INTEGRATED WATER AND FIRE MANAGEMENT STRATEGY TRAM CHIM NATIONAL PARK

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INTEGRATED WATER AND FIRE MANAGEMENT STRATEGY TRAM CHIM NATIONAL PARK

EXECUTIVE SUMMARY

This document is a product of the work of an a team of international and national experts brought together by the UNDP / IUCN / MRC / GEF Mekong Wetlands Biodiversity Programme's (MWBP) to develop an Integrated Water and Fire Management Strategy for Tram Chim National Park. It addresses the following challenge currently faced by Park Management: *Management practices which have focused on reducing the risk of fire (specifically within Melaleuca) are associated with significant ecological implications which are counter to the Park's mandate.* This is compromising the success of the Park in achieving its objective to:

> *"preserve the typical ecological system of the submerged land of the Mekong River Delta, making it a national-standard model of the submerged ecological system in the enclosed Dong Thap Muoi (Plain of Reeds) flood area; to preserve unique cultural and historical values while studying, rationally exploiting the regional ecological system for the nation's interests and for contribution to the protection of the common ecological environment of the Southeast Asian region."*

The objective of the Integrated Water and Fire Management Strategy is to provide management interventions which are designed to maintain and improve the health and character of the Park's different ecosystems and habitats whilst balancing the risk of uncontrolled fire. The strategy comes at an opportune time as a five year investment plan is under development for Central Government and a new Prime Ministerial Decision on forest management provides exciting opportunities to form partnerships with local communities in order to achieve resource management objectives whilst providing benefits to local people.

The Integrated Water and Fire Management Strategy initially describes Tram Chim National Park and the original ecosystem of Plain of Reeds. It outlines the current ecosystem of the Park, its management and the impacts of current practices. Through research undertaken within the Park and targeted management interventions the MWBP Team have identified issues within the Park with respect to water levels management, hydrological processes, fire management and invasive species management. The key issues identified through this process are that:

(i) ***Water levels within the Park are maintained are elevations which are sub-optimal to many vegetation communities and that in turn ecological changes have resulted.***
(ii) ***The important role of fire within the original ecosystem of the Plain of Reeds has been largely excluded.***

Specific issues identified by the MWBP Team which are detailed in the Integrated Water and Fire Management Strategy are that:

- *Eleocharis* in particular has been negatively impacted by higher water levels within the Park in part due to the reduction in the chemical conditions conducive to this particular species which is characteristic of the original Plain of Reeds.
- *Melaleuca* forests within the Park are impacted by the high water levels which reduce growth rates and limit reproduction and in turn lead to decadent stands.
- The composition of Tram Chim's bird population has been impacted by changes in water level regimes. Species such as Sarus Cranes which favour low dry season water levels have declined. The reduction in *Eleocharis*, the favoured food of the Sarus Crane, has contributed to this decline.
- High water levels reduce the rate of decomposition of biomass (e.g. leaf litter, twigs, small branches, dead grass) contributing to its accumulation within the Park.

- Dikes surrounding the Park and adjacent to canals constructed within the Park have reduced sheetflow.
- Reduced sheetflow limits the removal of biomass from the Park and contributes to its accumulation.
- Sediment deposition is probably more isolated to areas adjacent to the water control structures within perimeter dikes surrounding the Park.
- Water chemistry has been impacted by canal and dike construction. The exposure of acid-sulphate soils on dikes has enhanced the release of acid to surface water whilst the faster water movement within the canals transports low pH water throughout the Park. Reduction in sheetflow reduces the buffering of pH provided by slow movement of water through vegetation, in particular *Melaleuca*.
- Dikes around and within the Park fragment habitat in particular for fish.
- High levels of biomass available as fuel within the Park has led to conditions conducive to high intensity fire.
- Under current management the important ecological role of fire within the Park's *Melaleuca* stands has been largely eliminated.
- The Park is subject to colonisation by invasive species, most notably *Mimosa pigra* which is resulting in habitat degradation within grassland areas.

In order to tackle these issues the Integrated Water and Fire Management Strategy proposes as series of management tools and interventions. The expected outcomes of these changes to Park Management are outlined. The proposed management tools and interventions can be summarised as follows:

Water Level Management

- The adoption of **target water levels** developed for each management zone designed to establish water level regimes which are closer to those experienced historically.

Restoration of Hydrological Processes

- The construction of **new water control structures** in the perimeter dike around Zone A1 which are designed to enhance the exchange of water between this part of the Park and the surrounding areas and in turn enhance sheet flow.
- The planting of **vegetation buffer areas** adjacent to the new water control structures in order to trap incoming sediment.
- The **removal of dikes** along the new canal in the centre of the southern section of Zone A1 in order to improve connectivity between the canal and surrounding areas and in turn enhance sheetflow.

Fire Management

- The **official recognition of fire**, including the acknowledgement of the important ecological role it played within the original Plain of Reeds, by Park Management.
- The establishment of practices to ***routinely assess fire environment indicators during the dry season*** *in* order to inform fire management decisions.
- **Continued use of prescribed burning in grassland areas** in order to reduce the numbers of grassland wildfire ignitions and enhance the ability of fire fighters to suppress wildfires.
- **Experiment with prescribed burning in *Melaleuca*** in order to explore options for decreasing the risk of uncontrolled fire by reducing fuel loading.
- **Extraction of biomass by local people** under controlled conditions in order to reduce fuel loadings. This includes simple silviculture practices in *Melaleuca* (e.g. collection of dead woody material on the ground and cutting of low dead branches) and grazing in grassland areas.
- The use of **new techniques and equipment for fire fighting** to enhance the capabilities of suppressing wildfires using prescribed burning as a fire management tool.

Invasive Species Management

- The use of targeted burning, ploughing and, where required, irrigation to **remove *Mimosa pigra* and restore *Eleocharis* grassland**.

- **The involvement of local communities in *Mimosa pigra* removal** including the harvesting of *Mimosa* plants for fodder and other uses.
- **Monitoring of invasive species and early intervention** to prevent further expansion of *Mimosa pigra* into grasslands which may become more susceptible to invasion after the implementation of the recommended lower water levels. Monitoring should also be undertaken of the invasive golden apple snail which lower water levels could help to control. The collection of these snails by local people could also contribute to the control of this species.

The Integrated Water and Fire Management Strategy outlines recommended operational data collection and monitoring activities for Tram Chim National Park required to inform day-to-day management, assess whether targets are being achieved, evaluate ecosystem responses to management interventions and further improve management as knowledge of ecosystem functioning improves. It also provides an estimated of the costs of major components of the Strategy.

INTEGRATED WATER AND FIRE MANAGEMENT STRATEGY TRAM CHIM NATIONAL PARK

CONTENTS

1. OPPORTUNITIES STATEMENT AND THE MWBP WATER AND FIRE MANAGEMENT STRATEGY

1.1. Overview

This document is a product of the work of a team of international and national experts (hereafter "the Team") brought together by the UNDP / IUCN / MRC / GEF Mekong Wetlands Biodiversity Programme's (MWBP) to develop an Integrated Water and Fire Management Strategy for Tram Chim National Park (TCNP). It addresses the following challenge currently faced by Park Management:

Management practices which have focused on reducing the risk of fire (specifically within Melaleuca) are associated with significant ecological implications which are counter to the Park's mandate.

The conclusions of the Team come at an opportune time as a five-year investment plan is under development for Central Government and Decision No. 186/2006/QD-TTg regarding the issuance of regulation on management of three forest categories (special-use forest, protection forest and production forest) provides exciting opportunities to form partnerships with local communities in order to achieve resource management objectives whilst providing benefits to local people.

The Integrated Water and Fire Management Strategy:

- Provides management interventions which address ecological problems and are designed to maintain and improve the health and character of the Park's different ecosystems and habitats whilst balancing the risk of uncontrolled fire within the Park.
- Outlines continued monitoring activities aimed at supporting Park management and providing data required to evaluate the proposed management interventions.

1.2. The MWBP Water and Fire Management Initiative

Tram Chim was identified as a demonstration site for the MWBP and a large-scale project initiated. As part of this project an integrated study on water and fire management was undertaken. During an Interim Period (March 2005-September 2006) the Team worked collaboratively to research ecosystem impacts of management practices and strengthen existing Park capacities. During this period, the Park provided logistical and technical support to the Team whilst the MWBP provided additional funding for implementation of an Interim Water and Fire Management Strategy. During the Interim Period a moratorium on further canal building was agreed between Park Management, the International Crane Foundation and IUCN. Furthermore, the Park Director informally agreed to suspend work associated with a proposed fish pond in the southeast corner of A1 until the end of the Interim Period.

During the Interim Period, two interlinked documents, the Interim Water and Fire Management Strategy, and the Interim Period Workplan, provided guidance for Park Management and the work of the Team. These documents were developed during the Inception Phase of the project (March 2005) when Park Management, Technical Staff, and the Team, interacted through a series of meetings and field observations. The Interim Strategy and Workplan were presented to and endorsed by the Provincial Authorities at a meeting held in Cao Lanh in March 2005. The Interim Water and Fire Management Strategy described management strategy and specific actions of the Park during the Interim Period. In contrast, the Interim Period Workplan (comprising an overview document and separate documents detailing individual Workplan components) focused on research and allied work of the Team during the same period and was designed to provide enhanced understanding of the ecological functioning of the Park and the constraints facing management in order to provide guidance for long-term management. The current document synthesises the results of the Workplan whilst individual document detail the outcomes of individual Workplan components.

2. TRAM CHIM NATIONAL PARK

2.1. The National Park

Tram Chim National Park covers an area of 7,588 ha in Tam Nong District, Dong Thap Province, Vietnam. In 1994 Tram Chim was decreed a National Reserve and subsequently recognized as a National Park in 1999. The mandate of the Park as stated in Decision No. 253/1998/QD-TTg of December 29 1998 is to:

> *"preserve the typical ecological system of the submerged land of the Mekong River Delta, making it a national-standard model of the submerged ecological system in the enclosed Dong Thap Muoi (Plain of Reeds) flood area; to preserve unique cultural and historical values while studying, rationally exploiting the regional ecological system for the nation's interests and for contribution to the protection of the common ecological environment of the Southeast Asian region."*

The Park is divided into five separate management zones (A1-A5 – Figure 1), each surrounded by dikes and canals totalling 53 km in length. Other canals of varying depth and width run through the management zones (for example A1 has been divided into three units by additional major canals).

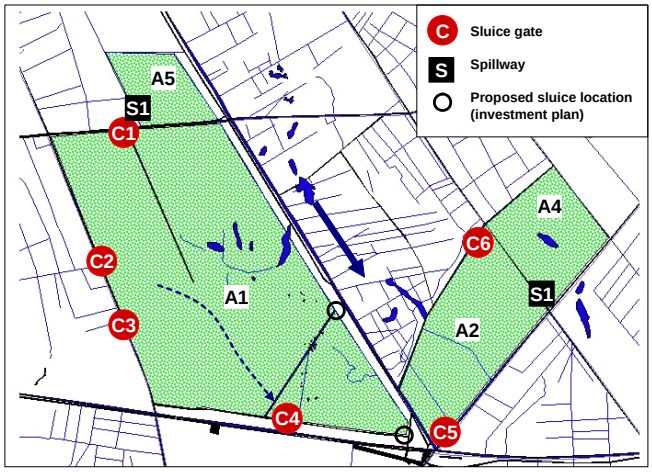


Figure 1. Tram Chim National Park: management zones and hydrological infrastructure

2.2. The Original Ecosystem of the Plain of Reeds

The original Plain of Reeds (*Dong Thap Muoi*) was an extensive (c.750,000 ha[1]) freshwater marsh within the Vietnamese Mekong Delta. The area lies within a large inland depression with a mean elevation of 1 m above mean sea level (mamsl). In common with all wetlands[2,3,4] hydrological processes were the driving force controlling the original Plain of Reeds ecosystem. Overbank flooding from the Mekong River, sheetflow originating from Cambodia and local monsoon rainfall would inundate the depression to a depth of 2-3 m[5]. Peak water levels would occur between September and November. The retardation of flow by the thick grass and reed vegetation caused the deposition of the majority of sediment so that by the time sheetflow reached the Tram Chim area sediment concentrations were low. Standing water was present for an extended period of up to seven months. When floodwaters receded, shallow water filled depressions and saturated soils were slowly depleted by evapotranspiration and natural drainage throughout the dry season. At the end of the dry season some low-lying areas remained flooded whilst elsewhere, where surface water had receded below the ground surface, topsoils were still saturated due to soil capillarity whilst thick vegetation acted as a mulch reducing evaporation. Only sandy highland ridges were completely dry. High soil moisture during the dry season prevented extensive oxidation and subsequent wide-spread acidification of the acid-sulphate soils which are characteristic of the area[6,7].

The Plain of Reeds derives its name from the extensive grasslands and reed swamps which covered the area. These are characterised by four main plant communities: *Eleocharis* spp., *Ischaemum rugosum*, *Panicum repens*, and *Oryza rufipogon* (wild rice). The distribution of these communities displays a marked gradient according to elevation (and hence flood depth and duration) with *Ischaemum* and *Panicum* usually found on "high" locations (> 0.85 m mamsl) which are drier and tend to be less acid. In contrast *Eleocharis* and *Oryza* were more dominant in lower situations (< 0.75 mamsl)[7,8] where the acid-sulphate soil layer is closer to the surface. Natural depressions tended to be flooded year round and were dominated by species such as Lotus (Figure 2). The relationship between topography and vegetation distributed is confirmed in Figure 3 which shows the topography and current vegetation distribution of Tram Chim National Park.

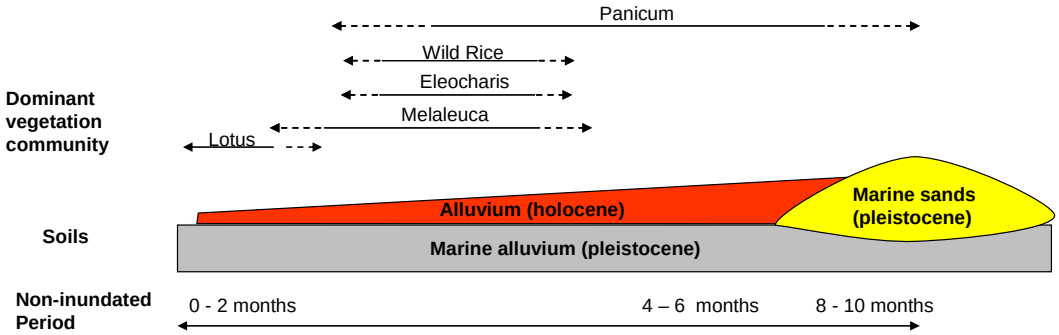


Figure 2. Distribution of dominant vegetation communities along an elevation, flood depth and duration gradient

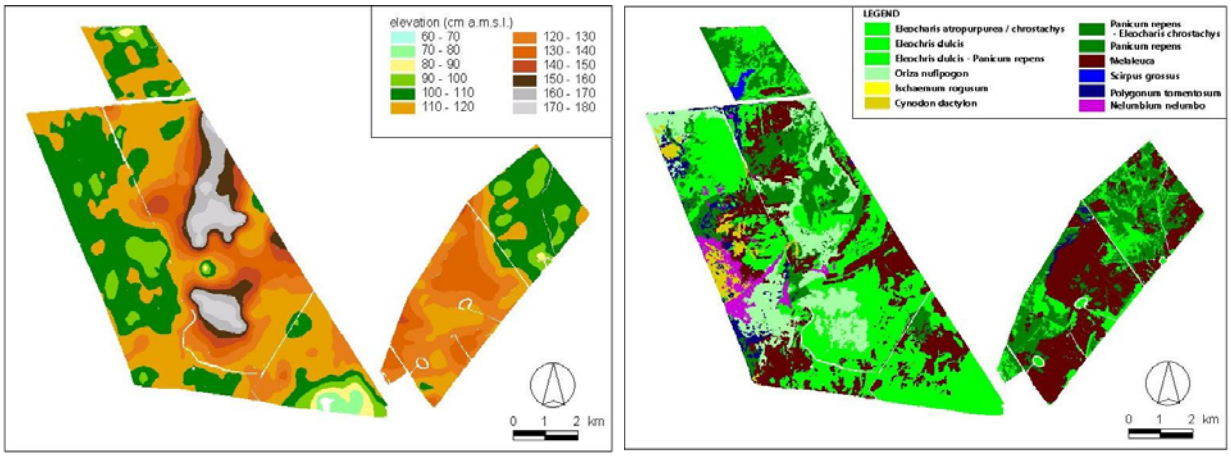


Figure 3. Topography and current vegetation community distribution within Tram Chim National Park

Folklore and older community members describe forested areas within the Plain of Reeds consisting of a number of tree species in addition to *Melaleuca*. Buried tree stumps from the genus *Eugenia* uncovered during agriculture activities corroborate this oral history[9]. Besides *Melaleuca* vegetations surveys undertaken within the Plain of Reeds in the last ten years have identified at least 80 native species of tree and shrub. The most common native tree species still found within the area include *Elaeocarpus hygrophylus*, *Nauclea orientalis*, *Baringtonia racemosa*, *Cobretum quadrangulare* and *Syzygium cumini*. Anecdotal information also reveals that anthropogenic fire in the Plain of Reeds was common. Burning was undertaken just before the onset of the wet season. This was associated with hunting as well as fishing since fires would remove impediments to fish fingerling movement during the wet season. The fire regime was frequent, low intensity fire in the forested areas that included *Melaleuca* stands, which kept biomass accumulation at low levels. *Melaleuca* has been shown to be superbly adapted to fire whilst burning favours the spread of *Melaleuca* by causing the release of vast numbers of stored seeds[9,10,11,12]. It is possible that fire also played an important role in the ecology of the grassland areas. By removing the mat of dead grass from previous seasons' growth fire can increase the competitive advantage of some species. Outside Vietnam *Eleocharis* spp. have been shown to increase their above ground standing crop two years after a burn[13,14]. Anecdotal observations of Sarus crane (*Grus antigone*) within Tram Chim

National Park indicate that feeding habitat is enhanced following a burn, presumably with increased *Eleocharis* component, their favoured food[9].

2.3. Overview of the Current Ecosystem of Tram Chim National Park

The original ecosystem of the Plain of Reeds described above has been significantly modified over the last half century. A widely employed diagram summarising the major ecological components of wetlands and their interactions[2,3] , but with the significant addition of fire (Figure 4), can be used to illustrate the nature of these modifications and the inter-relationships which are central to the functioning of the current ecosystem of Tram Chim National Park. Figure 4 shows that hydrological conditions within a wetland affects many chemical and physical wetland properties such as soil and water salinity, soil anaerobiosis, nutrient availability, pH and sediment properties such as deposition rate. Factors such as water depth and the period of inundation exert a strong influence upon wetland biotic characteristics including the composition and distribution of vegetation communities and the fauna which can be supported. Chemical and physical wetland properties also affect biotic characteristics. The substrate, including the availability of nutrients and, especially in the case of acid-sulphate soils, pH exerts a major influence upon plants as well as the range of habitat available for invertebrates, fish and other animal life. Hydrology exerts an influence upon fire. Water levels control the availability of dead fuels such as the mat of grass from previous years' growth and leaf litter and branches beneath *Melaleuca*. In addition, once water levels drop below the depth moisture is available to live grasses, the grass cures (i.e. changes from green to brown) and is more readily burnt. Meteorological factors impact the probability of ignition of fuels exposed by low water levels. Fuel characteristics and meteorological factors determine the intensity and duration of fires whilst their location and frequency are controlled by the presence of people who provide the ignition sources. In turn fire can induce a vegetation response and also release nutrients and other material.

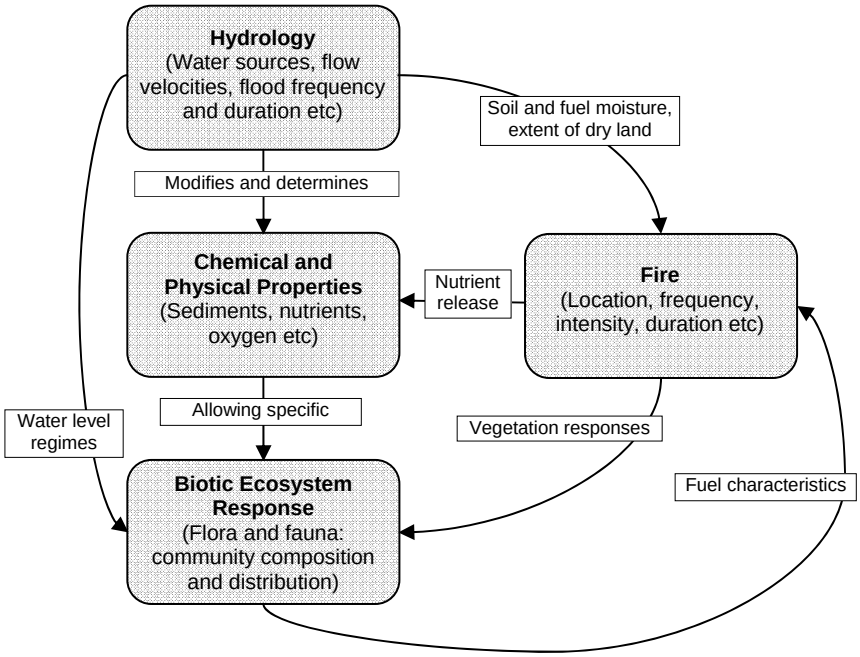


Figure 4. Plain of Reeds / Tram Chim National Park Ecosystem Component and their Inter-relationships

The inter-relationship of the different ecosystem components shown in Figure 4 means that changes in one can induce changes in others. During the conflict of the 1960s and 1970s a large network of canals was excavated across the Plain of Reeds to lower wetland water tables. This enhanced drainage altered the hydrological regime resulting in the desiccation of native vegetation whilst the incidence of high intensity fires increased[1]. Lower water levels within formerly waterlogged soils enhanced oxidation and hydrolysis lowering pH (pH < 3) and releasing toxic concentrations of iron and aluminium ions[1,6]. The result of these changes was the collapse of the complex food-web supported by the extensive wetland with negative implications for ecological systems and local human populations[1].

In response to these changes and as the human population of the Plain of Reeds increased, the dikes and canals around the management zones of Tram Chim National Park (then a nature reserve) were

constructed in order to retain water. This was initially successful but the isolation of the area within the dikes from the surrounding area and in particular the Mekong River floodwaters had a number of negative impacts. Subsequently, and following long-term collaboration with the International Crane Foundation (ICF), various water control techniques (sluices in Zones A1 and A2, sand-bag barriers and isolated dike lowering in Zones A3, A4 and A5) have been employed to manage water levels. In 2001, the dikes were raised from a maximum elevation of 3 m to 5 m above ground level with a view to improving the transportation of tourists around the Park as well as enhancing the ability of Park staff to patrol the area.

Current management of water levels within Tram Chim National Park is strongly influenced by the desire to prevent fires starting within *Melaleuca* areas or fires in grasslands spreading into *Melaleuca*. In addition, for fire fighting, canals have been excavated within the Park to distribute water and personnel whilst some ponds have been constructed to store water for fire fighting. The majority of the *Melaleuca* which is central to these policies has expanded from areas planted with *Melaleuca cajuputi* for production and now covers approximately 30% of the Park. These mono-specific woodlands do not reflect the mixed woodlands which characterised parts of the original Plain of Reeds (see Section 2.2).

Specific impacts of current management and recommended interventions are detailed in Section 4. A brief outline of the current situation with respect to major ecosystem characteristics is provided here.

Water Levels: Water level regimes within the different Park zones do not reflect those experienced historically. Water levels have generally been kept higher than historically in Zone A1 as the magnitudes of the dry season draw-downs are not as large as those experienced historically. Elsewhere within the Park conditions are drier than in the past. Un-repaired breaches in the dikes surrounding A4 and A5 have resulted in the permanent connection of these zones to the surrounding canal network. This has limited the ability to control water levels and as a result in the dry season these areas become parched.

Hydrological Processes: Dikes surrounding the Park management zones have reduced sheet flow and the exchange of floodwater into and out of the Park. Similarly, dikes alongside canals constructed within the Park limit the exchange of water between canals and surrounding areas whilst higher flow velocities occur within the canals. These changes to historical hydrological processes result in reduced mixing of dissolved nutrients and detritus from the Mekong with the wetland and a reduction in the export of decomposition by-products from the Park[1]. The dikes also fragment habitat in particular for fish.

Water Quality: Although the dikes around the Park are successful in reducing the influx of acid water which is washed into canals in the surround area at the start of the wet season[15], construction of canals and water storage ponds within the Park has altered water quality by releasing acidities due to the oxidation of exposed pyretic materials leading to increased acidity of surface water. The canal network facilitates the transport of acid water to areas that were previously less influenced by this low pH.

Fire: The risk of uncontrolled fires is greater in A4 and A5 due to the larger than historic draw-down. Higher water levels in some others parts of the Park (e.g. A1) will have limited the period when fires could occur. Ironically, however, high water levels combined with the reduction of sheet flow may have increased the chances of severe uncontrolled fires by enhancing the accumulation of dead plant matter beneath the *Melaleuca* canopy. Reduced incidence of low intensity fire, which under natural conditions would have removed dead biomass, coupled with the old National Park policy of restricting human exploitation of natural resources which would reduce fuel load (such as the collection of firewood) has compounded this problem. Similarly, in grassland areas the build up of dead plant matter may increase the severity of uncontrolled fires when they occur. Previous prohibition of human activity such as cutting grass for fodder has further exacerbated this problem.

Biological Implications and Biodiversity: As Figure 4 shows, the hydro-chemical changes resulting from current management practices can be expected to have impacts on the biological component of the

Tram Chim ecosystem. In areas where water levels are higher than in the past deeper water species have benefited at the expense of those which prospered under the historical water level regime of the Plain of Reeds which included a longer and lower draw-down. Many species which prospered under historical hydrological conditions are native species which are typical of the original conditions within the Plain of Reeds. A number are specialised and rare and so contribute to a more unique habitat. For example, evidence[8] suggests that *Eleocharis* spp do not produce below ground tubers under the current water level regime. This has implications for the National Park's flagship species, the Sarus Crane, which favours *Eleocharis* tubers as a food source. In the dry season the Park supported as much as 60% of the total population of Sarus Crane in the Lower Mekong Basin during the last decade. However, a marked decrease in numbers has been associated with the decrease in favoured habitat. Other bird species which prefer lower water levels such as Bengal floricans, Oriental praticoles and green bee-eaters, have been similarly impacted whilst those which favour deeper water (e.g. swamp hens and egrets) have increased in number. Water quality impacts, in particular those associated with low pH, will also have impacted aquatic organisms. Invasive species are also now a problem within the Park and include *Mimosa pigra* and the Golden apple snail (*Pomacea canaliculata*), which is indicative of permanent iniundation.

3. METHODOLOGY OF THE MWBP INTERIM PERIOD WORKPLAN

The Mekong Wetlands Biodiversity Programme's Interim Period Workplan was based on the conceptual understanding of the functioning of Tram Chim National Park illustrated in Figure 4. It addressed the four major ecosystem components: hydrology, chemical and physical properties (soil and water chemistry), biology and fire, and their inter-relationships. Two basic approaches were employed to collect new data and improve understanding:

- Survey and routine monitoring of ecosystem components.
- Monitoring of targeted management interventions designed to answer specific research questions and trial potential management techniques.

Table 1 summaries the activities and techniques associated with these approaches. These were supplemented by collection of existing data and other information from, for example, meteorological stations, maps and remotely sensed imagery as well as past research in Tram Chim and other wetlands in similar conditions. Individual component reports detail the approaches used and the results obtained.

4. THE FIRE AND WATER MANAGEMENT STRATEGY: MANAGEMENT OF ECOSYSTEM COMPONENTS, PROPOSED INTERVENTIONS AND EXPECTED OUTCOMES

The following sections outline the current situation within Tram Chim National Park with respect to water levels, hydrological processes, fire and invasive species expanding upon the outline of the current ecosystem provided in Section 2.2. For each of these issues the current management is reviewed and the impacts, as revealed by results of investigations undertaken within the MWBP Interim Period Workplan, on the ecosystem of Tram Chim National Park evaluated. Subsequently, management tools and interventions which have been devised from results of the Workplan are presented. The expected outcomes of these changes to existing management are discussed.

4.1. Water Level Management

The Current Situation:

As outlined in Section 2.3, current water level regimes within Tram Chim National Park differ from those which were characteristic of the original Plain of Reeds ecosystem. Within much of the Park, most notably Zone A1, water level regimes are driven by the over-riding priority to prevent fire. For example, due to the fear of fire water levels have generally been kept higher than natural in Zone A1

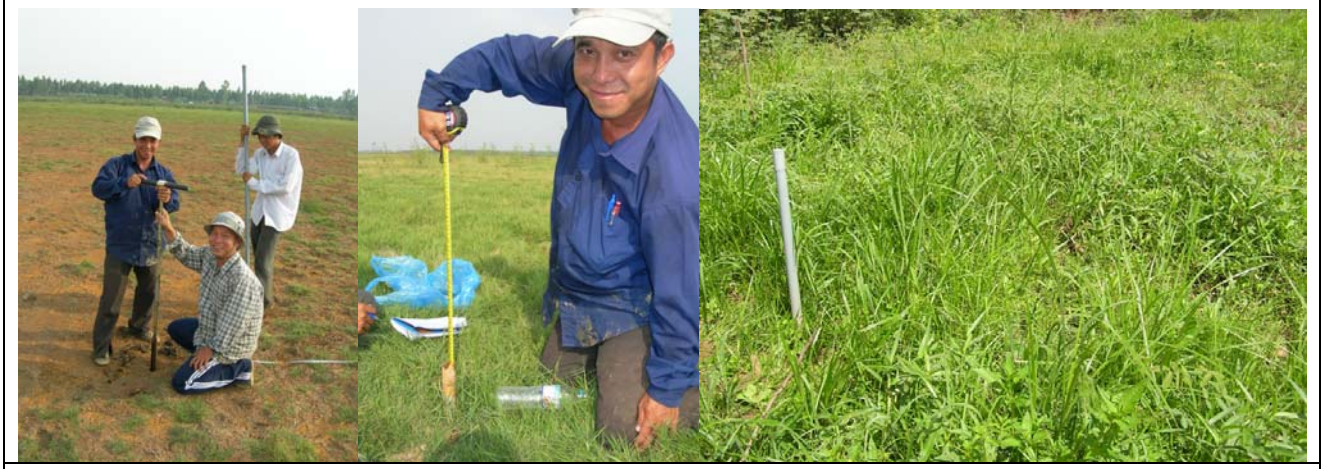
Table 1. Activities / techniques within the MWBP Interim Water and Fire Management Strategy Workplan

SURVEYING AND ROUTINE MONITORING

Hydrology

Surface water levels: *Staff gauges*

Groundwater levels: *Piezometers*



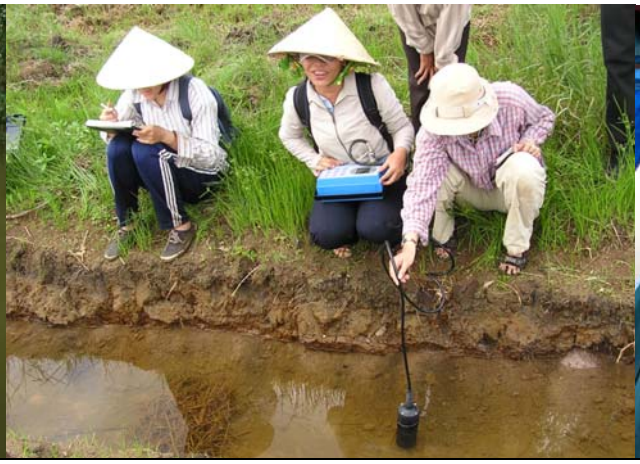
Meteorology: Precipitation - *Rain gauges*; Evaporation - *Evaporation pan*

Topography: *Topographic survey*

Table 1 cont. Activities / techniques within the MWBP Interim Water and Fire Management Strategy Workplan

Water chemistry and sediment

Water chemistry: *Water sampling and laboratory analysis*


Sedimentation: *Sediment mats*

Biology

Vegetation: *Vegetation surveys for different vegetation communities and burned areas; remote sensing mapping*



Birds: *Bird counts and habitat assessment*

Fish: *Fish catches and interviews with fishermen*



Table 1 cont. Activities / techniques within the MWBP Interim Water and Fire Management Strategy Workplan

Plankton: *Field sampling and laboratory analysis*


Fire

Past fire incidence: *Key informant interviews*

Meteorological parameters which influence fire risk and behaviour: *Meteorological observation*



MONITORING OF TARGETED MANAGEMENT INTERVENTIONS

Draw downs: *Opening sluice gates and monitoring water levels response in different parts of the Park*

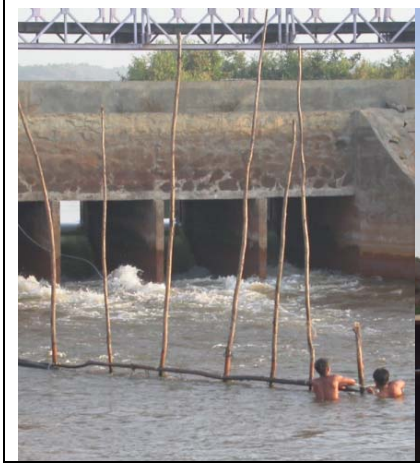



Table 1 cont. Activities / techniques within the MWBP Interim Water and Fire Management Strategy Workplan

New spillways: *Construction of spillways and monitoring of their operation*


Prescribed burning: *Field observations of fires (e.g. rate of spread, flame height) during prescribed burns; fuel characterisation; fire modelling*



Eleocharis re-establishment and Mimosa control: *Piloting of techniques (cutting, burning, ploughing and irrigation) and monitoring of effects*



and the magnitudes of the dry season draw-downs using existing sluice gates are not as large as those experienced historically. In 1998 the International Crane Foundation (ICF) recommended that the gates of existing water control structures be closed at the end of December so that minimum dry season water levels are 30 cm below the mean ground elevation, equivalent to 80 cm amsl. However, this recommended water level regime has been regarded as risky by Park management. Figure 5 shows that within Zone A1 rarely do dry season water levels fall as far as those recommended by ICF. This pattern is repeated in Zone A2. Elsewhere within the Park the ability to control water levels has been limited since 2001 by un-repaired breaches in dikes surrounding zones A4 and A5. These zones have therefore been permanently connected to the surrounding canal network so that their hydrological regimes respond to water levels in the wider area and in particular become very dry in the dry season. As part of the Interim Water and Fire Management Strategy simple water control structures (spill ways) have been installed in the dikes around these zones to provide a means of controlling water levels as those within Zone A1 can be controlled using the existing water control structures.

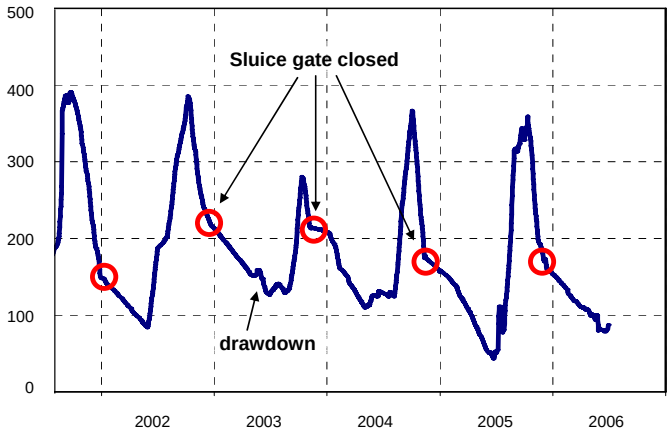


Figure 5. Water levels and sluice operation within Zone A1

Impacts on the Ecosystem:

A wetland's hydrological regime exerts a major control upon vegetation. The effect of high or low water levels upon both species growth and community composition can be dependent upon magnitude, duration, frequency and periodicity[3,16]. Vegetation species can have very sensitive ranges of tolerance to water levels. Results from vegetation components of the MWBP Interim Period Workplan[8] confirm the distribution of dominant communities along an elevation, flood depth and duration gradient (Figures 2 and 6). While *Panicum* has a wide tolerance to water level and can grow well in dry and wet conditions,

months dry ==>	0	1	2	3	4	5	6	7	8	9	10	11	12
Lotus	+	+	+	0	0	-	-	-	-	-	-	-	-
Meleleuca	-	-	-	+	+	+	+	+	+	+	+	+	+
Wild Rice	-	-	0	+	+	0	0	-	-	-	-	-	-
E. Dulcis	-	0	0	+	+	+	0	0	-	-	-	-	-
E. Atropurpora	-	-	-	0	0	+	+	+	0	-	-	-	-
Panicum	-	0	0	+	+	+	+	+	+	+	+	+	+
Ischaemum	-	-	-	0	+	+	+	0	0	0	-	-	-

legend	
Too dry	-
	0
good	+
	0
too wet	-

Figure 6. Optimum number of months without inundation of principal plant communities within Tram Chim National Park

the other grass species, *Eleocharis*, *Ischaemum* and wild rice have a narrower range. *Melaleuca* has a wide water level tolerance range within lower parts of the area whilst Lotus is found within deeper areas where the soil is usually flooded year-round.

Figure 7 shows that large areas of Zone A1 and A2 were too wet for many vegetation species compared to the optimum conditions shown in Figure 6. Within grassland areas the current higher water levels have benefited those species which thrive in deeper water or can survive in a wide range of water levels, most notably and *Panicum*. *Eleocharis* in particular has been impacted by the higher water levels especially in the dry season. Within Zone A1, for example, higher water levels are implicated in the reduction of this species. Vegetation surveys reveal no below ground tubers of *Eleocharis* in this part of the Park[8] since their formation requires that the groundwater table falls to between 30 cm and 40 cm below the

soil surface for a prolonged period during the dry season[17]. Where dry conditions suitable for *Eleocharis* are met within other drier parts of the Park (for example Zone A5) tuber production has been maintained[8]. Monitoring of vegetation responses to the draw-down experiment within Zone A1 in 2005 revealed the remarkable re-establishment of *Eleocharis*. However, it also showed that this re-growth was from seeds due to the death of underground tubers resulting from previously high water levels. A return to high water levels in subsequent years will kill the new growth of *Eleocharis* as their roots will not be fully developed. Prolonged health of *Eleocharis* including the production and sustained growth of tubers requires that lower water levels are repeated in subsequent dry seasons. The overall impact of the high water areas is therefore a reduction in the extent and quality of *Eleocharis*. *Panicum* has been the most notable species which has benefited at the expense of *Eleocharis*. Although *Eleocharis* growth is maintained in parts of the Park such as zones A4 and A5 which are currently drier, the inability to control water levels due to their permanent connection with the surrounding area has, until the recent construction of new spillways, limited management options in times of drought when water levels may fall beyond those required to maintain healthy vegetation growth.

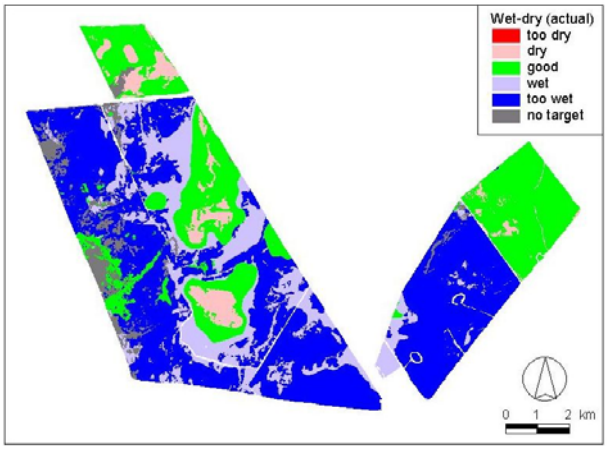


Figure 7. Too wet / too dry map for Tram Chim National Park under current water levels.

The map was derived through the comparison of actual inundation period (based on water level records for 1993-2004) to optimum inundation. Optimum inundation duration is based on vegetation distribution (Figure 2) and optimum number of months without inundation for different plant communities (Figure 6)

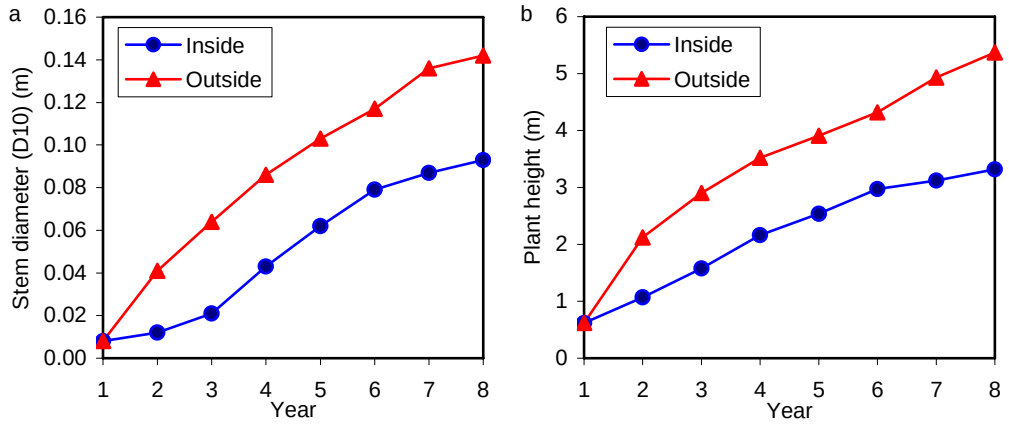


Figure 8. Melaleuca growth within and outside Tram Chim National Park (a) stem diameter; (b) plant height

Evidence[18] suggests that high water levels also impact the growth of *Melaleuca*, the protection of which is the main rationale for maintaining deeper water. Figure 8 shows mean stem diameter and plant height for stands of *Melaleuca* both within parts of the Park subject to high water and in areas outside of the Park characterised by larger and longer dry season draw-downs. It is evident that trees outside of the Park grow substantially faster than those within the Park where the main environmental difference is water level regime. Further potential negative impacts upon *Melaleuca* concern the accumulation of organic matter (leaves, twigs and branches) on the ground due to the reduction in decomposition rates under wetter conditions and the limited export of material by flood waters. Under current conditions lack of regeneration, slow growth and biomass accumulation has led to decadent stands with limited new growth. Similarly, in grassland areas reduced decomposition under wetter conditions leads to the

build up of dead plant material from previous seasons[8]. This leads to an increase in fuel loading and hence greater risk of fire. These impacts are discussed further in Section 4.3.

Soil water chemistry is likely to be impacted by the current high water levels with further implications for the Park's flora. Although, as discussed above, the extremely low water levels which occurred following the construction of the extensive canal network through the Plain of Reed resulted in very low pH and toxic concentrations of iron and aluminium ions, the historical annual draw-down would result in some oxidation in upper soil layers which favoured some vegetation species. Results from the soil and water chemistry components of the MWBP Interim Period Workplan[19] show that *Eleocharis* grows in areas with higher total soil acidity and aluminium concentrations, especially at a depth of 0.2-0.4 m (Figure 9). By limiting groundwater drawdown, the current high water levels are therefore reducing the chemical conditions conducive to this particular species which is characteristic of the original Plain of Reeds ecosystem.

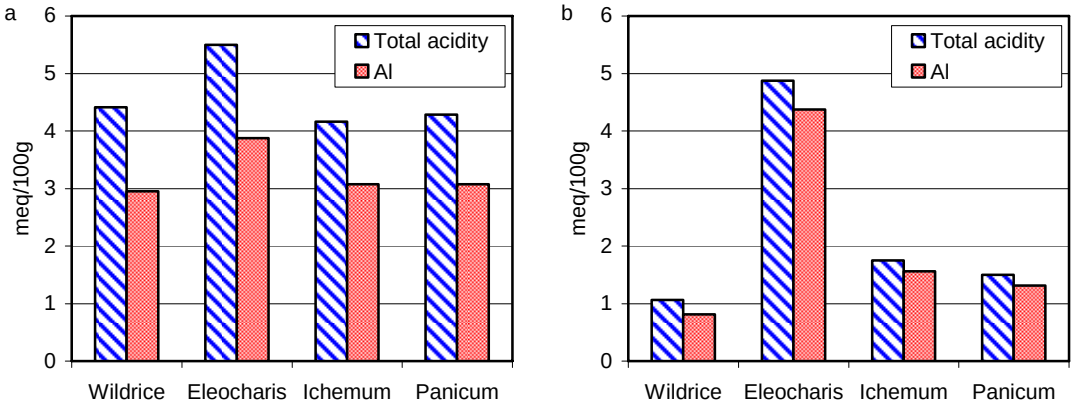


Figure 9. Soil total acidity and aluminum at (a) 0-20cm depth and (b) 20-40 cm depth in areas with different grassland vegetation communities

The composition of Tram Chim's bird population has been impacted by changes in water level regimes. As noted in Section 2.2, the most notable species impacted by higher water levels is the Sarus Crane (*Grus antigone*). The number of these birds, for which Tram Chim is internationally renowned, using the Park has declined in response to the decrease in favoured habitat. The reduction in the extent and quality of *Eleocharis*, including reduced tuber production, is cited as a particular reason for this decline. The main feeding area of the Sarus Crane is now Zone A5. Similarly, other bird species which prefer lower water levels such as waders have declined. Such species include Bengal floricans, Oriental praticoles and green bee-eaters. Higher water levels have favoured birds which prefer deeper water such as swamp hens and egrets which were less characteristic of the original bird populations with the Plain of Reeds.

Management Tools / Interventions:

Target Water Levels: The proposed management interventions advocated as a result of MWBP programme activities within Tram Chim National Park aim to re-establish more natural hydrological regimes within the Park thereby addressing the impacts discussed above and assisting the Park in achieving its stated goal of preserving the typical ecological system of the Plain of Reeds. Target water levels for Zones A1, A2, A4 and A5 have been developed[20] based on the:

- The hydrology and water balance of Tram Chim National Park.
- The distribution of principal plant communities (based on the current vegetation map - Figure 3) and their optimum non-inundated period (Figure 6).
- An idealised feeding pattern for Sarus Cranes with the target water levels intended to enable their feeding within grasslands in different Park management zones at different times as they fall dry.

Table 2 provides the target water levels for these four management zones. These are specified as the water elevation on the first day of each month. Target water levels are only provided for the dry season since wet season water levels are dictated by the height of the flooding and are therefore beyond the control of Park Management.

Table 2. Target water levels for Tram Chim Management zones (units = cm amsl)

Date	Target Water Level (cm amsl)			
	Zone A1	Zone A2	Zone A4	Zone A5
1 Jan	143 ± 5	161 ± 5	At least 110	At least 137
1 Feb	126 ± 5	144 ± 5	93 ± 5	120 ± 5
1 Mar	110 ± 5	128 ± 5	77 ± 5	104 ± 5
1 Apr	92 ± 5	110 ± 5	At least 59	At least 86
1 May	73 ± 5	91 ± 5	At least 40	At least 67
1 Jun	At least 60	At least 80	No target	No target
1 Jul	At least 70	At least 75	No target	No target
1 Aug	No target	No target	No target	No target
1 Sep	No target	No target	No target	No target
1 Oct	No target	No target	No target	No target
1 Nov	No target	No target	No target	No target
1 Dec	At least 156	At least 174	At least 123	At least 150

The target water levels have been translated into guidelines for the operation of sluice gates. If draw-downs take place under current management they are achieved by removing a large number of the flash board with the sluice gates resulting in a rapid reduction in water levels. This is not only labour intensive and dangerous for Park staff but also differs from the slower reduction in water levels which occurred under historical conditions. Therefore, the proposed operation of the sluice gates involves the gradual reduction in water levels through the progressive removal of flash board as shown in Figure 10.

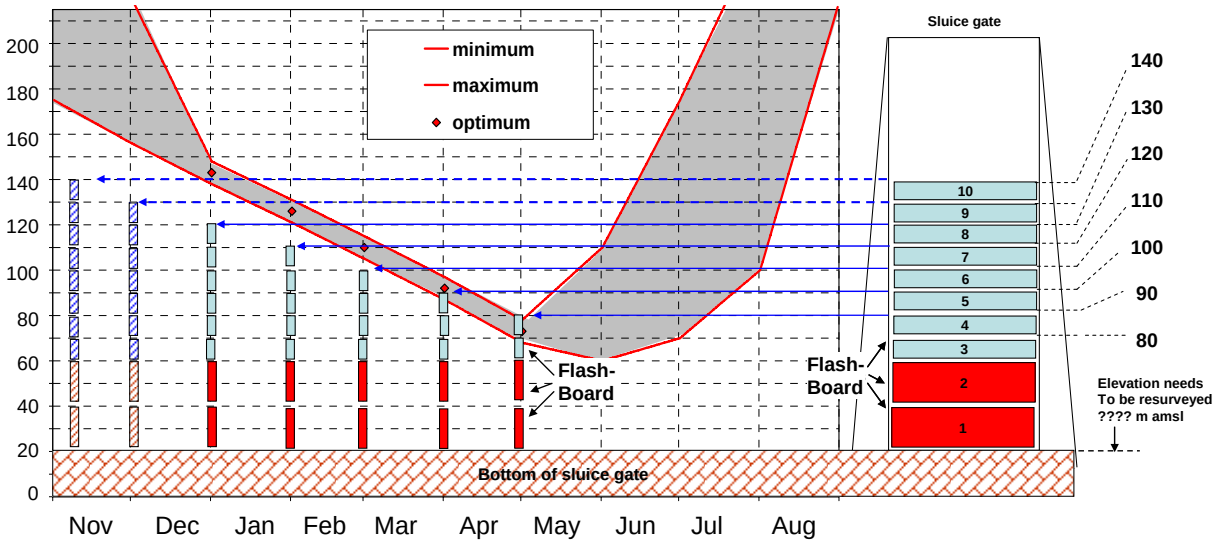


Figure 10. Operational guidelines for sluice gates designed to achieve the target water levels (this example for Zone A1)

Expected Outcomes:

The expected outcomes of implementing the recommended management interventions related to water levels within Tram Chim National Park are:

- The establishment of water level regimes which are more similar to those historically experienced throughout the Plain of Reeds and which include a larger-draw down in the dry season.

- The expansion in the area within the Park in which hydrological and hydrochemical conditions are conducive to the re-establishment of vegetation communities representative of the original Plain of Reeds but which have declined under current conditions (Figure 11) In particular it is expected that lower dry season draw-downs, which will cause the water table to fall below the ground surface for some time, will benefit the re-generation of *Eleocharis* including the production of below ground tubers.
- Positive impacts on rates of *Melaleuca* growth and enhanced decomposition rates of dead plant matter with positive implications for fire management (see Section 4.3).
- Improved habitat suitability for the native fauna typical of the original conditions within the Plain of Reeds. These species include the Sarus Crane, the Park's flagship species, which will especially benefit from the regeneration of *Eleocharis*.

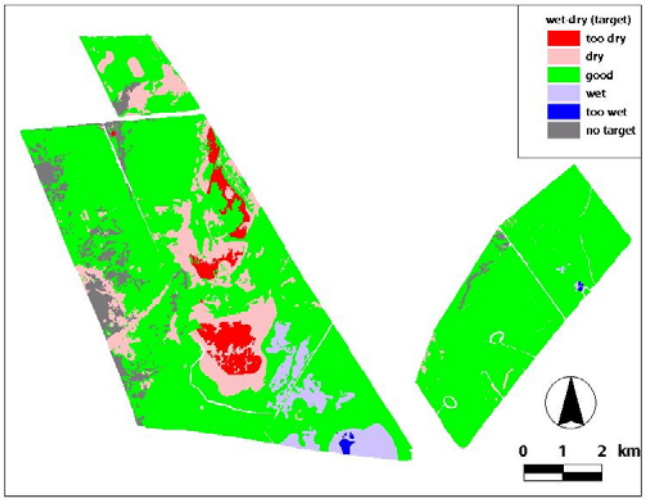


Figure 11. Too wet / too dry map for Tram Chim National Park under proposed target water levels.

4.2. Restoration of Hydrological Processes

The Current Situation:

Dikes surround the different Park Management zones. Although some have water control structures, the dikes still present significant barriers to the exchange of water, nutrients, organic matter and fish between the Park and the surrounding area, especially since they were raised from 3 m to 5 m above ground level in 2001. Canals have been excavated within some parts of the Park, often to provide access for fire fighting. These act as preferential pathways for water movement and induce higher flow velocities. The dikes which are created alongside these canals due to the piling up of excavated soil also act to cut off the canals from the surrounding areas.

Impacts on the Ecosystem:

Sheetflow was an important hydrological process within the original Plain of Reeds ecosystem. During the wet season the Tram Chim area would be inundated by a sheet of water moving in a general northwest-southeast direction in response to the shallow gradient across the area. The dikes surrounding the Park have dramatically reduced sheetflow within the Park, a phenomenon which has been reported in other wetlands cut off from their major water source by dikes and embankments[21,22,23]. The exchange of water is limited to water entering or leaving the Park through the water control structures. In the past any sediment carried by sheetflow would have been more evenly deposited across the area. Monitoring sedimentation within Tram Chim Park suggests that existing water control structures generally lower sedimentation rates whist sediment deposition is probably more isolated to areas adjacent to the water control structures. Similarly, reduced sheetflow limits the removal of biomass (such as leaf litter, twigs, small branches) from the Park. When combined with the lower decomposition rates under the current high water levels discussed above the reduction in sheetflow contributes to biomass accumulation within the Park with important implications for fire management (see Section 4.3).

Within the Park, canals have been excavated in the process creating further, albeit lower, dikes. These also isolate areas beyond the dikes from the canals at times when canal water levels are lower than the top of the dikes. The new north-south canal excavated in Zone A1 in particular has relatively high

(approximately 2 m above the surrounding ground surface) dikes. As well as disrupting natural hydrological processes these dikes also reduce visibility from boats travelling along the canal impacting the ability of Park staff and tourists to see beyond them into the Park. The more hydraulically efficient canals now act as preferential pathways for water movement in which flow velocities are greater than those of sheetflow.

The construction of canals within Tram Chim is likely to have impacted water chemistry. The dredging and exposure on dikes of acid-sulphate soils will promote oxidation and hydrolysis enhancing acidity and the release of iron and aluminium ions directly into the canals. For example, Figure 12 shows pH along a transect starting at the new north-south canal in the south of Zone A1 and extending into the surrounding grassland. It demonstrates that at both the start and end of the flooding period acidity is higher within water in the canals compared to the water inundating the grassland. Faster movement of water within canals transports low pH water rapidly throughout the Park whilst the reduction of sheetflow will reduce the buffering of pH provided by slow movement of water through vegetation, in particular stands of *Melaleuca* which have been shown to improve the quality of water passing through them. This is evident in Figure 13 which presents the results of an experiment[24] in which initially water levels in adjacent grassland and *Melaleuca* areas were maintained at a high level until in May / June 1999 a drawdown was undertaken. Subsequently water levels were allowed to rise naturally in response to rainfall between June and September 1999 until they reached pre-drawdown levels in October 1999 when some sheetflow from nearby canals occurred. Whilst the pH in the grassland area declined substantially during the period of lower water levels, in the *Melaleuca* the decline in pH was much smaller with values varying by relatively small amounts each month. Reduced sheetflow from the Park results in a reduction of the flushing of acids from the Park.

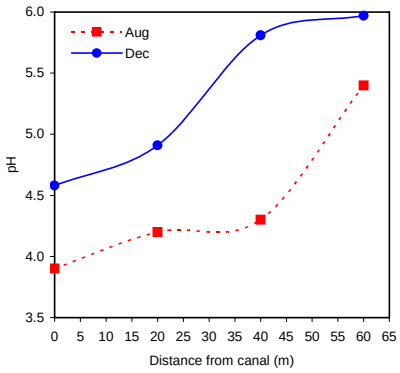


Figure 12. pH variability along a transect in Zone A1 starting at the new canal and extending into the surrounding grassland.

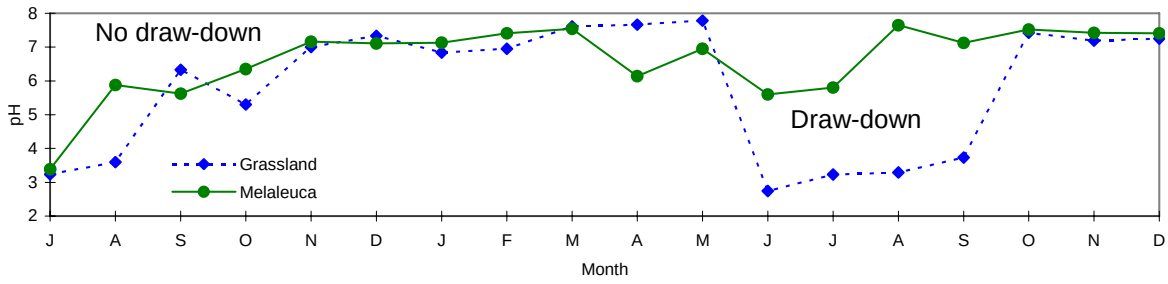


Figure 13. pH in adjacent grassland and Melaleuca areas between July 1998 and December 1999 (Ni, 2001)

Further water quality impacts are associated with the concentration of inflowing water through the water control structures. Current practices of keeping the control structures closed during the initial rise in water levels will reduce the influx of acid water associated with the first flush of acidity at the start of the wet season. However, once opened, the control structures concentrate the inflow of water from the surrounding area which may still be relatively high in acidity as well as containing agricultural fertilizers and pesticides. Water chemistry monitoring results demonstrate, for example, that water immediately outside the Park and adjacent to the water control structures has higher nutrient (phosphorous) concentrations.

The dikes around and within Tram Chim also fragment habitat in particular for fish. Migratory (white) fish migrate passively with the water flow at the beginning of the annual flooding season. However, they now have reduced entry to the Park due to the dikes, especially since they were raised in 2001[25]. This is shown in Figure 14 which illustrates the relationship between water levels outside of the Park

and dike elevation in relation to the life-cycle of some key local fish species. Local fishermen also state that they catch less resident (black) fish species outside the Park since they are unable to migrate easily through the sluice gates. The National Park has thus lost part of its role as a nursing ground for fish in the surrounding area which helps to support local livelihoods.

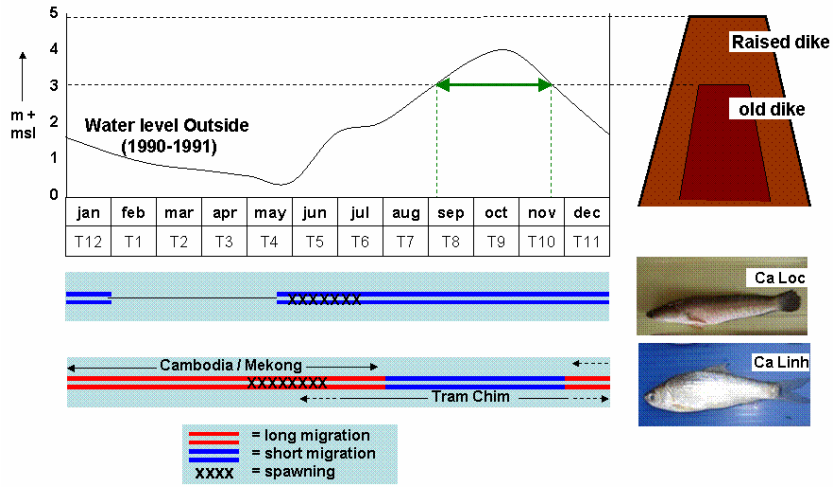


Figure 14. Water levels and dike elevation in relation to life-cycle of key resident (Ca Loc) and migratory fish species (Ca Linh)

Dikes constructed within the Park, such as those along the new north-south canal in Zone A1, provide favourable areas for initial colonisation by the invasive species *Mimosa pigra.* From the dikes, *Mimosa* can spread into the surrounding grassland (see Section 4.4).

Management Tools / Interventions:

The proposed management interventions advocated as a result of MWBP programme activities within Tram Chim aim to increase the role of sheet flow within the National Park thereby restoring more natural hydrological processes.

New Water Control Structures: The first proposed management intervention is the construction of new water control structures in the embankments surrounding Zone A1 which are designed to enhance the exchange of water between the surrounding area and this part of the Park and in turn enhance sheetflow. Figure 15 shows the proposed locations of these new control structures as well as the anticipated flow pattern which would result from their installation. The MWBP Technical Advisory Report for the new water control structures[25] details the justifications applied in selecting these sites. These include the need to have structures at both the upstream and downstream ends of the management zone in order to induce sheetflow through A1, the sitting of structures at locations where dikes have been damaged and so construction work is already required,

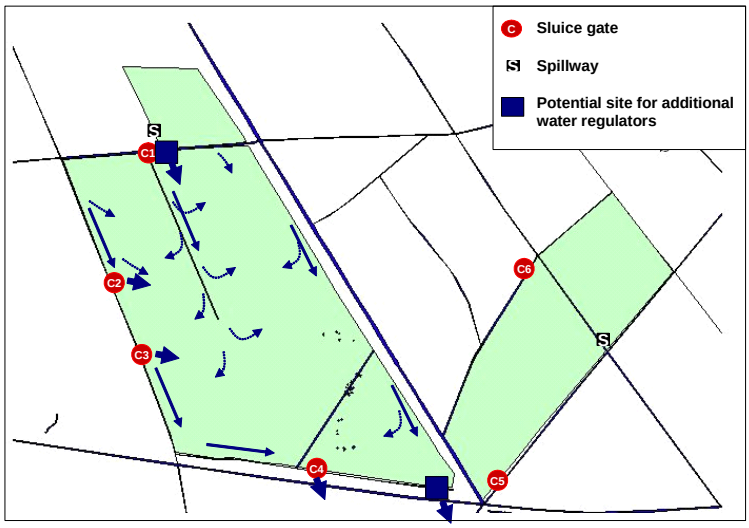


Figure 15: Locations identified as potential sites for new water regulating structures and expected flow pattern with all four structures (C? refers to existing control structures)

and the likely benefits for fisheries from locating at least one structure in the north from which the floodwater carrying migrating fish approaches Tram Chim.

The MWBP Technical Advisory Report[25] for the new control structures reviewed a number of potential designs. The recommended design is shown in Figure 16. It is designed such that floodwaters are only let into the Park once sediment loads have declined below the initially very high levels at the start of the flood season. Similarly, at this time pH is low as a result of the leaching of acid compounds by the first rains. Monitoring results show that sediment loads decline and pH rises once water levels are close to 2.5 mamsl so that the fixed crest of the spillway is set to this elevation.

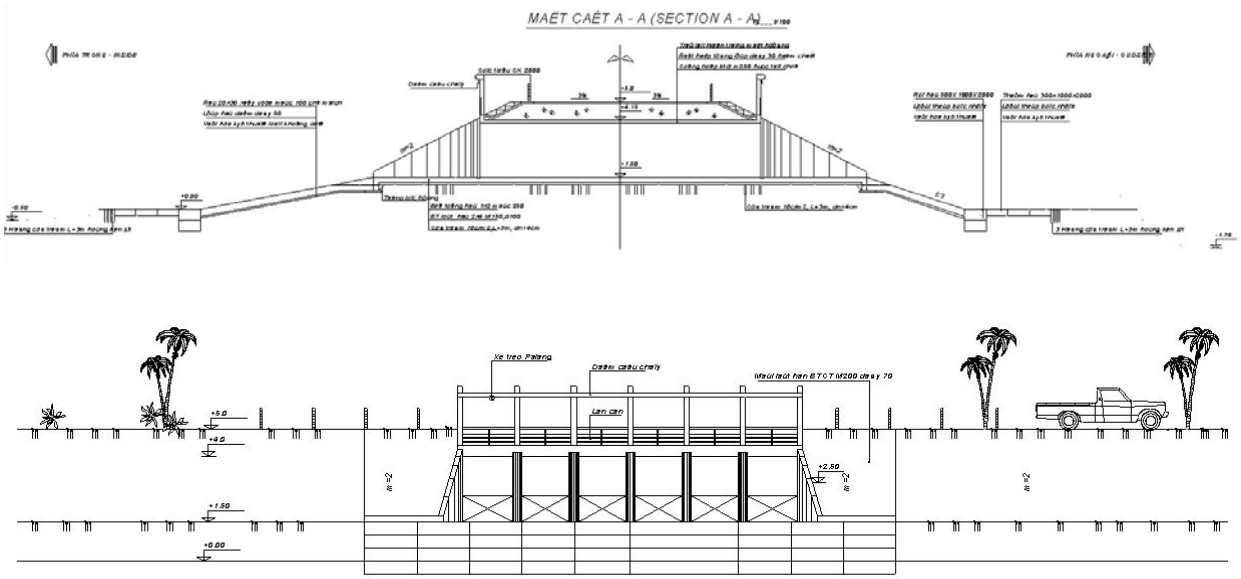


Figure 16. Recommended design of new water control structures designed to increase sheet flow in Zone A1

Vegetation Buffer Areas: In order to offset potential increase in local sedimentation rates within A1 as a result of the new control structures it is recommended that native tree species characteristic of the historic Plain of Reeds be planted within a radius of at least 100 m of the structures in order to filter sediment. These areas would also buffer nutrients and pesticides derived from upstream cultivated areas and prevent them penetrating deeper into this part of the Park. Results from sediment mats installed within Tram Chim, which show that wooded areas (in this case *Melaleuca*) are more effective in trapping sediment than grassland areas, support this recommendation. The species selected for these buffer areas should be appropriate for the envisaged water level regimes resulting from the recommended target water levels. Additionally the sitting of these buffer areas should avoid locations where current vegetation comprises rare grassland species (i.e. *Ischaemum* and wild rice). A further recommendation is that, if possible, negotiations with provisional and district authorities should be undertaken to promote the growth of these native species in the buffer zone surrounding the Park, in particular in the area immediately surrounding the new water control structures. It may be possible that planting these native species on the slopes of the dikes (currently planted with non-native Eucalyptus forest) could be employed to strengthen slope stability.

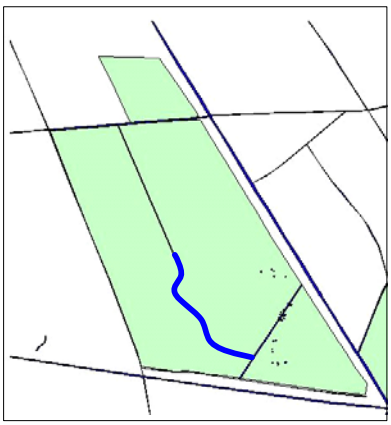


Figure 17. Location of the canal in the south of Zone A1 where dikes should be cut or

Dike Removal: A further recommended management intervention[26] is the removal of the dikes which run

alongside the new north-south canal excavated through the centre of the southern section of Zone A1 (Figure 17). The length of this canal is approximately 5.2 km and its dikes are roughly 8 m wide and rise to approximately 2 m above the local ground level. As noted above, these dikes act as hydrological barriers to sheetflow and the exchange of water between the canal and the surrounding area with implications for water quality and fish. They also restrict the visibility of Park staff and tourists travelling along the canal. In an ideal situation all of these dikes should be removed although this will entail the removal of substantial quantities of sediment.

Management of Fishing Activities: The existing sluice gates in the dike around Zone A1 are currently heavily utilised by local fishermen at the start of the flood season as they are able to catch fish with relative ease as they pass through the gates. The new water control structures would provide similar favoured fishing locations. However, at the start of the flood season many of the fish which are caught are mainly juveniles which would otherwise mature within the Park. It is therefore recommended that fishing at the current sluice gates and new water control structures be prohibited during the rising flood so that local communities can benefit from the larger fish which would leave the Park through the same structures as water levels fall at the beginning of the dry season.

Expected Outcomes:

The expected outcomes of implementing the recommended management interventions related to hydrological processes within Tram Chim National Park are:

- Enhanced exchange of water between the surrounding area and zone A1 which will enhance sheetflow throughout this Park Management Zone.
- Improved hydrological connections between canals and the surrounding land in the south-centre of Zone A1 with further enhancements to sheetflow and improved visibility of this part of the Park from the canal.
- More even sediment deposition within Zone A1 instead of the localised sedimentation characteristic of current conditions.
- Enhanced flushing of acids from Zone A1 and improvements in the buffering of acidity through the slow movement of water through vegetated areas.
- Enhanced removal of biomass from Zone A1 with positive implications for fire management.
- Improved access to Zone A1 for fish with positive implications for fish populations within the Park and fisheries in the surrounding area.
- Reduction in the extent of land within Zone A1 suitable for initial colonisation by *Mimosa pigra*.

4.3. Fire Management

The Current Situation:

As noted above, current management of Tram Chim National Park is driven by the prevention of fire within *Melaleuca* areas. This includes the prevention of uncontrolled fire within grasslands which can serve as a continuous fuel bed into the *Melaleuca*. Park Management is under pressure to avoid all forms of uncontrolled fire despite the historical role it played within the Plain of Reeds ecosystem. Human communities undertook burning for hunting and also benefited from the reduction in biomass which facilitated fish fingerling movement during the wet season. Fire took place in both grassland areas and *Melaleuca*. Despite current concerns regarding fire in *Melaleuca*, research[9] indicates that this species is extremely well adapted to fire. It has thick, spongy bark with outer layers that are flakey and burn vigorously. This conducts the fire into the canopy, igniting the oil-laden foliage. Although leaves and small branches are killed, dormant lateral buds on the trunk germinate within weeks of the burn. This prolific sprouting increases the surface area of small branches and therefore the tree's reproductive potential. Fire plays a significant role in the life cycle of *Melaleuca* by breaking the vascular connection

between seed capsules and branches. In this way a mature *Melaleuca* tree will respond to fire by releasing millions of seeds. Adult trees damaged by fire may also sprout vigorously from the roots, bole, or branches. Within Tram Chim National Park rapid regeneration of *Melaleuca* stands has been witnessed following fire. For example, Figure 18 shows mean stem tree diameter, tree height and stem density within two *Melaleuca* stands in Zone A2 of the Park. Both stands are close together but one is in an area that burned in 1995 when approximately 100 ha of mature *Melaleuca* was completely destroyed. The figure shows that within ten years trees in the burned area had recovered and were similar in size and density to those found within the non-burned area.

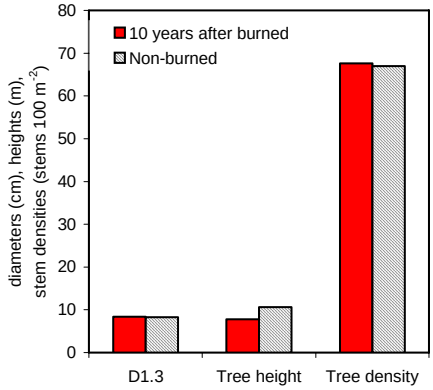


Figure 18. Mean values of tree diameter, tree height and stem density of two Melaleuca stands in Zone A2: 10 years of growth after burning and non-burned.

Impacts on the Ecosystem:

As the preceding sections have demonstrated current management, especially the maintenance of water levels which are higher than those experienced in the past, has had a number of ecological impacts. This section focuses on additional impacts not already discussed in detail which are related to the removal of the important role fire played within the Plain of Reeds and where current management practices could in the long run increase the risk of high intensity fire in *Melaleuca*.

As discussed above fire plays an important role in *Melaleuca* regeneration. This role will have been reduced under current management whilst, as discussed in Section 4.1 and illustrated in Figure 8, high water levels negatively impact *Melaleuca* growth rates. The reduction in the incidence of fire may impact the ecology of grassland areas. Results of MWBP vegetation monitoring demonstrate the build up of a mat of dead grass from previous seasons' growth[8]. As suggested in Section 2.2 this thick layer may impact the growth of some grassland species more than others. *Panicum* tends to out compete other grass species under dry soil conditions and less acidic conditions.

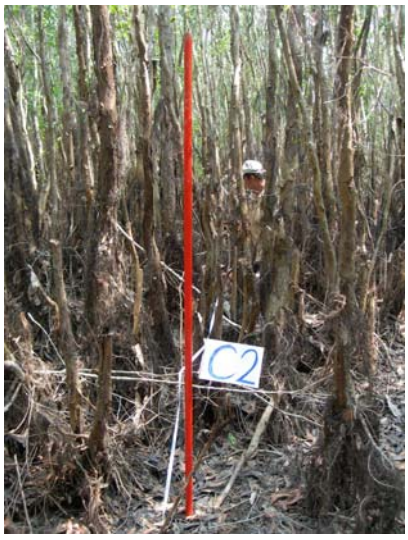


Figure 19. Example of dead biomass layers beneath Melaleuca stands

Table 3. Summary of dead and down fuel availability in sample plots beneath Melaleuca stands in Zone A1 of Tram Chim National Park

Plot in A1	Down dead material (t ha^{-1})†	Leaf fuel (t ha^{-1})‡	Total fuel (t ha^{-1})
A123	2.76	43.34	46.09
B123	3.68	23.20	26.88
C123	15.21	36.03	51.23
A456	6.73	17.34	24.07
B456	3.25	12.27	15.51
C456	7.36	25.87	33.23

† - evaluated using Brown's planar intersect method.
‡ - evaluated through the collection and weighing of all leaf litter within three 0.25 ×0.25 cm quadrats within each plot.
Notes: 1 ton = 10,000 kg; fuel availability expressed as dry weight.

The reduction in the incidence of frequent, low intensity fires under the current management regime will ultimately lead to greater risk of larger, high intensity fire within the *Melaleuca* due to biomass accumulation. Sections 4.1 and 4.2 referred to the accumulation of organic matter comprising leaves, twigs and branches on the ground beneath *Melaleuca* stands. Figure 19 provides an example of the accumulation of this biomass within *Melaleuca* areas within Tram Chim National Park. Table 3 presents the results of evaluations of dead and down fuels in a number of plots beneath *Melaleuca* stands in Zone

A1 of Tram Chim. These plots represent a range of fuel loading conditions. However, in all the plots the fuel load exceeds the threshold of 10 t ha^{-1} identified by fire managers in Vietnam as being conducive to high intensity fires. During the dry season, when water levels decline, this material provides an extensive supply of fuel for fires. The extension of this fuel layer up into the canopy by adventitious roots means that ground fires can quickly be carried into the tree canopy ("ladder fuels") leading to more intense fire with greater chances of longer-term detrimental effects to trees. The presence of large diameter ground fuels will in the event of a fire also increase tree mortality due to longer duration fires (i.e. longer "residence time") which can result in root damage. Frequent low-intensity fires, which were common in the past, would have removed some of this biomass and thereby reduced the chances of more intense fires. Instead, under current management, biomass continues to accumulate over time as shown in Figure 20. Under these high fuel load conditions it is only a matter of time before a major, high intensity fire occurs in a *Melaleuca* area within the Park. This is likely to occur in a dry year when due to high evaporation rates water levels will fall below the ground level in areas of *Melaleuca* irrespective of sluice gate operation whilst meteorological conditions (i.e. low relative humidity and high temperature) will be conducive to extreme fire behaviour.

Similar increases in high intensity fires can be expected in grassland areas where the mat of dead grass which accumulates each year also provides fuel for fires. Observations[9] show that regular burning of these areas and hence the removal of this mat, can reduce fire intensity in subsequent years. For example, local fire fighters have observed that flame lengths are approximately 1.5 m in areas burnt up to three years beforehand compared to 3 m elsewhere. Shorter flame lengths increase the probability of effective fire suppression actions thereby improving the chances of containing grassland fires and preventing them from spreading to *Melaleuca* stands.

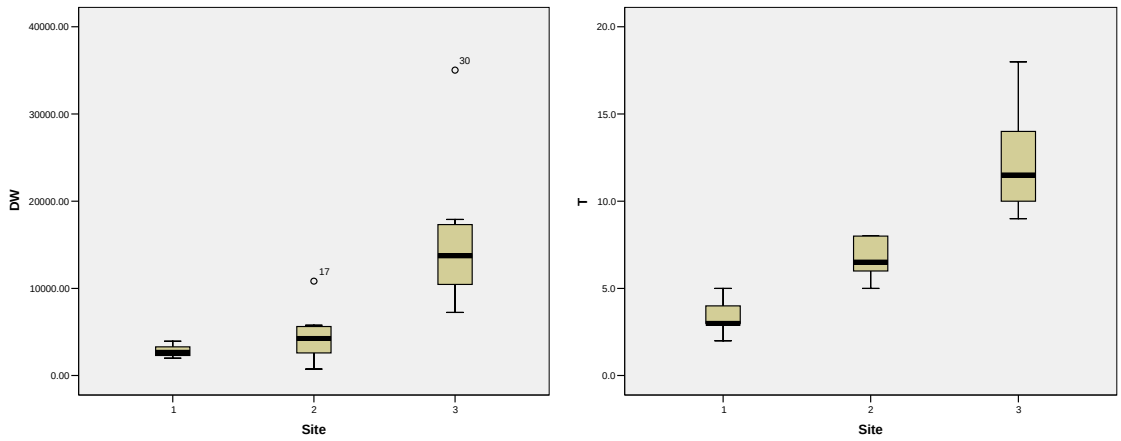


Figure 20. Dry weights (DW) and depth (T) of dead biomass layers beneath Melaleuca at three sites representing 5, 10 and 15 years of dead biomass accumulation

Similar increased fire risk has resulted from the old National Park policy of preventing local communities from harvesting useful materials from the Park. The collection of dead woody material for fire wood which was prohibited would have removed an important potential fuel from *Melaleuca* stands. Figure 21 compares the accumulation of biomass over an eight year period in two stands of *Melaleuca*, one outside the Park where dead plant material is removed and one within the Park where this removal was not permitted. The difference in fuel availability under these two management regimes is clearly demonstrated. Similarly, the past prohibition of grass cutting to provide fodder for domestic animals and for other uses will have contributed to the build up of the mat of dead grass and hence enhanced potential fuel availability. In

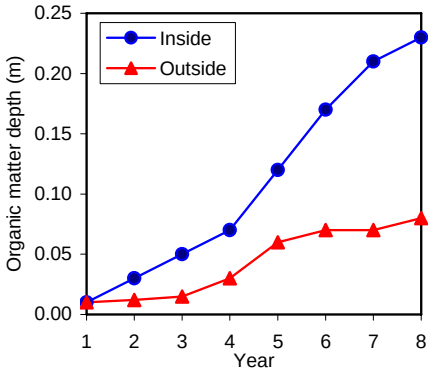


Figure 21. Accumulation of biomass within Melaleuca stands within and outside Tram Chim National Park

addition, deliberate past fire ignitions may have been an expression of dissatisfaction by local people frustrated at the lack of access to resources within the Park.

Management Tools / Interventions:

It is recognised that the lower water levels recommended in Section 4.1, which are required to establish hydrological conditions more representative of those within the original Plain of Reeds will increase the chances of fire[27]. Figure 22, based on actual fire occurrence records from Park Management, shows that as water levels decline and more dry land is exposed, the probability of fire increases. All fires are human-caused, and thus the most critical factor as water levels drop and increased land area is exposed, is the associated activities of illegal entrants from communities surrounding the Park. Park staff state that the number of illegal people in the Park is directly associated with the abundance and availability of fish. As water levels decline over the dry season, fisher-folk go to low areas to fish in small depressions. In a dry year, fish are more concentrated in low elevation ponds, thus there are more people fishing and more fires. Activity patterns of these fisher-folk are a critical determinant of fire ignitions. For ease of travel, they tend to walk along established paths in the higher elevations, then veer off to access newly exposed ponds as water level drops. Typical activities using fire are cooking lunch near the fishing pond, and stopping on the way to or from the fishing site to smoke while taking a break. Fires may also be lit as a diversion, when discovery of illegal activities by a ranger is imminent. Thus the number of human ignitions is directly related to area of land exposed above water, which is correlated with water level.

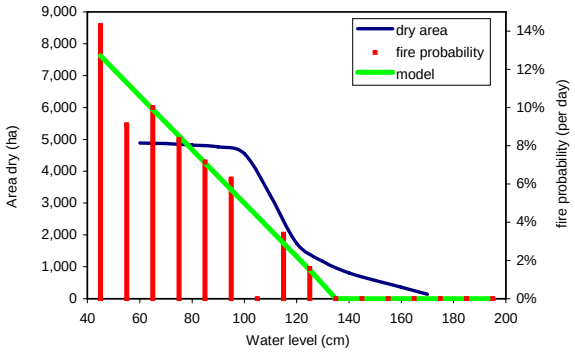


Figure 22. Relationship between water level, dry land area and probability of fire occurrence

The proposed management tools and interventions related to fire advocated as a result of MWBP programme activities within Tram Chim aim to re-establish the important role of fire within the ecosystem whilst at the same time lowering the risk of high intensity fire within the Park.

Official recognition of fire: The first recommended change in Park management is the official recognition of the important role of fire in the functioning of the Plain of Reeds ecosystem and that species including *Melaleuca* are extremely well adapted to fire as a disturbance process. This change in the official attitude to fire is an important pre-requisite for the other proposed management interventions. Given that potential fire incidence will be higher under the proposed new lower water level regimes the following management tools and interventions aim to reduce the risk of uncontrolled fires primarily through fuels manipulation. It is important to acknowledge that some reductions in fuel availability may also result from proposed changes in hydrological management of the Park. Enhanced sheetflow can be expected to remove more biomass from the Park whilst lower water levels may result in the more rapid decomposition of dead plant material. Official recognition of the role of fire combined with the proposed lower water levels provide a prescient opportunity to tackle the problem of high biomass accumulation and its impacts upon fuel availability.

Routine assessment of fire environment indicators during the dry season: The Park and FDP should establish routine practices to collect site-specific information on weather and fuel parameters that inform decisions related to fire suppression, preparedness levels, detection patrols, community awareness and timing of prescribed burning.

Continued use of prescribed burning in grassland areas: Forest Protection Department (FPD) fire fighters are highly skilled in the use of prescribed burning within grassland areas. Table 4, which shows the number of prescribed burns undertaken within the Park between 2001 and 2005, indicates that this

technique has been commonly applied. Prescribed fire reduces the dead fuel component provided by the mat of dead grass in the following years resulting in decreased flame lengths. Prescribed fire in corridors of human traffic and higher elevation areas eliminates fuels where fire starts have historically occurred. Therefore, the continued use of judiciously applied prescribed fire in grasslands is recommended as a means of reducing the numbers of wildfire ignitions and enhancing ability of fire fighters to suppress wildfires. Figure 23 presents results obtained from the BEHAVE3 fire modelling system using three different grassland fuel conditions ranging from: (a) grass not subject to burning within the last three years, (b) grass burnt within the last three years, and (c) grass cut and removed. These results demonstrate that recent burning reduces the flame length and rate of fire spread. Even larger reductions in these fire behaviour characteristics are associated with the cutting and removal of grass. The use of prescribed burning will therefore counteract the enhanced risk of fire resulting from lower water levels. Results from the soil and water chemistry components of the MWBP Interim Period Workplan suggest that prescribed burning does not change the soil character or surface water quality and should not affect the recovery of plant communities. Indeed, by removing the mat of dead plant material burning may provide a competitive advantage to native grassland species such as *Eleocharis* as long as appropriate soil chemical characteristics are created by the maintenance of appropriate water levels.

Table 4. Number of prescribed fires within Tram Chim National Park: 2001-2005

Year	Number of Prescribed Fires
2001	7
2002	21
2003	0
2004	3
2005	12

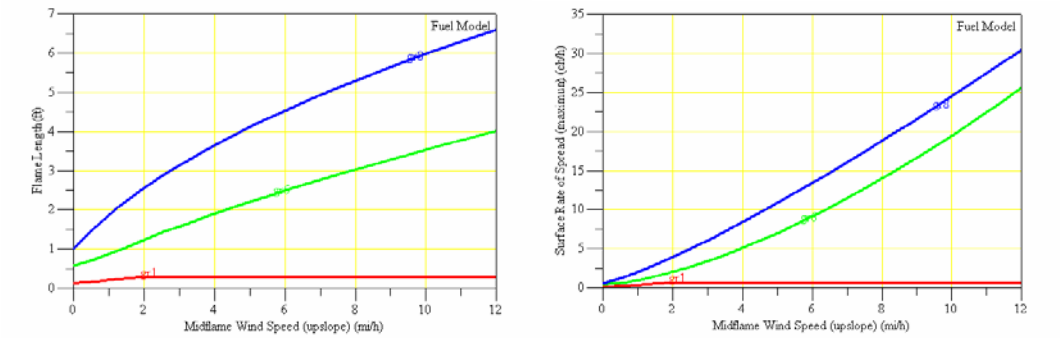


Figure 23. BEHAVE 3 fire modelling system results. Left: Comparison of fire flame length in varying grassland fuel conditions. Right: Comparison of fire rate of spread in varying grassland fuel conditions (Blue: grass not burned within the last three years, green: grass burned within the last three years; red: grass cut and removed)

Experiment with prescribed burning in Melaleuca: As outlined above, current conditions within *Melaleuca* stands in Tram Chim National Park are conducive to extreme fire behaviour. Observations from a *Melaleuca* stand that burned in 2005 and a wild fire in 2006 indicate that under certain conditions, fire can reduce fuel hazard significantly with little mortality. For example, Figure 24 demonstrates that there was little mortality within the stand burnt in 2005. The amount of dead and downed fuels is very low and ladder fuels are absent compared to other recently unburned stands such as those shown in Figure 19. It is therefore recommended that currently approved and planned experimental burning of *Melaleuca* proceed in order to refine burn prescriptions and techniques which will ultimately lead to the decrease in the fuel loading and lowered risk of uncontrolled fire. In some cases manual removal of biomass may be desirable prior to prescribed burning as a precautionary measure designed to reduce particularly heavy fuel loads (see the following recommendation for additional advantages of this approach). Figure 25 shows the impact on

Figure 24. Melaleuca stand burnt in March 2005 (photograph taken in April 2006)

fire behaviour characteristics (flame length and rate of fire spread) of prescribed burns in Melaleuca. Under these conditions fires will be less severe with less chance of tree mortality and fire suppression actions will be more effective. Operational tools to undertake these experimental burns are provided in the MWBP Report: Assessment of TCNP Fire Risk and Strategies under Varying Water and Fire Management Scenarios[27]. This includes guidelines for selecting and preparing the site, data collection during the burn and a prescribed burn operational plan.

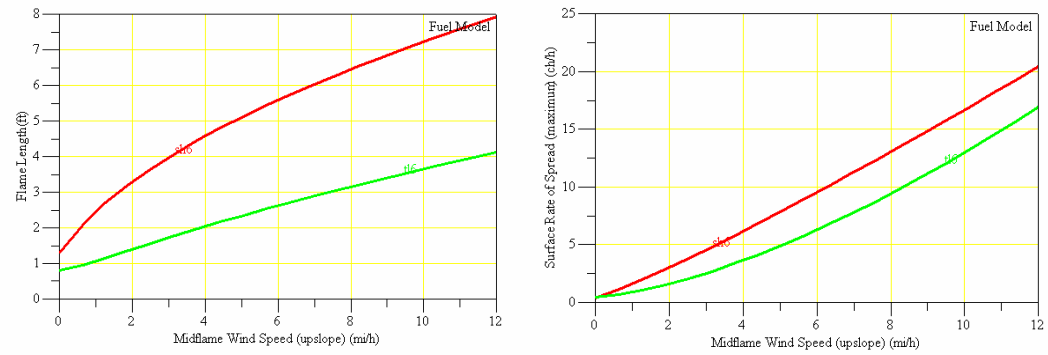


Figure 25. BEHAVE 3 fire modelling system results. Left: Comparison of fire flame length in treated and untreated Melaleuca. Right: Comparison of fire rate of spread in treated and untreated Melaleuca (Red: untreated, green: treated)

Extraction of biomass by local people under controlled conditions: Reduction of fuel loads should be achieved through the carefully controlled extraction of biomass by local people. The recent Decision No. 186/2006/QD-TTg regarding the issuance of regulation on management of three forest categories (special-use forest, protection forest and production forest) provides excellent opportunities to form partnership programmes with local communities in meeting fuel reduction objectives. Within *Melaleuca* simple silviculture practices such as thinning, pruning (e.g. cutting of lower branches) and the collection of dead woody material on the ground will reduce the available fuels and therefore the risk of uncontrolled fire and its severity should it occur. Similar positive impacts could be achieved through the removal of biomass from grassland areas. Allowing cattle to graze within the Park could lead to undesirable ecological impacts (such as soil disturbance, higher soil nutrient status and the spread of invasive species in particular *Mimosa pigra*) as well as higher chances of the ignition of fires resulting from the activities of people herding the cattle. However, the cutting of grass for fodder and other uses (such as mulching of vegetable crops and handicrafts) could be employed to reduce the fuel load in grassland communities. This approach would be particularly useful in grassland areas surrounding *Melaleuca* stands. When combined with the use of prescribed burning this technique will reduce the severity of fire behaviour in grassland and increase chances for fire suppression crews to have significant impacts in controlling the fire. Enabling people to extract these resources from the Park has the additional advantage of supporting rural incomes and improving relationships between the Park and local communities.

New techniques / equipment for fire fighting: Enhanced capabilities for fighting fire and using prescribed burning as a fire management tool can be achieved through the adoption of new techniques and the acquisition of additional equipment. The Fire Management Plan[28] developed through collaboration with MWBP, the Forest Protection Department and Park Management details recommended management of fire within the National Park.

Expected Outcomes:

The expected outcomes of implementing the recommended management tools and interventions related to the management of fire within Tram Chim National Park are:

- A change in the current management ethos towards recognition that fire does play important roles within the ecosystem of the Park.

- Through the routine assessment of fire environment indicators enhanced ability to make informed fire management decisions.
- Reduction of fuels in grassland areas through prescribed burning and carefully controlled cutting and removal of grass in order to reduce the risk of uncontrolled fires which could otherwise expect to increase due to recommended lower water levels. Fuel manipulation may also assist the restoration of native grassland species including *Eleocharis* with positive impacts for native fauna.
- Improved understanding of the use of prescribed burning within *Melaleuca* stands leading to the potential adoption of this strategy combined with simple, carefully controlled silviculture practices by local communities in order to reduce fuels in these areas in the future. The combination of these approaches will reduce the risk of uncontrolled fires which could otherwise expect to increase due to recommended lower water levels.
- Improved health of *Melaleuca* stands as a result of fuels management leading to vigorous tree growth and regeneration.
- Positive impacts on fisheries with the removal of impediments to fish fingerling movement within flooded *Melaleuca* stands during the wet season.
- Improvements in fire fighting capabilities that include the use of prescribed burning, adoption of new techniques and acquisition of new equipment.
- Improved relations with local communities through partnership programmes that meet fire management objectives while also providing benefits to communities in forms which include fuel wood and fodder.

4.4. Invasive Species Management

The Current Situation:

Tram Chim National Park has been impacted by alien invasive species, most notably *Mimosa pigra*, with knock-on impacts for other parts of the ecosystem.

Impacts on the Ecosystem:

Alien invasive species are recognised as posing a significant threat to wetland ecosystems[29]. Wetlands are particularly vulnerable to invasives since they are located at the interface between terrestrial and aquatic environments and so are susceptible to invasions from both directions. Invasive species can cause problems through predation, introduction of disease, competition for food and other resources, hybridisation, and habitat degradation[29]. The most important invasive species within Tram Chim is *Mimosa pigra*. This is an aggressive woody shrub forming impenetrable, prickly thickets of up to 4-5 m high[30,31]. It can make areas impenetrable to animals and people. Within Tram Chim *Mimosa pigra* is spreading into grassland areas where it out competes native grassland species such as *Eleocharis* resulting in habitat degradation[32]. Field studies conducted during 2000 - 2002 showed that the area covered by *Mimosa pigra* in Tram Chim has increased from approximately 450 ha to approximately 1,800 ha during this period (Figure 26). The introduction of *Mimosa* to the Park was initially associated with creation of favourable areas for colonisation provided by the banks created by canal construction and associated dikes. Large parts of zones A4 and A5 are now subject to *Mimosa* invasion whilst in zones A1 and A2 *Mimosa* is spreading from the west towards the centre of these parts of the Park due to the spread of seeds by floodwater (Figure 27). The recommended removal of some of these dikes within A1 (see section 4.2) should assist in the tackling its spread in this part of the Park. *Mimosa* is now contributing to the further reduction in habitat quality already impacted by current water management practices. The movement of *Mimosa* into grassland areas is particularly significant since it is this habitat which is emblematic of the original Plain of Reeds and upon which important species, including the flagship Sarus Crane, depend[33]. Anecdotal evidence suggests that the golden apple snail (*Pomacea canaliculata*) has become more abundant in Tram Chim, perhaps as a result of prolonged inundation. This snail can out-compete native snails resulting in lower diversity of native benthic fauna.

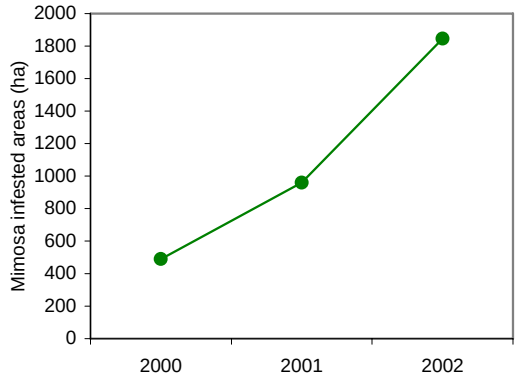


Figure 26. Expansion in the area of Mimosa pigra within Tram Chim National Park between 2000 and 2002

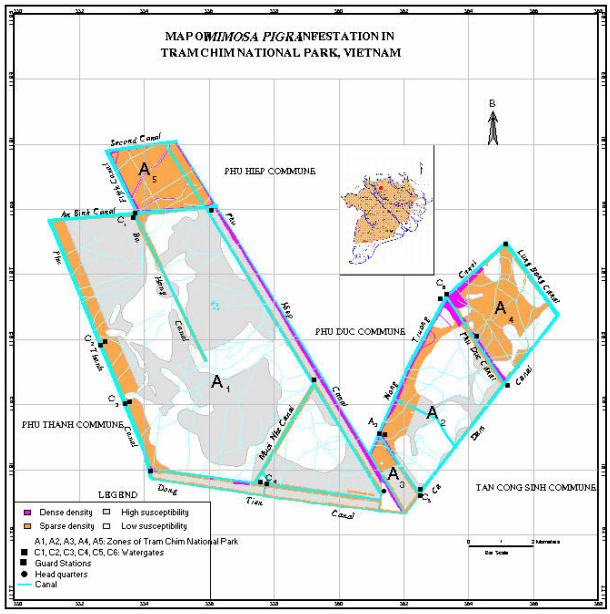


Figure 27. Extent of Mimosa pigra invasion within Tram Chim National Park (2002)

Management Tools / Interventions:

The proposed management interventions related to the management of alien invasive species within Tram Chim aim to assist the removal of *Mimosa pigra* and the restoration of native grassland species, in particular *Eleocharis*.

Mimosa pigra control and Eleocharis restoration: Experiments using different approaches to removing *Mimosa pigra* and promoting the re-establishment of *Eleocharis* were undertaken within Zone A4 as part of the Interim Period Workplan[17]. Results of these experiments lead to the following recommendations aimed at removing *Mimosa pigra* from areas which have been colonised by this alien invasive and in turn promoting the re-establishment of grassland, in particular *Eleocharis*. Areas to be restored should be burnt and then ploughed approximately two months before flood water arrive within the Park. This will kill most of the living *Mimosa* stems as well as *Panicum* grasses which can compete with *Eleocharis*. After ploughing the top soil should be kept moist by irrigated with water pumped from adjacent canals. Following the flood, water levels should be manipulated in accordance with the target levels recommended in Section 4.1 so that the ground water table falls to between 30-40 cm below the ground surface. This will provide the hydrochemical conditions most conducive to *Eleocharis* growth including the formation of tubers.

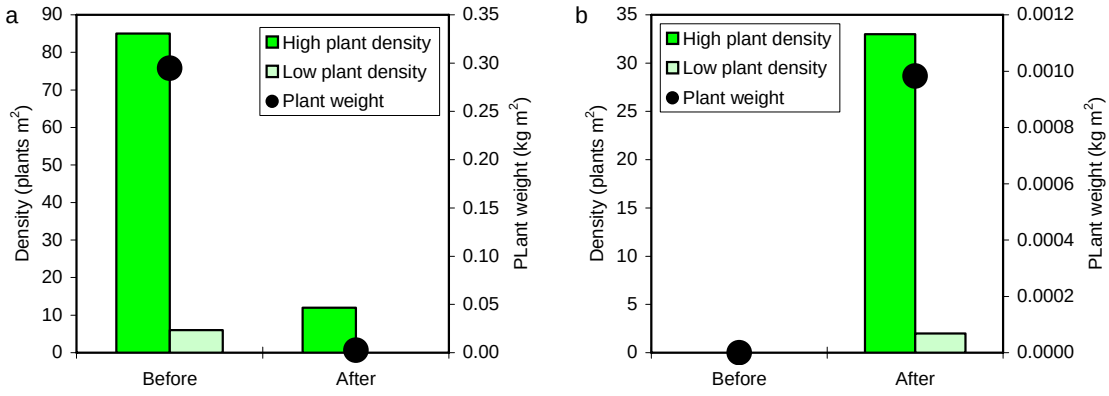


Figure 28. Experiment results of burning, ploughing and irrigating test plots(a) Mimosa Pigra, (b) Eleocharis.

Figure 28 shows that within experimental plots these treatments resulted in large declines in the density and weight of *Mimosa pigra* plants and the re-establishment of *Eleocharis*. It is evident that some *Mimosa*

plants did grow within the experimental plots due to the germination of seeds stored within the soil seed bank or released by fire. These new plants are, however, small and must be pulled up, a relatively easily accomplished task. Failure to remove these young plants will result in the re-establishment and potential spread of *Mimosa*.

Previous studies on the control of *Mimosa pigra* in Tram Chim also proposed integrated management programs employing different control methods (burning, cutting, immersing cut stems under flood water, using herbicides) with each method targeting different growing stage of the *Mimosa* plant. This integrated control program is currently being implemented at a pilot scale in a 10 ha heavily infested part of Zone A4).

Involvement of local communities in Mimosa pigra removal: As Figure 28 indicates, it is unlikely that the above treatments will remove all *Mimosa pigra* from areas targeted for grassland restoration. As noted above, new *Mimosa* plants which grow in these areas can, however, be pulled up relatively easily in the early stages of their development. It is recommended that local communities be involved in this work under careful control. Similarly, local communities can be involved in the removal of *Mimosa* from other areas within the Park not subject to the burning, ploughing and irrigation treatment described above. The removal of *Mimosa* by local people provides important opportunities for people to benefit from Park management activities. For example, demonstration projects in the Buffer Zone around the Park have shown the success of feeding goats on leaves and young stems of *Mimosa* whilst the thicker woody stems can also be used to grow mushrooms (Figure 29).

Figure 29. Potential uses of Mimosa pigra by local communities: Fodder for goats (left); growing of mushrooms (right)

Monitoring of invasive species and early intervention: Water draw-down may favour the spread of *Mimosa pigra* into grassland areas which, under current water management, are deeply inundated. Monitoring for new colonisations and early intervention measures using simple methods such as pulling up young stems should be implemented to prevent the further expansion of *Mimosa pigra*. Lower lower water levels which result in periods of no inundation may effectively reduce the abundance of golden apple snails. It is recommended that this should be monitored. Allowing the collection of these snails by local people for feeding ducks or fish should also be considered.

Expected Outcomes:

The expected outcomes of implementing the recommended management interventions related to invasive species (i.e. *Mimosa pigra*) within Tram Chim National Park are:

- A reduction in the extent of *Mimosa pigra* within the National Park through the application of the recommended treatments.

- Restoration of *Eleocharis* grasslands in areas previously subject to encroachment by *Mimosa pigra* and subsequent beneficial knock-on ecological impacts such as improved habitat suitability for native fauna including the Sarus Crane.
- Improved relations with local communities through the provision of fodder provided by the removal of *Mimosa pigra*.
- A reduction in the abundance of the golden apple snail through the application of recommended lower water levels and the collection of snails by local people.

4.5. Summary

In summary, the management tools / interventions with respect to water levels, hydrological processes, fire and invasive species which are recommended for adoption within Tram Chim National Park are as follows:

Water Level Management

- The adoption of **target water levels** developed for each management zone designed to establish water level regimes which are closer to those experienced historically.

Restoration of Hydrological Processes

- The construction of **new water control structures** in the perimeter dike around Zone A1 which are designed to enhance the exchange of water between this part of the Park and the surrounding areas and in turn enhance sheet flow.
- The planting of **vegetation buffer areas** adjacent to the new water control structures in order to trap incoming sediment.
- The **removal of dikes** along the new canal in the centre of the southern section of Zone A1 in order to improve connectivity between the canal and surrounding areas and in turn enhance sheetflow.

Fire Management

- The **official recognition of fire**, including the acknowledgement of the important ecological role it played within the original Plain of Reeds, by Park Management.
- The establishment of practices to ***routinely assess fire environment indicators during the dry season*** *in* order to inform fire management decisions.
- **Continued use of prescribed burning in grassland areas** in order to reduce the numbers of grassland wildfire ignitions and enhance the ability of fire fighters to suppress wildfires.
- **Experiment with prescribed burning in *Melaleuca*** in order to explore options for decreasing the risk of uncontrolled fire by reducing fuel loading.
- **Extraction of biomass by local people** under controlled conditions in order to reduce fuel loadings. This includes simple silviculture practices in *Melaleuca* (e.g. collection of dead woody material on the ground and cutting of low dead branches) and grazing in grassland areas.
- The use of **new techniques and equipment for fire fighting** to enhance the capabilities of suppressing wildfires using prescribed burning as a fire management tool.

Invasive Species Management

- The use of targeted burning, ploughing and, where required, irrigation to **remove *Mimosa pigra* and restore *Eleocharis* grassland**.
- **The involvement of local communities in *Mimosa pigra* removal** including the harvesting of *Mimosa* plants for fodder and other uses.
- **Monitoring of invasive species and early intervention** to prevent further expansion of *Mimosa pigra* into grasslands which may become more susceptible to invasion after the implementation of the recommended lower water levels. Monitoring should also be undertaken of the invasive golden apple snail which lower water levels could help to control. The collection of these snails by local people could also contribute to the control of this species.

Table 5 summaries the expected outcomes upon different groups of fauna and flora within Tram Chim National Park of the proposed management interventions associated with water levels management, the restoration of hydrological processes, fire management and invasive species management. Where it is not possible to predict impacts at present the impacts of implementing the proposed management interventions should be investigated through monitoring.

Table 5. Summary of impacts on ecosystem components of proposed management interventions (+: positive impacts; - negative impacts; 0 no impacts; ? impacts unknown)

Component	Water Level Management	Restoration of Hydrological Processes	Fire Management	Invasive Species Management
Grassland in general	+	0	+	+
Eleocharis	+	0	+?	+
Melaleuca	+	+?	+	0
Mimosa pigra	?	+	+ / - †	+
Birds: Waders, cranes etc	+	0	?	+
Birds: Deep water species	-	0	0	0
Fish	?	+	+	0
Plankton	+?	+?	0	0
Golden apple snail	-	0	0	-

† When combined with other recommended treatments fire can be employed to reduce Mimosa pigra, without these treatments fire can result in its expansion.

5. OPERATIONAL DATA COLLECTION AND MONITORING

Monitoring is an important element of any wetland management strategy[4]. It is required in order to inform day-to-day management (e.g. when to open sluice gates or undertake a prescribed burn), assess whether targets (such as, for example, water levels) are being achieved, to evaluate ecosystem responses to management interventions and to further improve management as knowledge of ecosystem functioning improves. Table 6 summaries the recommended data collection and monitoring activities for Tram Chim National Park. It identifies those activities which should be undertaken by Park staff as well as those for which external funding would be required or where external organisations such as universities could be involved. The involvement of universities within these activities will enhance Tram Chim's important role as an educational resource within Vietnam.

Table 6. Recommended operational data collection and impact monitoring activities for Tram Chim National Park

Parameter	Location(s) / Timing	Technique / Instrumentation	Participant
Water levels (O)	One location in each management zone and adjacent to Park Headquarters.	Staff gauges.	TCNP[1]
Sluice gate operation (O)	All sluices.	Dates and elevation of any changes made to the gates within the sluices.	TCNP
Meteorological factors relevant to fire management (relative humidity, wind speed and direction, maximum and minimum temperature) (O)	One location (i.e. Park Headquarters) on a daily basis throughout the dry season. On site immediately before and during any prescribed burns.	Techniques / instrumentation described in the Fire Management Plan.	TCNP / FPD[2]
Fuel moisture (O)	On site immediately before prescribed burns.	Fuel moisture sticks.	TCNP / FPD
Water quality (pH, DO, turbidity). (O & I)	Locations 1-13 employed within the Interim Period Workplan.	Monthly observations between September and May; bi-weekly between June and August. Evaluated using hand held field electronic probes.	TCNP

Mimosa pigra. (O & I)	Along all dikes and the adjacent grassland areas.	Once a month. Combining monitoring with early intervention by simple mechanical methods of removal (pulling, cutting stems).	TCNP
Dead and down fuel load within *Melaleuca.* (O +I)	Locations subject to manual biomass removal or fire.	Brown's planar intersect.	TCNP / FPD
Sedimentation rate (I)	Transects starting at new water control structures and extending 200 m into surrounding habitats.	Mesh traps deployed at low water level and recovered once exposed in the next dry season. Sediment weight evaluated in the laboratory.	TCNP / CTU[3]
Eleocharis grassland recovery and tuberization following water-draw down (I)	Three transects established within the Interim Period Workplan.	Once a month during dry season (January to June). Evaluated through field measurements of vegetation structure, aerial biomass, root biomass and tubers.	TCNP / UNS[4]
Grassland responses to prescribed burning (I)	Five main grassland types: *Panicum*, *Eleocharis dulcis*, *E. atropurporea*, Wild rice, and *Ischaemum.*	Once a month during the dry season (January to June). Evaluated through field measurements of vegetation structure and biomass.	TCNP / UNS
Regeneration of *Melaleuca* following fire (accidental and prescribed) (I)	Locations of fires.	Measurements of number of stems, DBH and diameter at base within 10 x 10 m plots.	UNS
Phytoplankton (I)	At water quality monitoring locations.	Three times a year: March, June and October. Evaluated through field sample collection using plankton net and laboratory analysis.	TCNP / UNS
Zooplankton (I)	At water quality monitoring locations.	Three times a year: March, June and October. Evaluated through field sample collection using plankton net and laboratory analysis.	TCNP / UNS
Birds (I)	Continue bird counts as at present.	Continue bird counts as at present.	TCNP / ICF
Fish (I)	At sluice gates, three times a year.	Nets positioned downstream of sluice gates.	TCNP / CTU
Golden apple snail and native snails (I)	10 sampling locations in A1 and A2 (5 locations in each zone).	Three times a year: March, June and October. Evaluated through field sample collection..	TCNP / UNS

(O = Data collection for operational activities associated with day-to-day management, I = Data collection and monitoring required for evaluation of impacts of proposed management interventions) 1 Tram Chim National Park; 2 Forest Protection Department of Tram Chim National Park; 3 Can Tho University; 4 University of Natural Sciences, Ho Chi Minh City)

6. BUDGET

Table 7 summaries the estimated costs for major infrastructure and equipment associated with the new Water and Fire Management Strategy. It also provides an estimate of the cost of operational data collection and monitoring.

Table 7. Summary of estimated costs of major infrastructure and equipment for the Water and Fire Management Strategy and annual costs of operational data collection and impact monitoring activities

Item	**Total cost (MVND)**
Sluice gates: re-surveying and new flash boards	50
Two new water control structures for sheetflow restoration in A1	2300
Planting of vegetation buffer zones inside Park and adjacent to new water control structures	20
Removal of dikes along central canal in south of Zone A1	300
Fire fighting equipment	1000
Operational data collection and monitoring (annual cost)	200 $year^{-1}$

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