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From sea turtle rehabilitation to verifiable conservation outcomes: an evidence-based framework for aquariums

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Zoos and aquariums increasingly identify conservation as a central institutional commitment, but their contributions require evaluation through verifiable outcomes. Sea turtle rehabilitation provides a useful context because appropriately managed rescue and rehabilitation can support individual welfare and generate information on health, disease, anthropogenic threats, and post-release recovery, yet release alone does not demonstrate population-level benefit. Although individual clinical care and rescue numbers represent essential frontline commitments, aquarium-based rehabilitation programs can further build upon this foundation through transparent clinical dispositions, evidence-based care, post-release monitoring, health and threat surveillance, peer-reviewed research, regional data sharing, and evaluated education. Published work from Taiwan illustrates how rehabilitation-derived information can support this broader conservation role. This perspective proposes an evidence-based framework for assessing and strengthening the conservation contribution of aquarium-based sea turtle rehabilitation.

KEYWORDS
aquarium conservation, conservation medicine, marine turtle health, post-release monitoring, sea turtle rehabilitation, wildlife rescue

1 Introduction

Zoos and aquariums have historically provided public recreation and education, and an increasing number now explicitly describe conservation as a central institutional commitment. Nevertheless, published scientific literature provides one means of evaluating conservation contributions through verifiable outcomes rather than institutional self-description alone. In a North American review of published conservation translocations, zoo-bred animals contributed to releases for only 40 of 279 translocated animal species (14%) and represented 25% of translocated species sourced from captive-bred populations (Brichieri-Colombi et al., 2019).

This finding does not imply that zoological institutions lack conservation roles. Brichieri-Colombi et al. (2019) noted contributions through research, veterinary expertise, education, funding, and collaboration, and argued that peer-reviewed sharing of expertise can strengthen recognition of zoological institutions as credible conservation partners. Complementing this perspective, a review of 243 conservation-translocation projects

reported in five editions of Global Re-introduction Perspectives found zoo or aquarium involvement in 35% of projects. Complementary survey data from European Association of Zoos and Aquaria (EAZA)-member institutions showed contributions beyond animal provision, including funding, staff, expertise, equipment, husbandry, veterinary support, and project coordination (Gilbert et al., 2017). For marine wildlife, this broader framing is especially important: the conservation value of a rehabilitation program may lie not only in returning an individual animal to the sea, but also in generating reliable information that improves future diagnosis, treatment, release assessment, and management.

Sea turtle rescue, resuscitation, rehabilitation, and release (RRRR) provide a useful test case. While individual welfare and compassionate clinical care remain indispensable ethical obligations of veterinary facilities, rehabilitation can support animal well-being, return suitable individuals to the wild, generate health data, and document human-caused threats. Nevertheless, release alone is not proof of population recovery. Conservation translocations are intended to provide measurable benefit at population, species, or ecosystem levels, not solely to benefit translocated individuals (Caillouet et al., 2016). Nevertheless, the relevant question is not whether aquariums are inherently conservation institutions, but whether their activities generate evidence that can inform conservation management.

2 From capacity to outcomes

Professional rehabilitation requires appropriate facilities and personnel. U.S. Fish and Wildlife Service (USFWS) standards illustrate the operational requirements of regulated sea-turtle rehabilitation facilities, including water-quality monitoring, suitable tanks and life-support systems, veterinary oversight, biosecurity, individual health records, and enhanced safeguards for turtles with fibropapillomatosis (FP) (U.S. Fish and Wildlife Service, 2019). These conditions suggest that suitably equipped aquariums can serve as valuable clinical and logistical nodes within stranding-response networks. While high-standard facilities, veterinary dedication, and clinical capacities represent critical institutional inputs, their full conservation potential is realized when linked to verifiable ecological and management outcomes.

A program's potential conservation relevance may increase as it moves through an evidence chain:

capacity → clinical disposition → release → post-release evidence and/or post-injury evidence in the wild → management and education

At minimum, facilities should distinguish deaths, euthanasia, transfer, permanent captivity, and survival-to-release. Nevertheless, stronger conservation inferences generally require documented release criteria, tagging, telemetry, resighting, or other post-release information, as well as evidence that health and threat data inform management. This approach shifts attention from institutional identity or rescue totals toward traceable outputs and outcomes.

3 Taiwan case study

Published research from Taiwan illustrates how an aquarium-based program can transform rescue cases into clinical and conservation-relevant evidence. Li et al. (2015) developed a summarized health index from clinical and clinicopathological variables to predict survival in stranded turtles. The study suggests that rehabilitation records may support early risk stratification and triage, although further validation across species and settings remains necessary.

Rescue-derived samples have also supported regional disease surveillance. Li et al. (2017) examined FP tumor samples from three green turtles found in Taiwanese coastal waters, including two live accidental-capture cases transferred to the National Museum of Marine Biology and Aquarium (NMMBA) for rehabilitation. Chelonid herpesvirus 5 (ChHV5) DNA was detected at three genetic loci, viral RNA was detected in most reactions, and histopathology identified epidermal intranuclear inclusions. Taiwanese ChHV5 sequences grouped with strains from Hawaii, Puerto Rico, and São Tomé. The study was necessarily small and cannot estimate disease prevalence or transmission pathways. Nevertheless, the findings suggest that rehabilitation-derived samples may contribute to regional pathogen surveillance.

Li and Chang (2020) further used records from 28 debilitated or injured green turtles admitted to NMMBA to evaluate clinical and clinicopathological differences associated with FP. These findings suggest that systematic clinical records may assist clinical assessment and case management, although the small FP-positive group and substantial body-size difference between groups require cautious interpretation.

Most directly, Tsai et al. (2026) analyzed 108 stranded turtles admitted to NMMBA between 2018 and 2024. Seventy-seven turtles survived to release (71.3%), whereas 31 did not survive to release, including one boat-strike case that was humanely euthanized after veterinary assessment because of poor prognosis and welfare concerns. In the complete-case multivariable model, buoyancy disorder [adjusted odds ratio (aOR) = 9.96, 95% confidence interval (CI) 3.21–30.85] and spirorchiid infection (aOR = 3.33, 95% CI 1.09–10.18) were independently associated with higher odds of death during rehabilitation. These findings should not be interpreted causally: the study was retrospective, single-center, and limited by incomplete fecal testing, selection bias, residual confounding, small samples for some species, and a limited number of mortality events per predictor. Nevertheless, the study illustrates how transparent disposition reporting and rehabilitation data may help identify higher-risk clinical presentations.

The same principle applies to anthropogenic threats and post-release evaluation. A single-case report documented marine-debris ingestion during rehabilitation of a bycaught green turtle, followed by release and 81 days of satellite tracking in southern Taiwan (Li et al., 2020). An analysis of sea turtle stranding records in Taiwan identified statistical associations between stranding quantity and selected environmental and anthropogenic variables, including heavy-metal indicators and fishing disturbance, illustrating how

standardized stranding records, when integrated with environmental and fisheries proxies, can support regional threat surveillance, hypothesis generation, and public communication (Chou et al., 2023). Long-term in-water photo-identification of free-ranging injured green turtles at Liuqiu Island documented natural post-injury recovery in the wild and illustrates the value of repeated resighting data for evaluating resilience after anthropogenic injury (Fong et al., 2026). Taken together, these studies suggest that clinical rescue data can contribute to the identification of potential threats and to post-release or post-injury evaluation.

4 International context

Published rehabilitation cohorts from several regions show that sea turtle rescue, clinical care, rehabilitation, and release are being undertaken by many institutions internationally. For example, published data are available from multi-center programs in Florida, wildlife rehabilitation in the Maldives, and a long-term loggerhead cohort in Gran Canaria, as well as from NMMBA in Taiwan (Baker et al., 2015; Himpson et al., 2023; Orós et al., 2016; Tsai et al., 2026). Taken together, these reports indicate that rescue, clinical care, rehabilitation, and release are undertaken by institutions in several regions. Nevertheless, these studies also suggest why a single release percentage should not be interpreted as a universal measure of program quality or conservation value: their cohorts differ in species composition, location, study period, admission pathway, clinical severity, threat profile, transfer and euthanasia practice, and outcome definition.

The Taiwan survival-to-release estimate should therefore be interpreted as descriptive information from a specific rehabilitation cohort rather than as an indicator of institutional quality. Published cohorts from other regions report heterogeneous release-related outcomes (Table 1), but direct numerical comparisons are not valid because their species composition, admission criteria, clinical severity, outcome definitions, and final-disposition practices differ materially. Rather than identifying a "best" institution, these published cohorts illustrate a common need for transparent denominator definitions, standardized reporting of final dispositions, and more comparable post-release evidence across regions.

International post-release evidence reinforces both the potential and limits of rehabilitation. In the United States, 34 facilities reported 11,417 releases, with re-encounters including turtles observed nesting; yet the fate of most released individuals was unknown (Innis et al., 2019). Satellite tracking of 31 rehabilitated juvenile loggerhead, green, and Kemp's ridley turtles from cold-stunning events in the northeastern United States found that most tracked long enough to assess movement resumed migratory and diving patterns comparable to those of wild-caught conspecifics; however, the study did not establish population-level benefit or later reproductive contribution (Robinson et al., 2020). Nevertheless, these findings suggest that post-release monitoring may provide an important bridge between release and conservation inference.

5 Regional information and education

The IUCN MTSG East Asia report compiles information on distribution, biological data, threats, conservation actions, and research (Ng and Matsuzawa, 2020). Although Ng et al. (2024) did not directly evaluate rehabilitation records, its synthesis of population genetics and connectivity provides regional context that may aid interpretation of rehabilitation-derived information when records include location, life-stage, and post-release data. Accordingly, standardized rehabilitation data may contribute to regional conservation needs by documenting species composition, location and timing of strandings, clinical findings, pathology, parasites, tumors, anthropogenic injuries, final disposition, release, and post-release movement.

Rehabilitation also provides a direct educational setting. USFWS guidance requires education involving captive turtles to address threats such as bycatch, vessel strikes, marine debris, and habitat loss. However, participation is not equivalent to educational impact. In a pre–post survey of two field-based sea turtle education programs, both programs increased participants' sea turtle knowledge and intentions to engage in turtle-advocacy behaviors, but neither had a major effect on pro-turtle attitudes or turtle-friendly beach behaviors (Mascovich et al., 2023). Nevertheless, where feasible, aquarium release events and rehabilitation-center visits could incorporate brief and repeatable outcome measures rather than rely solely on attendance figures.

TABLE 1 Descriptive release-related outcomes reported in published sea turtle rehabilitation cohorts.

Cohort	Outcome definition	Release-related outcome
NMMBA, Taiwan (Tsai et al., 2026)	Survived to release among 108 multi-species stranded turtle admissions	71.3%
Florida, USA (Baker et al., 2015)	Released among 1,700 turtles with known rehabilitation outcomes	36.8%
Maldives (Himpson et al., 2023)	Released among 398 live-found turtles, including 79 immediate releases and 319 rehabilitation admissions	65.1%
Gran Canaria, Spain (Orós et al., 2016)	Released among 1,634 live-admitted loggerhead turtles	86.29%

These estimates have different denominators, species compositions, admission pathways, clinical severity, study periods, outcome definitions, and final-disposition practices. They must not be interpreted as institutional rankings or direct measures of program quality.

6 Conclusion

Marine exhibits, coastal facilities, and conservation messaging can provide an important foundation for aquarium participation in marine conservation. Building on this foundation, transparent rehabilitation outcomes, evidence-based clinical care, post-release monitoring, health and threat surveillance, peer-reviewed research, regional data sharing, and evaluated education may further strengthen the potential for substantive and verifiable conservation contributions.

Sea turtles spend most of their lives at sea, making disease status, injury causes, contaminant exposure, and anthropogenic pressures difficult to observe systematically in free-ranging populations. When injured, ill, or stranded turtles enter rehabilitation, the primary responsibility is appropriate diagnosis, treatment, rehabilitation, and release assessment. However, when animal welfare, clinical care, and timely release are not compromised, these cases also provide an important opportunity to use clinical findings, pathology, parasitology, microbiology, injury patterns, treatment responses, and post-release monitoring to identify potential negative effects of human activities on turtles and their marine habitats.

The Taiwan case shows how an aquarium-based rehabilitation program can translate rescue cases and clinical records into conservation-relevant evidence on survival risk, disease and pathogen surveillance, clinicopathology, anthropogenic threats, and post-release outcomes. When these data are appropriately analyzed, transparently reported, and published through peer review, they can improve individual treatment and rehabilitation decisions while also building understanding of how human activities affect turtle health, injury, stranding, and recovery in the wild. Although these studies do not by themselves demonstrate population recovery, they nevertheless provide a testable basis for assessing how aquarium investment may be translated into conservation contributions relevant to management decisions.

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