EVALUATING ACCESSIBILITY OF SHRIMP SPECIES TO MANGROVE FOREST USING GIS AND REMOTE SENSING

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ABSTRACT

Estuarine mangroves are favourite nurseries of many shrimp species. These nurseries contribute to maintaining and increasing marine shrimp population that provides important wild broodstock for shrimp hatching and aquaculture industry. To utilize their favourite nurseries, shrimps need to access to mangrove areas. Therefore, shrimps' accessibility to mangrove plays important role in enabling shrimps to benefit from mangrove nurseries. For this reason, shrimps accessibility to mangrove is the focus of this study. Literature review was used to define the main influencing factors on shrimps' accessibility to mangrove that are hydrological factors and geographical factors. Hydrological factors are inundation patterns and current velocity. Geographical factors are surface elevation, mangrove-water interface, mangrove area and relative location to waterway system. They all in different ways and amplitudes affect on passively movement of shrimps that follows tidal water current. Accessibility of shrimps to mangrove forest can be considered as the potential that tidal water can flow into mangrove swamp. The conceptual model was built at two different levels of which the boundary, the space – time scale of the model, main components and their major sub-influence factors were defined. To apply the conceptual model, the mathematical model integrated with GIS is built to assess shrimp accessibility to mangrove using shrimp density as a quantitative measure. GIS and Remote Sensing data are employed in cartographic modelling which is a combination of map layers of variables to derive final result of shrimp density for each mangrove patch in Ngoc Hien district, Ca Mau province, Viet Nam. The model can properly operate. The results can be explained according to input data. Further studies are needed to calibrate and validate the model. Extending the model for larger space-time scale evaluation is also recommended.

1. INTRODUCTION

Mangroves are important nursery areas for prawns and fishes that have high commercial value amongst other marine species (Vance *et al.*, 1996). According to Phan and Hoang (1993), many high economic shrimp species were found in mangrove forest in Ca Mau Peninsula (e.g. Fanneropenaeus indicus, Metapenaeus ensis, Metapenaeus brevicornis and Penaeus monodon). During the life cycle of shrimp species, ability of survival in the early life stage is the most critical factor that influences the productivity of shrimp fisheries later on. Consequently, mangroves play a beneficial role in maintaining shrimp population. To make use of mangrove forest, the first important condition is that shrimp species can easily access to mangrove swamps.

The ability to enter the mangroves is very important for shrimps to utilize mangrove swamps as their nurseries. The other way round, mangroves are evaluated as valuable nurseries when they can be accessed and utilized. Evaluating the accessibility is, therefore partly evaluating nursery value of mangroves. Which factors can be the constraints of shrimps' accessibility to mangrove forest for utilizing their favourite nurseries? How to evaluate this accessibility? Although entire answers to these questions have not been fulfilled,

some studies (e.g. Browder *et al.*, 1989; Beck *et al.*, 2001; Manson *et al.*, 2005; Meynecke *et al.*, 2008; etc.) have recently taken this issue into consideration, although not all are particular for shrimp species and mangroves but for estuarine habitats and fisheries in general. However, evaluating the accessibility of shrimp species to the mangrove forest under impacts of environmental factors has not been fully investigated yet. Therefore, the focus of this study is placed on trying to draw out the general picture of primary constraints and their effects on shrimps' accessibility. The first necessary step is developing a generic conceptual model for evaluating accessibility of shrimp species to mangroves during the tidal inundation of the forest by the way of channels and rivers. GIS and Remote Sensing data have showed high potential not only for identifying, monitoring and detecting changes in mangrove forest over space and time but also for coastal zone and fisheries management in general (Bartlett and Jennifer, 2005). Answering the question whether it is practical to make use of GIS and Remote Sensing data to evaluate the ability of shrimps to enter mangrove swamps is also the main target of this study.

2. RESEARCH METHOD

Intensive literature review was carried out to identify the main environment factors that were recognised to have major influences on the accessibility of shrimp species to the estuarine mangroves. Based on the outcomes from literature review, the conceptual model was built at two different levels of which the boundary, the space – time scale of the model, main components and their major sub-influence factors were defined. To develop the conceptual model, these steps were followed (Fischenich, 2008): i. Defining model boundaries; ii. Identifying main components of model; iii. Defining entities of model components; iv. Describing mutual relationship amongst entities in model components and among model components; v. Explaining underpinning assumptions and limitations of the model.

To apply the conceptual model, the mathematical model integrated with GIS was developed using shrimp density as quantitative measuring variable. GIS and Remote sensing data, i.e. SPOT-5 satellite imagery at 5 meters resolution, were employed in cartographic modelling that is a combination of map layers of variables to derive final result of shrimp density for each mangrove patch.

3. CASE STUDY

The chosen test site is a small mangrove forest along the coastline of Ngoc Hien district, Ca Mau province in the Vietnam Mekong Delta (Figure 1). Ngoc Hien district is the southernmost district of Ca Mau province. The district covers an area of 743 km². The test site is located in the southeast of Ngoc Hien district and is enclosed by rivers in the Northwest and by the sea in the East. This area is characterized with dense canal and creek systems and mangrove forest cover. As topography of rivers and channels' bases in Ca Mau coastal areas have low slopes, tide water can come far into inland water way system (Doan *et al.*, 2005). Besides effects of rainfall and fresh water flow from rivers, water level of inland water way systems in Ca Mau Peninsula is mainly affected by tidal regime from both East China Sea and West China Sea of which tides from the East Sea strongly influence water level in the test site.

Figure 1: Test site

4. RESULTS & DISCUSSION

4.1 Influencing factors on shrimp accessibility to mangroves

In this study, shrimps' accessibility to the mangroves is defined as both the ability that young shrimps can enter the mangroves and the ability that sub-adult shrimps can move out of the mangroves. Few studies about the correlation between accessibility and shrimp productivity from different areas in the world imply its important role (Zimmerman *et al.*, 2000) and conclude that accessibility has positive correlation with marine shrimp catching productivity. The density of post larvae in mangrove water, in turn, depends on two other factors: the habitat that young shrimps favour and the accessibility (Figure 2). In the other way round, value of nursery area can be evaluated based on two main factors that are accessibility and utility (Beck, 2001).

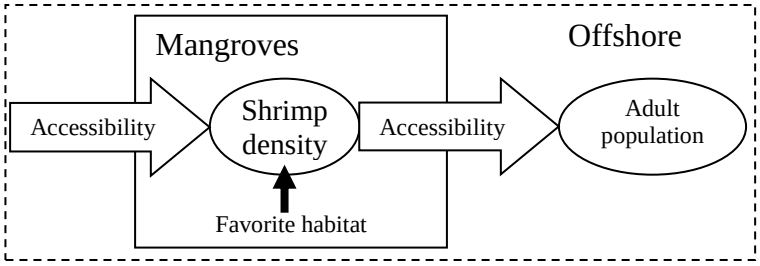

Figure 2: Influence of accessibility on young shrimps' density in mangroves and adult population offshore.

From literature review, the main influencing factors on shrimps' accessibility to the mangroves are hydrological factors and geographical factors (Table 1). Hydrological factors are inundation patterns and current velocity. Geographical factors are surface elevation, mangrove – water interface, mangrove area and relative location to waterway system.

Table 1: Influence factors on shrimp's accessibility to mangroves.

Influencing factors	References
Amount of edge habitat (intersection between vegetation and water), local pattern of inundation and shrimp movement pattern	(Roth *et al.*, 2008)
Hydrodynamic processes, depth and duration of tidal inundation	(Manson *et al.*, 2005)

Influencing factors	References
Tidal channel network, tidal regime, current velocity and landscape structure	(Simenstad *et al.*, 2000)
Tidal flooding patterns, amount of marsh/water edge and extent of connections between marsh systems and the sea	(Zimmerman *et al.*, 2000)
Water level at tidal creeks	(Meynecke *et al.*, 2008)
Local topography and water current	(Vance *et al.*, 2002)

4.2 Conceptual model for evaluating shrimp accessibility to the mangroves

Main assumption for developing a conceptual model in this study is that the movement of shrimps to mangroves, especially young shrimps, is completely dependent on tidal current. Movement here is the motion of school of shrimps in general, no individual movement was considered. The conceptual model was designed at two levels:

- Level 1 (Figure 3) is general to define the boundaries of model within the overall system and space - time scale of the model.

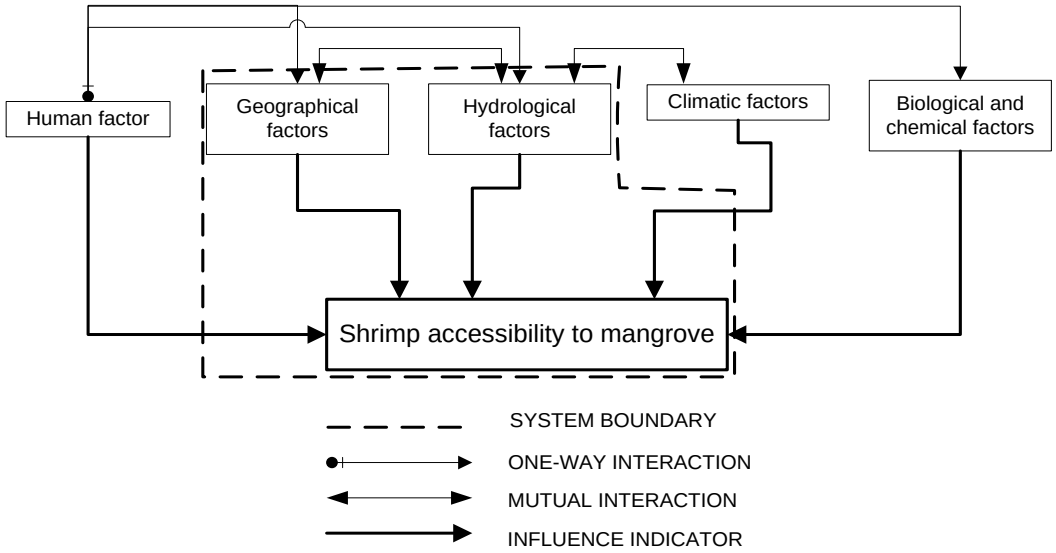

Figure 3: Generic conceptual model at Level 1

- Level 2 (Figure 4) elaborates main entities of the components within the defined boundary and their interactions, taking into account influencing hydrological and geological factors. For a short time assessment, these factors were classified into static factors (geographical factors) and dynamic factors (hydrological factors).

4.3 Results from the case study

The mathematical model for estimating shrimp density of each mangrove patch under the influences of the defined factors in the test site was defined as in equation 1:

$$SD_{(A,t)} = \frac{\mu \times MSD}{A} \times \int_{FA(t)} IE \times IL \qquad (1)$$

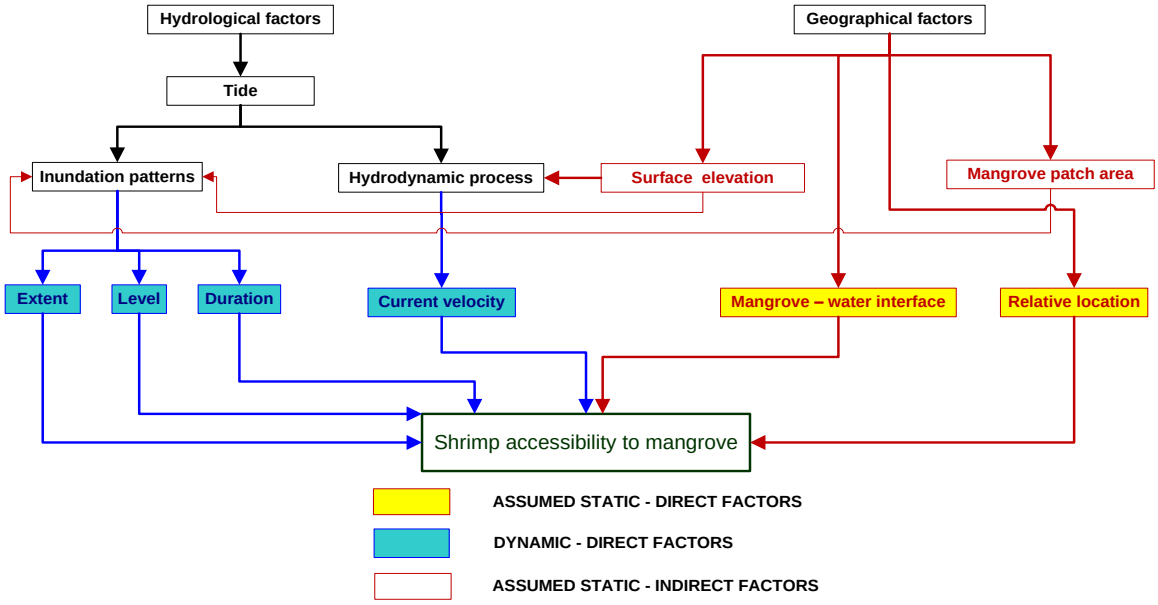

Figure 4: Generic conceptual model at Level 2

Where: SD is density of shrimp per unit mangrove area (kg or number of shrimps/m^2); A is area of mangrove patch (m^2); t is time factor; MSD is average density of shrimp per unit of volume water that is considered as a constant value for the whole test site (kg or number of shrimps/m^3); μ is a constant accounting for influence of relative location factor on mean shrimp density per unit volume of water in each mangrove patch; FA is flooded area in mangrove patch (m^2); IE: inundation extent per cell (m^2); IL: inundation level per cell (m).

The main inputs for the mathematical model were digital elevation, land use map, water level, map of waterway system and MSD = 2 shrimps/m^3. Figure 5 shows the results of running the model at six different tidal water levels: TWL (cm) = {90, 150, 200, 250, 350, 380}.

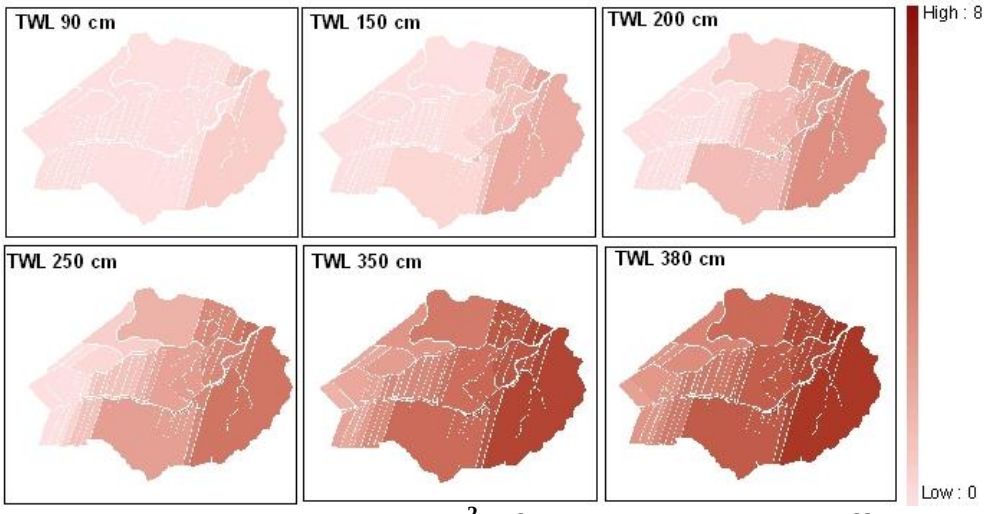

Figure 5: Shrimp density (shrimps/m^2) of mangrove patches at different TWL

The TWL is affected by the surface elevation and inundation patterns. Shrimp density in all mangrove patches decreases further inland and increases when TWL increases. This means that accessibility of shrimps to the mangroves increases with increasing tidal amplitude and with decreasing relative distance between the mangroves and the sea.

5. CONCLUSIONS

This study identifies the main influencing factors on shrimps' accessibility to mangrove that are hydrological factors and geographical factors. The conceptual model for evaluating shrimp accessibility to mangrove forest was developed and elaborated. The application of this conceptual model to a real case study shows that the model can properly operate and the results can be explained according to model inputs. It also indicates that GIS and RS data can be beneficial in evaluating shrimps' accessibility to the mangroves. The scope of using the model is recommended only for preliminary, rough and general evaluation. Further studies are needed to calibrate and validate the model. Extending the model for larger space-time scale evaluation is also recommended.

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