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Study On Navigation Method Used by Sea Turtles at Chagar Hutang Turtle Sanctuary Terengganu

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ABSTRACT

One of the most remarkable and mysterious elements of sea turtle is the ability to return to its nest area which is known as natal homing. Sea turtles can go to a specific course upon hatch and emerge from the sand. The migratory pathway of sea turtles does not mainly depend on earth magnetic fields, but previous research has revealed that it combines with another type of navigation. Thus, the purpose of this research is to determine the navigation method used by sea turtles. The types of navigation methods had been observed or tested on turtles at Chagar Hutang. The celestial method was tested by observing the movement of the hatchling on test rigs. The terrestrial method was determined by observing the geomorphology of the island and prominent landmarks of Chagar Hutang Bay. The magnetic method was determined by obtaining the magnetic declination of Chagar Hutang and the number of turtles landed. The result of the test and observation had verified sea turtles have the capability to navigate by using different methods, namely magnetic, celestial, and terrestrial. These navigation methods are used by turtle either separately or by combination any of two at one time.

1. Introduction.

The ability of sea turtle to navigate across the ocean in search of feeding areas and the ability to return to its originated nesting areas to lay egg has fascinated biologists and researchers. The ability of mature female sea turtle to return to nest in the same geographic area from which they originated referred to Natal homing (Lohman et. al, 2013). Sea turtle must rely on an efficient navigation system to guide them on their movement either along shallow water or in the immensity of the ocean. The first information about sea turtle might return to their originated nest came from the result of early tagging program of sea turtle in the 1950s and 1960s, as cited by Lohman et. al (2013). An efficient navigation system also helps sea turtles to find an accurate way to migrate either searching for a feeding spot, avoiding predators, mate, or return to natal beaches to lay eggs. To have an efficient navigation system that guides the sea turtle, a hypothesis has been made to study how mature female sea turtle navigates hundreds of thousand kilometers before return back to the same geographic area which they originated.

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2. Literature review.

2.1. Tagging and Satellites Tracking Studies.

Southeast Asian Fisheries Development Centre (SEAFDEC) has developed a regional sea turtle tagging program in the Southeast Asian region. Under this program, the migration, reproduction, growth, and mortality of the sea turtle will be better understood and it is possible to estimate the population size of certain species by tagging activities (Ahmad et.al 2006). Flipper tagging of sea turtle is defined as the external attachment, usually at the flippers as shown in Figure 1. The tag is made of metal, plastic, and inconel that inscribed with numbers and words. The tag also inserts with microchips so it can be detected by the electronic device to monitor the sea turtle (Ahmad et.al 2006).

Figure 1: Flipper Tagging.

Source: Seaturtle.org, 2020.

Tagging is the most important tool in studying sea turtle because it enables scientists to identify individual sea turtle. Information that can gather from tagging studies either by using flipper tagging or PTT tagging. To enable the sea turtle to be tracked, satellite tracking studies of sea turtle were published, Platform Terminal Transmitter (PTT) was attached to the back of sea turtle (Figure 2). PTT is satellite telemetry that allows the researcher to obtain up to date position data every time the sea turtle rises to the water surface to take a breath. Sea turtle usually can hold their breath for 45 minutes to one hour during routine activity, however, sea turtles normally dive for 4 to 5 minutes and they go to the surface for breath for a few seconds (Olive Ridley Project, 2019).

Figure 2: Sea turtle with PTT.

Source: Olive Ridley Project, 2019.

PTT that was attached to the back of sea turtle will transmit message signals that full of information to an orbiting satellite called Argos, which currently has six satellites that offer global coverage that orbiting approximately 900 km above the earth surface. The satellites then re-transmit the data to a receiving station that can be accessed through the researcher computer (ARGOS, 2020).

2.2. *Mechanism Used by Sea Turtle to Determine its Natal Homing.*

Natal Homing is a pattern of behaviour which animal migrates away from its geographical area of origin and they return to reproduce in the same location where they hatch (Brothers & Lohmann, 2015). An animal is capable of true navigation where the ability of an animal to travel to the precise target without the need for familiar landmarks (Gould, 2014). So, it is very important to know the mechanism used by female sea turtle that influences the migratory pathway and its natal homing.

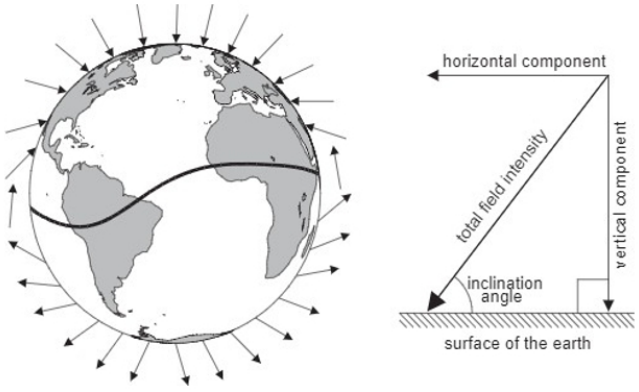
2.3. *Earth Magnetic Mechanism.*

Through a recent study, sea turtle has a significant part that involves magnetoreception. Magnetoreception is the ability of sea turtle to detect or sense the earth's magnetic field as a source of navigational information during their migrations and natal homing in female sea turtle (Kenneth J. Lohmann, 2007).

There are several features of earth magnetic fields that can be predicted across the surface of the earth and might be the principle used in natal homing position finding by a female sea turtle. At each location on the globe, the geomagnetic field lines intersect the earth's surface at a specific angle of inclination (Figure 3). Because of inclination angle vary with latitude, animal able to distinguish between different field inclinations and determine its approximate latitude (Taylor, Lohmann, Hester, & Lohmann, 1999).

Other than the inclination angle of earth magnetic fields, there is at least three other magnetic field element that can be predicted across earth surface and might be used in assessing a position. These include the intensity (strength) of the total field; the intensity of the horizontal field; and the intensity of the vertical field.

Figure 3: Inclination angle.



Source: Taylor et al., 1999.

2.4. *Celestial Method.*

The hatchling sea turtle that emerges from underground nest at night and never before been in ocean has established courses towards open sea. Hatchling sea turtle and female sea turtle that came for lay eggs must immediately reach the sea to avoid terrestrial predators. The course selected to find the sea is not based on an innate preference for a selected direction. While on the beach, hatchling and female sea turtle find the ocean by crawling toward the lower, brighter seaward horizon and away from the dark, elevated surface and dunes (Kenneth J. Lohmann & Lohmann, 1996).

But today hatchling sea turtle and female sea turtle not only has to deal with sea debris such as seaweed and shells that washed ashore but man-made debris such as plastic bottles, cups, and many more. Thus, hatchling sea turtle and female sea turtle must frequently ascertain the seaward direction without viewing the ocean directly.

To ascertain the seaward direction without viewing the ocean directly, hatchling sea turtle and female sea turtle must observe moonlight and starlight at night. Other than that, hatchling sea turtle and female sea turtle also observe the horizon that reflects the moonlight and starlight, this is because the oceanic horizon at night is nearly always slightly brighter than the landward horizon (Kenneth J. Lohmann & Lohmann, 1996).

2.5. Terrestrial Method.

The first theory that sea turtle used terrestrial cues in their navigation came up when the researcher makes a study on hatchling sea turtle that emerge from the underground nest at night. Terrestrial navigation is the method in which the position is determined through static landmarks or terrestrial objects such as an island, sea rock, and lighthouse as a reference point to know current latitude and longitude for the real-time position at sea (navigatorhelps, 2013).

An article about orientation and open-sea navigation in sea turtle by K.J Lohman and C.M.F Lohman, 2010 stated that hatchling sea turtles observe sea horizon that guides them to ocean at night, this is because sea horizon reflects lighter than land horizon. Other than that sea wave also plays an important role in guiding the hatchling sea turtle to the sea.

Adult sea turtles that migrate hundreds of thousand kilometres in the vast ocean will finally migrate back to shallow water in search of a feeding spot. Female sea turtle also will return to its originated natal beaches to lay eggs. So, to have a precise location in searching for feeding areas and return to its natal beaches, the sea turtle will use terrestrial navigation when landmarks are present in its vicinity.

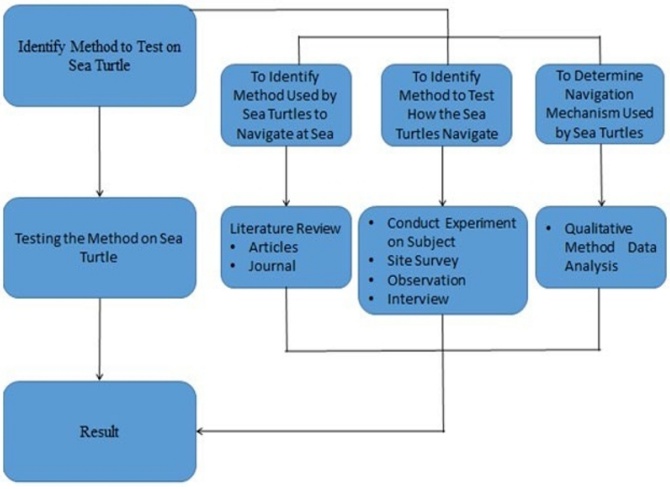
3. Methodology.

The overall research activities are shown in Figure 4 below.

The first step was to identify the method used by sea turtles for navigation. This was done by an extensive literature review on journals and conference proceedings related to methods used by sea turtles and other animals for navigation.

The second step was to conduct three types of tests to determine the type of navigation used by sea turtles, namely celestial, terrestrial, and magnetism tests. The study area is Chagar Hutang turtle sanctuary which is owned and manages by Sea Turtle Research Unit (SEATRU) of Universiti Malaysia Terengganu (UMT). The first was the celestial method test. A set of rigs as shown in Figure 5 was prepared to observe the crawling activity. The rig design was adapted from Rusli, Joseph, Liew, & Bachok (2015). The hatchling green turtles were used in this experiment. The observation on how the turtles set the pathway towards the ocean during the crawling activity would determine the type of navigation used. There are three sets: Set 1 is the lower part of raceway facing seaward; Set 2 is the lower part of raceway that facing seaward with a dim torchlight put in front of it; and Set 3 is the lower part of raceway that facing landward with a dim torchlight was put in front of it. Set 1 represents lower ground facing the sea without the presence of celestial bodies like moon and stars. Set 2 represents the lower ground facing the sea with the presence of the celestial bodies. Set 3 represents the lower ground facing the land with the presence of celestial bodies.

Figure 4: Overall research activities.



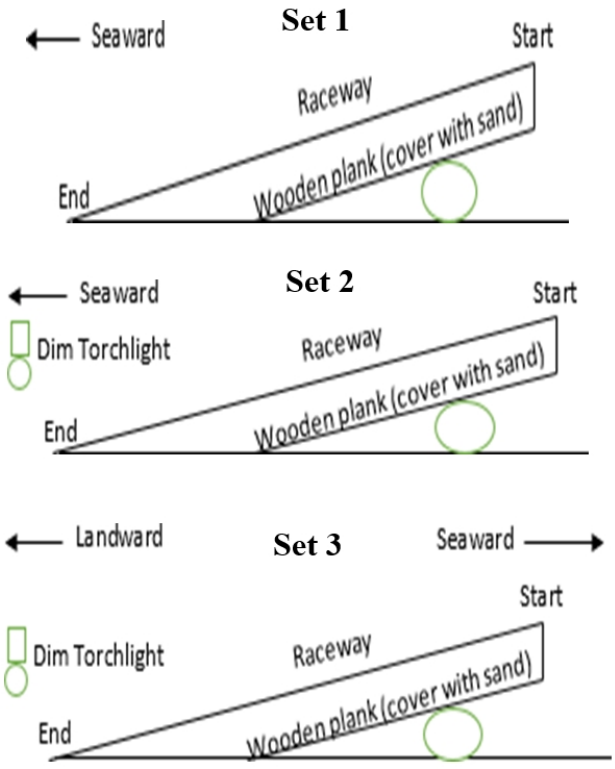
Source: Authors.

The second test was the terrestrial method by identifying a possible landmark at Chagar Hutang area and relate it with the number of sea turtle landing. A landmark is an important environmental feature that is unchanged in a location (Breed & Moore, 2012). The identified landmark may be used by sea turtle to determine the location of natal beaches. Observation with the sanctuary's ranger was conducted to identify the landmarks associated with the landing area.

The third test was to determine whether sea turtle is using the earth's magnetic field to navigate to its natal homing. For this purpose, the information on earth magnetic field variation of Chagar Hutang at coordinate (5° 48' 47.0412" N, 103° 0' 34.7184" E) for the past 10 years was determined by using an online Magnetic Field Calculator as shown in Figure 6 (Natural Resources Canada, 2019). Upon determining the earth's magnetic field of Chagar Hutang, the number and positions of sea turtle landing within the last 10 years were obtained from Sea Turtle Research Unit (SEATRU).

Once all the data had been collected, the relationship between the earth's magnetic field variation and the number and position of sea turtle landing within the last 10 years was established. This was achieved by presenting the data in the table and chart form. The result of these tests would determine the type of navigation used by sea turtles.

Figure 5: Rig for Celestial Navigation Test.



Source: Authors.

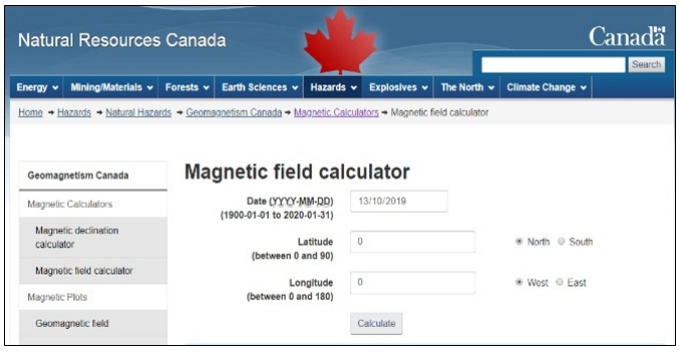
4. Result and Discussion.

The first objective in this research was to identify methods used by sea turtles to navigate at sea. Results from the literature review show that sea turtles are using the earth's magnetic field, celestial bodies, and terrestrial for navigation as shown in Table 1.

The second objective of this research is to determine the type of navigation used by sea turtles. The first test was a celestial navigation test on turtle hatchling. An observation of turtle hatchling by using test rigs in Figure 5. Results showed that the turtle hatchling crawled towards the dimmed light on Rig 2 and Rig 3, although the dimmed light in Rig 3 was located toward landward. The hatchling thought that the dimmed light was the reflection of the star or moon at the horizon of the sea. This finding is consistent with Lohmann & Lohmann (2019). Another explanation is water reflects more moonlight and starlight than land does, thus the oceanic horizon at night is slightly brighter than the landward horizon (Figure 7). The brighter horizon attracts the hatchlings and led to the hypothesis hatchlings locate the ocean by crawling towards the brightest horizon (Mrosovsky, 1972, 1978; Osovsky & Kingsmiix, 1985).

The second test was to test the terrestrial navigation used by sea turtle to its natal beach by identifying possible landmark at Chagar Hutang area. The Chagar Hutang sanctuary beach is the northernmost beach on Redang Island that facing the open sea (Figure 8). Another beach has a similar feature is Berjaya

Figure 6: Natural Resources Canada.



Source: Natural Resources Canada, 2019.

Table 1: Result of literature review on navigation method.

No	Navigation Method	References
1	Earth magneticfield	(Breed & Moore, 2012; Brothers & Lohmann, 2015, 2018; Fuxjager, Eastwood, & Lohmann, 2011; Girard, Sudre, Benhamou, Roos, & Luschi, 2006; C. M. F. Lohmann & Lohmann, 2019; K. J. Lohmann et al., 2008; Kenneth J. Lohmann, 2007; Kenneth J. Lohmann & Lohmann, 1996; P. Luschi, Papi, Liew, Chart, & Bonadonna, 1996; Paolo Luschi,2018; Paolo Luschi et al., 2007; Painter & Plochocka, 2019; Rusli et al., 2015; Shimada, Jones, Limpus, & Hamann, 2016)
2	Celestial bodies	(Breed & Moore, 2012; Girard et al., 2006; K. J. Lohmann et al., 2008; Kenneth J. Lohmann, 2007; Kenneth J. Lohmann &Lohmann, 1996; Painter & Plochocka, 2019; Shimada et al., 2016)
3	Terrestrial	(C. M. F. Lohmann & Lohmann, 2019; K. J. Lohmann et al.,2008; Kenneth J. Lohmann & Lohmann, 1996; Paolo Luschi, 2018; Rusli et al., 2015; Shimada et al., 2016)

Source: Authors.

Redang Resort beach located further south. According to Dr. Uzair Director of SEATRU UMT, the number of turtle nests per year at Chagar Hutang is around 1500, while at Pasir Mat Sempit (Red Triangle in Figure 8) dan Pasir Mat Simpan (Yellow Triangle in Figure 8) is less than 10. Although Berjaya Redang Resort or The Taaras beach (Figure 9) is longer and bigger than Chagar Hutang beach, no turtles have landed there. From the observation, female adult sea turtle started to appear from 4 pm at the shallow water area and lurking the surrounding area. It was believed that the turtles did the visual check on the water to ensure the site is the right place to lay eggs and safe from harm. This finding was verified by the rangers, which prohibit any water activities starting from 3 pm every day. The distinct physical feature of Chagar Hutang beach is the only sandy beach at the northern part of the island; having two horns (cape) with a relatively narrow bay; and the horns can be sighted easily when entering the bay from the sea (Figure 10, Figure 11, and Figure 12). Also, the turtle rock (Figure 13) and Chagar Hutang rock (Figure 14) are prominent landmarks in the area that can be used for terrestrial navigation. These aforementioned distinct physical features of Chagar Hutang bay and the prominent landmarks are possible features used by sea turtles to navigate them to their natal beach. This is supported by a high number

Figure 7: Brighter horizon in front of Chagar Hutang beach. No celestial bodies at the time and the lights were from fishing vessels.

Source: Authors.

of turtle nests in the area. This supports the research hypothesis sea turtle used landmarks for terrestrial navigation to its natal beach.

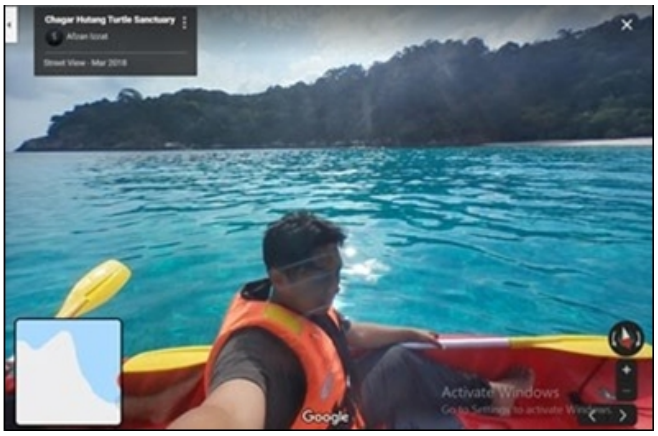
Figure 8: Chagar Hutang sanctuary (red marker) the northernmost beach of Redang Island; Pasir Mat Kepit (red triangle) and Pasir Mat Simpan (yellow triangle).

Source: Google Maps, 2020.

Figure 9: Chagar Hutang sanctuary distinct morphological feature with two capes and a sandy bay.

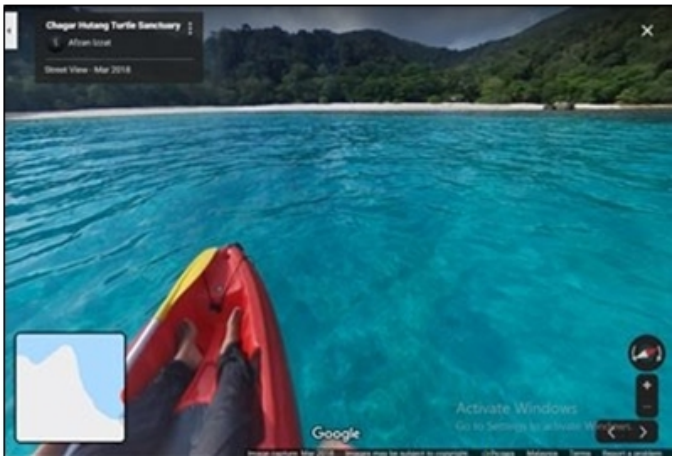
Source: Google Maps, 2020.

Figure 10: Right cape of Chagar Hutang bay.



Source: Google Maps, 2020.

Figure 11: Chagar Hutang beach view.



Source: Google Maps, 2020.

Figure 12: Left cape of Chagar Hutang bay.

Source: Google Maps, 2020.

Figure 13: Turtle rock of Chagar Hutang on the right cape. A red triangle in Figure 9.

Source: SEATRU, 2018.

Figure 14: Chagar Hutang rock. Yellow triangle in Figure 9.

Source: SEATRU, 2018.

The fourth test was to determine whether sea turtle is using earth magnetic field to navigate to its natal homing. The information on earth magnetic field declination at Chagar Hutang at coordinate (5° 48' 47.0412" N, 103° 0' 34.7184" E) for the past 10 years and a total number of sea turtles landed to lay eggs is shown in Table 2. The second column from left shows magnetic declination during a peak month (June or July) in a year, while the third column shows the annual magnetic declination.

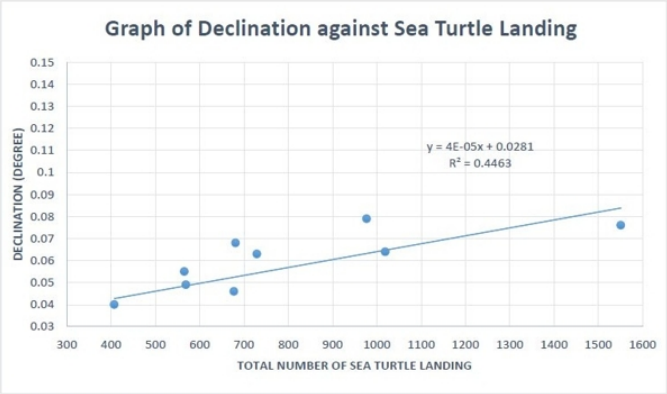
Table 2: Magnetic declination of Chagar Hutang and the total number of sea turtle landed.

year	Declination (degree)	Change per year (degree)	Total no of sea turtle landing to lay eggs
2008	0.021	0.02 W	610
2009	0.04	0.02 W	407
2010	0.046	0	677
2011	0.05	0	569
2012	0.055	0	565
2013	0.06	0	1019
2014	0.063	0	729
2015	0.068	0.02 W	681
2016	0.076	0.02 W	1551
2017	0.083	0.02 W	977

Source: Authors.

Data from Table 2 (column 2 vs column 4) are then being interpreted in the form of a graph as in Figure 15. The data is interpreted and plotted in the form of a graph to determine the R^2. The value of the R^2 is 0.45 and classified as a moderate correlation or a substantial relationship (Guilford, 1956). So, there is a moderate linear correlation between the magnetic declination (column 2) with the number of sea turtle landed to lay eggs (column 4). The number of turtles landed corresponds with the magnitude of magnetic declination.

Figure 15: Total number of sea turtle landed vs Declination of earth magnetic fields.



Source: Authors.

Results of the celestial, terrestrial and magnetic tests conducted at Chagar Hutang showed that sea turtles navigate using the combination of the aforementioned methods to the sea and its natal beach. Sea turtles select type navigation method based on situation and requirement. Turtle used magnetic navigation for long-range navigation that navigates the sea turtles back to Redang Island. The celestial navigation is used by the turtle hatchling to guide them to the sea and used by the turtles towards the landing area. The terrestrial navigation is used by turtle to identify the precise natal beach. These navigation methods may be used independently or by a combination of two methods at one time depends on need.

Conclusions.

Three types of navigation methods had been observed or tested on turtles at Chagar Hutang. The celestial method was tested by observing the movement of a hatchling on test rigs. The terrestrial method was determined by observing the geomorphology of the island and prominent landmarks of Chagar Hutang Bay. The magnetic method was determined by obtaining the magnetic declination of Chagar Hutang and the number of turtles landed. The result of the test and observation had verified sea turtles have the capability to navigate by using different methods, namely magnetic, celestial, and terrestrial. These navigation methods are used by turtle either separately or by combination any of two at one time.

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ing observation on turtles at Sea Turtle Chagar Hutang Sanctuary, Redang Island, Terengganu.

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