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CHAPTER 6

Sea turtle conservation in Peninsular Malaysia

MOHD UZAIR RUSLI[1]* and DIONYSIUS S. K. SHARMA[2]

Abstract: Sea turtle conservation in Peninsular Malaysia has undergone substantial changes since the publication of *The State of Nature Conservation in Malaysia* in 1991. This chapter critically examines developments in population status, scientific research, conservation investment, community participation and governance over the subsequent 35 years. Although sustained protection has coincided with encouraging increases in green turtle nesting, recovery remains uneven across species and regions. Long-term studies have revealed important changes in recruitment, body size and breeding periodicity, demonstrating that increasing nesting abundance does not necessarily reflect improvements in all aspects of population performance. In contrast, the near disappearance of Terengganu's leatherback turtles raises critical questions about whether scientific knowledge has been matched timely intervention and adequate conservation investment. Their unexpected return to nest in 2026, without successful embryonic development, further highlights unresolved reproductive uncertainties. Drawing on historical evidence, recent scientific findings and conservation experience, we argue for a stronger connection between research, strategic investment, institutional coordination and community stewardship. Future priorities should extend beyond protecting nests and producing hatchlings towards reducing mortality, safeguarding marine habitats and strengthening population viability. Ultimately, Malaysia's conservation progress must be judged not simply by the efforts undertaken, but by their measurable contribution to the long-term survival and recovery of sea turtle populations.

INTRODUCTION

Revisiting the conservation outlook

When Chan Eng Heng reviewed the state of sea turtle conservation in Malaysia in 1991, the outlook was troubling. Decades of egg harvesting, incidental capture in fishing gear, coastal development and poorly managed tourism had taken their toll. Terengganu's once-abundant leatherback turtles (*Dermochelys coriacea*) were already approaching local extinction, while green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and olive ridley (*Lepidochelys olivacea*) turtles faced mounting pressures (Chan 1991).

The recommendations were clear: strengthen legislation, protect nesting and marine habitats, improve hatchery management, sustain scientific monitoring and foster international cooperation. Much of this agenda remains relevant today. Malaysia has since made substantial progress. More nesting beaches receive protection, research programmes have produced increasingly sophisticated ecological knowledge, and conservation has attracted wider participation from communities, educational institutions and the private sector. Yet the outcomes have been far from uniform. Some nesting populations have increased considerably; others have dwindled to the point where even their reproductive future is uncertain.

[1] Sea Turtle Research Unit (SEATRU), Centre for Marine Conservation, Institute of Oceanography and Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
[2] Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
***Corresponding author: uzair@umt.edu.my**

This chapter examines what has changed in Peninsular Malaysia since the 1991 assessment, where conservation has made a difference and where persistent shortcomings deserve closer attention. Central to our assessment is whether scientific knowledge, conservation investment and institutional action have kept pace with the biological challenges facing different turtle populations.

Uneven progress across species and regions

The green turtle remains the most abundant and widely distributed nesting species in Peninsular Malaysia, with Terengganu providing its principal stronghold. Its global reclassification from Endangered to Least Concern in the 2025 IUCN Red List reflects encouraging recovery across numerous populations (Wallace and Broderick 2025). However, global improvement should not obscure the considerable differences among Malaysian nesting sites.

Boulven *et al.* (2024) analysed green turtle nesting records from 1996 to 2022 and found markedly different regional trends. Recorded nesting activity increased by an estimated 379% in Terengganu, with smaller positive trends in Pahang and Pulau Pinang. Perak, by contrast, experienced an estimated 62% decline, while Johor exhibited a slightly negative trend. Such differences caution against treating national nesting totals as a reliable account of every population's condition.

At Chagar Hutang Turtle Sanctuary, Redang Island, evidence of increasing nesting activity is particularly strong. Drawing on 32 years of monitoring (1993 – 2024) and records of 4,609 individually tagged green turtles, Tromp *et al*. (2026) reported a three- to fourfold increase in annual nesting abundance, from approximately 400 – 500 nests in the earlier years to 1,500 – 2,000 more recently ($R^2 = 0.52$, $p < 0.01$).

The underlying processes are revealing. Wenceslau *et al*. (2021) found that increasing nest abundance was associated with the recruitment of new nesting females ($R^2 = 0.516$, $p < 0.001$). Nesting fluctuations were also correlated with the El Niño–Southern Oscillation (ENSO) approximately 2.5 years earlier, suggesting that climatic conditions affecting distant foraging grounds may influence subsequent breeding activity.

More recent findings complicate the conventional picture of population recovery. From 18,707 carapace measurements, Hays *et al.* (2025) documented a decline in mean nesting female size from 100.8 cm in 2005 to 96.8 cm in 2022. The influx of smaller, first-time nesters partly explained this reduction, although neophytes themselves were also becoming smaller. Meanwhile, Tromp *et al*. (2026) analysed 1,399 breeding-interval records and found that the relative proportion of four-year versus three-year remigration intervals increased from 28% in 1997 – 2012 to 37% in 2013 – 2024. This shift was significantly associated with annual nest numbers ($R^2 = 0.23$, $p = 0.01$).

These observations raise an intriguing possibility: population growth may be accompanied by changes in reproductive performance. Density-dependent food limitation and changing environmental conditions are plausible explanations, although their relative contributions remain unresolved. Increased nesting is encouraging, but it does not necessarily imply that individual females are breeding more frequently or maintaining their former body size.

Elsewhere, the situation remains more precarious. Hawksbill nesting is comparatively restricted, with Melaka supporting an important aggregation along the west coast, while olive ridley nesting has become exceptionally rare across much of its historical range. Smaller nesting aggregations, including those in Perak, warrant protection despite their modest numbers.

The most severe loss, however, remains the collapse of Terengganu's leatherback population. Nesting became so infrequent that the historical aggregation was considered functionally extinct. After a single recorded nest in 2010 and two in 2017, no further nesting was documented until five events occurred in 2026. This unexpected reappearance offers a rare opportunity to investigate whether reproductive potential persists within or beyond the remnant population. It does not, by itself, indicate recovery.

THE EVOLUTION OF SEA TURTLE SCIENCE IN MALAYSIA

The development of Malaysian sea turtle science has changed not only what researchers know, but also the questions they can investigate. Early work by Hendrickson established a foundation for studies of nesting and movement, while the establishment of the Sea Turtle Research Unit (SEATRU) in 1984 strengthened systematic research, particularly on leatherbacks in Terengganu.

A notable advance came through incubation biology. Chan and Liew (1995) demonstrated that incubation temperature influenced leatherback hatchling sex ratios, revealing a consequence of hatchery management that could not be detected through hatching success alone. Research increasingly began to examine the biological quality of hatchlings rather than simply counting their production.

Experimental studies subsequently extended this approach. Rusli *et al.* (2015) showed that incubation methods could affect green turtle hatchlings' crawling and swimming performance. Further investigations demonstrated that synchronous digging reduces the energetic cost of escaping underground nests (Rusli *et al.* 2016). Acoustic monitoring later revealed changes in the coordination of digging activity before emergence, providing insight into behaviour previously hidden beneath the sand (Nishizawa *et al.* 2021).

These findings are relevant to practical conservation. A hatchling that emerges successfully has not necessarily experienced favourable developmental conditions or retained the energetic reserves needed for its initial journey offshore. Understanding these mechanisms allows hatchery practices to be assessed more critically.

Research has also followed turtles into their marine environment. Investigations at Chagar Hutang identified predation on hatchlings by juvenile blacktip reef sharks, illustrating the ecological pressures encountered shortly after entering the sea (Bashir *et al.* 2020). Satellite telemetry has revealed a different dimension of their lives. Pilcher *et al.* (2019) reviewed 104 transmitter deployments in Malaysia, with usable information from 102, documenting migrations that connect nesting sites with distant foraging areas across Southeast Asia.

The contrast between what is known on land and at sea remains striking. Nesting females have been studied intensively at several locations, yet demographic information concerning juveniles, males and survival in marine habitats is still limited. Genetic methods, remote sensing and digital monitoring offer ways to address these gaps, provided they are directed towards well-defined conservation questions.

We regard this progression as a considerable achievement. Malaysian research has moved from describing nesting activity towards explaining the physiological, behavioural and environmental processes that influence survival. Its next test is whether those explanations can improve management decisions, particularly where established approaches have proved insufficient.

Scientific investment and the leatherback conservation challenge

The value of scientific knowledge becomes most evident when conservation faces its greatest difficulties. Terengganu's leatherback history offers a sobering example of what can happen when recognised threats persist despite research, protection measures and public concern.

In 1956, the coastline supported an estimated 10,155 leatherback nests. By 1995, only 37 were recorded, equivalent to approximately 0.4% of the earlier abundance (Chan and Liew 1996). Egg exploitation, fisheries-related mortality, coastal disturbance and shortcomings in incubation practices contributed to this decline.

Many of these problems were understood before the population reached such critically low numbers. Research had documented the consequences of egg harvesting and fisheries interactions, while incubation studies identified concerns about hatchling production and sex ratios. Beyond Malaysia, stage-based population modelling demonstrated the importance of survival among larger juvenile turtles (Crouse *et al.* 1987). Frazer (1992) similarly warned that increasing hatchling production without addressing the causes of mortality could offer only a partial conservation solution.

The issue, therefore, extends beyond whether sufficient research had been conducted. It concerns the extent to which available knowledge was converted into timely intervention, supported by the resources, technical capacity and institutional commitment required to reduce threats.

Events in 2026 bring this question into sharper focus. Between 1 September and 10 October, five leatherback nesting events along the Terengganu coast produced 313 eggs. The intervals between nesting events suggested that the clutches may have originated from one female. Subsequent examinations found no detectable embryonic development, and all eggs failed to hatch (Bernama 2026a, 2026b).

These observations are biologically significant, but their interpretation requires care. The absence of observable embryonic development does not establish whether fertilisation failed or embryos died at a very early stage. Nor can nesting intervals alone confirm individual identity. Genetic analysis, reproductive diagnostics and appropriate embryological investigations are needed to distinguish these possibilities.

Other questions remain equally pressing. Does the returning female belong to the historical Terengganu population? Are breeding males present within the wider region? Where do surviving individuals spend their time between breeding seasons, and what threats do they encounter? Addressing such questions may require coordinated genetic sampling, satellite tracking, reproductive investigations and marine monitoring extending beyond Malaysian waters.

The difficulty is that opportunities to obtain this information have become exceptionally rare. Small populations can be scientifically demanding: individuals are difficult to locate, biological samples are scarce, and meaningful observations may occur years apart. Preparedness is therefore essential. Expertise, laboratory capacity, sampling protocols and financial resources must be available before an unusual nesting event occurs, not assembled only after the opportunity has passed.

This raises a broader question about the adequacy of conservation investment. We lack sufficiently consolidated historical financial data to quantify any funding shortfall or attribute the leatherback collapse specifically to inadequate expenditure. Nevertheless, the outcome warrants critical examination of whether investment was sustained, appropriately targeted and commensurate with the population's risk of disappearance.

The lesson is not that science failed to identify the problem. Rather, scientific knowledge alone could not secure the population. Effective conservation requires the ability to investigate remaining uncertainties while simultaneously reducing known threats.

Investment should therefore reflect more than the abundance of animals available for study. Extinction risk, biological uncertainty and the urgency of intervention are equally legitimate considerations. A species should not receive diminishing scientific attention simply because so few individuals remain.

FROM PUBLIC AWARENESS TO SHARED STEWARDSHIP

Scientific capacity is only one part of an effective conservation system. The protection of sea turtles also depends on people who live and work alongside their habitats, institutions with clear responsibilities, and economic activities compatible with conservation objectives.

Community initiatives in Terengganu illustrate how these relationships have developed. At Ma'Daerah, partnerships involving WWF-Malaysia, government agencies and residents supported nesting habitat protection and local conservation advocacy. The establishment of Persatuan Khazanah Rakyat Ma' Daerah (MEKAR) in 2005 provided a platform for community participation. In Setiu, Persatuan Wanita Kampung Mangkok Setiu (PEWANIS), formally registered in 2010, connected wetland conservation with women's participation, environmental education and alternative livelihood opportunities.

Chagar Hutang offers a complementary model as a living lab, where long-term research, conservation and education are brought together within a functioning sea turtle nesting sanctuary. Since 1998, SEATRU's volunteer programme has enabled members of the public to participate directly in nesting monitoring, habitat protection and field research, while its Outdoor Classroom provides opportunities for experiential environmental learning (Chan 2010). More importantly, Chagar Hutang demonstrates how a university-led conservation initiative can evolve into a shared platform for scientific discovery, public engagement and stewardship, extending its value beyond institutional boundaries while keeping the protection of nesting turtles at its core.

Such programmes contribute to public understanding and can develop future conservation advocates. Yet participation should not be mistaken for demonstrated behavioural change. Ting and Hassan (2025) reviewed publicly reported outreach activities of 18 Malaysian organisations during 2023 – 2024. All used knowledge dissemination, 17 incorporated hands-on activities, and only four included knowledge-application approaches. Their findings reveal the breadth of outreach provision, but do not establish whether these programmes produce lasting changes in behaviour.

Experience-based tourism is gaining prominence in sea turtle conservation, with activities such as swimming and diving with turtles, guided nesting experiences and hatchling release programmes attracting growing public interest. These experiences offer opportunities to strengthen environmental appreciation, support coastal livelihoods and generate conservation funding. However, increased participation also raises ethical and ecological concerns, particularly regarding disturbance to turtles in their natural habitats, inappropriate wildlife interactions and the handling or release of hatchlings. Clear, science-based guidelines are therefore essential to ensure that tourism activities prioritise animal welfare, minimise ecological impacts and deliver genuine conservation benefits rather than simply providing memorable visitor experiences.

Conservation must also be considered within wider coastal development decisions. A multidisciplinary assessment in Perak combined ecological surveys, local knowledge, habitat mapping and socioeconomic valuation to inform coastal planning. Its estimate of RM 1.34 billion in total economic value concerned the broader coastal and marine ecosystems assessed, not sea turtles alone. Community surveys also indicated support for conservation financing mechanisms, offering opportunities to link habitat protection with public benefits (Universiti Malaysia Terengganu *et al.* 2026).

Governance remains indispensable. Terengganu's 2021 amendment to the Turtles Enactment, which prohibited the sale of eggs from all turtle species from 1 June 2022, marked a significant legislative development (Bernama 2021). Its conservation value, however, depends on enforcement and the wider management of threats affecting turtles at sea and along developed coastlines. The next advance in community conservation should be judged by the durability of these arrangements: whether local people gain meaningful roles, whether environmentally harmful practices decline, and whether conservation continues when individual projects or funding agreements end.

THE WAY FORWARD

Malaysia now possesses an extensive body of research, practical experience and institutional knowledge (Table 1). The challenge is to organise these assets around a clearer set of conservation outcomes, with priorities reflecting the condition and needs of individual populations.

Table 1. Progress and remaining priorities in sea turtle conservation in Peninsular Malaysia.

Conservation priority in 1991	Progress by 2026	Remaining challenge
Reduce egg exploitation	Greater nesting beach protection; Terengganu became the last state in Peninsular Malaysia to prohibit the commercial sale of all sea turtle eggs in 2022	Enforcement effectiveness and differences in protection across jurisdictions
Improve hatchery management	Advances in incubation biology and hatchling performance research	Evaluating reproductive outcomes beyond hatching success
Protect critical habitats	Turtle sanctuaries established; migration and foraging habitats increasingly documented	Securing important habitats beyond nesting beaches
Reduce fisheries-related mortality	Greater recognition of marine threats and growing ecological knowledge	Limited population-specific mortality and intervention -effectiveness data
Strengthen scientific monitoring	Long-term tagging, reproductive studies, genetics and telemetry	Limited demographic information on juveniles, males and survival at sea
Improve institutional and international cooperation	Wider engagement among agencies, universities, NGOs and communities	Sustained coordination, shared data and long-term financing

Reliable population assessment is the starting point. Standardised nesting records should be linked, wherever feasible, with information on breeding females, recruitment, reproductive intervals, survival and population connectivity. The long-term findings from Chagar Hutang demonstrate the value of such monitoring, while differences among states show why consistent methods and interpretation matter.

Marine protection requires comparable attention. Nesting beaches are only one component of the habitat network used by sea turtles. Fisheries-related mortality, conditions at foraging grounds and the security of migration corridors can undermine gains achieved through egg protection. Tracking, habitat mapping and ecological models should therefore guide practical management measures and provide evidence for evaluating their effectiveness.

Research priorities also need to reflect population status. Relatively abundant green turtle aggregations permit detailed demographic investigation, whereas depleted leatherback and olive ridley turtle populations may require specialised, opportunistic and regionally coordinated approaches. Neither should be neglected. The appropriate scientific response depends on the questions that must be answered and the risks of leaving them unresolved.

We propose a coordinated national research and recovery framework built around existing government agencies, universities and conservation organisations. Shared monitoring standards, accessible databases, clearly assigned responsibilities and agreed research priorities would reduce fragmentation. Financing arrangements should provide continuity beyond individual project cycles and support periodic assessments of whether management interventions are achieving their intended results.

Community stewardship and economic planning should form part of this framework, with indicators extending beyond volunteer participation, education sessions or tourism income. Compliance, local conservation capacity, community benefits and improvements in habitat protection provide more meaningful evidence of social contribution.

Above all, the distinction between conservation activity and conservation success must be made explicit. Numbers of nests protected, hatchlings released, publications produced and people engaged describe what conservation programmes do. They are useful measures of effort, but they are not substitutes for evidence that mortality has declined, reproductive performance has improved, habitats remain secure or populations are becoming more viable.

Malaysia has demonstrated that sustained protection and research can coincide with substantial increases in sea turtle nesting. The loss of the historical leatherback aggregation shows, just as clearly, that effort and knowledge do not guarantee recovery. Both experiences should inform the country's next conservation priorities. The task ahead is not simply to do more for sea turtles, but to direct our scientific, financial and institutional resources towards the interventions most likely to secure their future.

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