RECOMMENDATIONS

FOR THE LONG-TERM GOVERNANCE, DESIGN AND MANAGEMENT OF PAK NAI -AN IMPORTANT ECOLOGICAL HOTSPOT

FEBRUARY 2025

TNC is a member of and is supported by

HONG KONG MARINE PROTECTION ALLIANCE 香港海洋保育聯盟



大自然保護協會

ABOUT THE NATURE CONSERVANCY

The Nature Conservancy (TNC)'s mission is to protect the lands and waters on which all life depends. Our vision is a world where the diversity of life thrives, and people act to conserve nature for its own sake and its ability to fulfil our needs and enrich our lives. Our headquarters is based in the United States and was founded in 1951. As a science-based, nonpartisan, non-profit organisation, TNC is the world's most respected organisation with over 70 years of conservation experience around the world, including 30 years of experience in estuary restoration science.

OUR VALUES

- Integrity Beyond Reproach
- Respect for People, Communities, and Cultures
- Commitment to Diversity
- One Conservancy
- Tangible, Lasting Results

THE NATURE CONSERVANCY'S WORK IN HONG KONG

The Nature Conservancy Hong Kong Foundation Limited was established first as a branch in 2002 and then registered in 2016 as a tax-exempt charity in Hong Kong. TNC is a self-financed organisation. In Hong Kong, TNC's vision is to build Hong Kong to be a sustainable city where people and nature thrive. Our goal is to protect and restore healthy oceans and coasts of the Greater Bay Area by catalysing public and private investment in nature-based solutions, carrying out inclusive community-based conservation models and revitalising sustainable aquaculture. Since 2017, we have been pioneering shellfish restoration science and working closely with local communities across Deep Bay to develop long-term solutions for conservation and sustainable development in the area. We have built a strong relationship with the local oyster aquaculture industry and local community in Pak Nai and collaborated with academic partners to understand the ecological, economic and social value of Hong Kong's estuarine ecosystems. Alongside our partners, we have been working in Deep Bay to rehabilitate Hong Kong's natural shellfish reefs to restore their ecological, social and cultural value, while helping the oyster aquaculture industry to become more sustainable and create less waste.

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THE NATURE CONSERVANCY'S GOALS FOR 2030

So much can occur in a single lifetime. Three quarters of the carbon dioxide emissions driven by humans have occurred since 1950. We have seen a nearly 70 percent average decline of birds, amphibians, mammals, fish and reptiles since just 1970. Our window of opportunity is open now! Our planet faces the interconnected crises of rapid climate change and biodiversity loss. We have years, not decades, to address these existential threats. The science is clear, we must act now to halt catastrophic climate change and biodiversity loss. What we do between now and 2030 will determine whether we slow warming to 1.5° C —the level scientists agree will avoid the worst impacts of climate change. Our actions will also determine whether we conserve enough land and water to slow the rapid acceleration of species loss. If we do both, we will safeguard people from the disastrous effects of these crises. TNC has six targets by 2030:

- 1. **Carbon Emission:** Reduce or store 3 gigatons of CO, emissions yearly
- 2. Helping People: Benefit 100 million people
- 3. Our Ocean: Conserve nearly 10 billion acres of ocean
- 4. Healthy Lands: Conserve 1.6 billion acres of land
- 5. Freshwater: Conserve more than 620,000 miles of rivers
- 6. Local Leaders: Support 45 million local stewards

**** **4.3**B

of the world's population.

🔊 2-3x

people live in the region, or roughly 60%

faster than the global average sea level

rise for low-lying areas in the Pacific.

42%

of all species in Southeast Asia could be lost by the turn of the century; at least half of these would be global extinctions.

迷 40%

of the region's coral reefs and mangroves are lost due to extensive coastal development and unsustainable exploitation of marine resources. • 2 2

or 63% of Asia Pacific's GDP at risk due

\$19Tr

to nature loss.

of the three largest emitters of carbon and other greenhouse gases are based in the region (China and India).

Figure 1. Why Asia Pacific Matters? The region is losing nature at a rate faster than anywhere else, yet its ecosystems are critical to combating climate change and biodiversity loss.

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(Cover photo: An endangered Chinese Horseshoe Crab and its foraging route on the restored mudflats at Pak Nai. In the background, a rehabilitated oyster reef, constructed by the project team and TNC volunteers, is visible. Tom Chan/TNC)



CONTENTS



FEATURES: OUR RECOMMENDATIONS FOR THE CONSERVATION AND LONG-TERM MANAGEMENT OF PAK NAI

22 Phase 1: Recommended Other Effective Area-Based Conservation Measures (OECMs) as a precursor to the establishment of Protected Areas

Sound design and planning, effective management and monitoring, and transparent decisionmaking processes

30 **Phase 2: Recommended Long-term Management Strategies under the newly established Protected Area**

Ensure connectivity with other protected areas, community-based conservation

- 1 About The Nature Conservancy
- 3 Executive Summary
- 5 Introduction
- 7 Part 1-Site Major Conservation Values
- 9 Part 2 Threats to Pak Nai's Sensitive Ecology
- Part 3 Habitat Management Activities, Monitoring and Evaluation (2021 - 2024)
 Habitat Restoration and Rehabilitation Work

II) Scientific Monitoring

- 19 Part 4 Ecotourism at Pak Nai: Challenges and Opportunities
- 21 Part 5 Recommendations for the Conservation and Long-term Management of Pak Nai

Phase 1: Recommended Other Effective Area-Based Conservation Measures (OECMs) as a precursor to the establishment of Protected Areas

Phase 2: Recommended Long-term Management Strategies under the newly established Protected Area

- 33 Conclusion
- 33 References
- 35 Acknowledgements
- 37 Appendices

Appendix A – Terminology and Definitions Appendix B – Survey Methodologies Appendix C –TNC Pak Nai Science Symposiums



EXECUTIVE SUMMARY

Pak Nai lies on the shores of Deep Bay, in the far northwest of the Hong Kong SAR. A variety of coastal wetland habitat types are present including mangrove forests, oyster reefs, soft shore and Hong Kong's largest expanse of seagrass *Halophila beccarii*. Pak Nai is also Hong Kong's largest nursery and foraging grounds for two locally threatened horseshoe crab species, and is regarded as an outstanding biodiversity hotspot. The intertidal areas are designated for oyster farming under a government short-term tenancy (STT), and the lands of Pak Nai are designated as either Coastal Protection Areas (CPA) or Agriculture Land (AGR), hence limiting the threats from urban development. However, the site is not designated as a statutory park (e.g. Marine or Country Park) and therefore does not benefit from active management. As a result, the presence of on-going threats including illegal fishing practices, invasive species, plastic pollution and other aquaculture debris and wildlife disturbance from unregulated tourism, compromise its ecological integrity.

In 2021, the Hong Kong government unveiled an ambitious project to transform a large area of northern Hong Kong into the Northern Metropolis. This new metropolis is set to accommodate over 2.5 million residents, create 650,000 jobs and partially transform rural areas into a high technology and logistics hub. Pak Nai is included in the Northern Metropolis blueprint as a strategic site for conservation and ecotourism development within the proposed 10 km long Coastal Protection Park (CPP) along the Deep Bay coastline.

With this context in mind, in 2021, The Nature Conservancy (TNC) was invited by local communities to carry out site-based habitat management activities to address on-going conservation threats. In response, TNC launched a communitybased conservation programme in collaboration with academic institutions, multiple environmental NGOs, local communities and public volunteers to actively manage over 50 hectares of shoreline at Pak Nai's Ap Tsai Hang. Over the past 4 years, we have been carrying out multiple habitat management activities, on-going scientific monitoring and evaluation of key biological indicators, and active stakeholder engagement. The results to date are promising, including a 190% increase in endangered horseshoe crab populations, while interviews with tourists reveal strong support for increased protection of the site. This shows that a community-based management model with a systematic science-based and collaborative approach can address threats, rehabilitate local ecosystems and foster local stewardship by providing opportunities for the development of sustainable tourism.



Figure 3. The 52 hectares of coastal area managed through community-based conservation, highlighted in blue. (© Sheila Wong/TNC)

This report aims to share the learnings of TNC's habitat management work in Pak Nai and contribute knowledge to the forthcoming feasibility study for the establishment of the CPP, which commenced in December 2024 and will last for 20 months. We include recommendations for the future management and monitoring of Pak Nai as a key conservation area within the CPP, as well as recommendations that can be applied to other areas of the CPP, hence the recommendations proposed in this report is applicable for the government-owned intertidal areas of Deep Bay. Recommendations are both derived from scientific data and consensus driven, with significant input from academic, conservation, and local community stakeholders from collaborating organisations, including but not limited to the Conservancy Association, Ha Pak Nai Education Centre, Hong Kong Bird Watching Society, Hong Kong Marine Protection Alliance, Kadoorie Farm and Botanic Garden, Outdoor Wildlife Learning Hong Kong, Swire Group Charitable Trust, and World Wild Fund for Nature Hong Kong. Finally, recommendations respect traditional ownership rights and aim to foster local stewardship by local communities and oyster farmers.

Priority recommendations and guiding principles include:

- 1. Establish Pak Nai's intertidal areas (from Sheung Pak Nai Site of Special Scientific Interest (SSSI) to Tai Shui Hang of Ha Pak Nai) as protected areas with active management and include core conservation no-go zones to safeguard the valuable coastal ecosystem and threatened species. We also recommend adopting the IUCN Green List framework as a global benchmark for protected areas.
- 2. Establish a Pak Nai advisory committee and carry out early stakeholder engagement: establish a management advisory committee comprising of government officials, academics, and local community and conservation stakeholders to agree on long term management objectives for the Pak Nai protected area. To avoid conflicting uses, it is important to actively involve all stakeholders early in the planning and design process to achieve consensus on spatial planning and management objectives.
- 3. Incorporate community-based conservation principles for long term management: encourage local stewardship and develop ecotourism activities to benefit local communities, in line with global ecotourism standards and principles as defined by the IUCN.



Figure 4. The proposed broad land use concept plan from the government indicates that there may be a coastal protection park planned to cover the coastline. The timeline, boundary and management models have not yet been defined. (Reference: Northern Metropolis Coordination Office, Development Bureau of Hong Kong Government)



INTRODUCTION

Pak Nai

Pak Nai is situated in the Yuen Long District, on the shores of Deep Bay, in the far northwest of the Hong Kong SAR, and 11km southwest of the Mai Po Nature Reserve. It is best known to the public as a location for watching sunsets overlooking Shenzhen. Designated areas that constitute "Pak Nai" cover approximately 4.2 km of coastline and include the villages of Sheung Pak Nai and Ha Pak Nai.

In terms of conservation value, Pak Nai comprises one of the city's largest intertidal mudflats and a mosaic of associated habitats, including mangroves and oyster reefs that nurture a diverse variety of marine and bird life. They also house Hong Kong's largest expanse of seagrass *Halophila beccarii* (Fong 1998) and provide nursing and foraging grounds for endangered horseshoe crab species *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*, as well as local and migratory birds. While none of the known horseshoe crab nurseries in Hong Kong are currently protected – nor are the species themselves, the site is one of the few remaining areas in the HKSAR and the entire Pearl River Estuary that still supports relatively high densities of Chinese horseshoe crabs. Not only does Pak Nai hold great potential for rehabilitating populations of horseshoe crabs, but it also serves as a natural extension of the Mai Po and Inner Deep Bay wetlands, increasing the area's capacity to support migratory shore birds.

TNC's Pak Nai programme summary

The aim of the "Managing Pak Nai's Ecologically Important Habitats to Preserve its Natural Beauty and Sensitive Biodiversity" <u>programme</u> was for TNC to take a partnerbased approach by working with members of the Hong Kong Marine Protection Alliance (HKMPA, see Appendix A) to protect, manage and restore Pak Nai's critical habitats for the long-term benefit of native biodiversity and species of conservation importance. Pak Nai has been selected by the HKMPA as one of four priority sites for enhanced protection. A dedicated HKMPA working group was established in 2023 to support site designation, which TNC facilitates. TNC also actively raises awareness about the importance of protecting Pak Nai through organising symposiums, public outreach activities, youth training and media interviews in the area. The program also aims to showcase a novel community-based management model that could be replicated in other vulnerable marine biodiversity hotspots.

Programme objectives:

1. Enhance the under-protected marine environment of Pak Nai by addressing critical issues of biodiversity loss, knowledge gaps, habitat management and improvement.

Tachypleus tridentatus



Figure 6. Map of the Pak Nai area showing different zonation. (Reference: <u>https://www.ozp.tpb.gov.hk/</u>)



Figure 7. Area covered by Government Tenancy STT 2266 and the preliminary proposed new Government tenancy area. (Reference: https://www.legco.gov.hk/yr2024/english/panels/fseh/papers/fseh20241008cb2-1168-3-e.pdf)





- 2. Promote responsible use and area management by addressing unregulated tourism and other detrimental activities.
- 3. Foster a blue culture by raising public awareness of the critical importance of Pak Nai's habitats and driving long-term behavioural changes to encourage local participation in marine protection.

Programme activities:

- 1. Site-based management to protect at-risk, vulnerable species and restore ecosystem integrity: Abandoned oyster farm restoration, invasive species removal, aquaculture debris removal, marine plastics removal.
- 2. Scientific research in partnership with academic institutions to address knowledge gaps and carry out monitoring and evaluation of our habitat management work: Horseshoe crab population surveys, habitat and species mapping, sediment and reef data collection. Findings are shared with the Agriculture, Fisheries and Conservation Department (AFCD) and local communities to guide science-based recommendations for improved protection and management.
- **3.** Foster local community stewardship and participation: We work hand in hand with the local community to share scientific findings, develop sustainable livelihoods from ecotourism and employ local community members as site rangers.
- 4. Outreach activities to increase public awareness of Pak Nai's ecological, cultural and social importance, and influence behavioural change: School field trips, volunteer events for hands-on conservation management work, knowledge-sharing sessions and interactions with local communities and tourists.

Pak Nai in the context of the Northern Metropolis

In 2021, the Hong Kong government unveiled an ambitious project to transform a large part of northern Hong Kong into the <u>Northern Metropolis</u>. This new metropolis is set to accommodate over 2.5 million residents, create around 650,000 jobs and partially transform rural areas into a high technology and science hub, with the vision to become an international information and technology center. The Government adopted six planning principles under the <u>Northern Metropolis Development Strategy</u>, which include "Creating outdoor ecorecreation tourism space " and "Proactive Conservation". For Pak Nai, this has translated into a proposal to create a 10 km Coastal Protection Park (CPP) along the Deep Bay coastline, spanning from Tsim Bei Tsui to Pak Nai, alongside a digital

Northern Metropolis





and ecotourism hub in the area.

In February 2024, further details were shared around the development proposal for the CPP and Lau Fau Shan area. The government announced the launch of a feasibility study for the establishment of the CPP, which will commence in 2025 and last for one year. TNC plans to actively engage in this process and present the HKMPA's long-term recommendations for the effective governance, design and management of Pak Nai. Building on over four years of lessons learned from on-site habitat management, scientific monitoring results, advice from expert ecologists, academic and conservation partners (including the HKMPA) and local community stakeholders, and with reference to the management framework of the IUCN Green List of Protected and Conserved Areas (Figure 8), our aim is to develop comprehensive, consensus-driven recommendations for Pak Nai within the CPP planning framework.

As a starting point to the CPP planning process, this document provides detailed recommendations around governance, design and management for the 52 hectares of coastal area of Pak Nai area specifically (Figure 3). In this report, we use the IUCN Green List framework as a global benchmark for protected and conserved areas, as well as the associated Sustainability Standard to assess our impact towards achieving desired conservation results (Figure 8). The IUCN Green List is a global programme of certification aiming to achieve and promote effective, equitable and successful protected and conserved areas by highlighting best practices and providing a benchmark for progress towards effective and equitable management (e.g. in the development of ecotourism). The standard provides guidance that could be useful to the CPP planning stage to ensure long-term conservation outcomes that benefit both nature and people. local participation in marine protection.

Good Governance

Sound Design and Planning

Successful Conservation Outcomes

Effective Management

site's goals and objectives. (Reference: IUCN)

Figure 8. Framework of IUCN Green List Standard – The four baseline components, i.e. good governance, sound design and plannina, effective management, and successful conservation outcomes that will attest the successful achievement of a

Create

6

PART 1 - SITE MAJOR CONSERVATION VALUES

1.1 Diversity of habitats

The coastal ecosystem of Pak Nai includes a diverse range of habitats, including soft shore mudflats, seagrass beds, natural oyster beds, abandoned oyster farms, native mangrove stands, sandy and rocky shores and estuarine streams.

1.2 Flagship species (species of ecological importance)

The high variety of coastal habitats are home to many intertidal organisms, for example, Hong Kong Oysters (*Magallana hongkongensis*), endangered Chinese Horseshoe Crabs (*Tachypleus tridentatus*), threatened Mangrove Horseshoe Crabs (*Carcinoscorpius rotundicauda*), threatened seagrass (*Halophila beccarii*) and mangroves (*Kandelia obovate*). According to the <u>eBird database</u>, over 240 bird species have been recorded from Pak Nai, 44 percent of which are reliant on coastal wetlands, including endangered Black-faced Spoonbills. From previous studies (*Anon 2018 and Anon 2019*), nests of Little Egrets and Chinese Pond Herons are also present in Pak Nai.





Figure 9. Chinese Horseshoe Crabs (Tachypleus tridentatus) at Pak Nai. (©Tom Chan /TNC) [IUCN Red List Status: Endangered/ last assessed: 2018/ Population Trend: Decreasing]





Left: Figure 10. Mangrove Horseshoe Crabs (Carcinoscorpius rotundicauda) at Pak Nai. (© Tom Chan /TNC) [IUCN Red List Status: Data Deficient / last assessed: 1996] Right: Figure 11. Hong Kong Oysters (Magallana hongkongensis) at Pak Nai. (© TNC)[IUCN Red List Status: Not Evaluate]

2018	Great Egret	Lit Egi	tle Blac ret crowr Night H	k- Ch 1ed P eron H	inese l ond eron	Eastern Cattle Egret	Total	%	Rank
Deep Bay area									
1. Mai Po Village		: 9	9 :	:	123	:	222	20.5	1
2. Mai Po Lung Village		: 14	4 :		53 :		67 :	6.2	6
3. Tung Shing Lane		: 4	9 :		35		84 :	7.8	3
4. Ngau Hom Shek		: 1	l :		18		19 :	1.8	15
5. Pak Nai 2	:	1	7 :		1		18 :	1.7	16
6. Shenzhen Bay Bridge	<u>.</u>	2	2	<u>:</u>	5		27 :	2.5	12
7. Sha Kiu Village		7	7		20		27 :	2.5	12
8. San Sang San Tsuen					1		1	0.1	21
9. Mai Po mangrove*	13	: 2	1 4			2	40	3.7	8
2019	Great Egret	Little Egret	Black- crowned Night Heron	Chinese Pond Heron	Eastern Cattle Egret	Un- identified	Total	%	Rank
2019 Deep Bay area	Great Egret	Little Egret	Black- crowned Night Heron	Chinese Pond Heron	Eastern Cattle Egret	Un- identified	Total	%	Rank
2019 Deep Bay area 1. Mai Po Village	Great Egret	Little Egret 91	Black- crowned Night Heron	Chinese Pond Heron 68	Eastern Cattle Egret	Un- identified	Total	% : 9.7	Rank 3
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village	Great Egret	Little Egret 91 41	Black- crowned Night Heron	Chinese Pond Heron 68 68	Eastern Cattle Egret	Un- identified	Total 159 109	% 9.7 6.7	Rank 3 4
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village 3. Tung Shing Lane	Great Egret	Little Egret 91 41 27	Black- crowned Night Heron	Chinese Pond Heron 68 68 68 38	Eastern Cattle Egret	Un- identified	Total 159 109 65	% 9.7 6.7 4.0	Rank 3 4 7
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village 3. Tung Shing Lane 4. Ngau Hom Shek	Great Egret	Little Egret 91 41 27 9	Black- crowned Night Heron	Chinese Pond Heron 68 68 68 38 38 18	Eastern Cattle Egret	Un- identified	Total 159 109 65 27	% : 9.7 : 6.7 : 4.0 : 1.7	Rank 3 4 7 12
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village 3. Tung Shing Lane 4. Ngau Hom Shek 5. Pak Nai 2	Great Egret	Little Egret 91 41 27 9 22	Black- crowned Night Heron	Chinese Pond Heron 68 68 68 38 18 18	Eastern Cattle Egret	Un- identified	Total 159 109 65 27 23	% 9.7 6.7 4.0 1.7 1.4	Rank 3 4 7 12 14
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village 3. Tung Shing Lane 4. Ngau Hom Shek 5. Pak Nai 2 6. Shenzhen Bay Bridge	Great Egret	Little Egret 91 41 27 9 22 20	Black- crowned Night Heron	Chinese Pond Heron 68 68 38 18 18 1 1 10	Eastern Cattle Egret	Un- identified	Total 159 109 65 27 23 30	% 9.7 6.7 4.0 1.7 1.4 1.8	Rank 3 4 7 12 14 11
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village 3. Tung Shing Lane 4. Ngau Hom Shek 5. Pak Nai 2 6. Shenzhen Bay Bridge 7. Sha Kiu Village	Great Egret	Little Egret 91 41 27 9 22 20 10	Black- crowned Night Heron	Chinese Pond Heron 68 68 68 38 18 18 1 1 10 10	Eastern Cattle Egret	Un- identified	Total 159 109 65 27 23 30 20	% 9.7 6.7 4.0 1.7 1.4 1.8 1.2	Rank 3 4 12 14 11 17
2019 Deep Bay area 1. Mai Po Village 2. Mai Po Lung Village 3. Tung Shing Lane 4. Ngau Hom Shek 5. Pak Nai 2 6. Shenzhen Bay Bridge 7. Sha Kiu Village 8. Mai Po mangrove^	Great Egret	Little Egret 91 41 27 9 22 20 10 5	Black- crowned Night Heron	Chinese Pond Heron 68 68 68 38 18 1 1 10 10	Eastern Cattle Egret	Un- identified	Total 159 109 65 27 23 30 20 557	% 9.7 6.7 1.4 1.8 1.2 34.1	Rank 3 4 7 12 14 11 11 17 1

* Some nests at the Mai Po mangrove, A Chau, Sha Chau, and Ma Wan were found in dense vegetation and may have been overlooked. The number of nests might have been underestimated.

^ Aerial photos of the Mai Po mangrove colony were taken for estimation of the number of nests. Special care was taken during the photo taking session to minimize disturbance to the breeding ardeids.

Table 1. The number of nests at surveyed colonies in Deep Bay in 2018 and 2019 from Anon's 2018 and 2019 studies.



Figure 12. Location of colonies in Hong Kong in 2018 (left) and 2019 (left) from Anon's 2018 and 2019 studies. The squares indicate the Deep Bay areas and point 5 on the maps refers to 'Pak Nai (Tin Hau Temple). (© Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government)



1.3 Site of rich cultural heritage

Oyster farming has more than 700 years of history in the Pearl River Delta and at least 250 years of history in Deep Bay.

The oyster farming technique is one of the traditional craftsmanship methods officially recognised as being part of the <u>Intangible Cultural Heritage</u> (ICH) of Hong Kong. While some oyster farmers employ the raft culture method to cultivate oysters on floating rafts, others (typically older generation farmers) adhere to the traditional bottom culture method. This method allows for natural recruitment of the oyster larvae from the sea on hard substrates in the intertidal zone, such as tailor-made concrete poles placed on the mudflats. These allow the oyster spat to grow to marketable sizes in about 3 years. The mudflats of Pak Nai contain the remnants of abandoned benthic oyster farms that reveal the traditional oyster culture in Deep Bay.





Figure 13. Ocean Turf Grass (Halophila beccarii) at Pak Nai. (© Tom Chan /TNC) [IUCN Red List Status: Vulnerable/ last assessed: 2007/ Population Trend: Decreasing]





Figure 14. Mangrove Kandelia obovata at Pak Nai. (© Tom Chan /TNC)[IUCN Red List Status: Not Evaluated] The mangroves act as .physical barriers (right) to reduce wave energy and hence protect the shoreline.







PART 2 - THREATS TO PAK NAI'S SENSITIVE ECOLOGY

The mudflats of Pak Nai, are currently not protected and face a multitude of threats, including invasive species, illegal fishing, trampling and other disturbance from visitors, and marine litter. Although no development is allowed in this critical area, it receives limited protection and lacks any active habitat management by the Hong Kong Government. Decades of over-harvesting, coastal reclamation, commercial dredging for lime, and have decimated the shellfish populations along with the long list of benefits they provide. Shellfish reefs are now the most endangered marine habitat on the planet with an estimated 85 percent global loss, including the oyster reefs of Hong Kong, but have great potential to be restored at Pak Nai. Likewise, Hong Kong's horseshoe crabs, whose populations are considered one of the key indicators of the success of our restoration efforts, are facing local extirpation due to human activities. Declines are estimated at over 90 percent, with *Tachypleus tridentatus* being listed as endangered in 2019 and a lack of recent data on the once thriving population of *Carcinoscorpius rotundicauda* in Pak Nai (*Shin et al. 2009*).



For context on the to threats noted horseshoe crabs below, an important study into iuvenile horseshoe crabs in Hona Kona concluded that "the overall status of the juvenile horseshoe crabs in Hong Kong is fragile and susceptible to extinction, since apart from potential habitat loss and degradation, the existing populations are small and discrete.

Figure 16. Population density of juvenile horseshoe crabs (Carcinoscorpius rotundicauda) with relatively few new found by walk-through surveys from 2004 to 2005 in Prof. Paul Shin's study recruits. Their limited

foraging range on the spawning/nursery shores is particularly vulnerable to localised habitat disturbances. The wide range of food sources for the juveniles is largely supported by seagrass biomass on the intertidal flats, which is also threatened by on-shore human activities" (*Kwan 2016*).

The various threats to Pak Nai can be summarised as follows:

2.1 Invasive species

Overgrowth of Spartina cordgrass on the mudflats

Smooth cordgrass (*Spartina alterniflora*) is a fast-growing invasive species that has established itself in Hong Kong's wetlands. The cordgrass was occupying a large area of the intertidal zone at Pak Nai, raising the ground level of mudflats by trapping more sediment in their extensive root systems and increasing soil sulphur levels that may be harmful to nearby soft shore organisms, including seagrasses.

2.2 Unregulated tourism (in order of the highest to lowest threats) Littering

There are no rubbish bins on or adjacent to the mudflat at Pak Nai and some visitors discard litter into the natural environment. Litter also washes ashore from the sea. The composition of litter at Pak Nai varies, and some have the potential to entangle mudflat organisms and/or smother plants, preventing the latter from receiving sunlight.

Physical disturbance and removal

Visitors to Pak Nai do come to engage in activities such as clam digging, oyster collection, collecting fallen mangrove propagules, camping and photography. The collection of oysters and removal of horseshoe crabs by visitors has also been known to occur. Access is not managed and visitors may inadvertently trample on seagrass and juvenile horseshoe crabs, which can be well camouflaged (*So et al. 2019*). Although only significant impacts of trampling to subtidal seagrass beds are studied (*N. Nadiarti et al. 2021*), it is believed that this may result in leaf loss and fragmentations of seagrass beds, injury and even mortality of young horseshoe crabs.

2.3 Oyster aquaculture Abandoned farms

Oyster aquaculture is no longer practiced at Pak Nai, but occurred there in the past. Many of the traditional concrete posts lay strewn over the mudflat when TNC initiated their project at Pak Nai. A study simulating the effects of these posts found that juvenile horseshoe crab densities were lower in areas of mudflat where posts were present and suggested that management of the posts should be considered (*Kwan et al. 2017*).

2.4 Fishing and aquaculture related impacts

Improper disposal of aquaculture debris and abandoned fishing gear, e.g. ghost nets

Commonly found aquaculture debris at the site includes long bamboo sticks and blue plastic barrels discarded from the floating oyster rafts, as well as abandoned fishing nets and cages from nearby fishermen. Gill nets pose a higher entanglement threat than regular marine litter.

Use of illegal snake cages

"Snake cages" are a form of trap comprised of an elongated "net tunnel" supported internally by metal frames and with multiple funnel entrances. They are designed to catch a wide variety of fish and invertebrates indiscriminately, and their use is prohibited in Hong Kong. Snake cages are deployed from mainland boats at high tide or by foot from the Hong Kong coast at low tide. While the snake cages may not be targeting horseshoe crabs specifically, entangled ones will die if not released within a few days.



Figure 17. Illegal snake cages (left) and abandoned fishing nets (right) create hazards for the wildlife living on Pak Naïs mudflats. (© Tom Chan /TNC)

2.5 Harmful algal blooms

Harmful algal blooms, commonly known as red tides in Hong Kong, are phenomena caused by the rapid multiplication of certain algae in the sea in response to high nutrient levels. Algal blooms sometimes occur in the coastal areas of Pak Nai during spring and winter, when strong monsoons stir up nutrient-rich seawater and sediment from the bottom to the surface. Although only a small portion of the algal species recorded in Hong Kong are chemically harmful to marine animals, algal blooms may reduce dissolved oxygen levels in the seawater and negatively influence the growth, survival and reproduction of fish, shellfish, and large zooplankton. (*Liang et al. 2023*).

2.6 Climate change

Increased extreme weather, temperature and rainfall

Climate modelling predictions for Hong Kong include increased temperature and heatwaves, increased rainfall and more extreme weather such as typhoons. While their impact on Pak Nai has yet to be examined in any detail, increased heat, lower salinity and more turbulent conditions is likely to increasingly stress flora and fauna on the mudflats and surrounding habitats.

Sea level rise and habitat loss

Long term sea level rise will likely reduce the size of the intertidal mudflats at Pak Nai, as the mangroves, houses and topography of the coast will prevent the mudflat from expanding inland.

The threats to Pak Nai reduce its ability to provide a number of ecosystem services. These have tentatively been identified by TNC in Table 2.

	Types of ecosystem services	Examples of some potential ecosystem services generated from the coastal ecosystem of Pak Nai
I	Provisioning services	 a) Food production (oysters, fish, crabs, snails etc.) b) Endotoxin testing reagent production from horseshoe crab blood
II	Regulating services	 a) Carbon sequestration by the seagrass beds and mangroves b) Enhanced shoreline resilience against flooding and erosion provided by the oyster reefs and mangroves. c) Denitrification of excess nutrient by oyster reefs. d) Water purification by oyster reefs
	Cultural services	 a) Oyster farming technique and craftsmanship b) Eco-tourism and education
IV	Supporting services	 a) Provision of nursery grounds for other organisms b) Oxygen production by mangroves and seagrass beds from photosynthesis c) Nutrient cycling from oyster reefs and seagrasses

Table 2. Examples of potential ecosystem services at Pak Nai, organised according to an IUCN framework



PART 3 - HABITAT MANAGEMENT ACTIVITIES, MONITORING AND EVALUATION (2021-2024)

I) Habitat restoration and rehabilitation work

Over 5,000 volunteers have participated in TNC habitat management works and supported TNC staff to rehabilitate the Pak Nai mudflats from July 2021 to November 2024.

Reconfiguration of abandoned benthic oyster farms

Reconfiguration of abandoned oyster farms involves aggregating concrete poles into smaller multilayered reef structures. Those smaller structures will grow into natural-looking oyster reefs in a few years and provide similar benefits to natural oyster reef patches, such as coastal protection. Meanwhile, the cleared areas formerly occupied by the poles are restored to exposed mudflats, expanding the feeding space for juvenile horseshoe crabs and allowing adult horseshoe crabs to move more freely from the sea to the mudflats or sandy shores for mating and spawning. This also creates more exposed mudflats for the growth of seagrass and use by other mudflat organisms.

Approximately 7,960 m² (71.9 percent out of 11,057 m²) of abandoned oyster farms have been reconfigured over the past three years. Based on our GIS mapping, more than 95 percent of the abandoned farm area has been restored to exposed mudflats, while around 4 percent of the area being reconfigured has become oyster reef structures.



Figure 18. Locations of the multilayered oyster reef structures (grey) on the restored mudflats as of January 2025. (© Sheila Wong/TNC)

Figure 19. Progress of reconfiguration of abandoned oyster farm from summer 2021 (top left) to summer 2024 (bottom right), areas of abandoned oyster farms and restored mudflats are highlighted in orange and yellow respectively. (© Sheila Wong/TNC)

Figure 20. Volunteers and TNC student ambassadors are helping with the reconfiguration of abandoned oyster farms. (© Tom Chan /TNC)

Figure 21. Recently restored mudflats with oyster reef structures. (©Tom Chan /TNC)

Figure 22. Aerial photos showing the restored mudflats, oyster reef structures and remaining areas of abandoned benthic oyster farm. (©Tom Chan /TNC)

Removal of invasive Spartina cordgrass

Manual removal of cordgrass involves digging out the whole plant including the root systems using shovels and placing it above the high tide mark so that it gets dried by the sun and decomposes. Diggers have been used to remove larger cordgrass patches closer to the shore.

About 2,614 m² of cordgrass has been removed. The area occupied by invasive Spartina in July 2024 was around 112 m², which is a 94.1 percent drop from the 1,951 m² occupied by Spartina cordgrass back in July 2021. However, as Spartina cordgrass is a fast-growing species, in some areas we had to remove it more than one time, leading to only a net reduction of just 1,839 m², despite us removing 2,614 m² in total.

Aquaculture debris and marine litter clean-up

A total of 471.5 m³ of aquaculture debris and over 3 tons of marine litter was collected and removed from the mudflat. Commonly found aquaculture debris included bamboo and plastic barrels from floating oyster rafts, as well as abandoned fishing nets and cages.





Figure 23. Decrease in areas occupied by invasive Spartina cordgrass (red) on Pak Naïs mudflats. (© Sheila Wong/TNC)



Figure 24. Invasive Spartina cordgrass grow on Pak Nai's mudflats and our volunteers are removing them manually. (© Miko Lui /TNC)



Figure 25. Beach and aquaculture debris clean-ups in Pak Nai. (© Sheila Wong/TNC,



Figure 26. Volunteers cleaning the snake cages from Pak Nai's mudflats and rescuing a pair of adult horseshoe crabs. (© CA)

II) Scientific monitoring

To scientifically monitor and evaluate the progress of our management work, TNC scientists, over 40 university ambassadors and our collaborators from The University of Hong Kong have carried out a variety of scientific monitoring since July 2021.

Sediment survey

We have collaborated with Dr. Christelle Not, at the Department of Earth Sciences & Swire Institute of Marine Science, The University of Hong Kong, on a sediment monitoring study. Samplings were conducted in the summers of 2021, 2022 and 2023 (see Appendix B for methodology). Over the past 3 years, the following scientific observations on the Pak Nai mudflats have been made:

- Surface sediment to the southwest of the Ap Tsai Hang estuary is coarser (sandier) than the muddier sediment to northeast, but the carbon (C) and nitrogen (N) contents in the western side of the Ap Tsai Hang estuary are lower than the eastern side.
- Based on the C¹³ signature and C/N ratio analysis, sediment found on Pak Nai's mudflats are mainly deposits from the sea (oceanic) instead from the river (terrestrial).
- There is temporal variability in sediment properties for all sampling zones and transects, but a similar distribution trend has been observed since the summer of 2021.
- Sediment in horseshoe crab hotspots on the mudflats has a larger grain size, and lower carbon and nitrogen contents compared to the sediment of nearby mudflats in Pak Nai.



Figure 27. The sampling location for 2021, 2022, 2023 and 2024. (© Dr. Christelle Not/HKU)

 Oyster reefs built in the reconfigured areas of the abandoned oyster farms captured coarser sediment but with lower carbon and nitrogen contents, compared to the abandoned farm areas with no constructed reefs nearby. This suggests that the constructed oyster reefs could potentially reduce wave energy from the sea and also prevent soil erosion by blocking coarser sediment. The changes in sediment characteristics may benefit the horseshoe crabs too, as those reef areas have more similar sediment characteristics to the existing horseshoe crab hotspots.

Horseshoe crab (HSC) population survey

The TNC team conducted HSC population surveys in the summers of 2021, 2022, 2023 and 2024. We have measured the species, prosomal widths, and GPS locations of the HSCs via both walk-through surveys (see Appendix B for details) and standardisation survey methods. The purpose of conducting HSC population size is because we considered their population as one of the key indicators to reflect on our conservation and restoration work. We also shared our result with the <u>IUCN Asian Horseshoe Crab Observation Network</u>, to facilitate the long-term systematic monitoring of horseshoe crab populations in Asia, and help to address the baseline gap for Asian horseshoe crab conservation and status assessment.

In the walk-through survey, we divided the Pak Nai mudflats into Pak Nai (PN), Ap Tsai Hang (ATH) and Sheung Pak Nai (SPN). At least 2 surveys were conducted for ATH and PN in each of the summers, and we took an average of the data, while surveys in SPN were put on-hold since the summer of 2022 due to safety concerns associated with walking on very deep and soft mud. The total number of Chinese HSCs in both ATH and PN increased from 126.8 individuals in 2021 to 144.5 individuals in 2022 to 198.0 individuals in 2023 and continued to increase to 370.0 individuals in 2024. This marks a 191 percent increase over the past 3 years and potentially represents a successful result of our active conservation work in Pak Nai.

Juvenile HSCs show frequent burrowing behaviour, and have been observed to rest after swimming for short periods of time (see https://kb.osu.edu/server/api/core/bitstreams/c07888b4-23e7-574a-860d-368c9ba1ada9/content). We therefore infer that the increasing horseshoe crab numbers at Pak Nai from 2022 to 2024 are more likely to be due to population recovery following site-based restoration and rehabilitation work, than migration from other areas of mudflats.



Figure 28. Horseshoe crab distribution on Pak Nai's mudflats from summer 2021 (top left) to summer 2024 (bottom right). (© Sheila Wong/TNC)

Year	Average number of HSC found in PN	Percentage change compared to 2021	Average number of HSC found in ATH	Percentage change	Total number of HSC found in PN and ATH	Percentage change
2021	113.8		13.0		126.8	
2022	78.5	-31.02%	66.0	+407.69%	144.5	+407.69%
2023	182.0	+59.92%	16.0	+23.08%	198.0	+56.15%
2024	347.0	+204.83%	23.0	+76.92%	370.0	+191.72%

Table 3. Number of HSCs found on Pak Nai's mudflats from 2021 to 2024. (©TNC)



Habitat Mapping

The TNC team conducts regular habitat mapping of seagrass, invasive Spartina cordgrass, and native and invasive mangroves to understand the dynamics between different habitats that make up the coastal ecosystem (see Appendix B for methodology).

One of the notable trends detected is that the areas covered by seagrass decreased to almost zero in 2023 from 21,466 m² in 2021 and 13,383 m² in 2022. The regrowth of seagrass in 2024 has been relatively slow, only 1299 m² was recorded in July 2024. While it not known why seagrass cover declined and is now recovering at the site, *Halophila* is recognised has having "low physiological resistance to disturbance" but with "rapid ability to recover" (Figure 30). We will continue to monitor the regrowth of seagrass.

The areas occupied by the invasive mangrove, i.e. Sonneratia spp., also reduced from 685 m^2 in summer 2021 to 368 m^2 in summer 2024, which is a 46% decrease over a three year period. This appears to be due to tree removal.



Figure 29. Areas of seagrass beds (blue) on Pak Nai's mudflats from summer 2021 (top left) to summer 2024 (bottom right) (© Sheila Wong/TNC)





Figure 30. The response to disturbance for different genus of seagrass (Reference: <u>https://www.sciencedirect.com/</u> science/article/abs/pii/S0048969715005124)



Figure 31. Areas of invasive mangrove on the Pak Naïs mudflats from 2021 summer (top left) to 2024 summer (bottom right). (© Sheila Wong/TNC)

With the habitat management and rehabilitation work conducted from 2021 to 2024, under the 'Managing Pak Nai's Ecologically Important Habitats to Preserve its Natural Beauty and Sensitive Biodiversity' programme, TNC has advanced inclusive, community-based conservation, bringing together local villagers, academics and NGO partners to better manage Pak Nai's unique mudflats and increase public awareness of the ecological importance of this site. In line with

the major programme objectives, we 1) Carried out targeted habitat management activities to restore ecosystem integrity and protect endangered horseshoe crab species; 2) Conducted scientific research to monitor the impact of various management activities and, 3) Engaged the local community and wider public to build awareness and support for the conservation of Pak Nai and estuarine ecosystems in Hong Kong.

	Habitat management	Concernation to reado	Results be	ing reflected in scientific	monitoring
	activities	Conservation targets	Sediment survey	HSC population survey	Habitat mapping
1	Reconfiguration of abandoned oyster farm structures	 Restored mudflats can: expand the feeding space for juvenile HSCs. allow adult horseshoe crabs to move ashore more freely for mating and spawning. enhance seagrass growth and use by other mudflat organisms. Concentrated oyster structures can: provide benefits similar to oyster reefs, including: (1) improved water quality, (2) enhanced biodiversity levels and, (3) reduced soil erosion. 	✓	✓	✓
2	Removal of invasive Spartina cordgrass	 Restored mudflats can: expand the feeding space for juvenile horseshoe crabs and migratory birds. enhance the living environment for mudflat organisms by reducing sulphur level. 		✓	✓
3	Aquaculture debris and marine litter clean-up	 Debris free mudflats can: reduce the obstacles affecting the feeding of juvenile HSCs. prevent mudflat organisms from being entangled. prevent plants being blocked from sunlight. 		✓	

Table 4. Relationship of the habitat management activities and conservation targets. (© TNC)

Thankstothe support of our community partners, the project has been a resounding success and surpassed many of its ambitious targets. Major achievements include engaging about 5,000 volunteers in habitat management, connecting more than 2,500 youths with nature at Pak Nai through school tours, and reaching more than 150,000 people on social media and through educational videos, media outreach,

university lectures and public talks on estuary conservation issues. We have also restored 7,960 m² of oyster ecosystem, cleared 2,614 m² of invasive cordgrass, and seen horseshoe crab populations increase for three years running, a major testament to the success of our habitat management strategy.

Figure 32. Pak Nai is renowned for its spectacular sunset and biodiversity. (© Kyle Obermann)

PART 4 - ECOTOURISM AT PAK NAI: CHALLENGES AND OPPORTUNITIES

TNC has conducted a number of awareness raising activities at Pak Nai, including on social media campaigns, conducting interviews with traditional media and erecting a banner at the site. In order to determine the baseline knowledge of visitors about Pak Nai, TNC conservationists and our university ambassadors have conducted interviews of tourists since December 2022. As of June 2024, 193 respondents were interviewed face-to-face and engaged. Our objective is to investigate the tourists' ecological knowledge of Pak Nai, as well as their attitude and behavior towards nature protection. Some key findings are:

4.1 **Purpose of visit**

• 45 percent of visitors visited Pak Nai for sightseeing, followed by viewing the sunset (26 percent) and clam digging (8 percent).

4.2 Knowledge of Pak Nai's ecology

- Respondents are more familiar with the presence of crabs, mudskippers and fishes in Pak Nai, only 31 percent and 15 percent of visitors can name the presence of oysters and horseshoe crabs, respectively.
- 52 percent of respondents know that mangroves can protect the coast from storm surges, however, only 26 percent of respondents know that oyster reefs have the same ecological function.
- Over 85 percent of respondents agree that Pak Nai has a high ecological value, but only 14 percent believe that conservation measures in Pak Nai are adequate.
- About 30 percent of respondents are aware of the conservation measures (e.g., oyster reef reconfiguration and species monitoring) conducted in Pak Nai, while 33 percent of respondents mistakenly believe that the government has already set up Pak Nai as a marine protected area.
- 67 percent of respondents agree or strongly agree that oyster reefs are important to the ecosystems in Pak Nai.
- 62 percent and 42 percent of respondents believe that the mangroves and oyster reefs can act as habitats for marine organisms, respectively.



Figure 33. TNC student ambassadors conducting oral interviews with tourists in Pak Nai. (© Jennifer Cheng/TNC)



Chart 1. The main purpose of tourists visiting Pak Nai. (© Jennifer Cheng/TNC)



4.3 Tourist attitudes towards measures to greater protect Pak Nai **MPA and government regulations**

• Over 56 percent of respondents agree that the conservation measures at Pak Nai can be strengthened by setting it up as a marine protected area or legislating environmental protection laws for it.

Tourist behavior

- 49 percent of respondents agree or strongly agree that the behaviour • of visitors could damage Pak Nai's ecosystem, while 38 percent of respondents voted neutrally, and 12 percent disagreed or strongly disagreed, respectively.
- For clam digging: ٠
- 80 percent of respondents believe that clam diggers affect the survival of horseshoe crabs, and 76 percent of them support the regulation of

clam, oyster and razor clam digging activities in Pak Nai.

- For cycling: •
- Over 65 percent of respondents believe that cycling activities affect the survival of horseshoe crabs and birds and agree to support the regulation of cycling activities in Pak Nai. However, only 30 percent of bikers knew that they should ride their bikes on the beach instead of on the mudflats.
- For watching the sunset:

(© Jennifer Cheng/TNC)

34 percent of respondents believe that watching the sunset in Pak Nai does not disturb the ecosystem. While this in itself is true, this discounts the trampling on mudflats, seagrass and sensitive areas proposed as core protected zones that typically occurs by sunset enthusiasts walking on the mudflats.



more than half of them think that existing conservation measures are not enough. (© Jennifer Cheng/TNC)

The tourist surveys reveal that watching the sunset and sightseeing are the most common purposes for visitors to come to Pak Nai. Both activities have great potential to be further developed into future eco-tourism activities of the proposed CPP. Pak Nai's tourists generally have some basic understanding of intertidal organisms, but they are not specifically aware of the uniqueness of the Pak Nai's ecology, or the presence of ovster reefs and horseshoe crabs. This suggests that TNC and our community partners can consider offering more education opportunities, e.g. banners and leaflets, to educate visitors on Pak Nai's biodiversity and importance during site visits. Continuing to train and station

eco-quides or ambassadors at Pak Nai during peak hours on weekends is another possibility.

In addition to that, most of the visitors believe that Pak Nai has a high ecological value and more than half of them agree Pak Nai should be set up as a MPA. Onethird of them already mistakenly believe that Pak Nai is already designed as a MPA. These provide a good level of support for the government to consider strengthening existing conservation measures and increasing the level of protection for Pak Nai, particularly by designating Pak Nai as a marine park or CPP.

Do you think Pak Nai has a high ecological value?

PART 5 - RECOMMENDATIONS FOR THE CONSERVATION AND LONG-TERM MANAGEMENT OF PAK NAI

Since 2017, TNC has been conducting community-based conservation in Lau Fau Shan and Pak Nai to help manage, rehabilitate and protect ecologically important areas along the coastline. Our inclusive community-based conservation model has proven to be successful in promoting collaboration amongst NGOs, academics and local community stakeholders, as well as rehabilitating targeted habitats and species. Our work also continues to provide an effective public engagement platform that connects people with nature and promotes sustainable visitor practices in Pak Nai.

As set out in the Northern Metropolis Action Agenda published in late October 2023, the Lau Fau Shan, Tsim Bei Tsui and Pak Nai areas will be an extension of the Hung Shui Kiu/Ha Tsuen New Development Area. As listed in the action agenda, the government would commence an investigation study in the first half of 2024 to further develop the use of individual land parcels for the formulation of a Recommended Outline Development Plan for LFS. Furthermore, the government will also conduct an Environmental Impact Assessment and market survey during the Investigation Study to estimate market interest in taking up the developments of key components in the proposed eco-tourism areas (LC Paper No. CB(1)228/2024(03)).

Based on the current government's planning, after the completion of the above assessments and studies, government-initiated works will commence around 2030 for the Lau Fau Shan, Tsim Bei Tsui and Pak Nai new development areas. That said, the level of development and conservation planned in Pak Nai is still at an early planning stage and it is unclear which areas of Pak Nai would be included in the designed CPP, and what type of existing or new legislation would be used to create the CPP. The potential impact on Pak Nai remains unclear, as are the impacts from climate change in the medium to long term, including stronger typhoons, more severe flooding and potential coastal squeezing.

TNC recommends that the intertidal areas of Ap Tsai Hang, Pak Nai and nearby areas, e.g. coastal areas from Pak Nai SSSI to Tai Shui Hang of Ha Pak Nai, (see www.pland.gov.hk/file/resources/sssi/pdf/plan31.pdf) should be established as protected areas in the near future to safeguard valuable coastal ecosystems and

threatened species. Options for designation include a marine park that covers the shallow water of Deep Bay and all intertidal areas near Pak Nai, or a CPP that includes both the landside and seaside portions of Pak Nai areas.

Before a protected area is established, a management authority comprising government officials, local stakeholders, ecologists and conservation groups, such as TNC, should be established to manage the coastal area of Pak Nai. It is important to actively involve green groups and surrounding communities in the management authority for the planning and design process of the protected areas and their development, as their expertise, knowledge and perspectives can provide valuable insights and help ensure that the development aligns with sustainable practices and considers potential impacts to local biodiversity and ecosystems. This authority should convene regularly to assess the effectiveness of the measures, make necessary changes and adaptations, and discuss potential threats for which precautionary measures should be taken. TNC believes that community-led planning and the inclusion of green groups would benefit the long-term sustainable development of Pak Nai.



Figure 34. TNC Pak Nai Science Symposium. (© Cody Yim)





As it may take a few years for the government to establish Pak Nai as a protected area, we have split our suggestions into:

Phase 1 – Recommended Other Effective Area-based Conservation Measures (OECMs) as a precursor to the establishment of formal Protected Area status.

Phase 2 – Recommended Long-term Management Strategies under the newly established Protected Area

The recommendations are built on scientific knowledge and conservation successes gained from site-based management work over the past four years, as well as available information for NM CPP. These recommendations are also consensus driven, collating input from ecologists, conservationists and local community stakeholders during TNC's 1st and 2nd Pak Nai Science Symposium held in April 2023 and June 2024. Finally, we also take into consideration:

- Major site values (both ecological and cultural) and threats to Pak Nai
- Lessons learned from on-site restoration work
- Results from in-situ scientific monitoring and tourist surveys
- The IUCN Green List of protected and conserved areas, a global certification programme for well-managed protected and conserved areas
- Resources from IUCN Other Effective area-based Conservation Measures (OECMs, see Appendix A)
- Reference to the design and management of other local and overseas protected areas, i.e. designated marine parks, marine reserves, country parks and nature reserves.





Figure 35. TNC Pak Nai Science Symposiums. (© Cody Yim and Cathy Kuo/TNC)





PHASE 1 – RECOMMENDED OTHER EFFECTIVE AREA-BASED CONSERVATION MEASURES (OECMS) AS A PRECURSOR TO THE ESTABLISHMENT OF FORMAL PROTECTED AREA STATUS

A. Sound Design and Planning

Recommendation A1: Zoning management

Zoning designation is a commonly used management strategy for protected areas with multiple uses. Spatial boundaries are drawn to indicate different areas within the protected site, based on the level of biodiversity (i.e., diversity and abundance) and conservation needs. These areas are then designated for specific human activities such as scientific research, habitat management activities, guided tours and ecotourism. One local example of zoning is the Tung Ping Chau Marine Park, which has a zone for recreational fishing, and another where anchoring is prohibited to protect coral communities.

Rationale

Recommended design

Based on the results of horseshoe crab population surveys, low physiological resistance of seagrass (Halophila beccarii), strong camouflage and concentrated population distribution of horseshoe crabs, and the globally declining population trends of both the threatened H. beccarii and the endangered Chinese Horseshoe Crab (Tachypleus tridentatus), it is important to strengthen the protection of these two species within the core protected zone through zoning management, especially from the threats of trampling and harvesting.

Because of the size of Pak Nai and its ecological value, the zoning management should consist of at least three management zones, namely a core protected zone (public no-go zone), wise use zone and public access zone. Except for land tenants and owners, the core protection zone should only be open to conservationists and ecologists that conduct ecological surveys and habitat management work within the area. The wise use zone should be open to conservationists and ecologists but also to volunteers and visitors accompanied by conservationists, ecologists and trained environmental educators to supervise their behaviour. The public access zone can be open for everyone, but educational signs should be displayed to remind visitors of appropriate code of conduct.

The southern side of the Pak Nai mudflats (the intertidal area between Ap Tsai Hang to Ha Pak Nai) should be managed as a core protected zone, while the northern side of the mudflats (Ap Tsai Hang to Sheung Pak Nai) should be managed as a wise use zone. About 80 percent of the juvenile horseshoe crabs will be protected within the core protected zone, based on the 2024 HSC population survey, but guided education tours in the wise use zone will enable visitors to observe some horseshoe crabs. The mangrove and sandy shore areas should be managed as a public access zone. The composition of the core protected zone, wise use zone and public access zone would ideally be reviewed and adjusted accordingly every 1 to 2 years based on the results of horseshoe crab population surveys and habitat mapping.

Expected interim outcomes

As physical disturbance from unregulated tourism is a threat to the ecosystem of Pak Nai, including horseshoe crabs and the seagrass habitats they utilize (Reed and Hovel 2006), implementation of the zoning management will continue to support horseshoe crab population recovery, which should be informed by on-going horseshoe crab population surveys and habitat mappings.









Figure 36. The hotspot areas (red) on Pak Nai's mudflats that house the denser population of juvenile horseshoe crabs in summer 2024. (© Sheila Wong/TNC) - Those areas should be designated as core protected zones.



Figure 37 and Table 5. Percentage of HSCs that can be protected if 1ha (=10,000m²) of core protected no-go zone is set up in Pak Nai, based on 2024 HSC survey results.

(*Total number of HSCs recorded in all walk-through surveys for PN and ATH in 2024 was 740)

	Polygon	Area (m²)	Number of HSC within polygon	Percentage of HSC protected*
	1	10486.90	141	19.1%
	2	10293.34	342	46.2%
•	3	10293.50	138	18.6%
	4	10293.67	17	2.3%



Figure 38. Access to Pak Nai is not managed now and cyclists and walkers may inadvertently run over or trample seagrass and juvenile horseshoe crabs. (© Tom Chan /TNC)



Recommendation A2: Build some eco-friendly facilities

Construct some eco-friendly facilities, e.g. boardwalk, bird hide etc, with low buildup and maintenance cost, to guide and direct visitors to designated areas in Pak Nai to learn about the ecosystem and cultural value of the site, while preventing them from disturbing the mudflats. These eco-friendly facilities should be planned, designed, constructed and managed with careful assessment, includes the EIA process, to minimize adverse impacts on Pak Nai's sensitive habitats and species.

Rationale

Recommended design

Pak Nai is renowned as one of the prime locations for sunset viewing. This natural spectacle draws numerous tourists to the mudflats, particularly during low tide on weekend evenings. However, the timing of low tide, governed by the lunar cycle, does not consistently coincide with sunset, resulting in sporadic crowding on certain days each month. The results from the tourist survey indicate a general lack of awareness among visitors regarding Pak Nai's ecological significance, leading to inadvertent harm to the environment. Examples include the collection of fallen mangrove propagules, mountain biking on the exposed mudflats and the harvesting of clams and oysters.

From a cultural perspective, the low-tide areas of the mudflats contain the remains of abandoned benthic oyster farms that showcase traditional oyster cultivation practices in Deep Bay. Oyster farming has about 700 years of history in Hong Kong and about 200 years of history in Deep Bay. Pak Nai is an excellent location for visitors to learn about these traditional techniques, which are recognised as a part of the intangible cultural heritage of Hong Kong.

From an ecological perspective, one of the primary threats to the soft shore ecosystem, particularly the beds of H beccarii seagrass, is trampling. This threat extends to horseshoe crabs, which possess effective camouflage and are typically small in size near the shorelines, so are easily missed and stepped on by tourists. Minimising the number of visitors on the mudflats will lessen these threats and also curtail the introduction of invasive species from visitors' boot treads and bike tyres (see https://lnt.org/

Construct eco-friendly facilities that begins at the sandy shore and extends towards the sea, terminating near the restored oyster reef structures and ruins of abandoned oyster farms. These eco-friendly facilities can traverse the mudflats, estuary and mangrove habitats, allowing visitors to observe various habitats, migratory birds and juvenile horseshoe crabs along their foraging trails, without impacting the sensitive mudflat environment and improving visitor safety during high tide.

Educational panels and notice boards can be placed alongside the eco-friendly facilities to inform the public about appropriate conduct, the ecology of Pak Nai and its ecosystem services, and ongoing conservation efforts in the area. These installations will also support on-site environmental education and serve as interpretive stations for eco-tours. Additionally, displays will feature content and props that celebrate the intangible cultural heritage of oyster farming and the traditional culture of Pak Nai and Deep Bay, highlighting the connection between the ocean and the people of Hong Kong.

The eco-friendly facilities can be designed with accessibility in mind, including features such as slopes for wheelchairs and fences for young children and the elderly, ensuring it is accessible to individuals with physical limitations. Educational content displayed will be bilingual to cater to both local and international visitors, promoting a broader understanding and appreciation of the site.

Expected interim outcomes

The threats posed by visitors to the soft shore of Pak Nai are reduced, creating a better environment for local wildlife. The eco-friendly facilities can also provide a safer, tide-independent venue for environmental education tours, which can help promote the ecological importance of Pak Nai to more of the general public.



Figure 40. Eco-friendlyfacilities in Sungei Buloh Wetland Reserve in Singapore allow visitors to observe the wildlife without stepping on the mudflats. (© Tom Chan /TNC)



Recommendation A3: Provide on-site training for local tour guides and environmental educators

Recommended design

Offer training to school teachers, environmental educators and tour guides who organise and lead tours to Pak Nai. This will help ensure that the tours are well-

structured and of high quality, delivering ecological knowledge and conservation messages with minimal impact on the natural environment of Pak Nai.

Rationale

The mudflats of Pak Nai are currently accessible to all. Various outbound companies, tour operators and community groups organise tours to Pak Nai for different activities, such as watching the sunset, bird watching and sightseeing. However, some tour operators lack ecological knowledge, an understanding of Pak Nai and the basic principles of environmental education. Consequently, they may disseminate incorrect "facts" and conservation messages that demonstrate a low awareness of the environmental impact of visitors to Pak Nai. It is important to provide training for tour operators and guides on the history, culture, ecology and wildlife of Pak Nai. This should include an introduction to a visitors' code of conduct, as well as an overview of the latest conservation efforts and their results. Our experience with organising five batches of student ambassador training suggests that three half-day sessions are sufficient to equip participants with the knowledge needed to lead or assist in eco-tours without negatively impacting the ecology of the mudflats, and to serve as rangers who can address most visitors' questions.

Expected interim outcomes

More quality eco-tours will be conducted in Pak Nai and participants can gain a deeper understanding of its ecological significance and unique cultural aspects, as well as the conservation and restoration efforts that have been undertaken. Interested groups of participants could have the opportunity to engage in on-site field habitat management work. This involvement is anticipated to foster significant positive changes in participants' attitudes and behaviours, promoting a supportive stance and a lasting impact on conservation.

Participants would also need to adhere strictly to the visitors' code of conduct, ensuring minimal to no environmental impact during their visit. This approach is expected to preserve the carrying capacity and biodiversity of the ecosystem, while allowing eco-tourism and other environmental education activities to thrive and potentially expand.



Figure 41. Training workshop organized in Pak Nai for geography and biology teachers (© Edmund/ LHK media)

B. Effective Management and Monitoring

Recommendation B1: Effective enforcement

Effective enforcement is crucial for the successful implementation of management recommendations and to achieve the expected outcomes. The success of enforcing these measures in Pak Nai depends on establishing a comprehensive management authority, ensuring a high level of community involvement, conducting more frequent on-site inspections and developing a reporting mechanism. There are few

precedents for this type of management arrangement in Hong Kong in the absence of formal protection, but it may be possible for the management of the coastal areas of Pak Nai, due to the government's tenancy (STT2266) of delineating areas to the farming industry as designated area of oyster farming activities (see <u>LC Paper No.</u> <u>CB(2)1168/2024(03)</u>).

Rationale	Recommended design	Expected interim outcomes
Enforcement will be necessary to ensure that visitors adhere to management measures, such as following the visitor's code of conduct, refraining from entering core protected zones and avoiding disturbance or removal of horseshoe crabs. It is important to engage and empower the local indigenous people, who have a strong sense of belonging to Pak Nai, are present at the site all year round and are sensitive to unusual activities, as part of the management authority.	Local indigenous people can be recruited and trained as rangers to promote the traditional oyster farming culture, the history of Pak Nai, local biodiversity, and enforce the visitor's code of conduct, as well as to monitor for illegal and inappropriate activities. They note that illegal and inappropriate activities may involve cross-boundary activities from the sea and that general reporting telephone hotlines (999 and 1823) have generally proved insufficient for preventing such activities in the past. Therefore, a dedicated reporting mechanism should be established and made accessible to other villages or the public to report illegal activities. A telephone hotline should be set up and contact information should be displayed on on-site signs and panels for villagers and visitors to report illegal activities immediately.	With support from local villagers and visitors, the on-site inspection and enforcement mechanism can be enhanced and hence the human impacts to Pak Nai's ecosystem will be reduced, creating a better environment for local wildlife.



Figure 42. Oyster collection (denoted by white empty shell see the arrows) by visitors from TNC rehabilitated reefs has sometimes been observed, potentially slowing down the restoration process. (© Tom Chan/TNC)



Figure 43. The removal of horseshoe crabs by visitors to the site has occasionally been seen. (© Tom Chan/TNC)



Recommendation B2: Long-term scientific monitoring and evaluation

Long-term scientific monitoring to determine the ongoing health of the ecosystem and inform the revision of management measures as required.

Rationale

Recommended design

The mosaic of habitats and the diversity of species in Pak Nai creates a complex food web with numerous interconnections, both within habitats and between species. Given that conservation is a top priority in Pak Nai, regular scientific monitoring is essential to gauge the health of ecosystems and the effectiveness of management actions. It is anticipated that the Pak Nai ecosystem will become more selfsustaining, with higher resilience to climate change, e.g. stronger typhoons and more severe floodings, and human disturbance after the intensive habitat management conducted from 2021 to 2024, and once recommendations A1, A2, A3 and B1 are in place. For example, the restored oyster reefs on the mudflats should grow naturally without much maintenance. Bird surveys and ongoing habitat mapping of restored oyster reefs, seagrass beds, invasive Spartina cordgrass and mangroves, as well as horseshoe crab population surveys, are recommended to be conducted annually to monitor ecosystem health.

Biodiversity surveys should also be conducted at regular intervals, say every two to three years, to assess the abundance of species besides horseshoe crabs and long-term conservation results. These surveys also offer an opportunity to identify newly established native and invasive species in Pak Nai, prompting necessary revisions to the monitoring plan.

Expected interim outcomes

Through the annual habitat mapping process, it is anticipated that the restored oyster reefs and native mangrove stands will continue to grow naturally, providing habitats for intertidal species and various ecosystem services, such as contributing to climate resilience in nearby areas. Meanwhile, seagrass beds, primarily Halophila beccarii, and horseshoe crab population are expected to continue to maintain stable population sizes, with potentially steadily increasing trends.



Figure 44. Habitat mapping conducted by TNC staff and student ambassador. (©Tom Chan/TNC)

Recommendation B3: Ecosystem-based management: address knowledge gap

Scientific and social studies to further enhance our understanding of the Pak Nai ecosystem and its ecosystem services, with a view to setting up a larger protected area with better management strategies.

Rationale

The ecosystem-based management approach requires a good understanding of the full array of interactions within an ecosystem, including human ones. When done well, it should allow the whole ecosystem to be maintained in a healthy, productive and resilient condition so that nature can be protected and provide a variety of ecosystem services, for example, food production, carbon sequestration, enhanced shoreline resilience, denitrification and nutrient cycling, eco-tourism and education, that humans need.

Although we have conducted habitat mapping, horseshoe crab population surveys, biodiversity surveys of the mudflats and oyster farms, and sediment monitoring since 2021, we have not yet mapped the full range of ecosystem services that Pak Nai provides. Hence, extra scientific and social studies are needed to help us understand the full range of interactions within the Pak Nai ecosystem and enable management strategies to be adjusted if needed.

Recommended design

Potential scientific and social studies in Pak Nai:

- Studies of the survival rate of juvenile horseshoe crabs, and tracking of adult and larger juvenile horseshoe crabs to better understand their habitat range and movement patterns.
- A baseline study and subsequent monitoring of seagrass distribution and diversity.
- Ecological studies on the habitat connectivity between landward and coastal CCP, Pak Nai and Ha Pak Nai etc.
- Modelling study on climate change and adaptation measures, for example, in response to sea level rise and flooding.
- Social study on number of visitors to Pak Nai using infrared cameras and drones.
- A comprehensive study on the carrying capacity of Pak Nai for ecotourism and impact assessment.

Expected interim outcomes

The results of these scientific and social studies can provide insights to management arrangements and the sustainable use of Pak Nai. For example, understanding the habitat range of adult horseshoe crabs can potentially provide support for larger protected areas that include more shallow water areas of Deep Bay.



Figure 45. The Pak Nai scientific monitoring result of summer 2024 (© Sheila Wong/TNC)-The complicated interconnections between different habitats and species of Pak Nai shows the importance of adopting EBM.

Recommendation B4: Long-term scientific monitoring and evaluation

Continue habitat management efforts to control the spread of invasive species, influx of marine litter and aquaculture debris to maintain the ecological integrity.

Rationale	Recommended design	Expected interim outcomes
Although the restored oyster reefs, horseshoe crab population and native mangrove stands are expected to largely self-sustain, after the intensive habitat management conducted from 2021 to 2024, the coastal ecosystem of Pak Nai still requires a certain level of active management, as it is continuously facing the problems of influx of marine litter, aquaculture debris and invasive species. Those environmental issues are hard to solve and control at the source, as marine litter and aquaculture debris may be brought by currents from far away, while invasive plants or their seeds may spread from nearby uncleared patches along the coast of Deep Bay. Therefore, continued habitat management work to monitor and remove invasive species, marine litter and aquaculture debris will be necessary to maintain the health of Pak Nai.	Removal of invasive species e.g. Spartina cordgrass and Sonneratia spp., should be conducted at least once every month. Regular monitoring of invasive species is required to limit their spread on the mudflats. The frequency of removal activities can be adjusted based on the growth rate of invasive species. However, removal activities need to be halted during the flowering and seed setting period, so as not to unintentionally promote the spread of these invasive species during their reproductive phase. Beach clean-up activities in the core protected zone should be conducted at least once every month and clean-up activities in wise use zone and public access zone should be conducted at least every two months. More clean-up activities may be needed after typhoons, as the storm surge may wash up more litter and aquaculture debris on to the shore.	Threats related to the spread of invasive plant species, marine litter and aquaculture debris are under control and minimized.

PHASE 2 - RECOMMENDED LONG-TERM MANAGEMENT STRATEGIES AFTER THE FORMAL ESTABLISHMENT OF A PROTECTED AREA

TNC encourages the government to set up Pak Nai as a protected area before the development of the Northern Metropolis project to safeguard Pak Nai's ecological integrity and function, and to prevent development within the protected areas and nearby buffer zones. Because of the tradition of land ownership in Pak Nai, we also recommend the government to take an inclusive approach during the protected area designation process and organize regular exchanges and engagement activities with the local communities, i.e. the villagers of Pak Nai and oyster farmers that are working inside the designated oyster farming areas.

An interim evaluation should also be conducted at the beginning of the establishment of Pak Nai as a protected area, to evaluate which management measures need to be carried forward and/or fine-tuned. Management strategies should be adjusted according to the latest scientific findings, ecological monitoring results, ecosystem health, newly emerged threats and the latest visitor pattern. Such evaluation of the design, planning and management measures of Pak Nai should be conducted regularly, say each year.



Table 6. Timeline of the recommended long-term management strategies for Pak Nai based on IUCN Green List framework.

In this section, we will provide the rationale for these recommended measures. However, the finer details of design and planning would need to be further discussed after the OECMs in Phase 1 are fully implemented and assessed. A clear timeline of the designation of Pak Nai as a protected area and the designation of a coastal protection park off the Deep Bay coast will also be needed.

A. Sound Design and Planning

Recommendation A4: Ensure connectivity with other protected areas

Rationale

The revised Northern Metropolis Development plan in 2023 includes the establishment of an approximately 145-hectare Coastal Protection Park (CPP), of which 60 hectares would also include new management measures for enhanced conservation. We recommended either establishing a continuous Coastal Protection Park connecting from Tsim Bei Tsui to Pak Nai to ensure connectivity within the protected area, or setting up Pak Nai as a marine park and connecting it with the Coastal Protection Park from Tsim Bei Tsui to Sheung Pak Nai. One of the primary intentions of such arrangements is to maintain and even enhance the connectivity between Pak Nai, Tsim Bei Tsui and Mai Po Nature Reserve, providing a wildlife corridor to facilitate the movement of species to interact, find resources and mate. This can preserve the ecological function and integrity of the Deep Bay area, as well as create higher resilience to natural disasters and human threats.

Recommendation A5: Provide sufficient buffer zone between PAs and low-density development areas

Rationale

The intention of the buffer zone, which is usually a green belt surrounding the protected areas, is to avoid any large-scale development occurring right next to the boundary of the protected areas, as this could significantly reduce the ecological carrying capacity of the protected areas. For example, high-rise buildings may affect the landing paths of birds, while residential lighting and sunlight reflected from the windows of nearby facilities may affect the

temperature and light intensity of protected areas, both of which could be disruptive to wildlife. To balance the need for sustainable development and opportunities for recreation, this buffer zone could be open to public access. Small-scale facilities and eco-friendly businesses, like education centres, nature warden offices, organic farms and fishponds could be allowed.

C. Good Governance

Recommendation C1: Adopt community-based conservation measures

Rationale

Since 2017, TNC has been conducting community-based conservation in Lau Fau Shan and Pak Nai to help manage, rehabilitate and protect key areas along the coastline. Our inclusive community-based conservation model has proven to be successful in promoting collaboration amongst NGOs, academics and local community stakeholders. It continues to provide an effective public engagement platform that connects people with nature and promotes sustainable visitor practices in Pak Nai, and can be considered for other sites of conservation value that are not subject to government management. It is important to actively involve groups with biodiversity expertise and surrounding communities in the planning and design process of the Northern Metropolis development moving forwards. Their expertise, knowledge and perspectives can provide valuable insights and help ensure that the development aligns with sustainable practices and considers potential impacts to local biodiversity and ecosystems.

Recommendation C2: Adopt Inclusive governance

Rationale

Form a Pak Nai Advisory Committee with government, academic, conservation experts, and local community stakeholders to ensure transparent decision-making

and incorporate community input into governance.

Recommendation C3: Set up adequate funding mechanisms

Rationale

Set up adequate funding mechanisms that support on going-site management, inclusive conservation and community stewardship.

For example, support on-site training programs for Ecotour Guides that to ensure sustainable visitor management.

CONCLUSION

Pak Nai is an outstanding biodiversity hotspot, being home to the largest seagrass bed in Hong Kong, and one of the most important nursery grounds for two species of horseshoe crabs in the region. Its estuarine and intertidal habitats are home to a wide array of birds and other flora and fauna but are under threat from a variety of anthropogenic impacts. The TNC project undertaken in conjunction with supportive local communities has shown that a systematic science-based and collaborative approach with proactive management can manage these threats and help the ecosystem recover, while interviews with tourists reveal strong support for increased protection of the site. The Nature Conservancy hopes the government and people of Hong Kong will better recognise the ecological and cultural importance of Pak Nai through this report, integrate its proposed recommendations into the Northern Metropolis plans for a Coastal Protection Park, and eventually turn Pak Nai into a Marine Protected Area so as to protect its valuable biodiversity and ecosystems. The management learnings from Pak Nai will also be more broadly applicable to the future design of the Coastal Protection Pak as it extends eastwards to meet the Mai Po Nature Reserve, and to the restoration of other degraded mudflat habitats in Hong Kong and the Greater Bay area, while the community-based management model could be replicated in other vulnerable marine biodiversity hotspots outside of Marine Protected Areas.

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Figure46. Close-up of a 2-year-old oyster reef structure. Live oysters scattered around the surfaces of concrete poles. (© Tom Chan/TNC)

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Figure 47. The coastal ecosystem of Pak Nai, Deep Bay. Oysters are observed to growth naturally on the stems and prop roots of Kandelia obovato (right side of the photo). (© Tom Chan/TNC)

E.

APPENDIX A - TERMINOLOGY AND DEFINITIONS

Protected Areas (PAs)

According to the International Union for Conservation of Nature (IUCN), a protected area is clearly defined as geographical space recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. The protected areas can be further categorised based on the management and governance model:

	Management Categories					
la	Strict Nature Reserve					
lb	Wilderness Area					
П	National Park					
Ш	Natural Monument or Feature					
IV	Habitat/Species Management Area					
V	Protected Landscape or Seascape					
VI	Protected areas with sustainable use of natural resources					
	Governance Types					
1	Governance by government					
2	Shared governance					
3	Private governance					
4	Governance by indigenous peoples and local communities					

Community-Based Conservation

In contrast with the conventional 'top-down' government-led conservation approach, whereby authorities control management of conservation sites, community-based conservation involves engaging with local communities within or close to the conservation sites as well as individuals that share common conservation interests. The goal is to cultivate local environmental stewardship within communities, motivating people to take proactive conservation actions to manage and protect the environment. This 'bottom-up' conservation approach usually focuses more on the interconnection of nature and culture. A longterm, holistic stakeholder engagement strategy is needed to foster this local stewardship.

Ecosystem-Based Management (EBM)

Ecosystem-based (or integrated ecosystem-based) management is an environmental management approach that recognises the full array of interactions within an ecosystem, including humans, rather than considering a single issue, species, or particular ecosystem service in isolation.

The goal of an ecosystem-based management approach is to maintain a healthy, productive and resilient ecosystem so that nature can be protected and can provide a variety of ecosystem services that humans would benefit from. Adjustments to management methods may be needed from time to time in response to a better understanding of the interaction between species and habitats, scientific monitoring results and the overall health of the ecosystem.

Other Effective Area-Based Conservation Measures (OECMs)

According to the IUCN, 'Other Effective area-based Conservation Measures' (OECMs) are measures that achieve the long term and effective in-situ conservation of biodiversity outside of protected areas. For more information <u>https://iucn.org/our-union/commissions/group/iucn-wcpa-other-effective-area-based-conservation-measures-specialist</u>

Eco-Tourism

According to the IUCN ecotourism program, ecotourism is generally defined and accepted as environmentally responsible travel and visitation to relatively undisturbed natural areas to enjoy and appreciate nature (and any accompanying cultural features) that promotes conservation, has a low negative impact on surrounding ecology and communities, and provides for beneficially active socio-economic involvement of local populations. According to the UN Tourism's definition, ecotourism refers to forms of tourism which have the following characteristics:

- 1. All nature-based forms of tourism in which the main motivation of the tourists is the observation and appreciation of nature, as well as the traditional cultures prevailing in natural areas.
- 2. It contains educational and interpretation features.
- 3. It is generally, but not exclusively, organised by specialised tour operators for small groups. Service provider partners at the destinations tend to be small, locally owned businesses.
- 4. It minimises negative impacts upon the natural and socio-cultural environment.
- 5. It supports the maintenance of natural areas which are used as ecotourism attractions by:
 - a. Generating economic benefits for host communities, organisations and authorities managing natural areas with conservation purposes.
 - b. Providing alternative employment and income opportunities for local communities.
 - c. Increasing awareness towards the conservation of natural and cultural assets, both among locals and tourists.

Hong Kong Marine Protection Alliance (HKMPA)

Officially launched in August 2022, the HKMPA hopes to play a role as a partner on marine conservation with the Hong Kong government. The HKMPA believes that the current legislation on marine biodiversity protection needs immediate reevaluation. As of July 2024, the alliance has 30 organisation members, including TNC and 17 individual members. The 5 asks of the HKMPA:

- 1. 30 percent of local waters to be designated by the government as marine protected areas (MPAs) or protected by OECMs by 2030, in line with the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity (COP15) and China national targets,
- 2. Pak Nai, Port Shelter, Ninepin Group and Shui Hau to be given priority and to be protected as MPAs,
- 3. Implement a robust management plan for MPAs to ensure protection, public enjoyment and restoration of these waters,
- 4. Increase the percentage of no-take zones to 20 percent within MPAs, and
- 5. Integration of marine education from local kindergarten to secondary school curriculums with clear learning goals, objectives and pedagogies with reference to international standards in ocean literacy by 2030.

APPENDIX B - SURVEY METHODOLOGIES

Habitat Mapping for Seagrass Bed, Spartina Cordgrass and Invasive Mangroves

Frequency: at least 1 survey conducted per year

Survey start date: June 2020

Remarks: one mapping of native mangrove (*Kandelia* sp.) has been conducted in 2023

Methodology:

- 1. Choose a low tide window for the survey, the lowest tide prediction should have reached 1.0m or below.
- 2. Survey is started once the tide reached 0.8m
- 3. Surveyors (at least one trained staff with volunteers) walked through Pak Nai from west to south and record all areas occupied by the targeted species with GPS logger, only location information and area are mapped.
- 4. Invasive mangroves and Spartina are mapped according to crown size, while only areas occupied with over 25% of seagrass will be recorded.
- 5. Survey for each target species have to be conducted on the same low tide window on the same day.

Horseshoe Crab Population Survey (walk-through survey)

Frequency: At least two surveys conducted for ATH and PN in each summer, from June to October.

Survey start date: July 2021

Remarks: Surveys in SPN had been on hold since 2022 due to accessibility issues.



Figure 48. The Transect 1 to 4 for PN, ATH and SPN for HSC walk-through surveys.

Methodology:

- 1. Choose a low tide window for the survey, tide prediction should have reach to 0.6m or below
- 2. Conduct survey in either SPN, ATH and PN in the same day
- 3. Start the survey at about 30 minutes after the tide pass by 1.2m
- 4. Surveyors(at least 2 trained staffs with volunteers) walked along the 4 transects in the same area, from T1 to T4 actively searching for horseshoe crabs on the mudflats. Horseshoe crabs spotted within 4 meters from the centre of the transect (i.e. 8 meter width total) would be measured and recorded.
- 5. GPS waypoint, species (TT or CR) and size (prosomal width) of the Horseshoe crabs will be measured and recorded.
- 6. Surveys in all four transects have to be completed on the same low tide window.

Horseshoe Crab Population Survey (standardization survey)

Frequency: At least one surveys conducted for in each summer, from August or October.

Survey start date: August 2021



Figure 49. The transect and quadrats for HSC standardization surveys.

For the standardization survey (i.e. transect and quadrat sampling), only the PN area was covered, and the main purpose was to quantify HSC numbers and density to compare with those in other HSC habitats in Asia-Pacific. Our Pak Nai data was regularly submitted to the IUCN Asia-Pacific Horseshoe Crab Observation Network to evaluate the survival of HSCs in the region and look for conservation collaborations.

Sediment Survey

Frequency: 2 to 3 samplings per year during summer Survey start date: June 2020

Remarks: This survey is in collaboration with Dr. Christelle Not from The University of Hong Kong

Sampling Site:

Pak Nai was divided into four working zones from North to South, namely zone 1, zone 2, zone 3 and zone 4. Surface sediment samples were collected from each sampling.

2021









Sampling strategies:

- Transect surface sediment sampling
- Surface sediment sampling around revitalisation work
- Surface sediment sampling around horseshoe crab

Analytical methods:

- Grain size analyses
- Carbon and Nitrogen Content, δ13C and δ15N determination
- Density measurement
- Water parameters

Tourist Surveys

Frequency: At least one surveys conducted for in each summer, either in September or October.

Survey period: March 2023 to May 2024

Count: 193 respondents interviewed, representing 625 visitors

Methodology:

- 1. Year-round interviews are conducted by teams of 2 to 3 interviewers on weekends.
- 2. Convenience sampling is employed; visitors who are finishing their visits are identified and invited to participate in the interview.
- 3. The interviewers will read out the questions from the questionnaires one by one and the visitors will pick the best suitable answer from it.
- 4. Respondents are required to answer all the questions in the questionnaire, and the whole interview will be completed in 3 to 5 minutes.
- 5. The number of accompanying individuals and equipment brought by the respondents is recorded during the interview for further analysis.

Questionnaire:

	Self-introduction	2.4	(only applicable to bike riders)	Never	Rarely	Seldom	Often	Always	I don't		Part 4: Knowledge	Filled by staff:
	I am XXX and I am studying in								know			
	university as a student majoring in							-		4.1	Do you think Pak Nai has a high ecological value?	Age :
	·		A. I only ride my bike on the beach and	1	2	3	4	5	6		Yes No	
	Lioined TNC (the Nature Conservancy)		B I take photos with my bike in the							42	Can you list 3 organisms that inhabit Pak Nai ?	
	as an intern with the intension to learn		mudflats.	1	2	3	4	5	6		can you lot o of Salionio that inhabit i ak nai :	Gender :
	the general public's knowledge on Pak											ochiaci
	Nai.	2.5	(only applicable to clam/oyster/razor-									
	the surface the surger of the state of the surface the		clam digger)							4.3	What services do you think a mangrove can provide?	
	It only takes roughly 4-5 minutes to complete this questionnaire, and		Δ I take away all the bivalves that I dug	1	2	з	4	5	6		Protect the coast from strong waves	Accompany
	which can come in handy for us to		up.	-	-	5		5	Ū.		Act as a habitat for marine organisms	(including
	adjust our conservation measures.		B. I always classify the size of bivalves	1	2	3	4	5	6		Barks can be used as dyes	respondent
			dug up and avoid taking away small ones.					_			All of the above)
	Part 1: Background Information		C. I catch and take away other organisms,	1	2	3	4	5	6			
1.1	What are you doing in Pak Nai?		such as crabs or fishes.	1	2	з	4	5	6	4.4	What services do you think an oyster reef can provide?	1+
			D. Fuse salt to catch bivalves.	1	2	5	- T	5	Ŭ		Protect the coast from strong waves	
		2.6	(only applicable to picnickers)								Purify seawater	Equipment •
1.2	How long are you staying in Pak Nai?		A. I feed leftover foods to wild animals in	1	2	3	4	5	6		Ovster shell has medicinal value	
	less than 30 minutes		the mudflat	1	2	2	4	-	c		Oyster shell can be turned into lime.	
	30 minutes to an hour		B. I wash my hands, utensils and	1	2	3	4	Э	0		All of the above	
	\square 1 to 2 hours		functions in the river of seawater.								🗌 I don't know	
	above 3 hours									45	Which of the full surface and matural herbitate in Daly Mai 9	
										4.5		
1.3	How many times have you been to Pak										Mudflat Intertidal zone	
	Nai?										Mangrove Sandy shore	
											Gei Wai Lowland flats	
	Three to five times										All of the above I I don't know	
	More than five times		Part 3: Views on conservation	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	l don't know	4.0	Which of the followings are conservation measures in Pak Nai?	
		3.1	I think that oyster reefs are important to	1	2	3	4	5	6	4.0	Oyster reef reconfiguration	
	Part 2: Behaviour		the ecosystems of Pak Nai.								Beach clean-up	Date :
2.1	Did you check tide times online before	3.2	I think clams, oysters and razor clams are	1	2	3	4	5	6		Research in species	
	\square Yes, I do. \square No. I don't.		important to Pak Nai's ecosystem.								Setting up a marine protected area	
	Do you check the time for sunset	3.3	I think horseshoe crabs are important to	1	2	3	4	5	6		Monitoring of species diversity	Time :
2.2	online before visiting Pak Nai?		the Pak Nai's ecosystem.								Tourists signage	
	Yes No	3.4	I think the behaviour of visitors damages	1	2	3	4	5	6		All of the above I don't know	
2.3	(only applicable to sunset watchers)]	Pak Nai's ecosystem.									
		3.5	I support the regulation of clam, oyster	1	2	3	4	5	6	4.7	Do you think the conservation measures in Pak Nai are	Surveyor :
	A. Do you think watching sunset in Pak Nai disturbs the ecosystems there?		and razor clam digging in Pak Nai.								Yes No II don't know	
	Yes No	3.6	I support the regulation of cycling	1	2	3	4	5	6			
			activities in Pak Nai.							4.8	How do you think Pak Nai can strengthen its conservation	
		3.7	I think that digging clams and razor clams	1	2	3	4	5	6		measures?	
			affects the survival of horseshoe crabs								Add more conservation ambassadors	
		3.8	ana piras.	1	2	3	4	5	6		Provide conservation-related activity classes and workshops	
			I think that excling affects the survival of								Hold more beach clean-up activities	
			horseshoe crabs and birds									
			horseshoe crabs and birds.								Set up a marine protected area	
		3.9	I think that cycling affects the survival of horseshoe crabs and birds.	1	2	3	4	5	6		Set up a marine protected area	
		3.9	I think that cycling affects the survival of horseshoe crabs and birds. I think that picnicking affects Pak Nai's ecosystem.	1	2	3	4	5	6		Set up a marine protected area Set up environmental protection laws	
		3.9	I think that cycling affects the solution of horseshoe crabs and birds. I think that picnicking affects Pak Nai's ecosystem.	1	2	3	4	5	6		Set up a marine protected area	

Raw data of responses:

Demographic Information

Demographic information 1 – Age distribution of the respondents

Response	Number of counts	%
12>	4	2.1
12-18	6	3.1
18-30	60	31.1
30-45	58	30.1
45-60	35	18.1
>60	19	9.8
Not willing to response	11	5.7
Total	193	100

Demographic information 2 – Gender of the respondents					
Response	%				
Male	100	51.8			
Female	93	48.2			
Not willing to response	0	0.0			
Total	193	100			

Demographic information 1 – Age distribution of the respondents

Response	Number of counts	%
12>	4	2.1
12-18	6	3.1
18-30	60	31.1
30-45	58	30.1
45-60	35	18.1
>60	19	9.8
Not willing to response	11	5.7
Total	193	100

<u>Question 1</u>

01.1 What are you doing in Pak Nai?							
Response	Number of counts (companion included)	%					
Sightseeing	281	45.0					
Viewing sunset	162	25.9					
Clam digging	49	7.8					
Taking a walk	41	6.6					
Eco-touring	24	3.8					
Hiking	19	3.0					
Photo taking	16	2.6					
Fishing	12	1.9					
Biking	10	1.6					
Picnicking	6	1.0					
Spiritual practice	3	0.5					
Doing research	2	0.3					
Total	625	100					
Q1.2. How long are y	ou staying in Pak Nai?						
Response	Number of counts (companion included)	%					
0.5hr>	141	22.6					
0.5hr-1hr	149	23.9					
1hr-2hrs	164	26.2					
2hrs-3hrs	134	21.4					
3hrs+	37	5.9					
Total	625	100					
Q1.3. How many tim	es have you been to Pak Na	i?					
Response	Number of counts (companion included)	%					
Once	438	70.1					
Twice	116	18.6					
Three to five times	35	5.5					
Over five times	36	5.8					
Total	625	100					

<u>Question 2</u>

Q2.1. Did you check tide times online before visiting Pak Nai?								
Response Number of counts %								
Yes	24	12.4						
No	169	87.6						
Total	193	100						

Q2.2. Do you check the time for sunset online before visiting Pak Nai?						
Response	Number of counts	%				
Yes	68	35.2				
No	125	64.8				
Total	193	100				

[Only applicable to sunset watchers] Q2.3. Do you think watching sunset in Pak Nai disturbs the ecosystems there?

Response	Number of counts	%
Yes	27	29.0
No	66	71.0
Total	93	100

[Only applicable to bike riders] [Only applicable to clam/oyster/razor-clam digger] [Only applicable to picnickers]					 Q2.4.A. I only ride my bike on the beach and avoid riding it in the mudflats. Q2.4.B. I take photos with my bike in the mudflats. Q2.5.A. I take away all the bivalves that I dug up. Q2.5.B. I always classify the size of bivalves dug up and avoid taking away small ones. Q2.5.C. I catch and take away other organisms, such as crabs or fishes. Q2.5.D. I use salt to catch bivalves. Q2.6.A. I feed leftover foods to wild animals in the mudflat. Q2.6.B. I wash my hands, utensils and lunchbox in the river or seawater. 												
	Q2	.4A	Q2	.4B	Q2.	.5A	Q2	.5B	Q2	Q2.5C		Q2.5D		Q2.6A		Q2.6B	
Response	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	
Always	2	20.0	2	20.0	0	0	3	37.5	0	0	0	0	0	0	0	0	
Often	1	10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Seldom	0	0	3	30.0	1	12.5	0	0	0	0	0	0	0	0	0	0	
Rarely	1	10.0	1	10.0	1	12.5	0	0	1	12.5	0	0	0	0	0	0	
Never	3	30.0	1	10.0	1	12.5	1	12.5	1	12.5	2	25.0	2	40.0	2	40.0	
l don't know	3	30.0	3	30.0	5	62.5	4	50.0	6	75.0	6	75.0	3	60.0	3	60.0	
Total	10	100	10	100	8	100	8	100	8	100	8	100	5	100	5	100	

<u>Question 3</u>

Q3.1.I think that oyster reefs are important to the ecosystems of Pak Nai.

03.2. I think clams, oysters and razor clams are important to Pak Nai's ecosystem.

03.3. I think horseshoe crabs are important to the Pak Nai's ecosystem.

03.4. I think the behaviour of visitors damages Pak Nai's ecosystem.

Q3.5. I support the regulation of clam, oyster and razor clam digging in Pak Nai.

03.6. I support the regulation of cycling activities in Pak Nai.

Q3.7. I think that digging clams and razor clams affects the survival of horseshoe crabs and birds.

Q3.8. I think that cycling affects the survival of horseshoe crabs and birds.

03.9. I think that picnicking affects Pak Nai's ecosystem.

	Q:	3.1	03	5.2	Q3	5.3	Q3	5.4	03	5.5	Q3	5.6	Q3	5.7	Q3	5.8	03	5.9
Response	Count	%																
Always	38	19.7	55	28.5	57	29.5	18	9.3	55	28.5	43	22.3	58	30.1	40	20.7	39	20.2
Often	90	46.7	103	53.4	90	46.6	77	39.9	93	48.2	88	45.6	97	50.3	94	48.7	79	40.9
Seldom	52	26.9	30	15.5	39	20.2	73	37.8	24	12.4	41	21.2	28	14.5	34	17.6	48	24.9
Rarely	5	2.6	1	0.5	3	1.6	22	11.5	12	6.2	18	9.3	7	3.6	21	10.9	25	13.0
Never	1	0.5	0	0	0	0	2	1.0	9	4.7	3	1.6	2	1.0	4	2.1	1	0.5
l don't know	7	3.6	4	2.1	4	2.1	1	0.5	0	0	0	0	1	0.5	0	0	1	0.5
Total	193	100	193	100	193	100	193	100	193	100	193	100	193	100	193	100	193	100

<u>Question 4</u>

04.1 Do you think Pak Nai has a high ecological value?							
Response	Number of counts	%					
High	165	85.9					
Low	13	6.8					
No comment	14	7.3					
Total	193	100					
Q4.2. Can you list 3	organisms that inhabit Pak	Nai?					
Response	Number of counts	% out of 193					
Amphibians	2	1.0					
Arthropods	32	16.6					
Arthropods- Crustacean	128	66.3					
Birds	46	23.8					
Fishes	113	58.5					
Insects	8	4.1					
Mammals	10	5.2					
Plants	29	15.0					
Shellfishes	124	64.2					
Don't know	14	7.3					

04.3. What services d	an provide?	
Response	Number of counts	% out of 193
Protect the coast from strong waves	100	51.8
Act as a habitat for marine organisms	119	61.7
Barks can be used as dyes	35	18.1
Have medical value	35	18.1
l don't know	51	26.4

Q4.4. What services do you think an oyster reef can pro-
vide?

Response	Number of counts	% out of 193
Protect the coast from strong waves	51	26.4
Purify seawater	70	36.3
Sanctuary for fish fry and crustacean larvae	82	42.5
Oyster shell has medical value	36	18.7
Oyster shell can be turned into lime	51	26.4
l don't know	70	36.3

Q4.5. Which of the following are natural habitats in Pak Nai?

Response	Number of counts	% out of 193
Swamp	63	32.6
Mudflat	108	56.0
Mangrove	160	82.9
Gei Wai	37	19.2
Freshwater pond	36	18.7
Intertidal zone	71	36.8
Sandy shore	80	41.5
Lowland flats	48	24.9
l don't know	23	11.9

04.6. Which of the followings are conservation measures in Pak Nai?

Response	Number of counts	% out of 193
Oyster reef reconfiguration	58	30.1
Beach clean-up	67	34.7
Beach clean-up	67	34.7

0			
protected area	65	33.7	
Setting up environmental protection laws	50	25.9	
Monitoring of species diversity	55	28.5	
Tourists signage	80	41.5	
l don't know	81	42.0	
Q4.7. Do you think the conservation measures in Pak Nai are adequate?			
Response	Number of counts	% out of 193	
Enough	28	14.5	
Not enough	113	58.5	
l don't know / No comment	52	26.9	
Q4.8. How do you think Pak Nai can strengthen its conservation measures?			
	5:		
Response	Number of counts	% out of 193	
Response Add more signs for tourists	Number of counts	% out of 193 46.6	
Response Add more signs for tourists Add more conservation ambassadors	Number of counts 90 84	% out of 193 46.6 43.5	
Response Add more signs for tourists Add more conservation ambassadors Provide conservation-related activity classes and workshops	Number of counts 90 84 79	% out of 193 46.6 43.5 40.9	
Response Add more signs for tourists Add more conservation ambassadors Provide conservation-related activity classes and workshops Hold more beach clean-up activities	Number of counts 90 84 79 90	% out of 193 46.6 43.5 40.9 46.6	

102

1

Set up environmental

protection laws

l don't know

52.8

0.5

APPENDIX C - TNC PAK NAI SCIENCE SYMPOSIUMS

TNC First Pak Nai Science Symposium

Date: 28th April 2023

Discussion topic: research gaps and site-based management activities for upcoming conservation management in Pak Nai:

- (A) More investigation into human threats to Pak Nai
 - Effects to the ecosystem brought by the human activities
 - Monitoring of illegal dumping/ pig farms
 - Potential impacts from floating oyster farms on subtidal benthos
- (B) Potential future development plans
 - Risk and opportunities related to the Northern Metropolis and railway
 - Associated economic assessments of ecosystem services
- (C) Ecosystem based approach/ interconnections between habitats
 - Integration of data / more collaboration across different research
 - Same sets of sampling points for seagrass, sediment and horseshoe crab studies
- (D) Other species related research
 - Impact of invasive cordgrass (Spartina) / testing effectiveness of removal methods
 - Adult HSC populations
 - Migratory birds
 - Microbiome and associated biodiversity of oyster reef/ Potential change in macrobacteria community after reef reconfiguration

TNC Second Pak Nai Science Symposium

Date: 28th June 2024

Discussion topic: suggested actions for the long-term management of Pak Nai

(A) Scientific Knowledge Gaps

- Survival rate of juvenile horseshoe crabs in the Pak Nai. Tracking of the larger juveniles.
- Adult horseshoe crab habitat range in subtidal areas of the Deep Bay.
- A long-term study and monitoring of seagrass distribution and diversity.
- Modelling study on climate change and adaptation of Pak Nai, e.g. sea level rise, flooding.
- Study on the habitat connectiveness between landside and coastal CCP, Pak Nai and Ha Pak Nai etc.
- Study on potential increase in ecosystem services with well-designed Nature Based Solutions projects.

(B) Education and Public Outreach

- Preservation of the conditions.
- Prevention of species harvest within Pak Nai.
- Buffer zone between future development and Pak Nai.
- Identify education opportunities.
- Arrange talks to schools and professional bodies.

(C) Zonation

- Turn Pak Nai as an IUCN Green List of Protected and Conserved Areas.
- Turn Pak Nai into a marine protected area/ Coastal Protected Park.
- Set up core sensitive area to restrict tourists from entering
- Create a walking path to direct the visitors not to step on the mudflats and provide eco-tours, reduce trampling on seagrasses and other mudflats organism.
- Lights off at night to reduce disturbance to nature.
- Patrolling and monitoring.
- Low density development in Lau Fau Shan / Pak Nai.
- Wastewater treatment from nearby farming industry, e.g. fishponds and farms.

(D) Tourist

- Baseline survey on number of visitor in Pak Nai (monthly/ seasonal/ annual basis), set up infrared camera at the entrance
- Sustainable tourism planning, carrying capacity and impact assessment
- Education on climate change, climate proofing, resilience and sea level rise
- Community engagement, Villagers have a role in tourism
- Introduce oyster reef biodiversity

(E) Stakeholder Engagement

- Public consultation with local communities aiming for social (and conservation) gains.
- Hire villagers/residents to conduct patrols and deliver conservation messages to visitors.
- Take Pak Nai residents to other ecological hotspots in HK, e.g. Mai Po/ Hoi Ha Wan, to provide ecological value of Pak Nai/ HSCs
- Relate President Xi's ecological civilisation principle to Pak Nai villagers and future consultations.
- Possible involvement of eNGOs in future management plan
- Engage the public consultation team in the AFCD feasibility study.

Figure 51. Abandoned benthic oyster farm in September 2020, before TNC starts the habitat management programmme at Pak Nai. (💿 Tom Chan / TNC)

3

