Eastern Pacific Leatherback Turtle: *Ex Situ* Research Strategy

A white paper based on the outcomes of the East Pacific Leatherback *Ex Situ* Research Strategy Workshop held in Panama City, Panama.

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On behalf of the participants of the *2025 EPLB Ex Situ Research Strategy Workshop* this document was compiled and edited by: Copsey, J., Prado, I., Bentley, B., Gabela, M.V., Guzman, H., Kuschke, S., Mustin, W., Ortega, A., Reed, K., Reina, R., Ross Salazar, E., Williamson, S., Wyneken, J., and Shillinger, G.
Translations provided by; Prado, I., Gabela, M.V., Ortega, A.
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A digital copy of this report and a Spanish translated version are available at: www.cpsg.org.

Executive Summary

In July 2020, the Conservation Planning Specialist Group (CPSG)[1] of the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) was enlisted by the international non-profit sea turtle conservation organization, Upwell[2], to design and facilitate a decision-making process to determine the extent to which *ex situ* management actions (specifically egg translocation and headstarting[3]) should be considered as complements to *in situ* conservation efforts for the critically endangered Eastern Pacific subpopulation[4] of the leatherback turtle (*Dermochelys coriacea*) (shortened to EPLB within the report). Experts participating in the decision-making process identified a need to develop plans to answer fundamental natural history, logistical and methodological research questions. The final recommendation developed was that, "any proposal to initiate a headstarting program would be preceded by extensive research and experimental trials to better understand the relative survival of hatchling leatherbacks as they live and grow in the *ex situ* environment, and the drivers that influence that survival, as well as the extent to which they survive and thrive after they are returned to their natural ocean habitat" (Copsey et al. 2021).

In preparation for the workshops carried out in 2020, a Population Viability Analysis (PVA) (Miller, 2021) was created with extensive input from regional and species experts. The PVA predicted that the decline of East Pacific leatherbacks would continue at its current rate (~15% year), in the absence of considerable bycatch reduction (up to 40%) across the entirety of the population's range. Modeled results indicated a high probability (>90%) of the Costa Rica subpopulation becoming extirpated in less than 45 years, and the Mexico subpopulation – as well as the combined metapopulation – becoming extirpated in less than 55 years. Given these dire trends, Upwell Turtles initiated the process to evaluate the research gaps and needs necessary to inform complementary *ex situ* recovery methodologies.

The "East Pacific Leatherback *Ex Situ* Research Strategy Workshop" was hosted in May of 2025 by Upwell, MigraMar, the Smithsonian Tropical Research Institute, and Ocean Blue Tree, with planning and facilitation provided by CPSG and the Center for Species Survival Argentina (CSS Argentina). The workshop was also referred to as "Plan B for Baula," referring to its goal to create a backup plan for persistence of leatherbacks in the Eastern Pacific, until effective bycatch reduction measures are in place to ensure recovery can be comprehensively addressed across the range of Eastern Pacific leatherbacks from the nesting beaches to the high seas and everywhere in between, throughout their entire life history from neonate to adult.

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[1] CPSG's mission is to save threatened species by increasing the effectiveness of conservation efforts worldwide www.cpsg.org.
[2] Upwell's mission is to protect and recover endangered populations of turtles through research and conservation actions that reduce threats at sea www.upwell.org.
[3] Headstarting is considered here to be the incubation and hatching of wild-harvested eggs and raising of subsequent hatchling turtles *ex situ* prior to release back to the wild.
[4] There are seven genetically-distinct subpopulations of this species globally (IUCN Red List, Wallace et al 2013). The Eastern Pacific subpopulation spans from the Gulf of California to Argentina, though nesting is concentrated in Mexico and Costa Rica.

The workshop convened experts to collaboratively develop research strategies addressing the aforementioned key uncertainties around *ex situ* interventions. Over the course of the workshop, participants from across the region, representing many different and relevant disciplines, contributed their expertise in four core areas: genetics, husbandry, movement, and socio-ecology. This report summarizes the workshop outcomes, including a research strategy to inform the design and implementation of pilot studies to investigate the potential feasibility and efficacy of complementary *ex situ* conservation methods.

Foreword

It is an honor for me to present this important regional report, which is the result of a collective effort guided by a common and urgent goal: the recovery of the leatherback sea turtle (*Dermochelys coriacea*) in the Eastern Pacific, an emblematic but critically endangered species. The leatherback sea turtle is not only an icon of our marine ecosystems but also a reflection of the health of our oceans. Its alarming decline is a wake-up call that transcends borders and demands that we act collectively, responsibly, and strategically.

While we all hope that current and strengthened in situ conservation efforts will reverse the decline of East Pacific leatherbacks, we must also prepare for a scenario where these actions are not sufficient. In this context, it is critical that the leatherback conservation community be positioned to implement ex situ measures that complement and reinforce existing in situ efforts. To do so, it is essential to conduct research to fill knowledge gaps before moving forward with ex situ efforts.

The workshop held in Panama in May 2025 created a space to exchange ideas and collaborate with regional and international experts, who provided essential input to identify and prioritize the knowledge gaps surrounding potential ex situ interventions. The workshop was attended by scientists with expertise in various topics related to sea turtles, and I would like to thank each of the participants on both an individual and an organizational level. Thanks to their contributions, this report, detailing alternatives and research strategies to address the main uncertainties related to ex situ interventions, was developed. With these lines of research, the technical community will have better options and tools to evaluate the feasibility and relevance of such measures, should they become necessary.

Panama is a megadiverse country, a biological bridge between two oceans, and has historically hosted key nesting sites for sea turtles on its Pacific and Atlantic coasts. On our Pacific coast, occasional nesting of leatherback turtles has been recorded, but in very low numbers, and today, it is practically non-existent. The decline of the leatherback turtle in the Eastern Pacific presents us with an urgent challenge, but also a great opportunity to strengthen our conservation efforts, restore critical habitats, and join forces within the region to reverse this trend. In this regard, I want to make a firm call for measures adopted in the region to be based on the principles of responsibility, sustainability, and profound respect for indigenous peoples, fishers, and local communities.

Recovering the leatherback turtle population in the East Pacific is a complex challenge, but not impossible. It requires political will, regional coordination, and technical support, with the commitment that these solutions integrate scientific knowledge, local wisdom, and experience.

I hope that the publication of this report will be an opportunity to strengthen cooperation, evaluate alternatives, build common strategies, and move toward a future where leatherback turtles can thrive in all our oceans.

Juan Carlos Navarro
Minister of Environment of Panama

Context

Species status

Leatherback sea turtles (*Dermochelys coriacea*), the largest of all sea turtle species, are a flagship conservation species and a key member of healthy marine ecosystems. As a highly migratory species, they undertake extensive transboundary migrations between nesting habitats and feeding areas, occupying diverse habitats in both temperate and tropical latitudes (Dunn et al. 2019; Wallace et al. 2025). As seen in Figure 1, seven leatherback regional management units (RMUs) or subpopulations have been identified. Although leatherback turtles are classified as Vulnerable by the International Union for Conservation of Nature (IUCN) (Wallace et al. 2013), population trends for each of the seven subpopulations vary in size, range and status.

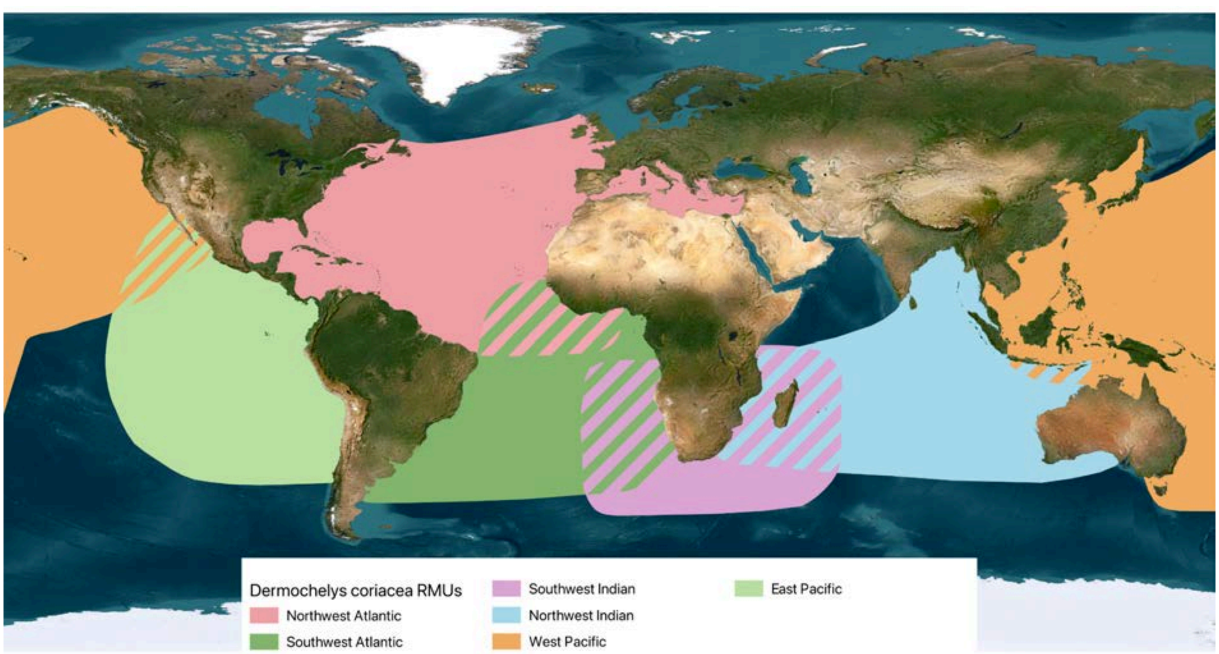


Figure 1: Global leatherback turtle regional management units (Adapted from Wallace et al. 2023).

The Eastern Pacific subpopulation (hereafter EPLB) of the species nests along the eastern coast of Central and South America, from Mexico to Ecuador, and migrates south to the Eastern Pacific Ocean off the coasts of Ecuador, Peru and Chile (Shillinger et al. 2008; Bailey et al. 2012; Laúd OPO Network 2012). Once considered the largest breeding subpopulation in the world, Eastern Pacific leatherbacks have experienced a precipitous decline in abundance in recent decades (Pritchard, 1982; Spotila et al. 2000; Shillinger et al. 2008; Benson et al. 2015; Laúd OPO Network, 2020; Copsey et al. 2021; Miller, 2021).

Having declined by more than 95% since the 1980s, the EPLB are currently regarded as one of the most endangered sea turtle populations in the world (Laúd OPO Network, 2020). Primary nesting beaches now exist in only three states in Mexico and one province in Costa Rica, with an estimated fewer than 650 mature females remaining. As a result, this subpopulation is currently listed as Critically Endangered by the IUCN, the highest level of threat preceding extinction.

Threats to the species include egg harvesting and habitat degradation of nesting beaches, though the current primary threat to the species is high levels of incidental capture (bycatch) by fisheries, particularly in international waters (Wallace et al. 2025). Despite the significant progress made in minimizing egg harvesting and ensuring long-term protection of nesting beaches, the persistence of current bycatch trends could lead to this subpopulation being functionally extinct by 2080 (Laúd OPO Network, 2020).

Previous Workshop Summary

Between November 2020 and February 2021 a two-step multi-stakeholder, decision-making process was facilitated online to determine the extent to which *ex situ* management activities (specifically headstarting and egg translocation) should be considered as complements to ongoing *in situ* efforts for the species. The process involved the participatory development of a Population Viability Analysis (PVA) model for the subpopulation (Miller, 2021), reflecting both its status and trajectory, as well as potential future trajectories based on different conservation management interventions (both *in situ* and *ex situ*). This first phase was then followed by a second participatory planning phase, in which a wider group of stakeholders from both within and beyond the region were led through a series of meetings to develop a shared recommendation for future work (Copsey et al. 2021).

The final recommendation statement developed and agreed upon by meeting participants was that, given current uncertainties concerning the practicability of *ex situ* management activities, such actions should not be embarked upon at the current time, though they merited further examination and study. The recommendation acknowledged the pressing need to continue efforts to protect nesting beaches and reduce bycatch of older life stage individuals, in line with the main threats to the species. The recommendation went on to state:

'...we urge that, before ex situ actions are considered and implemented, studies are conducted to fill key knowledge gaps about the biology and ecology of this population, as well as to confirm/update important demographic assumptions that were made as part of the PVA

process. While these studies…may not be directly focused on ex situ conservation per se, the results would be instructive for prioritizing ex situ actions if or when such efforts are pursued.

Considering the challenges of egg translocation and hatchling rearing, we also recommend that leatherback husbandry practices continue to be refined. This may be achieved via egg translocation trials, the development of novel husbandry infrastructure that promotes the survival of leatherback post-hatchlings in captivity, including captive study of live turtles to fill knowledge gaps related to poorly-understood life stages.'

Multiple research themes that merited further investigation were identified by participants to help reduce uncertainties surrounding the *ex situ* management approaches proposed. Filling these important knowledge gaps would ensure that, should ongoing *in situ* interventions be unsuccessful in slowing population decline, or an urgent need for *ex situ* actions be identified, *ex situ* conservation practitioners will be better equipped with the knowledge and capabilities to maximize the probability of success of additional *ex situ* measures.

Population Variability Analysis

The PVA developed to inform this multi-stakeholder process was designed to evaluate the potential for *ex situ* management strategies to contribute meaningfully to the recovery of the East Pacific leatherback turtle (*Dermochelys coriacea*) population. PVAs are frequently used to compile essential data on population demography and life history, allowing researchers to simulate future trajectories under various management scenarios.

This analysis was conducted using the stochastic simulation software Vortex (Version 10.4), which runs multiple iterations incorporating environmental variability in key parameters such as breeding success and mortality rates. The structural foundation of this PVA was adapted from a model developed by The Laúd OPO Network (2020), with significant modifications and extensions to allow analysis at a finer, nesting beach-scale resolution for the East Pacific population. This higher spatial resolution enabled a more nuanced assessment of the effects of alternative management strategies on local population recovery. Additionally, the analysis expanded the scope and scale of *ex situ* interventions beyond those included in the Laúd OPO model.

In situ management actions were modeled as a 50% increase in annual hatchling production from index nesting beaches in Mexico or Costa Rica. Bycatch reduction, another *in situ* measure, was simulated as a proportional decrease (ranging from 5–40%) in annual subadult and adult mortality. *Ex situ* management was evaluated through four alternative scenarios:

- **HS (Headstarting)**: Leatherback eggs from local beaches are incubated, and hatchlings are raised in captivity for three months before offshore release.
- **ET–A (Egg Translocation A)**: Eggs from an unspecified external source are relocated to artificial nests or hatcheries, with hatchlings allowed to self-release under natural conditions.

- **ET–B (Egg Translocation B)**: Eggs from an external source are incubated and hatched within a facility, with hatchlings released 24–48 hours post-emergence.
- **ET–C (Egg Translocation C)**: Eggs from an external source are incubated in a facility, and hatchlings are reared for three months before offshore release.

Each scenario incorporated key assumptions that were identified and discussed in collaboration with a team of stakeholders during model development. Management actions were simulated over a 25-year period and evaluated at three levels of intervention intensity, defined by the number of eggs collected annually (2,000; 4,000; or 6,000). Another key assumption of the captive rearing scenarios was that leatherbacks could only be reared without adverse side effects until three months of age. Since the creation of this model, new research indicates that a greater rearing duration (six, nine, or 12-months) could be possible with new data on captive survival to these ages (Kanghae et al. 2023). The PVA presented here could be easily adjusted with this new information—potentially demonstrating higher persistence, faster recovery and increased abundance—to further inform conservation planning.

Under current management conditions, model projections indicated that both the Mexico and Costa Rica subpopulations would continue to decline at an estimated rate of 15% per year—consistent with findings from the 2020 Laúd OPO model. Our results also suggest a high probability of local extinction, with the Costa Rica subpopulation potentially extirpated in fewer than 45 years, and the Mexico subpopulation in fewer than 55 years. These findings underscore the value of finer-scale analysis, which can reveal critical local population trends and extinction risks that broader-scale, metapopulation models may overlook.

Among *in situ* strategies, reductions in fisheries bycatch—resulting in lower subadult and adult mortality—showed potential to slow or reverse population declines. However, increases in nesting female abundance over a 60-year period required aggressive and immediate mitigation. Due to the estimated 12-year maturation period before female leatherbacks can become reproductively active (Avens et al. 2020), *in situ* interventions alone required over a decade to produce observable effects on population trajectories. For the Mexico subpopulation, bycatch mortality mitigation exceeding 30% was necessary to increase nesting female abundance after the 60-year simulation period. The Costa Rica subpopulation, however, did not recover to initial nesting levels after 60 years, even with 40% bycatch mortality mitigation.

A sensitivity analysis was conducted on a key assumption: the survival rate of headstarted turtles released at three months of age. If post-release survival is equal to or lower than that of wild hatchlings, headstarting would likely offer limited or even negative effects on population persistence. As a result, any implementation of headstarting should be preceded by extensive research and experimental trials to determine the post-release viability of headstarted individuals.

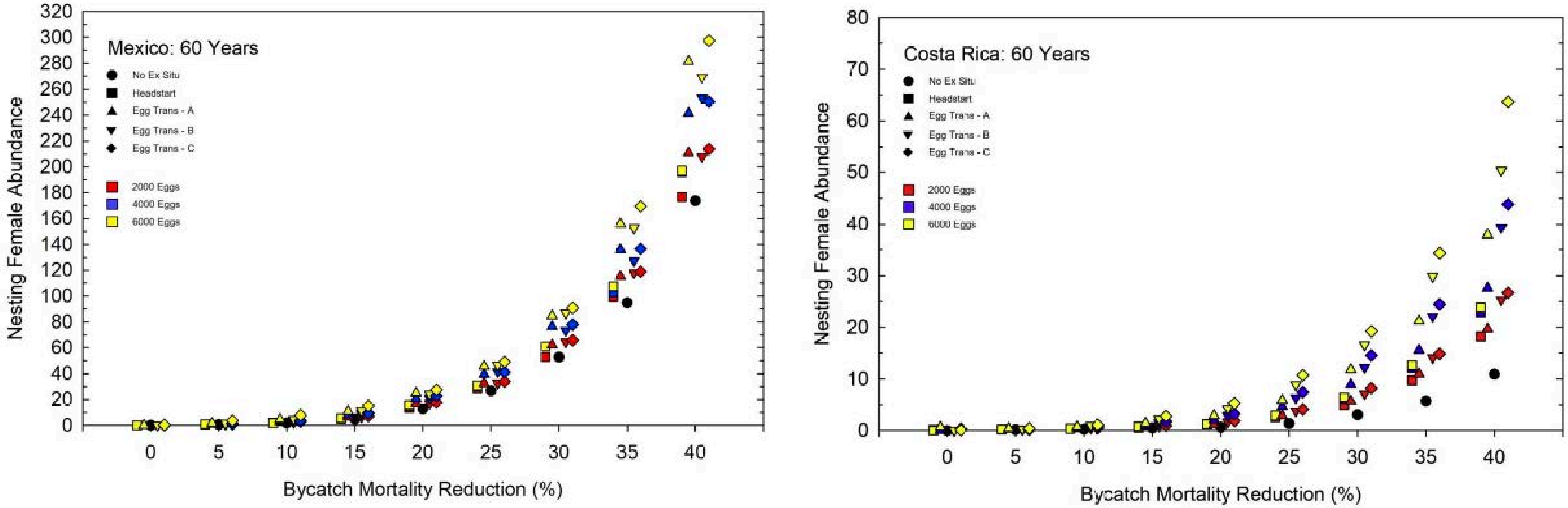


Figure 2. Predicted mean abundance of nesting females in the Mexico and Costa Rica subpopulations at year 60 under various *in situ* and *ex situ* management scenarios. Black circles represent *in situ*-only strategies, while different symbols and colors denote *ex situ* options and their implementation levels (egg collection rates). Symbol positions are jittered for clarity; see legend and text for additional detail.

Despite this uncertainty, *ex situ* management options were incorporated into the model and yielded the following insights:

- Increasing the scale of *ex situ* interventions (from 2,000 to 6,000 eggs per year) improved the probability of population persistence, particularly when combined with increasing levels of *in situ* management (i.e., increased bycatch mortality reductions).
- Among *ex situ* options, **egg translocation scenario C (ET–C)** generated the greatest increases in nesting female abundance over time, while **headstarting (HS)** provided the least.
- Although the Costa Rica subpopulation remained smaller than that of Mexico, it exhibited greater proportional increases in nesting female abundance under *ex situ* interventions.

Overall, results suggest that **egg translocation scenarios**, particularly ET–C, may offer greater long-term benefits for population persistence than headstarting or *in situ* strategies alone. Nevertheless, combining *in situ* and *ex situ* measures provided the most promising outcomes for avoiding local extinction. During stakeholder workshops, participants raised important considerations, including the capacity of translocated individuals to adapt to new nesting environments. These discussions emphasized the need for rigorous experimental testing before implementing *ex situ* strategies in real-world conservation programs. Nonetheless, the modeled *ex situ* options have the potential to reduce extinction risk for both subpopulations in the short term.

While *ex situ* interventions can contribute large numbers of individuals to population abundance, their impact is limited unless paired with effective *in situ* efforts—particularly reductions in bycatch mortality that enable these individuals to survive to reproductive age. Given the complex and time-consuming nature of bycatch mitigation, a combined management approach that integrates both *in situ* and *ex situ* actions may provide the most effective strategy for preventing near-term extinction and facilitating long-term recovery.

Decisions regarding the role of *ex situ* management in East Pacific leatherback conservation should not rely solely on quantitative modeling. Implementation must be guided by a broader evaluation of factors identified by stakeholders, including: the financial costs of both *in situ* and *ex situ* strategies; potential demographic impacts to source populations; the risk of diverting resources from existing conservation efforts; and opportunities for meaningful engagement with local communities. By taking this comprehensive approach, conservation practitioners can build a coordinated, evidence-based strategy to safeguard the future of East Pacific leatherback subpopulation.

Results

Vision

This project aims to support the recovery and long-term sustainability of the EPLB population through science-based, collaborative exploration of *ex situ* conservation strategies to augment fundamental *in situ* conservation actions.

By 2030, we will have…

- Refined husbandry techniques capable of increasing the output of turtles reaching 2 months of age, and implemented tiered and incremental approaches to increase durations of healthy growth (e.g., 3 months of age or more) beyond a threshold of 80% survival at 2 months.
- Determined the genetic compatibility of EPLB turtles with potential source populations for translocation.
- Identified through field trials and modeling, the factors governing the dispersal behaviors of juvenile turtles.
- Built strong partnerships with people, organizations and governments who are directly connected to and invested in this vision.

Research Themes

At the 2020 workshop, participants agreed further research was needed in order to inform *ex situ* actions (Copsey et al. 2021). The workshop report identified focal areas for future study: Life history and vital rates, including survival, growth and reproduction; Health, husbandry and headstarting; Development and sex ratios; Early life stage translocation practices; Dispersal and early survival; Genetics; Socio-politics and public engagement; and Potential climate change impacts.

The goal of the East Pacific Leatherback *Ex Situ* Research Strategy Workshop from May 12-15, 2025 was to develop a collaborative set of research proposals to address outstanding questions on key *ex situ* research themes. To facilitate this process, the workshop organizers condensed the focal areas into four groups: Genetics, Husbandry, Movement and Socio-Ecology (Figure 3), with recommended assignments for participants based on their respective areas of expertise.

The task of each group was to identify and articulate the most urgent research questions and to outline priority research proposals, complete with scientific methodologies to answer these questions. Some research questions span the domains of multiple groups, necessitating interdisciplinary crossover and coordination.

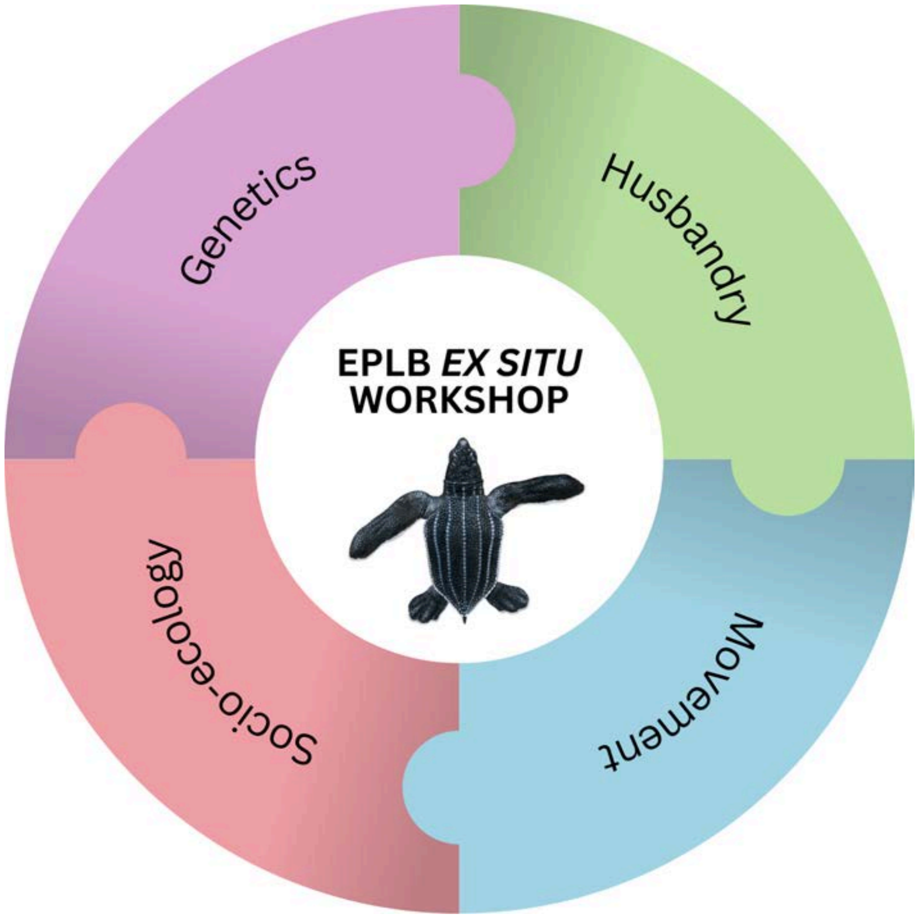


Figure 3: The four focal areas and research groups of the workshop.

Genetics

Understanding the potential genetic implications of *ex situ* conservation interventions is essential to ensure success. Genetic compatibility, diversity and population structure all play critical roles in determining the success and long-term sustainability of these efforts. This research theme explores the genetic makeup of potential source and recipient populations, evaluates potential risks and benefits of mixing genetic stocks, and seeks to ensure that conservation strategies do not inadvertently result in maladaptive consequences that impede population recovery.

Our research goals center around understanding the genomic health of both the EPLB population, and the potential source populations, as well as their genomic compatibility and connectivity. These overarching goals were broken down into four general themes, each aiming to answer fundamental components of the goal.

1. **Assess the feasibility of *ex situ* strategies through genetic analyses addressing the compatibility, adaptability and genetic health**
   Introducing individuals from an outside source location may inadvertently lead to adverse impacts on the source population. The most pressing consideration for potential *ex situ*

conservation interventions is whether the source and recipient populations are genetically compatible. Leatherback turtle populations have been isolated for substantial periods of time, allowing processes such as adaptation and genetic drift to potentially alter genomes to the point of reproductive incompatibility. Our objectives within this goal are to determine (1) overall genomic differences between populations, (2) whether there is evidence of genomic incompatibility between populations, (3) whether they show local adaptation that may be diluted through mixing of populations and (4) their overall genomic health.

Objective summary:

- Determine the level of gene flow and genetic variation between populations
    - Population genomic structure
- Assess evidence for genomic incompatibility between populations
    - Structural genomic rearrangements
- Identify genomic evidence of local adaptation
    - Identify the potential for outbreeding depression
- Assess population genomic health
    - Quantify levels of heterozygosity/diversity, inbreeding, genetic load and demographic history across global populations

Expected timelines:

- Many of the components of this study are currently being investigated in a global analysis of leatherback genomics through the University of Massachusetts Amherst and NOAA Southwest Fisheries Science Center, in collaboration with global partners. It is expected that this research will be published within 12 months.
- While the current analyses contain representation from the EPLB population, collecting and sequencing additional samples, as outlined in the research plan, could commence immediately and should take <2 years to add to existing datasets.

2. **Determine genetic underpinning of reproductive outputs and hatchling viability**

It is important to understand if there is a link between parental genotype and reproductive output. The goal of this objective is to understand what makes a genotypically “good” parent.

Objective summary:

- Understand if there is a correlation between parental genotypes and reproductive outputs
- Understand correlation between genotype and hatchling viability
- Determine if there is a genetic link between consistently choosing good nesting habitat and genotype

Expected timelines:

- This will require a high number of samples and access to eggs. Depending on this ease of access, the research question could be answered in 3 to 5 years or may take more time if samples are more limited.

3. **Determine if there is a genetic contribution to nest site fidelity, foraging site fidelity, and migration**

Leatherback turtles display wide-scale migrations between breeding sites to foraging sites. They also generally return to their natal regions/beaches and repeatedly nest in similar areas. The translocation and rearing of eggs from one population to another may have a net zero effect if breeding adults return to the source locations, rather than the translocated location, if due to genomic factors that dictate migration paths. Our objective here is to determine if there is a genetic component to the migratory behaviors of leatherback turtles that will impede the success of *ex situ* conservation interventions. We acknowledge that this research goal is complex, and it will likely require the use of alternative organisms where data already exist, which will constrain robust inferences directed at leatherbacks.

Objective summary:

- Examine potential underlying genetic components associated with:
    - Natal homing
    - Nest site and foraging site fidelity
    - Migration patterns

Expected timelines:

- The timelines of this objective will vary greatly depending on the availability of samples that have already been collected
- If this project were to commence without in-kind support (i.e., facilities, staff time), it is unlikely to be achievable over proposed project timelines

4. **Determine the genomic impact of using "doomed" nests for translocation**

A potential *ex situ* conservation intervention method that has been proposed is to source eggs from ‘doomed’ nests, either within the East Pacific leatherback turtle population or from a source location. The objective here is to determine if actively *selecting for* these nests may have long-term negative effects on the population(s). Rearing and releasing hatchlings from doomed nests will act as a form of artificial selection, which may result in future populations consistently laying doomed nests if there is a heritable genetic component to nest-site selection. We aim to genotype individuals from doomed nests and successful nests to determine if there are any genotypes associated with sub-optimal nests.

Objective summary:

- Determine if we are selecting for poor-quality hatchlings by taking eggs from doomed nests
- Determine if we relocate doomed nests back into the source population, and take a healthy nest in place of it, if we are reducing or having a negative impact on the source population

Expected timelines:

- Once funding has been acquired, this project can proceed rapidly; it will only require sampling of doomed and successful nests, and measures of hatchling performance.

Husbandry

It is critical in any *ex situ* conservation effort to understand and optimize husbandry conditions that support the survival, health and long-term viability of leatherback turtle hatchlings. This research theme focuses on identifying the environmental, nutritional and microbial factors that influence hatchling development, and on developing best practices that replicate natural conditions while minimizing disease, stress and mortality. A key priority is to ensure that captive-reared hatchlings are physically and physiologically equipped for successful release into the wild and eventual contribution to the reproductive population.

We addressed five major husbandry and health research goals to support the *ex situ* conservation of leatherback turtles, each tied to specific research questions and objectives.

1. **Increase Hatching Success**
   This goal addresses the question of why natural hatching success is low and what causes embryonic death. The first objective involves compiling and standardizing historical and current nesting data globally, focusing on maternal identity, environmental conditions and staging of unsuccessful embryos. This low-cost effort could begin immediately, though due to the time needed to gather data across multiple languages and implementation of that data, this objective will likely take 1-3 years depending on funding and personnel. The second objective proposes controlled experiments to isolate environmental and genetic factors affecting development, including molecular analyses. These studies, requiring significant resources and collaboration, are projected to take 3–5 years.

2. **Identify Best Practices for Egg Translocation**
   To answer questions about egg transport procedures and impacts, this goal includes two objectives. The first objective is to investigate the effects of hypoxia and other transport conditions on hatching success and early performance, with trials across multiple sites over two years. The second objective aims to produce a publicly available manual summarizing best practices, contingent on the completion of the first objective. These efforts are essential for improving the success of long-distance egg relocation. Both objectives require dedicated and reliable modest funding across multiple years, and completion should be possible in 1-3 years for both.

3. **Optimize Captive Rearing and Release Timing**
   This goal seeks to determine the ideal size, age and timing for releasing captive-reared neonates. Objectives include literature reviews, genetic fingerprinting (for future identification), satellite tagging and health assessments. These long-term studies (up to 20 years) require substantial annual funding and collaboration across regions. They aim to maximize post-release survival and inform release protocols.

4. **Improve Hatchling Health and Husbandry Protocols**
   To enhance large-scale captive rearing success, this goal includes five objectives: (1) identifying reliable performance indicators, (2) refining incubation methods, (3) establishing husbandry standards, (4) exploring scalable alternatives to current

husbandry practices, (5) and creating a tiered care protocol manual. These efforts range from short-term (2 years) to long-term (20 years), with a focus on practical approaches to animal care. All objectives require reliable funding, facilities, and staff to meet expectations. However, given the urgency of this fundamental goal, meeting the short-term timeline of 2 years is essential when possible. Additionally, the 20 year timeline should be structured to be met incrementally given the dire status of this subpopulation.

5. **Reduce Mortality from Mycotic Dermatitis**
   Focusing on the lethal fungal disease caused by *Fusarium* spp., this goal includes five objectives: (1) developing sand sampling protocols, (2) conducting fungal testing, (3) identifying treatments, (4) investigating pathogen sources and (5) comparing regional differences that might explain the variable incidence of disease. Timeframes vary from 2 months to 5 years and require international collaboration. Objectives 1 and 2 likely require 1-3 nesting and hatching seasons dependent upon access to relevant sand samples. Objectives 3, 4 and 5 will likely require 2-5 years. Funding requirements are moderate.

Movement

Understanding the movement patterns of leatherback turtles is essential for informing *ex situ* strategies. This research theme focuses on how leatherbacks move, particularly during their vulnerable early life stages, and how this knowledge can inform the optimization of translocation, captive-rearing and release strategies.

Although there have been extensive tracking studies conducted on adult leatherbacks (particularly internesting and post-nesting females), the movements of hatchlings and juveniles remain poorly understood. These early stages are critical to survival and population recovery. This theme examines how leatherbacks disperse offshore, the cues they use for orientation and how different rearing conditions affect their subsequent movements and behaviors. Addressing movement research questions relies on models and satellite tracking data to fill key data gaps, refine release strategies and guide long-term conservation planning.

We identify five major research goals, each with targeted research objectives and methodologies:

1. **Determine the optimal release strategies—where, when and at what age—to maximize the survival of captive-reared turtles.**
   To increase the chances of post-release survival of captive-reared turtles, it is critical to determine (a) where juveniles will be found at specific ages and (b) the best sites to increase post-release survival. The Sea Turtle Active Movement Model (STAMM) (Gaspar and Lalire 2017; Lalire and Gaspar 2019; Gaspar et al. 2022), can be used to address both objectives. As technology and our understanding of sea turtle behavior evolve, we anticipate refining STAMM further and incorporating complementary modeling approaches and methodologies. Initial modeling efforts will include existing movement

data, but ongoing refinement will be necessary as new movement information becomes available (see below).

2. **Understand the migratory patterns and dispersal behaviors of juveniles and the influences of key environmental covariates.**
   Leatherback dispersal behavior, both horizontal and vertical, is shaped by environmental cues such as ocean currents, sea surface temperature and prey availability. To understand these dynamics, we will fit captive-reared juveniles of different age classes with satellite tags to track them over time after their release from different locations. Data from these deployments will be used to refine the aforementioned models and improve our understanding of early life stage movements. This work will be closely coordinated with the Husbandry team to align with turtle readiness and release locations.

3. **Assess how different rearing conditions affect the movements and survival of juvenile leatherbacks.**
   We will compare the movement and survival of turtles reared under different conditions: (a) captive-reared turtles hatched from incubators, (b) turtles hatched *in situ* on nesting beaches and then reared in captivity and (c) translocated turtles reared under both conditions. By deploying satellite tags on turtles from each rearing scenario, we can examine differences in survival, dispersal and movement patterns. These insights will be critical in optimizing rearing practices and will also require close collaboration with the Husbandry group.

4. **Determine the presumed survival of juvenile leatherbacks during the first and second years post-release.**
   Juvenile leatherback survival is one of the most uncertain but impactful variables in leatherback population dynamics. Estimating survival during this period is essential to evaluating the efficacy of complementary *ex situ* measures such as captive rearing, headstarting and translocation. Satellite tracking of juvenile turtles of different age classes reared under different conditions (see above) will provide critical demographic data to inform population viability analyses, status assessments and the potential development of novel recovery measures.

5. **Examine how different imprinting techniques influence leatherback migration, survival and, ultimately, philopatry.**
   Imprinting during early life stages may influence the movement patterns and natal philopatry of turtles returning to their natal areas or release sites. We will explore this topic through DNA fingerprinting methods. All released turtles, regardless of their translocation or rearing condition, will be genetically profiled to develop a gene bank. Over time, as juvenile and adult turtles are encountered in the wild (e.g., via fisheries or monitoring programs), DNA will be collected and matched to the reference database to determine their origin and assess site fidelity (e.g., nesting, mating and foraging habitats as well as migration corridors). This will require close collaboration with the Genetics group to standardize protocols and with the Socio-Ecology group to build stakeholder

capacity for collecting samples. This approach will demonstrate the efficacy of *ex situ* measures as a population recovery measure for leatherbacks.

Socio-Ecology

This research theme focuses on how *ex situ* conservation initiatives can be designed to complement and reinforce *in situ* conservation priorities, to achieve an integrated conservation approach for the Leatherback turtle in the Eastern Tropical Pacific (ETP). This will be achieved through the establishment, expansion and maintenance of the protection of nesting beaches and marine/natural protected areas. *Ex situ* measures, such as captive rearing and release programs, must be aligned with and bolster ongoing efforts like nesting beach protection and bycatch reduction. For instance, a captive rearing and release program could provide a tangible rationale for continued protection of nesting beaches facing pressures from real estate development. The success of *ex situ* conservation hinges on public support, policy alignment, local engagement and sustainable funding. Ultimately, the goal is to design holistic conservation programs that are ecologically sound, socially valuable and economically sustainable.

To address this research theme, six research goals were developed, most of which have a regional scope for the Eastern Pacific, although they are also considered at secondary national and local scales. Some of these require implementation within defined timeframes, such as one year, while others are best approached dynamically with updates made on an ongoing basis.

1. **Identify existing regulations and potential gaps for *ex situ* conservation measures.**
   This goal aims to carry out a legal diagnosis at a regional and national scale to identify differences in regulations and the potential legal gaps that could hinder the implementation of *ex situ* activities within the strategy.

2. **Identify and address the public and political concerns that must be tackled before implementing *ex situ* conservation measures.**
   To address any public or political concerns regarding *ex situ* conservation, this goal aims to (1) compile the scientific data that supports these strategies, including success cases of *ex situ* actions and (2) implement a communication strategy that efficiently communicates this information to the public.

3. **Map the key stakeholders in the region.**
   The objective of this research goal is to identify and prioritize relevant stakeholders (i.e., fishermen, community conservation groups, local authorities, protected areas officials, teachers, the private sector, women and young people) for implementing this strategy. It is based on understanding their concerns and finding the best way to address them through an inclusive approach. This should also involve securing strategic allies from source and recipient countries that can contribute (whether biological resources or monetary resources) to or implement *in situ* or *ex situ* conservation measures in the Eastern Pacific.

4. **Identify policy tools or government relations that can be leveraged to secure bycatch reductions or protections for key leatherback habitats.**

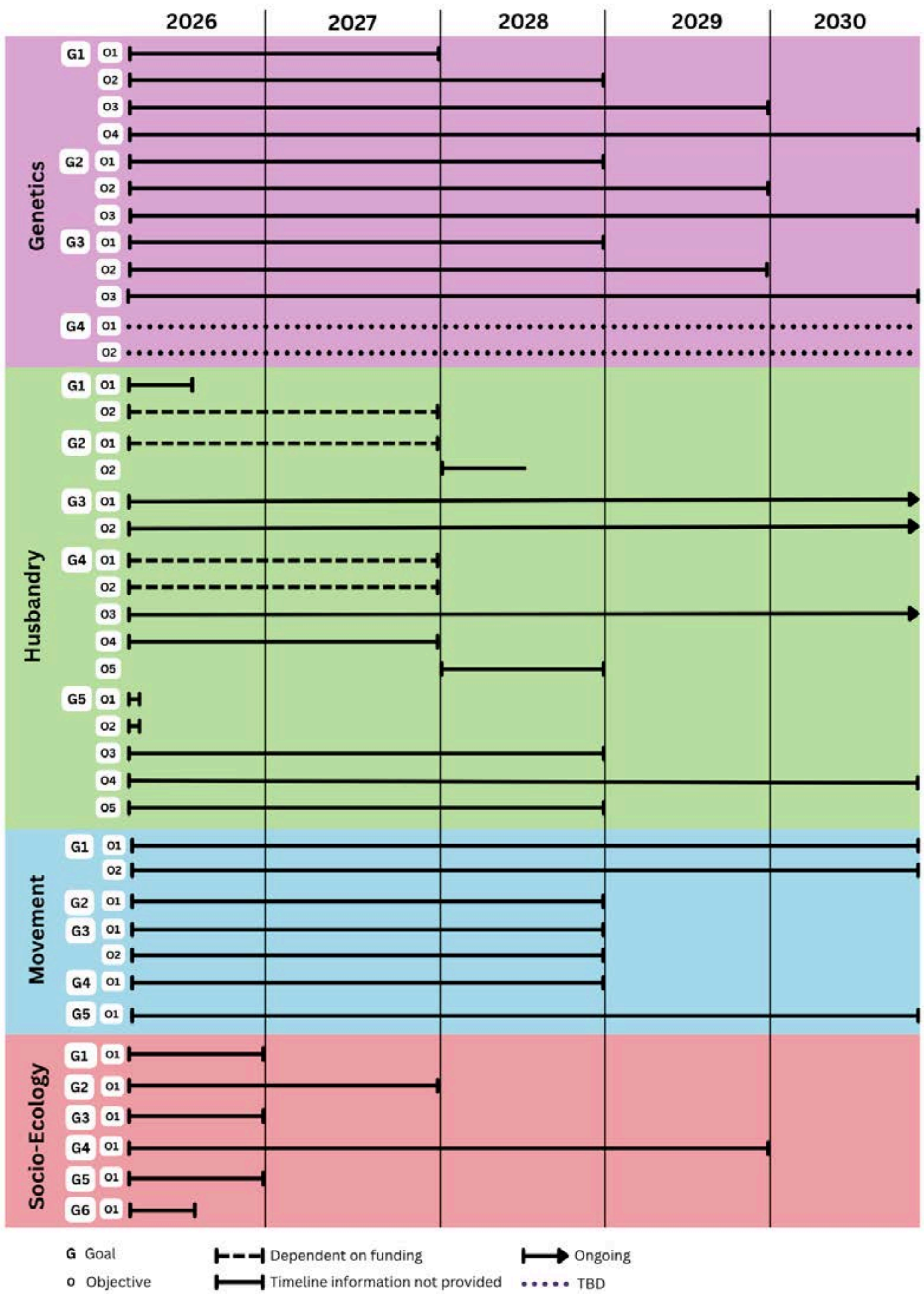
This goal seeks to analyze national, regional and international fisheries regulations that could reduce bycatch in the region and how to ensure their dissemination in key habitats, with the participation of fisheries organizations as strategic allies alongside *ex situ* conservation investments.

5. **Determine the key socio-ecological aspects to consider in potential *ex situ* conservation areas.**
   This overarching goal aims to integrate the various aspects described in the previous goals, culminating in a socioecological diagnosis of the strategic *ex situ* sites, with the involvement of local communities and organizations. This would entail conducting a social, socioeconomic and ecological feasibility study to develop the project in certain areas or facilities.

6. **Facilitate the integration of *ex situ* actions into *in situ* conservation.**
   The sustainability of *ex situ* conservation actions depends on its integration with existing *in situ* strategies. This goal consists of two objectives. The first aims to identify the diverse *ex situ* conservation actions that can complement the *in situ* programs. The second is to develop an integration strategy for the *ex situ* conservation action plan and complement it with the activities in the *in situ* conservation plan, facilitating the implementation of both in key locations.

Action Timeline

The following timeline illustrates each group's estimated timeframe for achieving their research goals and objectives. A key to each group's research plan is provided in Appendix B.



Governance Framework

In addition to individual research action leads and collaborators, implementation of the *Ex Situ* Research Strategy will be coordinated and supported through the establishment of a simple governance framework. Migramar and Upwell will help to coordinate and support goal delivery at the cross-thematic level. Each thematic research area will have its own coordinator who will liaise directly with those implementing actions and feedback information to and from Migramar and Upwell so they can provide the most efficient and effective support for strategy implementation (Figure 4).

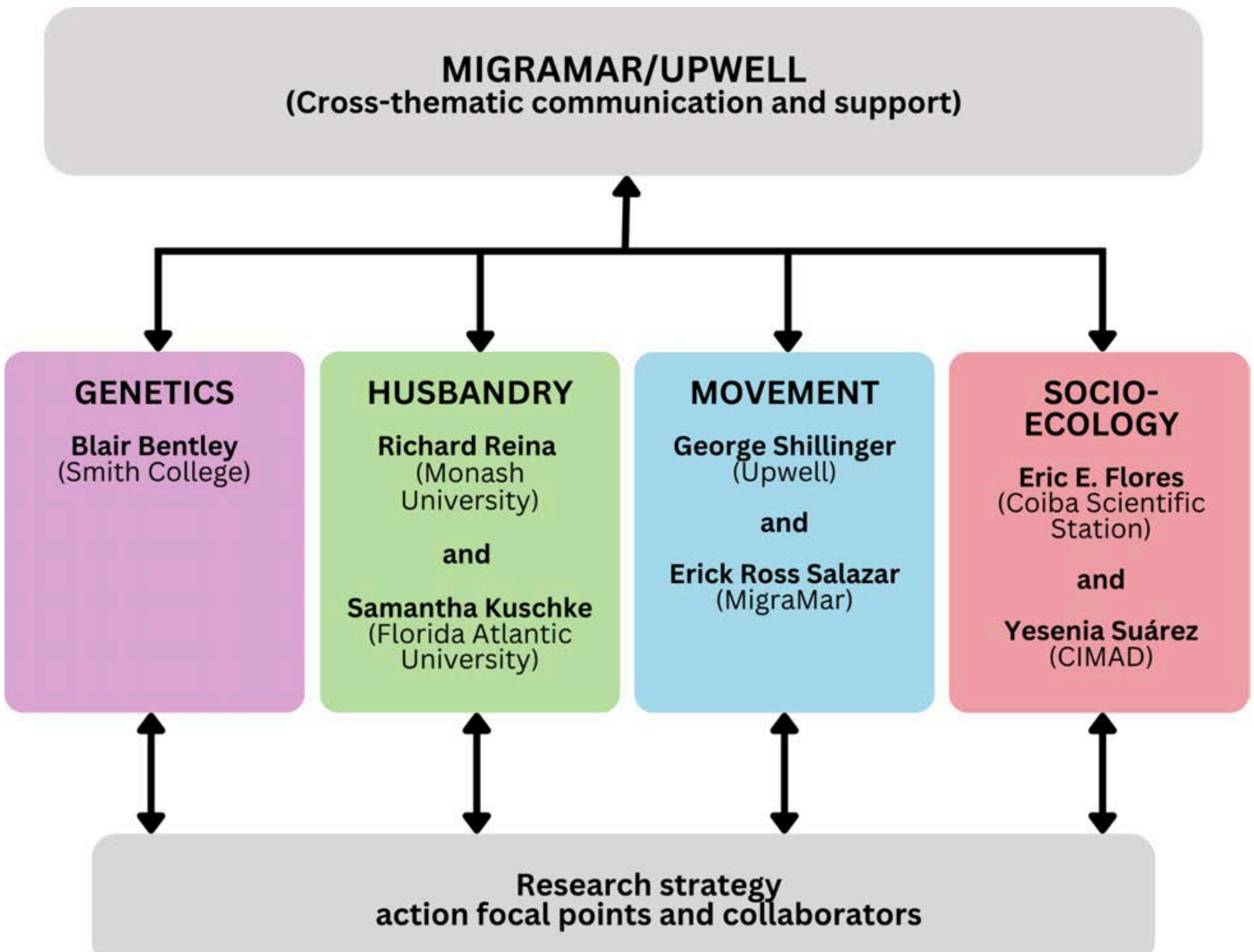


Figure 4: Governance framework to support communication and delivery of the strategy.

Process

Facilitating organization

The process to produce this *Ex Situ Research Strategy* was designed and facilitated by the Conservation Planning Specialist Group (CPSG) of the International Union for Conservation of

Nature (IUCN) Species Survival Commission (SSC). CPSG has been designing and facilitating collaborative species conservation planning processes for governments, non-government and other conservation organizations for more than 40 years. The process met the following planning principles drawn from the CPSG Species Conservation Planning Principles and Steps:

1. **Plan to act:** the intent of planning is to promote and guide effective action to improve conservation management. This principle underpins everything the CPSG does.
2. **Promote inclusive participation:** inclusivity refers not only to who is included in the planning process but also to how their voices are valued and incorporated.
3. **Use sound science:** working from the best available science is crucial to good conservation planning. Using science-based approaches to integrate, analyze and evaluate information supports effective decision making.
4. **Ensure good design and neutral facilitation:** collaborative planning is designed to move diverse groups of people through a structured conversation in a way that supports them to coalesce around a common vision and to transform this into an achievable plan. Critically, neutral facilitation eliminates potential or perceived bias in the planning process, helping participants to contribute their ideas and perspectives freely and equally.
5. **Reach decisions through consensus:** effective species conservation planning results in decisions that all participants can support or accept. Recognizing shared goals, seeing the perspective of others and proceeding by consensus helps to galvanize participants behind a single plan of action that is more likely to be implemented.
6. **Generate shared products quickly:** producing and sharing the products of a conservation planning process quickly, freely and widely are key factors in its success.
7. **Adapt to changing circumstances:** effective plans are those that evolve in response to new evidence and knowledge, and to the changing biological, political, socioeconomic and cultural circumstances that influence conservation efforts. Plans should be considered living documents that are reviewed, updated and improved over time.

This collaborative approach to conservation planning encourages the development of a shared understanding across a broad spectrum of participants' levels of training and expertise. CPSG's role as a neutral, third-party facilitator is designed to reduce actual and perceived bias. Consequently, these principles support the creation of functional working agreements that directly address the conservation problems at hand, along with the management decisions and actions required to mitigate those problems. As participants work as a group to appreciate the complexity of the conservation problems at hand, they take ownership of the process and of the ultimate management recommendations that emerge.

Process participants

The process was initiated by Upwell, the organization that initiated the 2020 workshop, working in partnership with MigraMar. A team consisting of individuals from seven organizations formed the 'Organizing Team' (OT), established to work with CPSG to identify wider workshop participants and inform process development and purpose. This team was selected to reflect the diversity of expertise and regional representation needed to inform the process appropriately.

The OT identified 34 individuals from 29 institutions from across the region to participate in the *Ex Situ* Research Strategy development workshop process. All of these individuals were able to participate in the four-day workshop (Appendix A).

Workshop process

The process to develop the strategy was based around a four-day, in-person workshop, held in Panama City, from the 12th to the 15th of May, 2025. The workshop was designed to maximize consensus-building around the priority research questions. Day 1 of the workshop began with an introduction to the process and a review of species status, with a particular focus on the EPLB subpopulation. This was followed by presentations on both the PVA process undertaken in the 2020 series of meetings and a more recent PVA process to identify potential source sites for leatherback turtle egg and hatchling translocation. Experience to date of managing leatherback turtles *ex situ* was then presented, including the example presented by work undertaken in Thailand. Participants were then led through a 10-year research strategy vision development process before ending with an overview of the four research themes presented as the basis for the strategy (Husbandry, Movement, Genetics and Socio-ecology) with an opportunity provided for participants to suggest changes and additions and to agree on working group composition.

Day 2 of the workshop was largely spent in working groups, identifying potential research questions to form the focus for the strategy. Included in Day 2 was a World Cafe session in which all workshop participants had the opportunity to contribute to generating research questions within all four research themes. From this point forward, participants worked within one of the four thematic research working groups. Day 3 involved the refinement of the prioritized research questions-based on a participant-agreed set of ranking criteria- and the development of research projects to answer the questions. This involved the identification of research goals and objectives within each of the four research themes. Day 4 involved completion of this research project development process, involving working groups identifying research leads, collaborators, timelines and means of verifying metrics for completion of each research component. Working groups also began to identify the potential resource implications for each identified research project and any dependencies that execution of the research might rely upon being in place. Day 4 also saw the drafting of a governance structure, undertaken by all workshop participants, together. This structure would provide oversight, communication and decision-making opportunities to support implementation of the strategy once finalized.

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Appendices

Appendix A-Workshop Participants

Attendee	Affiliation	Day 1	Day 2	Day 3	Day 4
Anna Barbanti	WWF Mediterranean Marine Initiative	X	X	X	X
Anna Ortega*	Upwell Researcher, University of Western Australia	X	X	X	0
Blair Bentley	Smith College	X	X	X	X
Carlos Delgado-Trejo	Universidad Michoacana de San Nicolás de Hidalgo, México	X	X	X	X
Digna Barsallo	Ministerio de Ambiente de la República de Panamá	X	0	0	0
Eric Flores	Coiba Scientific Station (COIBA AIP)	X	X	X	X
Erick Ross Salazar*	MigraMar	X	X	X	X
Felipe Vallejo	Equilibrio Azul	X	X	X	X
George Shillinger*	Upwell Turtles	X	X	X	X
Hector Guzman*	Smithsonian Tropical Research Institute	X	X	X	X
Irene Arroyave	Central American Development Bank	X	X	X	X
Isabella Prado	Upwell Researcher	X	X	X	X
Jamie Copsey	IUCN	X	X	X	X
Jeanette Wyneken*	Florida Atlantic University (FAU)	X	X	X	X
Kelvin Saint García	Costasalvaje	X	X	X	X
Kristin Reed*	Upwell Turtles	X	X	X	X

Attendee	Affiliation	Day 1	Day 2	Day 3	Day 4
Luis Ángel Rojas Cruz	Costasalvaje	X	X	X	X
Maria Virginia Gabela*	MigraMar	X	X	X	X
Marino Abrego	DICOMAR - Ministry of Environment Panama	X	X	X	X
Martha Harfush	Centro Mexicano de la Tortuga	X	X	X	X
Montse Mon Amores	Ocean Blue Tree	X	X	X	X
Natalia Gallego-García	Turtle Survival Alliance	X	X	X	X
Pablo Dovico	Center for Species Survival Argentina (CSS Argentina)	X	X	X	X
Philippe Gaspar	Mercator Ocean International	X	X	X	X
Randall Arauz	Centro Rescate Especies Marinas Amenazadas (CREMA-Costa Rica)	X	X	X	X
Richard Reina*	Monash University	X	X	X	X
Rodney Piedra	IAC Costa Rica and Chair of the Conference of Parties	X	X	X	X
Roldan Valverde	Sea Turtle Conservancy and The University of Texas Rio Grande Valley	X	X	X	X
Rory Moore	Blue Marine Foundation	X	0	0	0
Samantha Kuschke	Florida Atlantic University (FAU)	X	X	X	X
Sean Williamson*	Monash University; Queensland Marine Turtle Network	X	X	X	X
Shirley Binder	Pew Bertarelli Ocean Legacy	X	X	X	X
Tony Candela	Upwell Turtles; Mercator Ocean International; Aquarium La Rochelle, Centre d'Etudes et de Soins des	X	X	X	X

Attendee	Affiliation	Day 1	Day 2	Day 3	Day 4
	Tortues Marines				
Vandanaa Baboolal	Cayman Turtle Centre	X	X	X	X
Walter Mustin*	Cayman Turtle Centre	X	X	X	X
Yesenia Suárez	CIMAD	X	X	X	X

*Members of the Organizing Team (OT)

Appendix B-Action Timeline Key

Genetics			
G1	**Assess the feasibility of targeted ex situ strategies through genetic analyses addressing the compatibility, adaptability and genetic health**	O1	Determine levels of existing genomic variation and gene flow between EPLB population and source population(s).
		O2	Identify evidence of local adaptation within populations to determine adaptive potential of translocated individuals.
		O3	Assess genomic compatibility between EPLB and source population(s).
		O4	Assess population genomic health.
G2	**Determine genetic underpinning of reproductive outputs and hatchling viability**	O1	Understand if there is a correlation between parental genotypes and reproductive outputs.
		O2	Understand correlation between genotype and hatchling viability.
		O3	Explore potential genetic link between consistently choosing good nesting habitat and turtle genotype.
G3	**Provide supporting information for the movement objectives and for strategic planning of release.**	O1	Explore potential underlying genetic components associated with natal homing.
		O2	Explore potential underlying genetic components associated with nest site fidelity and foraging site fidelity.
		O3	Explore potential underlying genetic components associated with migration patterns.
G4	**Determine the genomic impact of using "doomed" nests for translocation.**	O1	Find out if we are selecting for poor-quality hatchlings by relocating eggs from doomed nests.
		O2	Find out if relocating doomed nests back into the source population and taking a healthy nest in its place reduces a possible negative impact on the source population.

Husbandry

G1	**Increase hatching success**	O1	Standardize and compile current and historic nest excavation data on hatching success, emergence success, egg staging data, environmental conditions and maternal identity in multiple populations.
		O2	Identify the exact environmental factors that lead to the highest level of *ex situ* hatching success, emergence success and isolate the environmental effects that lead to death at each stage (i.e., early embryonic development vs. late development). This can include both environmental and genetic factors.
G2	**Identify best practices for egg translocation**	O1	Investigate the impact of different lengths of hypoxic conditions and other environmental conditions during transport on leatherback eggs as measured by hatching success, early performance test and, potentially, success in a captive setting for 2 months.
		O2	Create a publicly available summary or manual of best practices for egg translocation and incubation.
G3	**Identify at which point during the captive rearing process leatherback neonates should be released**	O1	Identify the size of hatchling that results in the most significant increase in survival
		O2	Identify the age and time in which we can balance the best health with survival in the wild. Consider having multiple ranges or points of release as they may have different purposes or success in the wild.
G4	**Improve overall success during large scale captive rearing**	O1	Identify and test indicators of increased performance and or health in the captive setting and determine if they are repeatable and reliable.
		O2	Identify the incubation methods that increase hatchling performance in the captive setting.
		O3	Identify the minimum and maximum standards of husbandry that can be used for the success level(s) we want/need to reach.
		O4	Investigate alternative options to current husbandry practices that are easily replicated and scalable.

		O5	Create a standardized protocol or manual for best husbandry practices. This should include a tiered system for implementation of care with the base level being the minimum effective system of care with the goal of incrementing up to increasingly useful and ideal standards of care.
G5	**Prevent or treat the most common cause of mortality in captive leatherbacks, mycotic dermatitis caused by Fusarium spp.**	O1	Create a standard protocol for sand collection, shipment to FAU and fungal cultures. Begin sample collection.
		O2	Perform fungal testing and analysis on sand from source and destination populations.
		O3	Identify treatment or prevention options for mycotic dermatitis.
		O4	Identify the source of the fusarium that results in mycotic dermatitis and possibly its pathogenesis.
		O5	Compare factors (environmental, physiological, microbial) that may be different between leatherback neonates in Thailand versus Florida.

Movement			
G1	**Determine where should captive reared turtles be released to optimize their survival**	O1	Model where juvenile turtles will be found at specific ages.
		O2	Identify the best sites to increase post-release survival.
G2	**Determine the migratory routes of juveniles (horizontal and vertical) and the environmental variables**	O1	Understand the influence of environmental variables that shape the turtles' migratory routes.

	(including magnetic fields) that are shaping those routes		
G3	**Determine movement patterns of juvenile leatherback turtles reared under different conditions**	O1	Understand the differences between captive reared hatched from incubators and turtles developed *in situ* and reared in captivity.
		O2	Understand the differences between migration patterns and foraging of translocated turtles and *in situ* developed turtles.
G4	**Determine the presumed survival rate of juveniles as they disperse over the first one or two years of life**	O1	Determine the survival rates of juveniles over the first two years of their lives.
G5	**Establish the imprinting techniques that are better suited for migration**	O1	Develop a gene bank of released turtles.

Socio-Ecology			
G1	**Identify the existing regulations and gaps for *ex situ* conservation measures in the region**	O1	Carry out a legal diagnosis of the related regulations in the region.

G2	**Identify public or political concerns that must be tackled before implementing *ex situ* conservation measures in the region. Identify the best way to introduce *ex situ* research, tackle these concerns, and involve local actors, governments and researchers in actions regarding *ex situ* conservation**	O1	Prepare the scientific data that supports *ex situ* conservation strategies.
G3	**Identify local stakeholders in the region**	O1	Identify strategic allies from source and recipient countries (whether biological resources or monetary resources) that can contribute to or implement *in situ* or *ex situ* conservation measures in the Eastern Pacific.
G4	**Identify policy tools or government relationships can be leveraged to secure bycatch reductions or protections for key leatherback habitats alongside *ex***	O1	Elucidate and analyze the fisheries regulations in each conservation site, key habitats and the existence of natural areas under protection by decree.

	***situ* conservation investments.**		
G5	**Identify the key socio-ecological aspects to consider in the selection of a site to develop *ex situ* conservation**	O1	Conduct a socio-ecological diagnosis of the identified strategic sites with the involvement of local communities and organizations.
G6	**Identify what kinds of *ex situ* conservation actions can complement existing *in situ* conservation programs and how to integrate them.**	O1	Identify diverse *ex situ* conservation actions that can complement *in situ* programs.
		O2	Develop an integration strategy for the *ex situ* conservation action plan and complement it with the activities in the *in situ* conservation plan and facilitate the implementation of both *in situ* and *ex situ* activities in a key location.