Research article

The Impact of *Mimosa pigra* on Local Livelihood in the Stung Sen Core Area, Tonle Sap Biosphere Reserve

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Abstract The Stung Sen Core Area is situated at the southeastern end of the Tonle Sap Lake, and comprises an area of 6,355 ha. It was created under the Royal Decree on the establishment of the Tonle Sap Biosphere Reserve (TSBR), dated 10 April 2001, and aims to protect unique evergreen riverine forests and associated vegetation assemblages. Stung Sen is the buffer zone of the three core zones within the TSBR, and provides the most important inland wetland in Southeast Asia, both for biodiversity conservation and for livelihoods based on the harvesting of aquatic resources and agricultural farming in the surrounding areas. This core area has been interrupted by an invasive alien plant, namely *Mimosa pigra (M. pigra)*, which has had significant physical and economic impacts upon the natural habitat, local community livelihoods, animals and plants, human health, jobs and the ecosystem. This study discusses the negative impacts of the invasive *M. pigra* on local livelihoods. It uses economic analysis to calculate the cost of its impact and the cost for recovery; and then provides recommendations on how these impacts can be mitigated. The distribution of *M. pigra* in core areas has been mapped, and only those areas, which have a high-density of *M. pigra*, are identified for economic analysis in this study. Face to face interviews were carried out with local authorities, rangers, community members, and farmers within the Stung Sen Core Area, Phat Sonday District. The data analysis is focused on the impact on farming land, fishing yields, local income generation, and natural habitat distruction. This paper is developed on the basis of the results of a pilot site experiment on methods of removing *M. pigra* to explore the best option for mitigating the spread of *M. pigra*, and removing existing *M. pigra* from the Stung Sen core area.

Keywords *Mimosa pigra*, impact, local livelihood, Stung Sen Core Area, Cambodia

INTRODUCTION

Invasive alien species (IAS) is non-indigenous plant, animal and microorganism that have been delivered or accidentally introduced into new areas beyond their native ranges by people, or as a result of their activities; as well as through natural means such as wind, water, or animal movement, and which then spreads, impacting negatively on the biodiversity, the ecosystem and economic development (Chornesky and Randall, 2003). *Mimosa pigra* is a thorny invasive alien plant which originates from tropical South and Central America and has been spreading into all tropical regions (Heard, 2009). Richard (2007) indicated that *M. pigra* is a branched prickly bush that can grow up to 6 meters and can withstand low nutrient levels and a wide range of soil types. *M. pigra* has invaded and subsequently become invasive across Southeast Asian countries. It is one of the most common invasive species found in Cambodia, and it spreads through many parts of wetland areas, lakes and river edges, canals, ponds, floodplains and wherever water flows with its seeds.

The Royal Government of the Kingdom of Cambodia (RGKC) recognizes the Tonle Sap and Mekong rivers as priority inland water ecosystems for management due to their significant role in food security and agricultural productivity (NBSR, 2016). The Tonle Sap is a primary source for jobs and incomes and around 3 million people live on or beside it. Approximately 750,000 people live in the flooded villages, 40% of them live on the floodplains, with the remainder living dependently on the lake (Mak, 2005). The priority occupation for those living on or beside the Tonle Sap is fishing, either as a whole family business or on a smaller scale.

Stung Sen Core Area (SSCA) is one among many core areas of the Biosphere Reserve located in Kampong Thom Province on the lower part of the Stung Sen. Stung Sen River receives water from 3 major sources: 57% from the Mekong mainstream, (52% through the Tonle Sap River, and 5% from overland flooding), 30% from tributaries of Tonle Sap Lake, and 13% from direct precipitation (Kosal, 2011). A population of 5,252, equals to 1,164 households is living in the SSCA, and their major incomes are from fisheries and seasonal vegetable farming. However, the change in land use in the region, in particular an increase in rice cropping, has been a significant factor in the spread of *M. pigra*, with neglected or abandoned fields being particularly susceptible to invasion. Recently, the major pathway and spread of *M. pigra* surrounding the Tonle Sap Lake, especially within the SSCA, has resulted in negative impacts on the biodiversity, the ecosystem, agriculture, socio-economic, health, and other economic activities. Therefore, this study explores the negative impact of *M. pigra* on local livelihoods and the ecosystem in SSCA.

OBJECTIVE

This study aims to assess and analyse the methodologies and strategies for interrupting and eliminating the negative impacts of *M. pigra* that are harming the economic growth of local communities. The study also aims to introduce applicable methods to remove barriers to invasive species management in the production and protection of wetland ecosystems in Cambodia; with the ultimate goal of enhancing biodiversity conservation and management within protected areas through local livelihood improvements.

METHODOLOGY

Data and information about the *M. pigra* in SSCA and around the Lower Mekong Basin (Fig.1) was mainly collected through conducting face-to-face interviews with 80 key local authority representatives, community members, rangers and the director and deputy director of the SSCA.

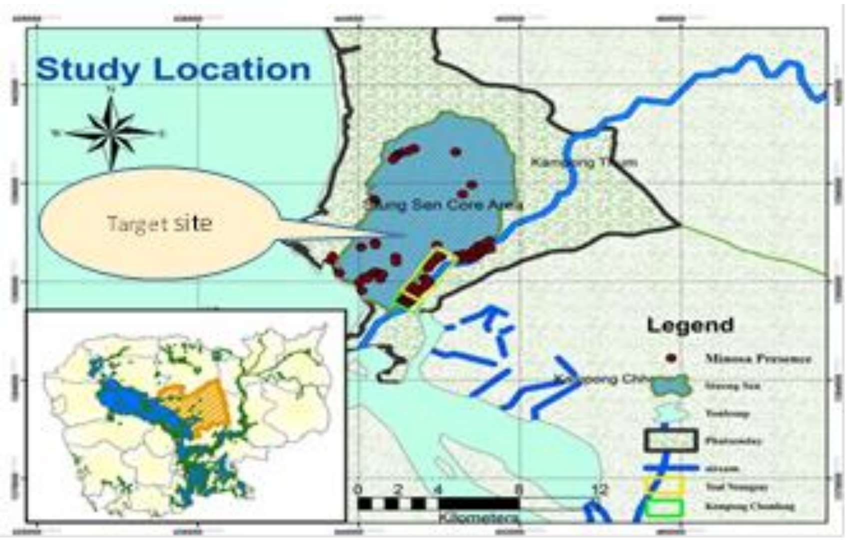


Fig. 1 *M. pigra* distribution map in SSCA

The consultation process for selecting these specific stakeholders was underpinned by this study. Survey questionnaires and interview questions were developed to focus on the status of *M.*

pigra and its distribution, the socio-economic impact, local income generation and the impact of *M. pigra* on that. Best practice and/or methods used by the local community to prevent/remove *M. pigra* was also taken into account. The secondary data collection focused on previous or similar projects from scientific publications, case studies, relevant literature, the media, books, websites, documents and other related publications, and was used to support or confirm the findings of this study. A distribution map of *M. pigra* within the SSCA was produced according to data obtained from GPS The dataset on the income generation status and land occupancy by *M. pigra* was utilized to assist analysis of the negative impacts on socio economics and natural habitats in the SSCA. The study also draws upon experimental results from existing projects for policy recommendation on methods to remove *M. pigra*.

RESULTS

Distribution of *M. pigra*

M. pigra has encroached into Cambodia for decades from its neighboring countries. It was originally considered to be a wild plant and was introduced from Indonesia to Thailand for controlling riverbank erosion, covering tobacco crops, and producing natural fertilizer (Napompeth & Wara, 1983). In 1949, the *M. pigra* was found in northern Thailand and had spread into Vietnam, most likely before 1970 (Thi et al., 2004); it continued its advance into Long An province by 1979 (Triet et al., 2004). The weed spread into Cambodia from 1980 around the Tonle Sap Great Lake and especially along the Mekong Rivers where it occupied thousands of hectares of flooded wetlands and abandoned fields (Samouth, 2004). Around 1997, *M. pigra* had encroached into many provinces of Cambodia, including Steung Treng, Kratie, Kampong Cham, Kandal, Kampong Chhnang, Kampong Thom, Pursat, Battambang, Siem Reap, Prey Veng, Svay Rieng, Takeo and some parts of Kampong Speu (GSSD, 2013). Fig. 1 shows the distribution of *M.pigra* within the SSCA, however the target site for this study is Phat Sonday Commune in Kampong Thom Provine, which has a high density of *M. pigra*.

Socio Economics and Income Generation in the SSCA

According to the field interviews with 80 families in the SSCA and 90 families in Phat Sonday Commune, their major income is earned from the fisheries sector. Their secondary income is based on farming the surrounding SSCA (Table 1).

Table 1 Occupation and income generation

Major Income of Phat Sonday/SSCA			Occupation of Phat Sonday/SSCA		
Source	No. of family	Percent (%)	Occupation	No. of family	Percent (%)
Fisheries	53	66	Fisherman	48	53
Farmer	17	21	Farmer	34	38
Animal husbandry	3	4	Animal husbandry	5	6
Other	7	9	Other	3	3
Total	80	100	Total	90	100

Impact Analysis of *M. pigra*

Table 1 shows that more than 50% of local income depends on fishing activities whilst the second main income comes from farming. Four major factors have been identified as reasons for the negative impact to the fisheries yields: invasive species (*M. pigra*), climate change, illegal fishing, and poisoning from chemical usage in agriculture. The results of the survey suggest that *M. pigra* has the most significant impact factor (60%), while illegal fishing is the secondary factor (20%), and climate change & poisoning present around 20% of the impact. Therefore, this section analyses the impact of *M. pigra* on local livelihoods especially in relation to incomes earned from fishing activities.

Two indicators "Time Spent" and "Income" earned from fisheries have been identified to measure the impact of *M. pigra* on local income generation. Data on both indicators "before" and "after" presentation of *M. pigra* have been collected by category. As shown in Figs. 2 and 3, "time spent" for fishing was classified into 4 categories (G_1 = 1-2 hrs, G_2 = 2-5 hrs, G_3 = 5-8 hrs, and G_4 = 8-10 hrs), and "income" received from fishing was grouped into five categories represented by C_1 = 2.5-5 \$, C_2 = 5-10 \$, C_3 = 10-20 \$, C_4 = 20-30 \$, and C_5 > 30 \$. The average income "benchmark" has been set at 17 \$ per day per fisherman in accordance with the data received from the interviews with 50 fishermen as shown in Table 2. The results in Fig. 2 clearly indicated that as *M. pigra* continued to spread, the fisherman had to engage in fishing activities for at least 7 more hours to earn an income at the benchmark level. Previously they had only needed to fish for 2-5 hrs to achieve that benchmark figure. This result is evidence that *M. pigra* has disturbed the fish habitat and its ecosystems that and has led to fish stock shortages. Fig. 3 shows the trend of local incomes from fisheries before and after *M. pigra* presented. The "before" graph represents incomes received from fisheries before *M. pigra* presented, and the "after" graph represents the post *M. pigra* situation. The "before" graph represents a high proportion of fishermen who received a good daily income of between \$15-\$25, whilst the "after" graph clearly shows quite dramatic reductions in the fishermen's incomes to between just \$5 and \$10 per day.

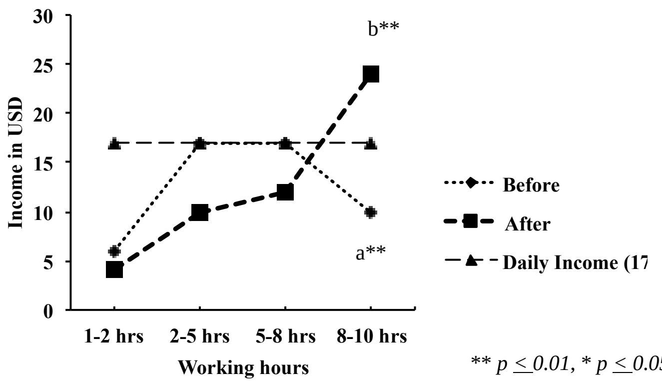
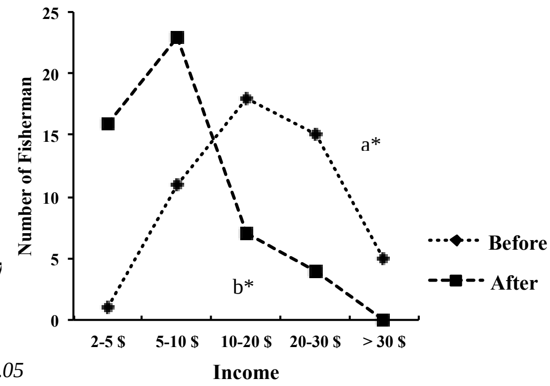


Fig. 2 Change in time spent on fishing



** $p \leq 0.01$, * $p \leq 0.05$

Fig. 3 Change in income from fishing

Table 2 Daily and annual profit loss after presentation of *M. pigra* in the SSCA

Description	Income earned from fisheries by category					Total family		Income	
	C_1=5\$	C_2=10\$	C_3=20\$	C_4=30\$	C_5=50\$	Survey	SSCA	Family	SSCA
Before (family)	1	11	18	15	5	50	1,164		
After (family)	16	23	7	4	0	50	1,164		
Daily income									
Income before	\$5	\$110	\$360	\$450	\$250	\$1,175		\$24	\$27,936.00
Income after	\$80	\$230	\$140	\$120	0	\$570		\$11	\$12,804.00
Daily and annual profit loss									
Daily income loss								\$13.00	\$15,132.00
Annual income loss								\$4,745.00	\$5,523,180.00

Table 2 shows daily and annual incomes from the fisheries sector and the profit loss of the 1,164 families in the SSCA. This figure is based on the results of the interviews with 50 selected families in the target area.

$$DI=\frac{Nf_1x + Nf_2xC_2 + Nf_xC_3 + Nf_4C_4 + Nf_{x5}C_5}{TNf} \qquad \text{Eq. (1)}$$

Where DI = daily income; Nf = Number of family/category
C = Value/category; TNf = Total number of family for survey

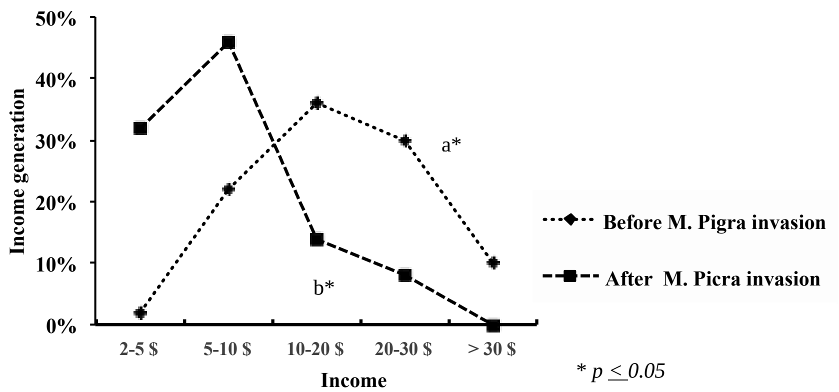


Fig. 4 Change in daily income from fishing

This assignment used the Eq. 1 to estimate local incomes in each category identified in Table 2. According to this calculation, when *M. pigra* had not yet presented, each family in around 30-35% of the total population, was able to generate a daily income of between $ 20 to $ 30; but after *M. pigra* had presented, each family in nearly half of the total population was only able to earn $ 10 per day. Therefore, each family had experienced a loss of more than 50% of their income to a rate of $ 13 per day and an overall loss of $ 4,745 annually due to the fish habitat being interrupted by *M. pigra.* In addition, the total profit loss for the SSCA amongst 1,164 families has been the huge amount of more than 5.5 million dollars annually.

RECCOMENDATIONS

Experiment and Control Methods to Remove *M. pigra*

Several methods have been applied in the developed countries to control the quick invasion of *M. pigra*, including physical controls, chemical controls, re-vegetation, and biological controls (Marko, 1999). Each method has always had its pros and cons. In Cambodia, three methods have been applied and one method is currently under assessment.

1. Physical methods: Hand clearance was the first method used by local people to deal with *M. pigra*; this included cutting stumps, uprooting seedlings and stumps, and burning them. This method was very labor intensive and thus expensive, because a significant seed store in the soil appeared and the plants would geminate in the next rainy season and re-infest the cleared areas; so more labor was required to go back and deal with the new emerging seedlings. The longer the plant was allowed to grow, the more costly it became to clear them because the plants just grew bigger which made it more difficult every time, and it took much longer to destroy them. According to the results of an experiment conducted by the biodiversity department team (BDB) of General Secretariat of the National Council for Sustainable Development (GSSD) in 2013, this form of control can only be cost effective when undertaken on a small scale.

2. Chemical methods: Foliar spraying of herbicides, specifically glyphosates, on weeds like *M. pigra* is a method that is often used in Cambodia. However, this method has been attempted within the SSCA by applying glyphosates onto the cut stumps of the plant, which is a combination technique of both physical and chemical methods. This technique is also very labor intensive but it provides significant results in terms of destroying the *M. pigra* compared to just using the physical control method alone. The chemical method is usually applied during the dry period, when bark spraying, stem injection and soil treatments are followed by burning. Unfortunately, due to the SCCA being located inside the Tonle Sap Protected Areas, herbicide usage is not recommended, and this method could provide negative impacts on the water quality and natural habitat, especially if there is over-usage of the herbicides or their use is uncontrolled.

3. Biological controls methods: Biological control is the use “Bio-Agene” to destroy the stems, flowers, leaves, seeds, or roots of M. pigra. These agents include phytophagous insects, species that attack roots, stems, leaves, flowers, and fruits, either as larvae or as adults or in both stages, and fungal pathogens. Four hundred and forty-one phytophagous insects have been found on *M. pigra* in Central and South America (Harley et al., 1995; Marko, 1999). Based on a survey report (DBD, GSSD/MoE, 2013), even though this method has been applied in Thailand and Vietnam on *M. pigra*, there is no evidence that biological controls succeed in eliminating the weed. When DBD, GSSD conducted a survey of insects in the SCCA and the 8 provinces that surround the Tonle Sap Great Lake, the results showed that different insects and larvae are damaging the stems, leaves and flowers of *M. pigra*, but there is no proof that those insects are bio-agene to *M. pigra* and this requires further research.

4. Re-vegetation methods: This is a method of rehabilitating native species or installing plantations of local vegetation in degraded land to prevent the sunlight reflecting on the buried *M. pigra* seeds. It can be rehabilitation of degraded ecosystem, plantations of fast grow vegetables and plantations of native trees. Re-vegetation produces better results with fast growing species. Part of this method includes local people using water hyacinth and water spinach to suppress new seedlings and the sprouting of *M. pigra* on their agricultural land. This practice is very common and costs less through just capturing and keeping water hyacinth and water spinach in agricultural land during the flooding season. When the water recedes, all of the trapped water hyacinth dies before it is able to spread and cover the agricultural land. People are then able to grow crops such as maize and pumpkins by cultivating small patches of the land.

Fig. 5 Re-vegetation through native plant

5. Policy recommendations: This study demonstrates that *M. pigra* negatively impacts not only on natural habitats, but also on local income generation. Although there are four methods that can be introduced to tackle the weed, very few of the methods have been effective in its complete eradication. The re-vegetation method proved to be the more feasible option for larger scale attempts to suppress and kill *M. pigra,* and this method was the least costly; while physical methods have proven to be too expensive and unsustainable. Chemical methods have been effective but have produced negative side effects and result in negative consequences on the ecosystem and water quality. In this regard, any policy recommendation should consider both short and long term solutions. Supporting and encouraging local people to continue their practice of using water hyacinth and water spinach to suppress new seedlings and the sprouting of new *M. pigra* on agricultural land can only be a short term solution to the problem. Longer term solutions should concentrate on the development of plantations and the planting of native species to rehabilitate degraded ecosystems and land.

CONCLUSION

According to the results and discussions conducted through this study, it can be concluded that the SSCA is not only rich in biodiversity, but it has contributed enormously to national and local economic growth. Each family living in Phat Sonday commune has the ability to earn around $8,760 annually from fisheries alone; and they are also able to generate an additional income from agriculture and farming the surrounding areas. Unfortunately, the SSCA has been effected by the Invasive alien species *M. pigra* which was introduced into Cambodia from 1980 and which has rapidly spread, surrounding the Tonle Sap Great Lake as well as along the Mekong Rivers. The impact of this IAS on the ecosystem and fish stock at the SSCA has led to profit losses of at least 5.5 million dollars annually; and this does not include the impact on agricultural production and farming yields. In order to respond to the rapid invasion of *M. pigra*, four methods of control have been introduced in an attempt to eradicate *M. pigra.* These have included physical controls, chemical controls, biological controls, and re-vegetation controls. Based on the geographical area of the SSCA and the limited research available on bio-agenes, chemical and biological controls are not a recommended method going forward. Therefore, only the physical and re-vegetation controls should be applied, even though the physical method can be costly and *M. pigra* is not permanently removed through utilising that method.

Aware of serious impacts from the spread of *M. pigra* to local livelihoods, ecosystems, and natural habitats, this study highlights two possible policies recommendations: 1) for the short term strategy, continue use local methods to suppress new seedlings and sprouting of *M. pigra* on agricultural land with local vegetable cover such as water hyacinth and water spinach to suppress growth; and 2) develop and implement rehabilitation programs to replant native species on abandoned agricultural land and degraded ecosystem areas as a long term strategy.

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