



Vol. 4 No. 3 (March) (2026)

Beneath the Surface: Global Lessons in Technology-Integrated Aquarium Design and the Case for a Public Aquatic Museum in Karachi, Pakistan

Ar. Rida Hussain

Assistant Professor, School Of Architecture And Planning, University Of Management And Technology Email: rida.hussain@umt.edu.pk

Ar. Mahjabeen Memon

Architect, The University Of Modern Sciences
Email: mahjabeenmemon0410@gmail.com

Ar. Sabeen Shah

Lab Supervisor, Department Of Architecture, Mehran University Of Engineering And Technology Email: sabeen.shah@faculty.muet.edu.pk

Ar. Ume Aeman

Lecturer, Department Of Architecture, Mehran University Of Engineering And Technology Email: ume.aeman@faculty.muet.edu.pk

ABSTRACT

This paper is a synthesis of literature on environmental degradation of the marine ecosystems and loss of biodiversity in Pakistan and a comparative review of nine internationally acclaimed aquariums and marine life attractions which were chosen in consideration of their scale, technological integration or design significance. The public aquarium are more and more conceived as a combination of species conservation, environmental education, tourism and public recreation, all at the same time. The review finds that there are five common design principles that can be found in these facilities: mobile interpretation, augmented-reality interpretation, record-scale engineering for visitors, non-linear and zoned circulation with a narrative, and site-adaptive, accessibility-focused planning. The strategies are then applied to Pakistan's own marine landscape, from the endangered Indus River dolphin, to the decrease in fish diversity along the coast, to the long-standing closure of the country's only public aquarium in Clifton, to support the argument that a new, technology-facilitated aquatic museum could fill a real need for marine education and conservation in Pakistan. The paper ends with recommendations for designers and institutions that are thinking of installing such a facility in Karachi or similar coastal cities in the Global South.

Keywords: Public Aquarium; Marine Conservation; Indus River Dolphin; Interactive Exhibit Design; Karachi; Museum Technology

Introduction

Public aquariums are becoming ever more important as tools of informal science education, biodiversity conservation, and urban tourism for coastal countries. From the oldest of the aquaria like the Monterey Bay Aquarium to newer, technology-centric aquaria like the Dubai Aquarium and Underwater Zoo, it is clear that exhibit design,



Vol. 4 No. 3 (March) (2026)

digital interpretation, and site planning all contribute to the understanding a visitor may gain of a marine habitat. While Pakistan has a long coast line, an economically important fisheries sector, and is home to significant species like Indus River dolphin, the public aquarium facilities are quite sparse. The Clifton Fish Aquarium of Karachi, which is the only free-standing public fish aquarium in the country, has been closed for a prolonged period, which has left a gap in the marine-education system in the city. This paper combines two existing sources of information: (a) published research and reports on marine environmental degradation, fish diversity and endangered fish species in Pakistan, and (b) descriptive and design oriented information about internationally recognised aquariums that employ interactive (or immersive) technology. The aim is to document the empirical research in the field itself rather than to report on it and to compare the way leading facilities have engaged in the process of making marine science accessible to the public, and to derive design implications for the revival of a public aquarium in Karachi.

Literature Review

Marine Environmental Degradation in Pakistan

Pakistan has ratified international treaties on protection of marine environment but marine pollution is still a serious issue in Pakistan. Coastal waters around Karachi are visibly affected by untreated sewage, plastic waste and industrial effluent, including heavy metal contamination associated with the ship-breaking industry at Gadani, and unmanaged industrial areas add to wastes entering the sea. Fish and other marine organisms take up these harmful chemicals and pass them on to humans, and many coastal communities rely on fisheries for a large share of their economic livelihood. It is estimated that plastic debris represents most of the debris which is found on the shores of Pakistan.

Fish Diversity and Its Decline

Dozens of species of fish were sampled at multiple stations on the downstream portion of the Indus River during field surveys and a significant proportion of these were considered low commercial value or "trash" fish, reflecting pressure on higher-value fish populations. Sampling was also expanded along the Arabic Sea coastlines of Balochistan and Sindh, and another 40 families and species were recorded, with a remarkably unbalanced distribution of species, reflecting over-exploitation and habitat stress. The results show that, although Pakistan's marine biodiversity is significant, there is still a lack of public awareness about it and it is not protected from the synergic effect of pressures in the environment.

The Indus River Dolphin as a Conservation Flagship

Four-fifths of the Indus River Dolphin's historic range was lost due to habitat fragmentation from irrigation barrages, a nearly blind, echolocation-dependent cetacean endemic to the Indus basin. The population has been estimated at about two thousand with a focus in the area between Guddu and Sukkur barrages in Sindh. Habitat fragmentation is exacerbated by entanglement in fishing gear and stranding in irrigation canals as well as pollution due to agricultural and industrial run-off. The species is one of just a few remaining freshwater cetaceans and thus is a good choice for a programme for conservation and education, similar to some of the aquarium houses discussed below.



Vol. 4 No. 3 (March) (2026)

Technology as an Informal-Education Tool in Aquariums

The use of digital and interactive technology in informal science settings is a recurring theme in the aquarium literature. A preliminary study conducted at the South Carolina Aquarium using the use of handheld tablets also revealed that they did not detract from the immersive and escapist experience that visitors are seeking within the galleries, but rather added to and enhanced the content of exhibits. The Smithsonian National Museum of Natural History is creating its holographic orca installation in much the same way; a large-scale digital projection replaces a live orca. Ripley's Aquarium of Canada has other augmented- and virtual-reality projects, including a mobile app that overlays interpretive content onto physical exhibits and an experience that simulates a shark dive. Together, this literature points to a tendency for digital layering in lieu of physical specimens and tanks to extend the engagement, enhance story within story, and engage audiences who may not have had physical access to the specimens or tanks.

Comparative Case Analysis of International Aquarium

The South Carolina Aquarium, the marine hologram gallery at the Smithsonian National Museum of Natural History, Chimelong Ocean Kingdom, Underwater World Pattaya, the Dubai Aquarium and Underwater Zoo, the Aquarium of Canada in Ripley, the ArtScience Museum in Singapore, the S.E.A. Aquarium in Resorts World Sentosa and the Monterey Bay Aquarium were chosen for review because of their scale, technological integration or their design significance. They are summarised in terms of scale, signature features and the transferable design lesson that each offers in Table 1.

Facility	Location	Scale	Signature Technology Feature	Design Lesson
South Carolina Aquarium	Charleston, USA	10,000+ specimens; 385,000-gal. Great Ocean Tank	Tablet-based roaming interpretation supplementing live exhibits	Low-cost mobile technology can raise engagement without displacing the exhibit experience
Smithsonian National Museum of Natural History	Washington DC, USA	Single flagship gallery	Large-scale holographic orca projection	Immersive projection can substitute for live specimens of threatened species
Chimelong Ocean Kingdom	Hengqin, China	49 million-litre system; 2,072 ha park	World-record acrylic viewing panel and dome	Record-scale ambition must be matched by maintenance capacity to avoid degraded visitor experience
Underwater World Pattaya	Pattaya, Thailand	3.8 million-litre, 100 m tunnel; 5,000 fish	Zoned tunnel journey (coral, shark/stingray, jellyfish)	Universal-design circulation broadens access for older and disabled visitors
Dubai Aquarium &	Dubai, UAE	10 million litres; 140	Retail-integrated aquarium with diver	Co-locating an aquarium within a



Vol. 4 No. 3 (March) (2026)

Underwater Zoo		species; record acrylic panel	and experiences feeding	high-footfall commercial destination sustains visitation
Ripley's Aquarium of Canada	Toronto, Canada	5.7 million litres; 20,000+ animals	AR mobile app and VR shark-dive experience	Layered AR/VR content extends learning beyond the physical tank
ArtScience Museum	Marina Bay, Singapore	1,500 sq. m permanent gallery	Interactive digital floor and participatory "sketch aquarium"	Merging art, science and play increases dwell time and repeat visits
S.E.A. Aquarium, Resorts World Sentosa	Sentosa, Singapore	60 million litres; 100,000 animals, 800+ species	Ten geographically themed zones telling a regional-water narrative	Organising exhibits around a coherent regional-water story strengthens conservation messaging
Monterey Bay Aquarium	California, USA	322,000 sq. ft.; 35,000+ specimens	Adaptive reuse of a former cannery; free-flow non-linear circulation	Site-specific storytelling and building reuse can lower cost while deepening local relevance

Table 1. Comparative summary of reviewed aquarium and marine-life facilities.

Scale as Spectacle:

The superlatives are a feature of several facilities: Chimelong Ocean Kingdom's 22.7-million-litre aquarium, which holds the Guinness record for the largest acrylic panel tank; Dubai Aquarium's acrylic panel record tank; and the S.E.A. Aquarium's acrylic panel 60-million-litre system. The strategy works well for tourism positioning but must be sustained by an equivalent long-term maintenance budget – as is evident in the record scale ambition, visible cracking, a viewing window removed for extended maintenance and water-quality problems, noted by the Chinese state media, within the first year of operation at Chimelong.

Digital and Immersive Interpretation

A second group of facilities distinguishes itself not so much by its size as by its multiple layers of digital content. The Art Science Museum's "sketch aquarium" and interactive floor, as well as Ripley's AR/VR programs, and the South Carolina Aquarium's Tablet program are just a few examples of the potential impact comparatively small investments in interactive technology can have on how visitors interact with a static exhibit, especially children and repeat visitors.

Narrative Zoning and Circulation

The S.E.A. Aquarium's visitor experience is divided into ten geographically themed zones, each of which follows a path of events from Southeast Asian waters to the Arabian Gulf, weaving in conservation messages in a sustainable regional story. In



Vol. 4 No. 3 (March) (2026)

contrast the Monterey Bay Aquarium decided against following the linear path and opted for a free flow circulation model, where visitors are allowed to pursue their own journey through habitats specifically chosen from within Monterey Bay. In both cases, by tailoring the exhibit sequence around a body of water, instead of providing a general world overview, the approach is very relevant to a Karachi facility that is arranged, for example, around the Indus Delta and the Arabian Sea.

Accessibility and Site Adaptation

Leading facilities, such as underwater world pattaya, reveal that disability access is a major design consideration, not an afterthought. Leading facilities such as underwater world pattaya show the importance of disability access as a design consideration, not an afterthought. Reusing an existing waterfront infrastructure like Monterey Bay Aquarium's former sardine cannery, which reused the buildings' seawall and pump house, is another example of how adaptive reuse of waterfront infrastructure can lower capital costs and strengthen a facility's sense of place and industrial and ecological heritage.

Implications for a Public Aquarium in Karachi:

There are currently only a few aquarium-type facilities in Pakistan, and Clifton Fish Aquarium in Karachi, the country's main standalone, public aquarium, has been shut down for years with various offers of reopening. This is despite the fact that the city is situated beside the Arabian Sea and in close proximity to the Mangroves of the Indus Delta and the range of the Indus River dolphin, and thus the raw materials of the local ecology are available for the development of a rich regional narrative. The comparative analysis above indicates that a direction for designing such a revival of the facility can be made without the capital investment that would be needed to build it in Chimelong or Dubai. It could incorporate the following:

Interpretive layers on a tablet or an app similar to those found at the S.E.A. Aquarium in South Carolina and Underwater World Pattaya, which are relatively low-cost and usable on a larger scale;

A zoned circulation narrative that incorporates the geographic narrative logic of the Indus Delta, the Arabian Sea, and mangrove habitats instead of a generic global survey, like the Monterey Bay example;

The Indus River dolphin as a flagship exhibit for conservation, similar to the Smithsonian's approach with the Gulf Stream whale, where live animals are not possible, the narrative is holographic or digital projections;

Accessibility and adaptive site planning as a baseline, from the beginning, as at the S.E.A. Aquarium in South Carolina and Underwater World Pattaya. A facility designed in this fashion would directly cater to, and address the themes of environment already established in the regional literature – coastal pollution, diminishing fish diversity and the endangered Indus river dolphin, turning these abstract research papers into a public facing conservation story.

Recommendations

From the comparative results, the following recommendations are suggested for those institutions or agencies that want to embark on a public aquarium project in Karachi or any other coastal city:



Vol. 4 No. 3 (March) (2026)

Make a coherent regional-water story (Indus Delta and Arabian Sea) more prominent than a non-discriminatory global species collection, in order to bolster the local relevance and conservation messaging.

Invest in scalable Digital Interpretation (Tablets, mobile AR) before investing in record-scale tank engineering; lower capital and maintenance.

Do not consider physical access and universal design as an after-thought. If live endangered or protected species like the Indus River Dolphin cannot be ethically kept, consider holographic or digital projection as an alternative conservation-education tool.

When possible, consider adaptive reuse of existing infrastructure relating to waterfront or parks, rather than total new construction to minimize costs and maintain site history. Include maintenance and water-quality budgets at the outset of the project, based on experience with operation of larger record-scale facilities.

Conclusion

This review of nine internationally significant aquariums and marine-life attractions, read alongside the documented state of marine biodiversity and environmental pressure in Pakistan, indicates that a revived public aquarium in Karachi could meaningfully close a gap in the country's marine-education and conservation infrastructure. The comparative evidence suggests that effective design does not depend solely on record-breaking scale; rather, coherent regional storytelling, layered digital interpretation, and accessibility-conscious planning are the features most consistently associated with strong visitor engagement across the facilities examined. Applied to Karachi's own coastal context — and to species such as the Indus River dolphin that already carry international conservation significance — these principles offer a practical and comparatively low-risk design direction for future development.

References

- [1] Gillani, S. A. (2019). Pakistan and the sea: Preserving the marine environment. *The Diplomat*.
- [2] Sheikh, M., Laghari, M. Y., Lashari, P. K., Khooharo, A. R., & Narejo, N. T. (2018). Fish diversity of downstream Indus River, Sindh, Pakistan. *Pakistan Journal of Zoology, Supplementary Series*, 13, 184–190.
- [3] Hassan, H. U., Mahboob, S., Masood, Z., Riaz, M. N., Rizwan, S., Al-Misned, F., et al. (2023). Assessment of fish diversity in the Arabian Sea (Sindh and Balochistan coasts). *Brazilian Journal of Biology*, 83, e24921.
- [4] WWF Pakistan / River Dolphins Programme. Indus River dolphin conservation status and threats. Retrieved from riverdolphins.org.
- [5] South Carolina Aquarium. (2015). Interpretation and technology: Integrating tablets into gallery experience. Charleston, SC.
- [6] Smithsonian National Museum of Natural History. New holographic experience takes a 3D dive into marine conservation. *MuseumNext*.
- [7] CLAD Global. Chimelong Ocean Kingdom, Hengqin, China: Design and engineering overview.
- [8] Domus. (2020, March 15). The world's largest aquarium reveals the complexity and contradictions of marine architecture.
- [9] Underwater World Pattaya. Facility overview and accessibility information. Pattaya, Thailand.
- [10] Dubai Aquarium & Underwater Zoo. Facility and Guinness World Record overview. Dubai, UAE.
- [11] Ripley's Aquarium of Canada. Technology and augmented/virtual reality features. Toronto, Canada.
- [12] ArtScience Museum. Future World and Sketch Aquarium exhibit overview. Marina Bay



Vol. 4 No. 3 (March) (2026)

Sands, Singapore.

[13] Resorts World Sentosa. S.E.A. Aquarium and Marine Life Park overview. Sentosa Island, Singapore.

[14] Monterey Bay Aquarium. Facility history, design, and sustainability overview. Monterey, CA.