

# Living museums in the sea: the past, present and future of underwater cultural heritage preservation

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**The living museums in the sea (LMS) is a conservation model that promotes the study and protection of submerged cultural resources while encouraging ecological resiliency, public outreach and sustainable tourism. In collaboration with local, national and international stakeholders, Indiana University established the first network of LMS sites in the south-eastern Dominican Republic in 2011 – including Captain Kidd’s 1699 CE *Quedagh Merchant*, and is currently working to establish a second network of sites in *Punta Cana*. This article discusses the challenges and successes associated with management of these marine protected areas, photogrammetric monitoring techniques and ongoing interdisciplinary research.**

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## Introduction

THE living museums of the sea (LMS) model seeks to preserve submerged cultural resources as publicly-accessible Marine Protected Areas (MPAs); emphasizing the preservation of submerged historic shipwrecks and the associated biodiversity for the benefit of present and future generations. Consistent with recently developed UNESCO guidelines<sup>1</sup>, this model recognizes underwater cultural heritage as important ecological habitat, the mutual preservation of which serves to enhance local, sustainable tourism opportunities. In this way, LMS also strives to educate the public about our shared cultural past and environmental present and encourages community stewardship of these resources by promoting a sense of ownership and incentivizing their preservation. Indiana University’s (IU’s) Centre for Underwater Science has been and continues to be highly invested in the protection, documentation and interdisciplinary research conducted on LMS sites and other submerged cultural and biological resources in the Dominican Republic<sup>2</sup> and is working to establish additional regional networks throughout the country.

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## Establishing a living museum

Since 2002, IU faculty and students under the direction of Charles Beeker have been working to establish a system of MPAs in the Dominican Republic<sup>2</sup>. The LMS concept draws from earlier IU efforts to establish park sites to protect both submerged cultural resources and the associated biodiversity – most notably with regard to collaborative efforts to establish the Historic Shipwreck Trail in the Florida Keys National Marine Sanctuary – and shares many of the same goals: protecting biological and cultural resources, furthering sustainable tourism, promoting research and providing public outreach and education<sup>2,3</sup>.

In establishing MPAs, the LMS model seeks to promote success by incorporating governmental and local stakeholders from the outset. Hanselmann and Beeker have outlined the principles for establishing LMA: (i) proposal to governing bodies, including all site data; (ii) establish park boundaries; (iii) install appropriate buoy system; (iv) place an underwater plaque; (v) create an underwater guide; (vi) create a land-based component; (vii) publish a brochure or other materials; (viii) organize a dedication ceremony; (ix) establish site monitoring procedures and (x) encourage continuous public involvement<sup>4</sup>. Involvement of governmental jurisdictional authorities, local businesses and community members is intertwined throughout this process. This proves to be one of the more challenging elements of establishing MPAs, as often stakeholders have different interests and ideas for the management of the area and regulations that should be enforced. Encouraging a sense of community ownership of the MPA and its resources is critical to encourage public stewardship and buy-in. Additionally, the LMS model incentivizes the preservation of cultural and biological resources by associating regular economic benefits with responsible MPA management. The message is simple: a cannon can be extracted and sold only once, but if left *in situ* it can be sold everyday forever.

## Living museums in the sea regional network: Bayahibe

In partnership with the Dominican government, local stakeholders, the US Peace Corps and the US Agency for

International Development (USAID), IU inaugurated the first network of living museums in the sea in 2011. The three sites are located off the south-eastern coast of the south-eastern Dominican Republic, near the town of Bayahibe. Making up the network are two mock shipwreck exhibits and the *in situ* 1699 CE shipwreck of Captain Kidd's *Quedagh Merchant*.

### *Guadalupe underwater archaeological preserve*

Created in 2002 by Indiana University students and faculty, the 1724 CE Guadalupe underwater archaeological preserve (GUAP) was the Dominican Republic's first living museum in the sea. The preserve is located about 244 m off the coast of the Viva Wyndham Dominicus Beach Resort near the town of Bayahibe, Dominican Republic. The GUAP consists of a mock 18th century shipwreck in about 6 m of water. This mock shipwreck creates an underwater museum exhibit with historic artefacts from the 1724 CE *Guadalupe*.

The *Nuestra Señora de Guadalupe* sank in Samaná Bay in 1724 CE during a hurricane<sup>5</sup>. In the 1970s it was excavated by the Dominican Republic's Commission for Underwater Archaeological Recovery, as a treasure salvage endeavour, splitting artefacts between private salvors and the government. In 2002, IU requested the official loan of *Guadalupe* artefacts in government custody, which were relocated and placed underwater to create the GUAP. The artefacts include seven cannons, one dead eye, various cemented and non-cemented ceramics and cannon balls. In addition to artefacts from the *Guadalupe*, there is also an admiralty anchor moved to the site from Saona island prior to IU involvement.

The GUAP is the most comprehensive example of a successful marine protected area in the living museums of the sea system in the Dominican Republic. The site features a safety spar buoy system marking the seaward boundary of the preserve and a robust mooring system to account for the heavy use of the site by local dive charters. Due to the tremendous popularity of the park, the mooring system is regularly filled with dive boats and large catamarans carrying over 100 people frequently visit the park. The IU faculty and students, along with visiting scholars and Dominican government representatives, visit annually to ensure proper maintenance of the site, monitor its archaeological and biological components, track coral growth and decline and conduct other interdisciplinary research. Unfortunately, there is little enforcement, and illegal spearfishing often takes place within the preserve, endangering recreational divers and adding strain to the fish population. Enforcing regulations within MPAs presents a challenge in areas where local law enforcement does not have the resources or political will to patrol them. As with all LMS sites, IU produces an annual evaluation including this and other information,

which are submitted to government and local stakeholders in the form of a rapid assessment report.

### *1699 CE Quedagh Merchant*

In June 2007, a team of IU researchers began their survey of a site about 6 m from the iron shore of Catalina island in the Dominican Republic. IU was asked to investigate this site after a local snorkeler recognized an assemblage of cannons in the shallow Caribbean waters and contacted the Dominican Republic's Oficina Nacional de Patrimonio Cultural Subacuático (ONPCS)<sup>1</sup>. Investigations of this site took place from 2007 to 2011 and included archival research, partial excavation, recording and mapping of the shipwreck.

The shipwreck had variety of attributes that closely resembled the documented description and records for the infamous Captain William Kidd's *Adventure Prize*, originally the *Quedagh Merchant*. The shipwreck was confirmed to be the *Quedagh Merchant* based on three primary factors from Kidd's testimony: the eclectic assemblage of stacked and scattered cannons and anchors, the rabbeted teak wood (*Tectona grandis*) hull construction and the establishment of ballast stone provenance to the Deccan Traps of Surat, India, following geochemical analysis<sup>6</sup>.

The site is dominated by at least 27 cast iron cannons of eclectic size and morphology. The largest feature is an assemblage of cannons stacked muzzle to breech atop at least three anchor crowns and other unidentified iron conglomerates as would have been typical in a cargo hold. Additional cannons are scattered throughout the site, some of which may be in a deployed pattern roughly outlining the hull profile. Kidd stored and collected cannon 'with 20 cannons ... in the hold and 30 ... deployed'<sup>7</sup>. In addition to the iron artefacts, spatial analysis of the site indicated that there was room for other goods, likely sugar and saltpeter<sup>6</sup>. During excavations of the site in 2008, divers discovered a segment of wood hull underneath layers of encrustation. After laboratory analysis, the remains were determined to be teak, a wood indigenous to India and commonly used there for shipbuilding. Since the *Quedagh Merchant* was, according to Kidd, 'built in Surat' the teakwood hull and ballast stone analysis tying this shipwreck to that region are powerful arguments for identifying the shipwreck as the *Quedagh Merchant*<sup>6</sup>.

The *Quedagh Merchant*'s site is also an excellent recreational dive site. In addition to being an authentic, *in situ* and undisturbed 17th century CE shipwreck, the site and surrounding reef offer abundant biological life and a large amount of endangered Elkhorn coral *Acropora palmata* (Figure 1). The combination of these historical and ecological values make the *Quedagh Merchant* a premier living museum in the sea. Despite occasionally rough waters, the site is frequently visited by snorkelers with no

diving experience, who can easily dive into the past and experience one of the most exciting historical shipwrecks in the Caribbean. Just a short swim from the wreck itself, the surrounding reef has a wide variety of coral growth and even a deep wall for more advanced divers.

### *18th century CE Morales underwater archaeological preserve*

The Morales 18th century CE shipwreck, situated about 1.6 km west of the East National Park on Guaraguao Reef, consists of another 18th century CE mock shipwreck exhibit. This mock shipwreck includes six cannons with numerous cannon balls and various ceramic amphora fragments dating to the 18th century. Since the establishment of the site, annual IU site assessments have noted that several of the cannons have begun to sink into the sand, several pottery fragments and cannon balls have disappeared, and a large barrel sponge was removed by divers from a biological monitoring station. This may be due to the remote (relative to other LMS sites) and fragile nature of this site, exemplifying the need for regular maintenance and MPA enforcement to prevent resource deterioration.

### **Future living museums in the sea regional network: Punta Cana**

IU continues to work towards expanding the living museums in the sea system and establishing more marine protected areas in the Dominican Republic. Currently, IU is collaborating with the Dominican government, the



**Figure 1.** Healthy *Acropora palmata* colonies on the site of Captain Kidd's 1699 CE *Quedagh Merchant* shipwreck site illustrate its success as a living museum in the sea.

Fundación Grupo Punta Cana and other stakeholders to assist in inaugurating a new regional network of three LMS sites in the Punta Cana region. This network would encompass a new mock shipwreck, an intentionally sunk military vessel and an *in situ* 16th century CE merchant shipwreck.

### *Sixteenth century CE Punta Cana shipwreck*

The 16th century *Punta Cana* shipwreck lies in an exposed, offshore area near Punta Cana. The shipwreck was subject to two years of salvage ending December 2013 and although this caused significant damage to the site, the shipwreck retains much of its archaeological integrity and merits protection and research through LMS establishment. Based on diagnostic artefacts removed during salvage and presently owned by the Dominican government, the ship was an inbound merchant vessel, likely Spanish, during the mid-sixteenth century.

### *Enriquillo (USS Stallion)*

The tug *USS Stallion* served in the United States Military from 1945 to 1969, used in ocean towing, offshore salvage and rescue salvage operations. The *USS Stallion* was present at the Battle of Okinawa and served there through the end of the Second World War<sup>8</sup>. Following its decommissioning, it was gifted to the Dominican Navy and renamed the *Enriquillo*. The *Enriquillo* was intentionally sunk as an artificial reef and dive site and remains one of the more popular dive sites in Punta Cana. Its rich history, location and established popularity make it a prime candidate for additional protection and inclusion in the Punta Cana network of LMS sites.

### *Coliseum mock shipwreck park*

The 'Coliseum' is the current name for a shallow dive site where scientists from the Fundación Grupo Punta Cana and their partners are out-planting coral recruits in the hopes of re-establishing a strong population of the critically endangered Staghorn coral, *Acropora cervicornis*. In the summer of 2017, IU researchers assisted in creating a mock ballast pile, which was distributed in the sand near the coral nursery. IU also worked with the Dominican government to select several cannons and other shipwreck artefacts for placement on the site, using the already established model based on the Guadalupe and Morales underwater archaeological preserves. IU and Fundación Grupo Punta Cana placed artefacts on the site in summer 2019, creating a new mock shipwreck park to promote dive tourism and coral recruitment growth. The success of the GUAP and Morales LMS sites suggests that the *Coliseum* will become a popular dive site and an important coral nursery research area.

## Management and documentation

### *Public outreach and education*

As an integral part of the LMS model, these underwater exhibits and *in situ* sites will be left mostly undisturbed for the future, benefiting the tourist economy and local people interested in the heritage of their country. Multilingual underwater guides have been developed for LMS sites in the Bayahibe network, and workshops have trained local stakeholders on site monitoring procedures, development of cultural heritage tourism, and interpretation of the sites<sup>7</sup>. Local involvement is key to the success of sustainable tourism at LMS sites. Local dive shops, hotels, and citizens continue to work with IU to ensure that the LMS sites are being properly used and protected; they are an irreplaceable part of the LMS model.

In the United States, IU continues to use LMS examples from the Dominican Republic to teach up-and-coming underwater scientists about the importance of preservation, management, and the relationship between cultural and biological resources. Additionally, the exhibit ‘Treasures of the Earth’ at the Children’s Museum of Indianapolis exhibited a cannon from the *Quedagh Merchant* for five years, serving dual purposes of conserving the piece for the Dominican government and educating 1.2 million visitors per year about our underwater cultural heritage<sup>7</sup>. The LMS system has taught millions of people worldwide about the importance of a conservation model that emphasizes research and preservation of archaeological and biological resources in contrast to extractive practices.

### *Advances in MPA monitoring: computer vision photogrammetry*

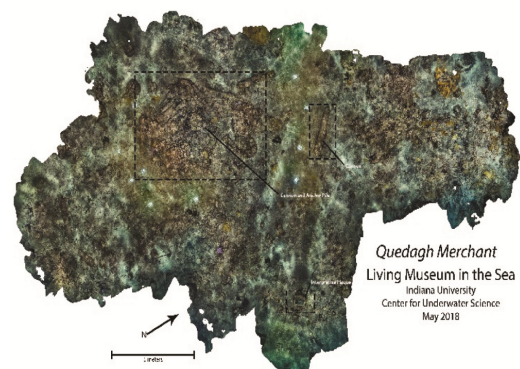
In order to track the changing conditions of cultural and biological resources within MPAs, regular site monitoring through a rapid assessment protocol is necessary for site management and is a hallmark of the LMS model. Traditional baseline recording and monitoring of LMS sites has been conducted with a combination of line drawn site plans generated from direct diver survey and underwater photography. While both these methods are still used for recording and monitoring purposes, they are limited by the amount and selectivity of the information collected and, in the case of line drawn site plans, in the time and expense to record the necessary data. The advent of reliable computer vision photogrammetry has revolutionized IU’s monitoring efforts, allowing routine and comprehensive recording of LMS sites in three dimensions.

Computer vision photogrammetry comes out of efforts to design systems for the interpretation of the visual world and tasks the computer with assembling a scene as a whole, including the shape, appearance, orientation and location of objects in the scene<sup>9</sup>. Photogrammetry has

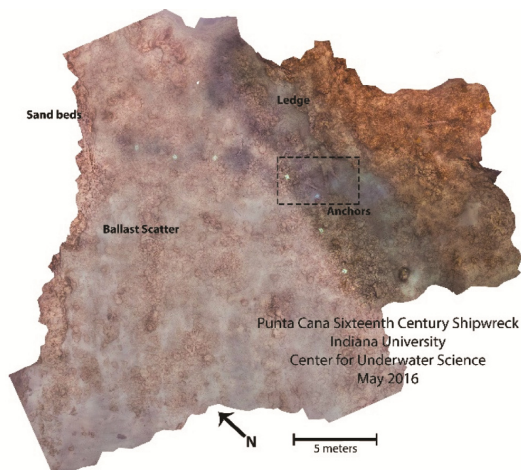
recently evolved from a technique that requires specialist equipment, manual inputs and a high degree of technical knowledge to a quick low-cost recording tool<sup>10</sup>. Computer vision photogrammetry uses structure-from-motion techniques, which utilize feature-based algorithms for the alignment of overlapping digital images. In this way, 360° models of objects can be made, as well as 180° models of a planar scene, also known as orthophotogrammetry. IU researchers utilize this type of photogrammetry to produce high-accuracy site maps and models, which can be compared year-to-year in order to document even the smallest disturbances.

Because photogrammetry requires minimal field time, IU uses it to produce highly accurate site maps for use in research and public outreach. The *Quedagh Merchant* photogrammetric site map, produced in 2017, involved only three divers and less than an hour of dive time, which is much more efficient than traditional mapping methods (Figure 2). In preparation for its inclusion in an LMS network, IU researchers have documented the *Punta Cana* 16th century CE shipwreck several times, to ensure no evidence of looting or other detrimental impacts. Two orthomosaic site plans resulting from these photogrammetry surveys, one produced in 2016 and the other in 2018, reveal that, while there is no evidence of recent human impacts to the site, there was significant redistribution of coral debris, ballast stones and sand across the site, presumably as a result of hurricanes and other powerful weather events (Figures 3 and 4). The reef around the GUAP is being monitored yearly by IU students, who use photogrammetric documentation to record colonies of endangered *Dendrogyra cylindrus* coral. In addition to monitoring through site-wide photogrammetry, this technology also contains capabilities for volumetric and surface area measurements, which allow researchers to easily document and observe coral growth and decline within these living museums.

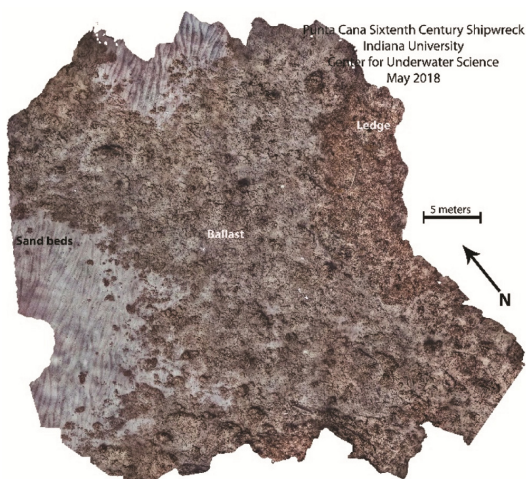
Photogrammetry allows for much more efficient documentation of submerged sites. Reliable and comprehensive photogrammetric monitoring of LMS sites over time is now possible, due to the relative ease and speed with



**Figure 2.** Orthophotogrammetric site plan of the 1699 CE *Quedagh Merchant* living museum in the sea, created May 2017.



**Figure 3.** Orthophotogrammetric site plan created in 2016 of the sixteenth century CE *Punta Cana* shipwreck site, a future living museum in the sea.



**Figure 4.** Updated site plan of the sixteenth century CE *Punta Cana* shipwreck site, created in 2018. (Note the difference in ballast scatter and feature cover from 2016, caused by hurricane impact).

which sites and features can be recorded<sup>11</sup>. Finally, photogrammetric models generated in this way are powerful outreach tools that may be used to improve public access to LMS sites and their interpretation through digital venues by hosting three-dimensional models of shipwreck sites and artefacts on websites such as Sketchfab.com<sup>12</sup>.

## Conclusion

Through the successful preservation, public outreach and research endeavours centred on the Bayahibe regional network, IU has demonstrated the validity and importance of the living museums in the sea model. With established infrastructure, positive collaboration efforts and research already underway, the *Punta Cana* network is

situated to be a positive addition to the growing national network of marine protected areas in the Dominican Republic. Although there are challenges present in establishing protected sites and successfully promoting preservation and interdisciplinary research, with previously established strategies and new technologies such as computer-vision photogrammetry, the future looks positive and productive.

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