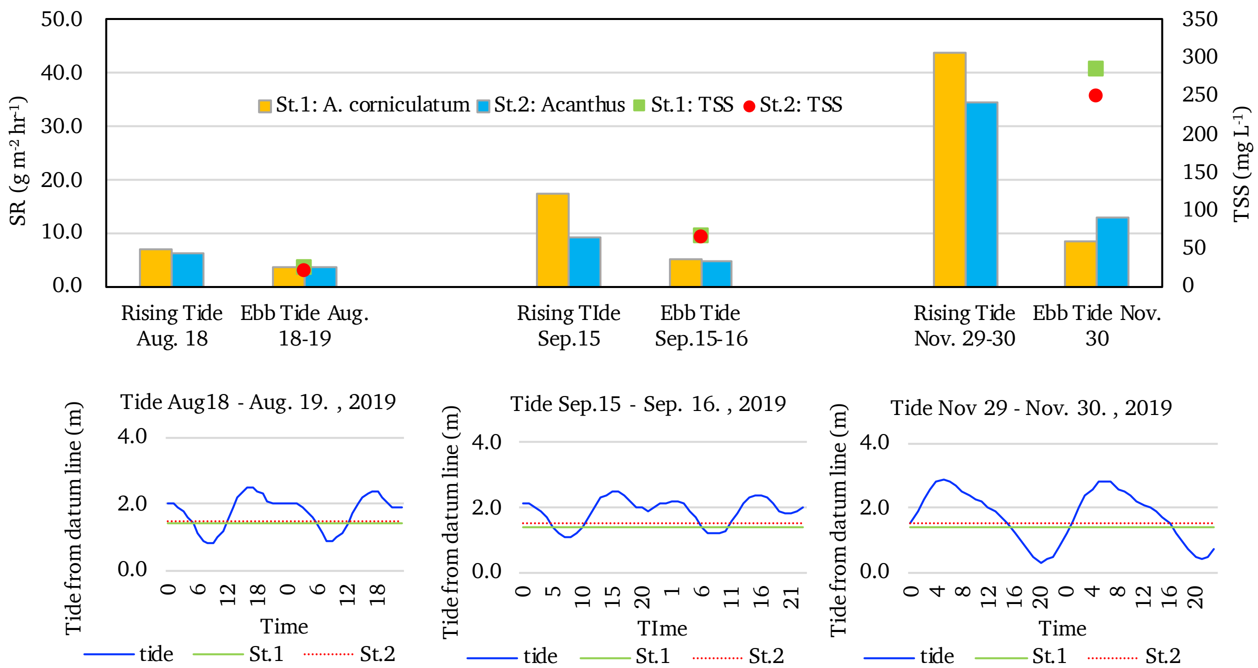

Figure 6. Sedimentation rates, TSS and tide fluctuation. (a) [top] Sedimentation rates and TSS, St.1 is inundated over 1.40 m in LH (1.20 m in LH + 0.20 m in trap height), St.2 is inundated over 1.50 m in LH (1.30 m in LH + 0.20 m in trap height); (b) Tide fluctuation chart on Aug. 18-19 [bottom-left], Sep. 15-16 [bottom-middle], and Nov. 29-30, 2019 [bottom-right].

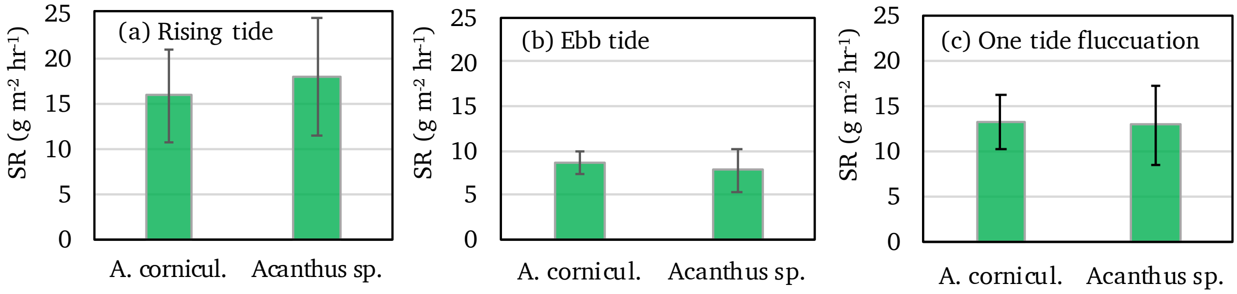

Figure 7. Sedimentation rates (average ± SE) at St.1 (*A. corniculatum*) and St. 2 (*Acanthus* sp.). (a) Comparison of SR at rising tide between St.1 and St.2; (b) Comparison of SR at ebb tide between St.1 and St. 2; and (c) Comparison of SR at rising tide and ebb tide between St. 1 and St.2

stand and the *A. corniculatum* (75%) with *Acanthus ilicifolius* (20%) stand in rainy season. They are from 25.7 g m^{-2} h^{-1} to 66.1 g m^{-2} h^{-1} and from 1.0 g m^{-2} h^{-1} to 6.8 g m^{-2} h^{-1}, respectively. It ranges widely and the figures in this study are in between them. The previous study reported, at the same time, one order smaller figures of long-term sedimentation by means of core sample observation; from 0.27 g m^{-2} h^{-1} to 0.35 g m^{-2} h^{-1} (Santen et al., 2007). Difference in these two figures might attribute to consideration without flushing out of sediments after sedimentation in the former case. SRs in this study are gross amount of sediments trapped, not considered resuspension and flushing out of sediments. Therefore, further study on actual sediment retention rates is needed to evaluate reduction of pollutant loads in the shrimp-culture ponds.

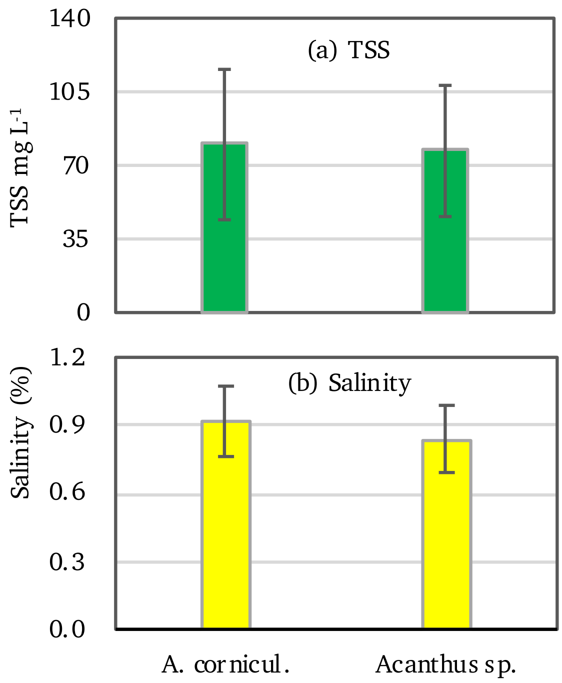

Figure 8. TSS and salinity (average ± SE). (a) TSS; (b) salinity of St.1 (*A. corniculatum*) and St.2 (*Acanthus* sp.)

Previous studies reported that herbaceous species such as salt marsh grasses tend to trap more sediments than woody mangrove species (Willemsen et al., 2016), but SRs of *Acanthus* sp. are not different from those of *A. corniculatum* in the study site. Sediment trapping is caused by hydraulic mechanism; changing current velocity and directly caught by vegetation (Willemsen et al., 2016). *Acanthus* sp. have a hard stem, thus both *Acanthus* sp. and *A. corniculatum* probably affect hydraulic conditions in the same way when they are submerged. *S. caseolaris* is tall tree up to 15 m with pneumatophore (Tomlinson, 1986). It is a canopy forming species, thus, tree density is much smaller than that of *A. corniculatum* (*S. caseolaris*; 0.04 indv. m^{-2}, *A. corniculatum*; 0.07 indv. m^{-2} in the study site; Table 1). When it is matured it develops pneumatophores, which are effective to trap sediments (Bird and Barson, 1977), but it does not have many pneumatophores emerged at younger growth stage. Therefore, considering sedimentation effect under canopy species; *A. corniculatum* and *Acanthus* sp. are required at early stage of restoration.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Ahmed N, Thompson S, Glaser M. 2018. Integrated mangrove-shrimp cultivation: Potential for blue carbon sequestration. Ambio 47:441–452. doi: 10.1007/s13280-017-0946-2.

Ashton E. 2008. The impact of shrimp farming on mangrove ecosystems. Perspective in agriculture, veterinary science, nutrition and natural resources 3. doi: 10.1079/PAVSNNR20083003.

Averyanov L, Cribb P, Loc P, Hiep N. 2003. Climate zone. In: Dickerson SE (Ed), Slipper orchids of Vietnam. Compass Press Limited, Kingston Upon Thames, UK.

Batcheler C, Craib D. 1985. A variable area plot method for assessment of forest condition and trend. New Zealand Journal of Ecology 8:55–84.

Bird E, Barson M. 1977. Measurement of physiographic changes on mangrove-friend estuaries and coastlines. Marine Research in Indonesia 18:73–80.

Chen H, Xu B, Wei S, Zhang L, Zhou H, Lin Y. 2016. Nutrient resorption and phenolics concentration associated with leaf senescence of the subtropical mangrove *Aegiceras corniculatum*: implications for nutrient conservation. Forests 7:290. doi: 10.3390/f7110290.

Clarke P. 1995. The population dynamics of the mangrove shrub *Aegiceras corniculatum* (Myrsinaceae): fecundity, dispersal, establishment and population structure. Proceedings of the Linnean Society of New South Wales 115:35–44.

Clough B, Johnston D, Xuan T, Phillips M. 2002. A Description of systems and management practices. In: Silvofishery farming systems in Cau Mau province, Vietnam. World Bank, Network of Aquaculture Centres in Asia-Pacific, World Wildlife Fund and Food and Agriculture Organization of the United Nations Consortium Program on Shrimp Farming and the Environment, Vietnam.

De Graaf G, Xuan T. 1998. Extensive shrimp farming, mangrove clearance and marine fisheries in the southern provinces of Vietnam. Mangroves and Salt Marshes 2:159–166. doi: 10.1023/A:1009975210487.

Duke M. 2006. Australia's mangrove. Queensland: The University of Queensland.

FAO. 2008. Loss of Mangroves Alarming. http://www.fao.org/newsroom/en/news/2008/1000776/index.html. Accessed 21 November 2019.

Fitzgerald WJ. 2002. Silvofisheries: integrated mangrove forest aquaculture systems. In: Ecological Aquaculture–the Evolution and the Blue Revolution. Oxford: Blackwell Science.

Furukawa K, Wolanski E. 1996. Sedimentation in mangrove forests. Mangroves and Salt Marshes 1:3–10. doi: 10.1023/A:1025973426404.

Giang P, Toshiki K, Sakata M, Kunikane S, Vinh T. 2014. Modelling climate change impacts on the seasonality of water resources in the upper Ca River watershed in Southeast Asia. The Scientific World Journal :1–14doi: 10.1155/2014/279135.

Good N, Good R. 1972. Population dynamics of tree seedlings and saplings in mature eastern hardwood forests. Torrey Botanical Club 99:172–178. doi: 10.2307/2484571.

Hastuti E, Budihastuti R. 2017. Nutrient accumulation in the sediment of silvofishery ponds in Semarang. Makara Journal of Science doi: 10.7454/mss.v21i4.6475.

IFRRCS. 2011. International federation of red cross and red crescent societies.

Jiang Z, Guan W, Xiong Y, Li M, Chen Yand Liao B. 2019. Interactive effects of intertidal elevation and light level on early growth of five mangrove species under *Sonneratia apetala* buch. Forests 10:1–13. doi: 10.3390/f10020083.

Kathiresan K. 2003. How do mangrove forests induce sedimentation? Revista de Biología Tropical 51:355–360.

Khoon G, Aksornkoae S, Tri N, Vongwattana K, Fan H, Santoso N, Barangan F, Havanond S, Sam D, Pernetta J. 2004. Shrimp farming. In: mangrove in the South China Sea. UNEP/GEF Project Coordinating Unit, United Nations Environment Programme.

Lewis LL. 1999. Key concepts in successful ecological restoration of mangrove forests. Proceedings of the TCE-Workshop No .II, Coastal Environmental Mangrove/Wetland Ecosystems.

OC. 2019. Cua Hoi. In: Quanng DN (Ed), Tide Tables 2019. Center for Oceanography, Hanoi, Vietnam.

Phuong V. 2014a. Geographical distribution of mangrove forest in Vietnam. National report on mangroves in South China Sea Vietnam. Research Centre for Forest Ecology and Environment (RCFEE), Hanoi, Vietnam.

Phuong V. 2014b. Species distribution and formation. National report on mangroves in South China Sea Vietnam. Research Centre for Forest Ecology and Environment (RCFEE), Hanoi, Vietnam.

Santen P, Augustinus P, Janssen-Stelder B, Quartel S, Tri N. 2007. Sedimentation in an estuarine mangrove system. Journal of Asian Earth Sciences 29:566–575. doi: 10.1016/j.jseaes.2006.05.011.

Takahashi K, Tuyen T, Linh N, Tu S. 2019. In press. Study on stand structure of secondary mangrove forest; *Sonneratia caseolaris* – *Aegiceras corniculatum* stand for introducing silvofishery systems to shrimp-culture ponds [In Press]. Proceedings of International Conference on Economy Development Ecosystem Sustainable, Hanoi, Vietnam.

Takashima F. 2000. Silvofishery: an aquaculture system harmonized with the environment. In: Primavera JH, Garcia LMG, Castaños MT, Surtida, MB (Eds), Mangrove-Friendly Aquaculture: Proceedings of the Workshop on Mangrove-Friendly Aquaculture. SEAFDEC Aquaculture Department, Philippines.

Thu PM, Populus J. 2007. Status and changes of mangrove forest in Mekong Delta: Case study in Tra Vinh, Vietnam. Estuarine, Coastal and Shelf Science 71:98–109. doi: 10.1016/j.ecss.2006.08.007.

Tomlinson P. 1986. The Botany of Mangroves. Cambridge University Press, Cambridge, UK.

WB. 2012. Report on Vietnam - managing natural hazards project: environmental assessment, Annex three, background on key river basins. volume 3.

Wei L, Kao SJ, Liu C. 2020. Mangrove species maintains constant nutrient resorption efficiency under eutrophic conditions. Journal of Tropical Ecology 36:36–38. doi: 10.1017/S0266467419000336.

Willemsen P, Horstman E, Borsje B, Friess D, Dohmen-Janssen C. 2016. Sensitivity of the sediment trapping capacity of an esturine mangrove forest. Geomorphology 273:189–201. doi: 10.1016/j.geomorph.2016.07.038.

WVS. 2011. Vinh City People's Committee Project Preparation Unit for Vinh Urban Development Sub-Project. In: Report on medium cities development project Vinh subproject, Environment Impact Assessment. volume 5.

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