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# Marine turtles used to assist Austronesian sailors reaching new islands

## *Les tortues de mer pour aider les navigateurs austronésiens à trouver de nouvelles terres*

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ABSTRACT

Austronesians colonized the islands of Rapa Nui, Hawaii, the Marquesas and Madagascar. All of these islands have been found to harbor Austronesian artifacts and also, all of them are known nesting sites for marine turtles. Turtles are well known for their transoceanic migrations, sometimes totalling thousands of miles, between feeding and nesting grounds. All marine turtles require land for nesting. Ancient Austronesians are known to have had outstanding navigation skills, which they used to adjust course directions. But these skills will have been insufficient to locate tiny, remote islands in the vast Indo-Pacific oceans. We postulate that the Austronesians must have had an understanding of the marine turtles' migration patterns and used this knowledge to locate remote and unknown islands. The depth and speed at which marine turtles migrate makes following them by outrigger canoes feasible. Humans have long capitalized on knowledge of animal behavior.



RÉSUMÉ

Les Austronésiens ont colonisé des îles éloignées, comme Rapa Nui, Hawaii ou les Marquises, ainsi que Madagascar. Des artéfacts austronésiens ont été découverts sur ces îles, qui sont aussi des sites de nidification pour les tortues de mer, qui sont connues pour effectuer de longues migrations transocéaniques, parfois de milliers de kilomètres, entre les sites de reproduction et les pâtures océaniques. Les anciens Austronésiens sont connus pour leur maîtrise de la navigation hauturière ; cependant, ces compétences sont insuffisantes pour localiser de petites îles dans les vastes océans Pacifique et Indien. Nous postulons que les Austronésiens ont dû comprendre la migration des tortues de mer et

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utiliser cette connaissance pour localiser des terres isolées et inconnues. Une pirogue peut suivre une tortue de mer compte tenu de la profondeur et de la vitesse auxquelles celles-ci migrent. Les Hommes ont ainsi utilisé les compétences des animaux à leur avantage depuis bien longtemps.



## 1. Introduction

Austronesians discovered almost every island in the Pacific, including Hawaii, the Pitcairns and the Marquesas or Rapa Nui. They are amongst the most isolated islands (Fig. 1). These islands were then colonized by the Austronesians at ca. AD 1200 [1,2]. Austronesians have been sailing the Pacific for thousands of years, expanding into the far reaches of the Eastern and Northern Pacific as early as 3000 to 4000 years ago [3]. Without any navigational instruments, they developed skills for oceanic voyaging by using monsoon and trade winds, and the ocean currents. The Austronesians were the most advanced explorers of their time [3], using trade winds and accompanying currents to undertake voyages over distances of 6000 to 7000 km to the Americas [4], or between Hawaii, Tahiti and New Zealand [5], among the islands of Samoa, Tonga, and Fiji [6], or the Timor in the Maritime Southeast Asia [7]. The Austronesians were able to:

- determine direction in order to set an accurate course towards their known destinations;
- keep track of position en route and make any necessary directional adjustments;
- actually land on the island or stretch of coast to which they were heading [8].

While these skills may be sufficient to navigate to known destinations, it is unclear how those early sailors were able to locate at the time unknown (is)lands in the Pacific and Indian oceans. We hypothesize that the early Austronesians used the migration routes of sea turtles towards their nesting grounds to locate islands in the Pacific and Indian oceans.

## 2. Methodology

We compiled a set of > 700 references on turtles, ecology, island biogeography, allochthonous and autochthonous species, migrating species, Austronesians,

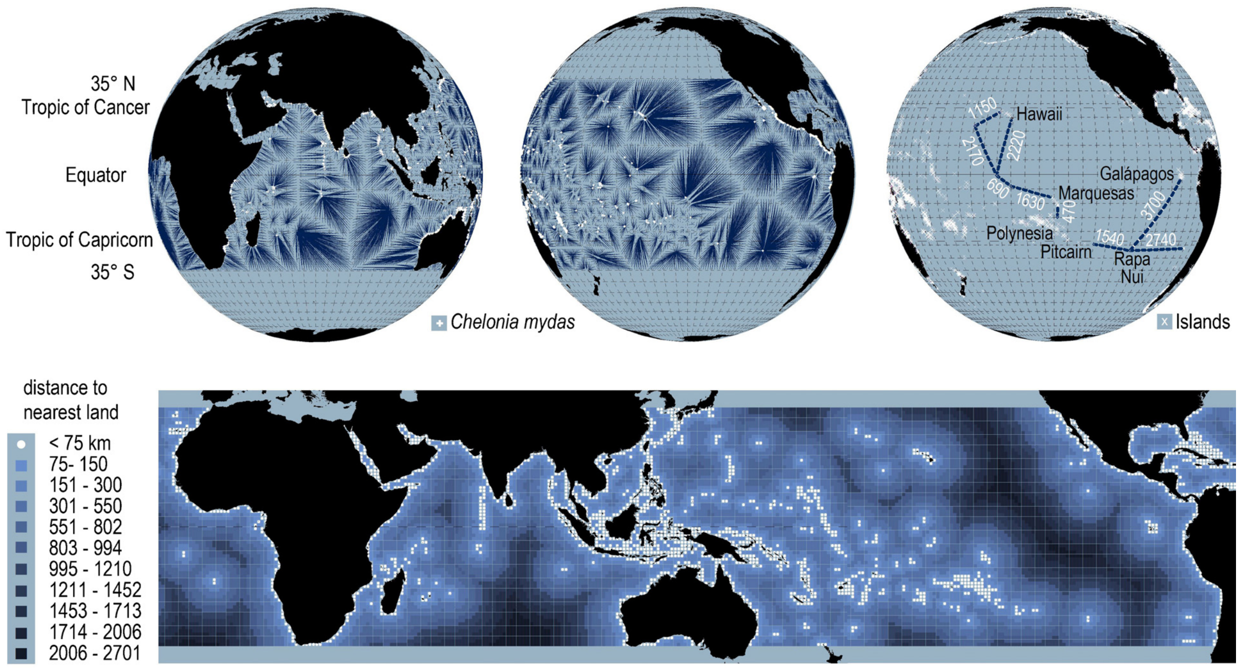


**Fig. 1.** Distribution of Green sea turtles (*Chelonia mydas*) and islands in the Pacific and Indian oceans [9]. Dark lines represent distances from points plotted every 1° longitudinal and latitudinal in the oceans to the nearest land. Distances between labeled islands are in kilometers (black for land masses, blue-grey for ocean; green turtles are breeding on the majority of the islands between 35°N and S). The South Central part of the Indian Ocean between Australia and the Mascarenes, and the Eastern and Northern parts of the Pacific Ocean are depauperate in islands. Islands like the Hawaii, the Marquesas, the Pitcairn and Rapa Nui are remote, the nearest land from Rapa Nui is at a distance of 1540 km.

seafaring, archaeology, oceanography, geography, geomorphology, and geology. Data of *Chelonia mydas* have been plotted in the Indian and Pacific Ocean from a database provided by The State of the World's Sea Turtles (SWOT), completed with data extracted from the bibliographical references compiled. Islands with an area > 1 $km^2$ have been plotted on a map according to a published list of islands [9]. To visually and quantitatively illustrate the breadth of the Indian and Pacific Ocean, as well as the remoteness of some of the islands, arbitrary points at every 1° longitude between 35° latitude N and 35° latitude S have been plotted (to cover the green turtle's range). From the 18,476 remaining points (10,271 in the Pacific, 4363 in the Atlantic, and 3841 in the Indian Ocean), distance and bearing to nearest land (continents and islands > 1 $km^2$) have been calculated with ArcView macro 'Nearest Features v. 3.8b' (www.jennessent.com) and polylines have been saved (Fig. 1). The nearest land from the Ocean points was mostly islands (11,215/18,476), mainly in the Pacific Ocean (84.1%, 8639/10,271). Only a third of the points were located in the Indian Ocean (33.2%, 1277/3841) and still less in the Atlantic Ocean (29.8%, 1299/4363). The islands in the Pacific Ocean between 35°N and 35°S represent only 2% of the total area (Table S1), but are mainly distributed in Western Pacific, while the Eastern and Northern Pacific, as well as Central Indian Ocean are depauperate in islands (Supplementary Material: Fig. S1, Table S1, Table S2). The majority of these islands are still being used as breeding grounds by Chelonians.

## 3. Sea turtle migration

Sea turtles spend most of their lives in the ocean but are dependent on land for breeding. They are well known for their transoceanic migrations between feeding and nesting areas [10,11]. They also show a distinct fidelity for these feeding and nesting grounds [12]. Sea turtles return to their natal beaches for reproduction, sometimes after extended periods of some 20 years, relying on the earth magnetic field [13–15]. The longest ever recorded migration of an adult cheloniid turtle is 3979 km, for a green turtle nesting on Diego Garcia (Chagos archipelago in the Indian Ocean) and foraging along the Somalian coast [16]. In case a sea turtle gets lost during homing, it either turns back to where it started its journey, or it lands on a new island [11,17,18]. In either case, it will eventually end up at or close to land. Near homing islands, *C. mydas* uses wind-born cues to locate homing islands. Individuals moved 50 km upwind from their nesting sites, may fail to find their way to their natal sites successfully and if this happens, instead they tend to head back to their feeding grounds [19].

For adult *C. mydas*, surface drag is minimized at swimming depths of approximately 2.5–3 times the animal's body thickness. Migrating turtles hence spend much of their time at a depth of approximately 0.9–1.5 m [20]. During migration to their breeding grounds, dives of Hawaiian *C. mydas* are shallow (1–4 m) and short (1–18 minutes) during the day, but deep (up to 135 m) at night. Up to 96% of deep dives are performed at night [21]. Turtles keep their general migration direction at night too, but with reduced travel speeds during darker nights [22].

## 4. Austronesian seafaring and discoveries of new land

Several studies have shown that it was possible for the Austronesians to sail from island to island [2,23–28]. For instance, Madagascar was colonized by few women originating from the Pacific [28]. East Polynesia was rapidly colonized [2,25,26], whereas some islands have been colonized, but experienced subsequent extinction – an example is Hendersen Island among the Pitcairns [23]. Early sailors were able to discern indications of land at a distance, for example with the help of clouds or flocks of foraging birds. But these phenomena can be used only over tens to a few hundred kilometers. Winds and stars could have been used as directional cues in order to reach known destinations. But Austronesians must have had some clues to follow when setting out in search for new land. One option might have been to follow marine turtles. Flying birds are too fast, with speeds above 30 km/h [29]. Migrating fish, including sharks [30], do not emerge so they cannot be followed. Migrating marine mammals show propulsive swimming speeds varying between 2.5 and 6.5 km/h [31]. This is compatible with the speed of a canoe. Whales are known to migrate at a low speed [32], but as is the case with all Cetaceans, they do not rely on land, and usually do not head towards any small islands. Pinnipeds do emerge when at sea, but they make extremely deep, long dives. They breed on land, but show a limited range on the extreme east of the tropical Pacific Ocean and are absent from tropical Indian Ocean [33]. Austronesian petroglyphs feature turtles and sharks; no whales (e.g., [34,35]).

Sea turtles have been documented to travel in a large group towards their breeding grounds, and even if distances between the individuals can be several hundreds of meters [36], this makes it easier to follow them. Sea turtles can swim at speeds of 1–2.8 km/h while migrating [37]. These movements makes following by outrigger canoe feasible – the average speed of people travelling in outrigger canoes is about 3 knots (5.6 km/h), almost twice as fast as a turtle [38]. The density of marine turtles at sea and along feeding and nesting grounds was much higher in the past than is the case today (e.g., "A turtle-fishing party on the Fitzroy River, c.1930" [39, p. 256]).

Austronesians may have been able to recognize some individuals, for example, turtles with bite marks from tiger shark attacks [40] and this may have facilitated recognition of turtle migration patterns. In the Torres Strait area (between Australia and Papua New Guinea), Carr and Main [41] compiled a list of rookery with the support of resident Islanders. The authors noticed (p. 22) that "hawksbill sea turtle from different island nesting colonies showed strong divergence in pattern. The differences involved both pigmentation and marking". Later in their report (p. 49), they highlight "the animal husbandry standards of the Torres Strait Islanders; their ingenuity and their obvious ability to handle turtles". This indicates an intimate knowledge of these turtles. Early Austronesians were known to 'farm' sea turtles. The description of their farming techniques can be interpreted as ranching since they had been collecting the eggs from wild populations. They were also known to keep hatchlings in an enclosure until these were large enough to be released [42]. The rearing of green turtles has been observed in the central south Pacific [43]. In 1923, Burrows [44] reports the tale of 'Hina and the turtle' in which Hina sails on the back of a sea turtle between Fiji and Tonga. Shipman [45] listed 10 advantages of animal domestication, inter alia, the discovery of new human habitat thanks to marine turtles.

A common archeological evidence is the presence of marine turtle remains [46–49]. Sea turtles are commonly represented on petroglyphs throughout the Pacific islands, and their cultural importance has been highlighted all over the Pacific [34,42,48,50] where rituals and taboos have been reported. In Madagascar, which has also been discovered by Austronesians [28], rituals linked to the consumption of sea turtles have been reported among the Sakalava people along the western coast of the island [51, p. 57]. It has been shown that Pacific islanders afforded some kind of protection to sea turtles by limiting their consumption [42,48]. The reason for any such protection has not been elucidated, nor the reason why only the marine turtles, out of many other food sources, has been promoted [42]. The special treatment given to sea turtles is a feature of ancestral Polynesian society [52] but the reason for such treatment of these turtles remains unknown. In terms of the quality of its flesh, the green turtle ranks above all other marine turtles (e.g., [38]).

The first people landing on Madagascar did not arrive by chance. Green sea turtles do navigate between the African eastern coastlines towards Madagascar, from north-eastern Madagascar coastlines to the Mascarenes and back, and from Madagascar to Aldabra [53]. While the Mascarenes may not have any known Austronesian archaeological sites, the suspected presence of early sailors may be inferred from artifacts linked to allochthonous animals or plants, as it has been done in the Pacific with *Rattus exulans* for example [2].

Early Polynesian presence has been documented in Chile [54–56] but not in the Galápagos, where human presence began only with European discovery [57]. There is currently no breeding population of green turtles in Chile, but the presence of *C. mydas* is documented since prehistoric time and the southeast Pacific is a migratory route and a potential feeding ground for sea turtles, therefore facilitating a prehistoric discovery of Southern America by the Austronesian seafarers. On another hand, the breeding population of green turtles in the Galápagos has its feeding grounds close to continental America [58], and their migration route is therefore between the Galápagos Islands eastwards to the continent, while the Austronesians were located several thousands of kilometers from the south and west of the Galápagos (Fig. 1).

## 5. Conclusion

The archaeology and prehistory of the Pacific islands, eastern Pacific continental coastline, or southwestern Indian Ocean is still poorly documented. A number of archaeological studies have been able to demonstrate how the Austronesians have been moving between islands in the Pacific Ocean. However, it takes a multidisciplinary approach to explain how the early sailors were able to discover previously unknown (is)lands over long distances. Any island in the Indian and Pacific Ocean with extant sea turtle presence could shed light on the understanding of protohistorical human discovery. We conclude that humans have understood and used animal skills for much longer than just recent centuries.

## Disclosure of interest

The authors declare that they have no competing interest.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.crvi.2015.12.001.

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