MONITORING SEA TURTLE FORAGING POPULATION IN GILI MATRA MARINE TOURISM PARK USING PHOTO ID

Cakra Adiwijaya [1], Maisy Fuller [2], Aulia Rahmania Putri [1], Mahardika Rizqi Himawan [3]

[1]Yayasan Gili Matra Bersama, Gili Air – Lombok Utara, NTB, Indonesia
[2]Gili Shark Conservation, Gili Air – Lombok Utara, NTB, Indonesia
[3]Jurusan Perikanan dan Ilmu Kelautan, Fakultas Pertanian, Universitas Mataram, Kota Mataram, Indonesia
*Email : cakra@gilimatrabersama.org

ABSTRACT

Sea turtles are experiencing a global decline and are at the centre of national and international conservation efforts worldwide. Accurate assessments on what? are vital to gauge the effectiveness of these conservation efforts. While nesting surveys dominate scientific literature, research on foraging populations is limited. To bridge this gap, this study explored citizen science-assisted photo identification to assess foraging sea turtle populations in the Gili Matra Marine Tourism Park (GMMTP). Photographs were collected from citizen scientists who either snorkelling or SCUBA diving within the park and analysed using the I3S application. Ten dive sites in GMMTP, including Turtle Heaven, Shark Point, Meno Slope, and Hans Reef, showed significant turtle abundance. Since 2019, 369 individuals of green turtles and 116 individuals of hawksbill turtles have been identified. These findings demonstrate the potential of using citizen scientist photographs to assess foraging sea turtle populations in coastal waters. Addressing sampling bias and improving metadata collection are necessary steps for further refinement.

Keywords : *Sea turtle, photo identification, population assessment, citizen science, tourism*

INTRODUCTION

Situated within the Coral Triangle and housing 12.5% of the world's total coral reef area (Susiloningtyas *et al.*, 2018), Indonesia is a globally recognised centre of marine biodiversity (Allen, 2008) and a critically important habitat for six species of sea turtle (Chaloupka *et al*., 2004; Halim *et al*., 2001; Nuitja, 1992; Shanker & Pilcher, 2003). As charismatic megafauna experiencing global population decline, turtles are at the centre of national and international conservation programmes (Pauwelussen and Swanson, 2022), with projects worldwide working to remove recognised threats and establish accurate population estimates.

Within Indonesia, steps have been taken to remove known threats to turtle populations, including poaching, coastal development, fisheries bycatch, and human disturbance. All species are protected by Government Regulation No. 7 of 1999 and Government Regulation No. 8 of 1999, which prohibits the trade of turtles, whether alive or dead (Nurhayati *et al*., 2022). Indonesia's Ministry of Marine Affairs and Fisheries has also taken steps to protect marine biodiversity and promote sustainable fisheries and tourism through the creation of marine reserves (Ruchimat *et al*., 2013). However, studies indicate that less than 15% effectively meet their management objectives (Burke *et al*., 2012).

Whilst the efforts to remove the threats facing turtles are essential, the effectiveness of this work cannot be quantified without accurate population assessments (Fitzsimmons and Limpus, 2014). Within Indonesia, extensive sea turtle research has been undertaken, with results indicating a significant decline in turtle populations. However, due to accessibility, population estimates rely primarily on nesting surveys (Halim *et al*., 2001; Rahmadyani *et al*., 2022; Syaputra *et al*., 2023; Tapilatu, 2017), with only limited research conducted on foraging turtles either using satellite tags

(Tapilatu *et al*., 2022) or qualitative interviews with fishermen (Jupri *et al*., 2020; Tapilatu, 2017). The reliance on nesting turtle data does not provide a comprehensive understanding of the total population size (Bjorndal, 1999; Sims *et al*., 2008), resulting in a significant gap in scientific knowledge of turtle population dynamics within Indonesia.

In recent years, photo identification (PID) has emerged as a valuable method for identifying foraging turtles across different habitats and life stages. This method addresses the limitations of traditional tagging techniques that allow in-water identification (Calmanovici *et al*., 2018; Read and Jean, 2021), such as artificial flipper tags and passive integrated transponder (PIT) devices (Reisser *et al*., 2008; Schofield *et al*., 2008) that suffer from high loss rates and can be expensive to purchase (Calmanovici *et al*., 2018; Schofield *et al*., 2008).

PID utilises the unique facial scales of individual turtles, which remain stable throughout their lives (Carpentier *et al*., 2016). By capturing photographs of both sides of the turtles' faces, PID enables their identification whilst foraging without requiring their removal from the water. When combined with GPS coordinates, this in-water data offers valuable insights into the movement patterns of turtles, both within specific locations and across regions (Calmanovici *et al*., 2018). This approach proves particularly effective for species with small foraging home ranges, such as green and hawksbill turtles (Makowski *et al*., 2006).

One of the key advantages of PID is its accessibility to a wider range of contributors. Citizen scientists, with no specialised training required, have been able to provide crucial photos that contribute to more extensive and comprehensive datasets (Baumbach *et al*., 2019; Conrad and Hilchey, 2011; Chassangneux *et al*., 2013; Hudgins *et al*., 2017; Papafitsoros *et al*., 2021; Williams *et al*., 2015). This participation from the public significantly enhances the understanding of foraging turtle populations and their behaviours. In addition to increasing environmental awareness and inspiring positive behavioural changes among participants (Cigliana *et al*., 2015; van Noordwijk *et al*., 2021).

To streamline the identification process, researchers have developed automated recognition software packages (Carpentier *et al*., 2016; Carter et al., 2014; Lloyd et al., 2012). Among these, the Interactive Individual Identification System (I3S) has emerged as a promising tool for turtle identification (Araujo *et al*., 2016; Dunbar *et al*., 2014). The I3S Pattern software employs a reference system that relies on three easily identifiable points on the turtle's body, creating unique "fingerprints" for accurate identification (Calmanovici *et al*., 2018). This software has proven its effectiveness in identifying both green and hawksbill turtles, utilising images obtained from scientific surveys and contributions from the public (Calmanovici *et al*., 2018).

In this study, utilising photographs taken by citizen scientists, we undertake PID and analysis using I3S of foraging turtles over five years within Gili Matra Marine Reserve in Lombok, Indonesia. Identifying whether citizen science led PID provides an accurate assessment of foraging turtle populations. The ability to rapidly identify foraging turtles holds significant potential for expanding our understanding of turtle populations, migrations, and behaviour within the marine park and can potentially be applied to similar locations worldwide.

MATERIALS AND METHODS

Site Description

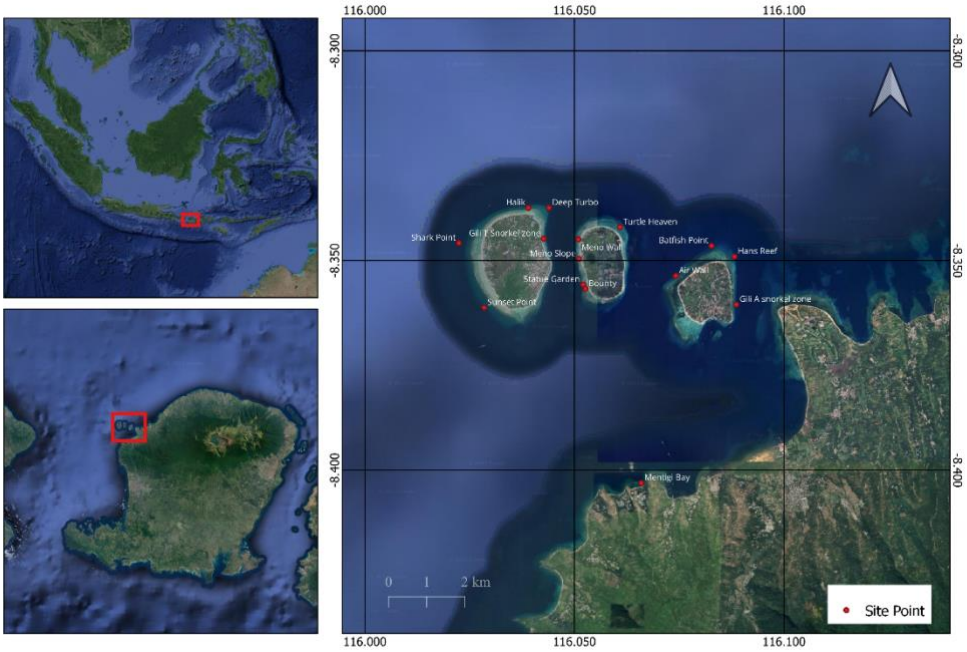


Figure 1. Research location, the location mostly inside of Gili Matra Marine Park in North Lombok, West Nusa Tenggara - Indonesia.

The Gili Matra is a small island chain in western Lombok consisting of Gili Trawangan, Gili Meno and Gili Air (Rahmadyani *et al*., 2022). Gili Matra is a biodiverse marine area surrounded by seagrass beds and fringing coral reefs that support a large foraging and nesting turtle population (Ahyadi and Jupri, 2008; Bowen *et al*., 2013; Ministry of Marine Affairs and Fisheries, 2014; Monk and De Fretes, 2012) with three species identified, green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricate*) and the more rarely sighted olive ridley (*Lepidochelys olivacea*) (Rahmadyani *et al*., 2022).

Gili Matra was designated as a Marine Tourism Park in March 2009 (Ministry of Marine Affairs and Fisheries, 2014), establishing it as a nationally protected area (Rahmadyani *et al*., 2022). The objective of this designation was to ensure that the tourism increase within Gili Matra contributed to the conservation of the marine ecosystem (Kurniawan *et al*., 2016). The additional protection enforced by the formation of the Gili Matra Marine Tourism Park (GMMTP) is essential as during peak seasons, tourists can number up to 61,000 per month (Kurniawan *et al*., 2022; Ministry of Marine Affairs and Fisheries, 2014; Saputra, 2020) putting additional pressure on and degrading the marine ecosystem (Eider *et al*., 2023; Kurniawan *et al*., 2016; Solihin *et al*., 2021; Suana and Ahyadi, 2012;). This tourism is critically important to the local community, with GMMTP contributing up to 70% of the North Lombok economy and more than 50% of the Gili Matra population working in tourism-related jobs (Rahmadyani *et al*., 2022)

A selling point for most marine tourism experiences with GMMTP is the guarantee that turtles will be seen as other marine megafauna, such as sharks and rays, are seen infrequently (Saputra, 2019). This can lead to over 100 tourists congregating in some reef areas, threatening their decline (Cirjakovic, 2015; Eider *et al*., 2023; Solihin *et al*., 2021). This decline has become apparent with decreased fish biomass and reduced encounters with marine megafauna, including turtles (Rahmadyani *et al*., 2022), with local fishermen reporting a decline in foraging sea turtles from

10-25 between 1990-200 to 5-7 from 2010 onwards (Jupri *et al*., 2020).

Data Collection

Photographs of turtles' facial scales were collected by citizen scientists using diving and snorkelling. The depth profile of each method was 5-20 meters and 5 metres, respectively. When possible, photographs were taken of both sides of the face; however, if this was not possible, that data was still included in the analysis. Metadata, including species, carapace size, and gender, was correlated with the photographs taken. Data were submitted to researchers who analysed the images using the I3S application, with each individual given a unique name.

Data Validation and Analysis

The data collected in the form of photos and other records is recapitulated in a log book and poured into digital data. Folders are created accordingly and photos are renamed with locations and dates. After that the photo begins to be identified using the I3S Turtle ID application, when we get a new individual we will name the individual with a new name and for the individual found the second time we will enter the database in the same folder with the meeting code to how much and so on.

RESULTS

A total of 486 individual turtles were identified using PID between 2019-2023 (Fig 2.). Over 75% of these individuals were green turtles, with 369 identified. This is followed by 116 hawksbills and one olive ridley. The year with the greatest number of new individuals identified through PID was 2022, followed by 2023 and 2019. These results exclude any resightings of turtles already included within the database.

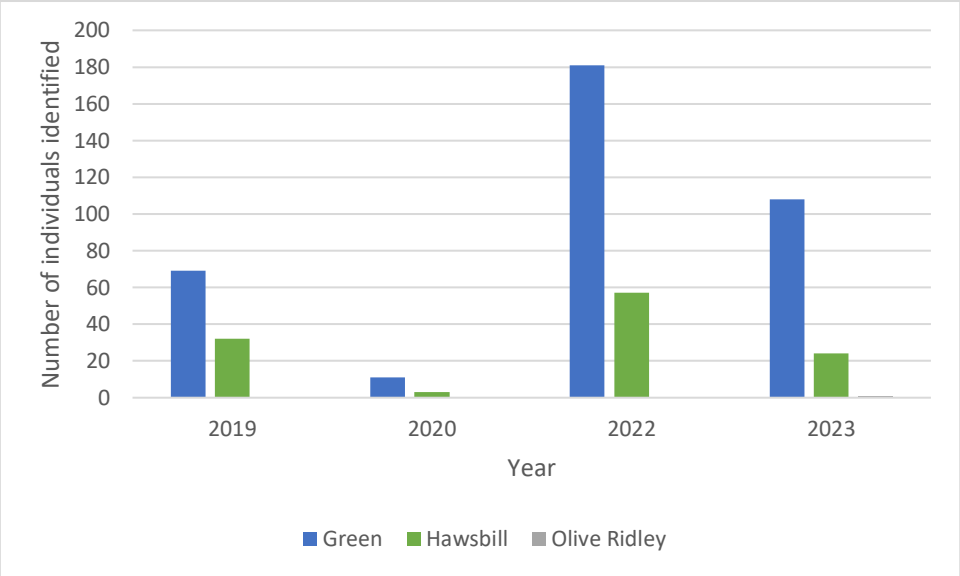


Figure 2. The total number of individual turtles identified within the GMMTP between 2019 and 2023, excluding resightings. Results are separated by year and species.

Turtles were initially identified from various areas within GMMTP, with the highest percentage found in the waters of Gili Trawangan (Fig 3.). The site with the most significant number of initial sightings was the Gili Trawangan Snorkel Zone, followed by Shark Point and Turtle Heaven. Over 24% of the initial turtle sightings did not include location information.

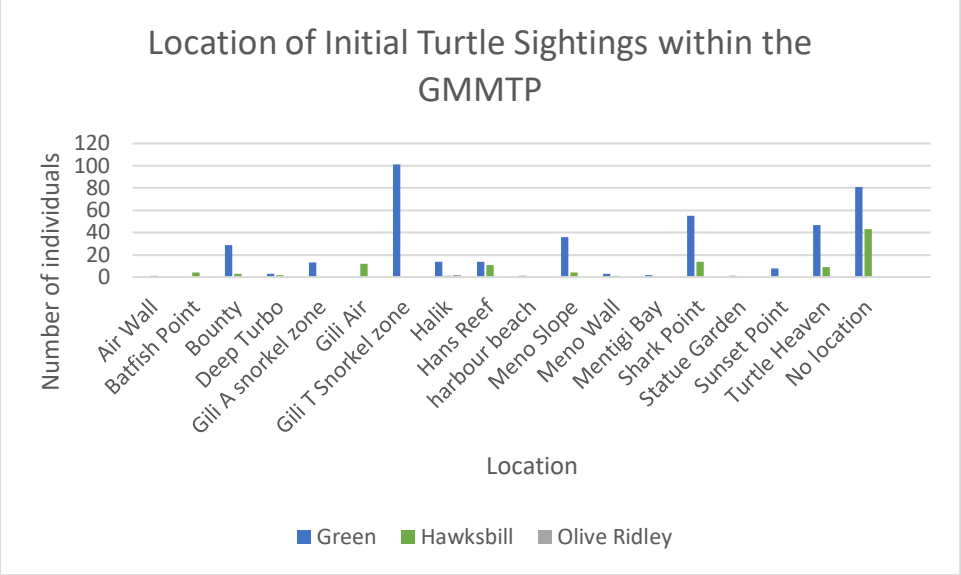
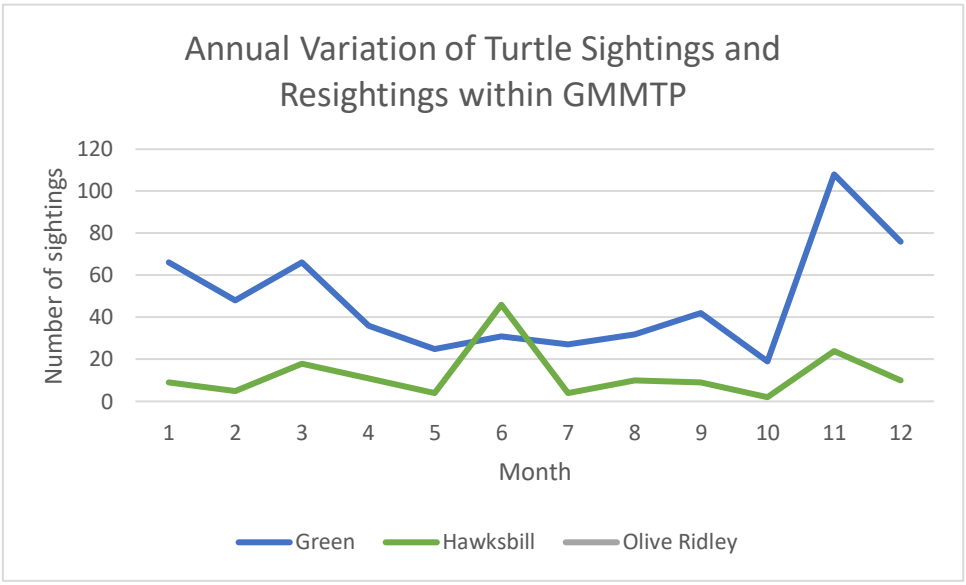


Figure 3. The location of individual turtles identified within the GMMTP between 2019 and 2023, excluding resightings. Results are separated by year and species.

The number sightings and resightings of turtles every month is fairly dynamic (Figure 4.). The appearance of green turtles is at its lowest in October at 19 individu before increasing dramatically to 108 individu in November. After this peak the number of sightings generally



.

Figure 4. The total number of sightings and resightings of individual turtles identified within the GMMTP between 2019 and 2023. Results are separated by month and species.

decreases until May where numbers are low until October. For hawksbills, the highest appearance of turtles is 46 individu in June, with only two to ten individuals in the remaining months. The singular sighting of an olive ridley was in March.

Across all species and years, the greatest number of individuals identified were female. 64% of sea turtles identified were female followed by 7% for male, 12% for juvenile. Overall, for 43% of individual turtles, gender was not recorded. This ranged between 7-43% depending on year.

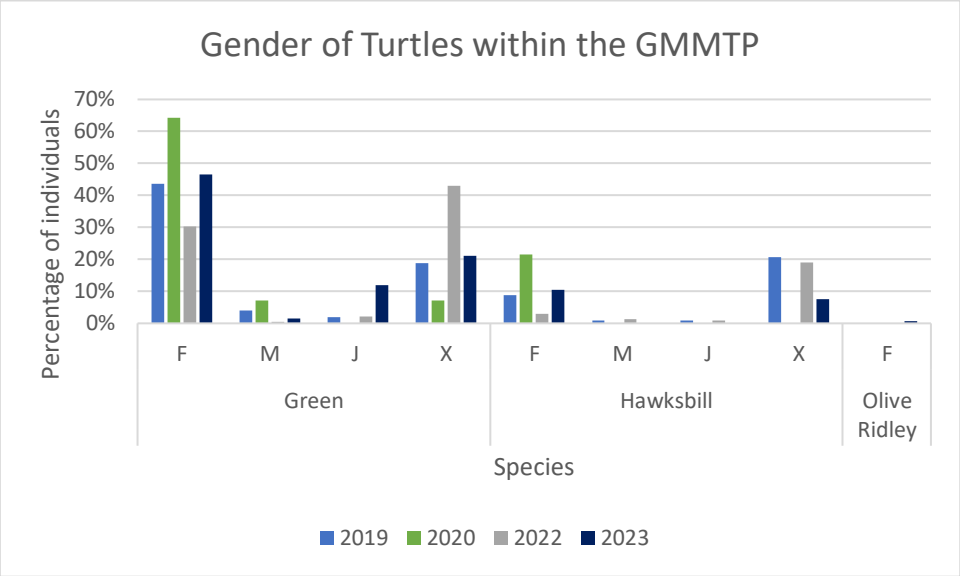


Figure 5 The gender of sea turtles sighted with GMMTP between 2019-2013. Results are separated by year and species. Genders: female (F), male (M), juvenile (J), unknown (X)

DISCUSSION

The observed populations of green and hawksbill turtles in the study area confirm previous reports of high foraging populations (Ahyadi and Jupri, 2008; Bowen *et al.*, 2013; Ministry of Marine Affairs and Fisheries, 2014; Monk and De Fretes, 2012). Unlike the olive ridley turtles (Rodríguez-Zárate, *et al.*, 2018), both green and hawksbill turtles exhibit high fidelity to their feeding areas (Limpus, 2009; Hart and Fujisaki, 2010; Read *et al.*, 2014; Read and Jean, 2021). This finding supports our observation of green and hawksbill turtles resightings and explains the absence of olive ridley turtle sightings. The highest abundance of green and hawksbill turtles was found in the Gili Trawangan Snorkel Zone, followed by Shark Point and Turtle Heaven. This distribution pattern aligns with existing scientific literature, as foraging green and hawksbill turtles are known to inhabit shallow coral reefs and hard substrate (Gaos *et al.*, 2011; Tapilati *et al.*, 2022), despite their different diets of macrophytes for greens (Limpus and Nicholls, 2000) and marine sponges for hawksbills (León and Bjorndal, 2002). However, the locations with the highest abundance of green turtles do not correspond to the abundance of seagrass beds within GMMTP, which are primarily found to the west of Gili Trawangan, southwest of Gili Meno, and west, north, and east of Gili Air (Ayustina *et al.*, 2018). The absence of turtle records within these areas may indicate spatial sampling bias.

When conducting population assessments, it is essential to ensure a homogeneous coverage of sampling effort in both time and space (Evans and Hammond, 2004). However, this is challenging when relying on citizen scientists whose in-water location depends on SCUBA and snorkelling operators. Within GMMTP, underwater tourism is concentrated in areas with high fish biomass, coral cover, and exotic marine fauna (Ministry of Marine Affairs and Fisheries, 2014). These areas are easily accessible snorkelling sites and locations like Turtle Heaven, Shark Point, and Halik, typically reached by boat (Eider *et al.*, 2023). These sites correlate with the locations where the most significant number of individual turtles were identified and resighted, indicating sampling bias.

Regarding sampling efforts across time, as with most tourist destinations, there is a flux in the number of tourists, and in this case, citizen scientists across the seasons. GMMTP attracts higher tourism during the dry season (May-September) due to favourable weather and diving conditions (Partelow and Nelson, 2020). Therefore, the highest number of sea turtle sightings is expected during this period, reflecting the sampling bias. Hawksbills had the highest number of sightings in June, corresponding to this period of high sampling effort. Surprisingly, the highest number of sightings of green turtles occurs between November and March, which coincides with lower sampling effort. The number of resightings for both species also falls within this period, suggesting green and hawksbill display higher site fidelity during these months. The migration patterns of turtles foraging in GMMTP to their nesting habitats are poorly understood, with considerable variation in nesting seasons across the Indo-Pacific region alone (Vargas *et al.*, 2016). However, the decrease in resightings during the higher sampling periods may indicate the migration of turtles away from GMMTP to their nesting grounds before returning later in the year. Further research is necessary to determine these migration patterns. The reduction and lack of sampling in 2021 and 2022 is attributed to the COVID-19 pandemic, with the tourism industry severely depleted during this time.

Despite the evident sampling bias in time and space, our results demonstrate that the general public can capture identification-worthy photographs of turtles with minimal training through SCUBA diving or snorkelling. This is likely facilitated by the fact that turtles are charismatic megafauna frequently photographed by tourists (Pauwelussen and Swanson, 2022), which increased citizen scientist engagement and enabled the identification of hundreds of individual sea turtles within GMMTP. Generally, citizen scientists were also able to identify the gender of turtles with our findings support current literature of over 80% of adult turtles being female in greens (Blechschmidt *et al.*, 2020) and hawksbills (Bell and Jenson, 2018). However, in many instances, necessary metadata such as carapace size, gender, and location were often not reported, replicating the findings of Williams *et al.* (2015). Collecting this data is essential for establishing accurate population dynamics during future data collection efforts. Furthermore, as the left and right facial profiles differ for turtles, there is bias in the data, with individuals potentially being counted twice within our analysis, replicating the findings of Read and Jean (2021).

Future directions

Increasing citizen scientist participation in data collection would partially address the bias of sampling locations and provide a more spatially accurate assessment of turtle populations (Chandler *et al.*, 2017). One proven method of increasing engagement is the use of smartphone applications and digital tools that enable data to be submitted quickly and easily (Frigerio *et al.*, 2021; Hyder et al., 2015; Luna et al., 2018; Silvertown *et al.*, 2013). Therefore, developing a smartphone application or an online form accessed through a QR code is a priority for this research.

This application may also enable a broader demographic of citizen scientists to become involved in data collection. Affluent Western tourists took the majority of photos submitted to this study, indicating a global trend in citizen science, with very few studies worldwide achieving diverse participation (Pandya, 2012; van Noordwijk *et al.*, 2021). In addition to developing an application, removing other barriers to inclusion will enable the local community to be involved with this research. These barriers may include access to cameras and the ability to swim and SCUBA dive. By removing these, other areas of the GMMTP can likely be sampled as local community members may utilise different reef areas compared to tourists.

However, providing an easily accessible online data input system for citizen scientists will not address the lack of metadata collected, such as turtle location and carapace size and number of turtles with only one side of the face captured. Whilst the majority of citizen scientists involved in data collection underwent basic training in taking suitable photographs for identification without disturbing turtles, results indicate a lack of training in collecting metadata and photographs of both sides of the face. By providing training for this, either in person on through the data input system, citizen scientists will be able to collect higher-quality data (Baumbach *et al*., 2019; Williams *et al*., 2015) and address knowledge gaps within the current dataset.

CONCLUSION

Using citizen scientist photographs for sea turtle PID is a viable way of assessing foraging sea turtle populations in coastal waters. However, efforts must be made to reduce sampling bias towards popular diving and snorkelling locations. This can be addressed by increasing the number and diversity of people participating in data collection. Furthermore, to establish population dynamics, citizen scientists must undergo sufficient training to capture required metadata on sea turtle gender, carapace size and location.

REFERENCES

Ahyadi, H., & Jupri, A. (2008). Analisis perubahan ekosistem terumbu karang untuk menunjang pengelolaan kawasan TWAL Gili Indah yang berkelanjutan. *Laporan kegiatan riset dan pengembangan daerah.* Mataram, Indonesia: Badan Perencanaan Pembangunan Daerah

Allen, G. R. (2008). Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic conservation marine and freshwater ecosystems,* 1*8*(5), 541-556. DOI: https://doi.org/10.1002/aqc.880

Ayustina, R., Aulia, Z., Mustakin, H., Alam, F., Amron, A., Yuwono, D., Ahmad, T., Prayogo, A., & Sari, F. (2018). Classification of shallow water seabed profile based on Landsat 8 imagery and in-situ data. Case study in Gili Matra Island Lombok, Indonesia. In *E3S Web of Conferences* (Vol. 47, p. 04002). EDP Sciences. https://doi.org/10.1051/e3sconf/20184704002

Baumbach, D. S., Anger, E. C., Collado, N. A., & Dunbar, S. G. (2019). Identifying sea turtle home ranges utilising citizen-science data from novel web-based and smartphone GIS Applications. *Chelonian Conservation and Biology: Celebrating 25 Years as the World's Turtle and Tortoise Journal*, *18*(2), 133-144. DOI: https://doi.org/10.2744/CCB-1355.1

Bell, I., & Jensen, M. P. (2018). Multinational genetic connectivity identified in western Pacific hawksbill turtles, Eretmochelys imbricata. *Wildlife Research*, *45*(4), 307-315. DOI: https://doi.org/10.1071/WR17089

Blechschmidt, J., Wittmann, M. J., & Blüml, C. (2020). Climate change and green sea turtle sex ratio—preventing possible extinction. *Genes*, *11*(5), 588.https://doi.org/10.3390/genes11050588

Bowen, B. W., Rocha, L. A., Toonen, R. J., & Karl, S. A. (2013*).* The origins of tropical marine biodiversity. *Trends in Ecology & Evolution*, *28*(6), 359–366. DOI: https://doi.org/10.1016/j.tree.2013.01.018

Burke, L., Reytar, K., Spalding, M., & Perry, A. (2012). *Reefs at risk revisited in the Coral Triangle*. Retrieved from: https://policycommons.net/artifacts/1360491/reefs-at-risk-revisited-in-the-coral-triangle/1974017/

Bjorndal, K. A. (2017). Foraging ecology and nutrition of sea turtles. In P.L, Lutz (Ed.). *The Biology of Sea Turtles, Volume I* (J, Musick (2nd Ed.). pp. 199-231). Florida, USA: CRC Press.

Calmanovici, B., Waayers, D., Reisser, J., Clifton, J., & Proietti, M. (2018). I3S Pattern as a mark-recapture tool to identify captured and free-swimming sea turtles: an assessment. *Marine Ecology Progress Series*, *589*, 263-268. DOI: https://doi.org/10.3354/meps12483

Carpentier, A. S., Jean, C., Barret, M., Chassagneux, A., & Ciccione, S. (2016). Stability of facial

scale patterns on green sea turtles Chelonia mydas over time: a validation for the use of a photo-identification method. *Journal of Experimental Marine Biology and Ecology*, *476*, 15-21. DOI: https://doi.org/10.1016/j.jembe.2015.12.003

Carter, S. J., Bell, I. P., Miller, J. J., & Gash, P. P. (2014). Automated marine turtle photograph identification using artificial neural networks, with application to green turtles. *Journal of experimental marine biology and ecology*, *452*, 105-110. DOI: https://doi.org/10.1016/j.jembe.2013.12.010

Chandler, M., See, L., Copas, K., Bonde, A. M., López, B. C., Danielsen, F., Legind, J. K., Masinde, S. , Miller-Rushing, A. J., Newman, G., Rosemartin, A., & Turak, E. (2017). Contribution of citizen science towards international biodiversity monitoring. *Biological conservation*, *213*, 280-294. DOI: https://doi.org/10.1016/j.biocon.2016.09.004

Chassagneux, A., Jean, C., Bourjea, J., & Ciccione, S. (2013). Unraveling behavioral patterns of foraging hawksbill and green turtles using photo-identification. *Marine Turtle Newsletter*, *137*, 1-5.

Cigliano, J. A., Meyer, R., Ballard, H. L., Freitag, A., Phillips, T. B., & Wasser, A. (2015). Making marine and coastal citizen science matter. *Ocean & Coastal Management*, *115*, 77-87. DOI: https://doi.org/10.1016/j.ocecoaman.2015.06.012

Cirjakovic, V. (2015). Impacts of Recreational Activities on Marine and Coastal Areas in Gili Trawangan, Indonesia. *Bogor Agricultural University*. Retrieved from: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=52c7aa7ef5bfa5db10ff6a6f4988e4738fd3acb1

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental monitoring and assessment*, *176*, 273-291. DOI: https://doi.org/10.1016/j.jembe.2013.12.010

Eider, D., Partelow, S., Albrecht, S., Adrianto, L., & Kluger, L. C. (2023). SCUBA tourism and coral reefs: a social-ecological network analysis of governance challenges in Indonesia. *Current Issues in Tourism*, *26*(7), 1031-1050. DOI: https://doi.org/10.1080/13683500.2021.2006612

Evans, P. G., & Hammond, P. S. (2004). Monitoring cetaceans in European waters. *Mammal review*, *34*(1-2), 131-156. DOI: https://doi.org/10.1046/j.0305-1838.2003.00027.x

FitzSimmons, N. N., & Limpus, C. J. (2014). Marine turtle genetic stocks of the Indo-Pacific: identifying boundaries and knowledge gaps. *Indian Ocean Turtle Newsletter*, *20*(July), 2-18. Retrieved from: http://www.iotn.org/wp-content/uploads/2015/09/IOTN-20.pdf#page=4

Frigerio, D., Richter, A., Per, E., Pruse, B., & Vohland, K. (2021). Citizen science in the natural sciences. *The science of citizen science*, 79-96. DOI: 6. https://doi.org/10.1007/978-3-030-58278-4_5

Gaos, A. R., Lewison, R. L., Yañez, I. L., Wallace, B. P., Liles, M. J., Nichols, W. J., Baquero, A., Hasbun, C. R., Vasqiez, M., Urteaga, J., & Seminoff, J. A. (2012). Shifting the life-history paradigm: discovery of novel habitat use by hawksbill turtles. *Biology Letters*, *8*(1), 54-56. DOI: https://doi.org/10.1098/rsbl.2011.0603

Hart, K. M., & Fujisaki, I. (2010). Satellite tracking reveals habitat use by juvenile green sea turtles Chelonia mydas in the Everglades, Florida, USA. Endangered Species Research, 11(3), 221-232. DOI: https://doi.org/10.3354/esr00284

Halim, M. H., Silalahi, S., & Sugarjito, J. (2001). Conservation and utilisation trend of marine turtles in Indonesia. *Tigerpaper (FAO)*, *28*, 10-18. Retrieved from: https://www.fao.org/3/ak883e/ak883e.pdf#page=12

Hudgins, J. A., Hudgins, E. J., Ali, K., & Mancini, A. (2017). Citizen science surveys elucidate key foraging and nesting habitat for two endangered marine turtle species within the Republic of Maldives. *Herpetology Notes*, *10*, 473-475. Retrieved from: https://www.biotaxa.org/hn/article/view/26126

Hyder, K., Townhill, B., Anderson, L. G., Delany, J., & Pinnegar, J. K. (2015). Can citizen

science contribute to the evidence-base that underpins marine policy?. *Marine policy*, *59*, 112-120. DOI: https://doi.org/10.1016/j.marpol.2015.04.022

Jupri, A., Putri. B. R. A., Ahyadi, H. & Zamroni, Y. (2020). Stakeholder perception on the Sea Turtle conservation in Gili Matra Tourism Area, Lombok- West Nusa Tenggara. *Journal of Marine and Island Cultures*, *9*(2), 124-135. DOI: https://doi.org/10.21463/jmic.2020.09.2.09

Kurniawan, F., Adrianto, L., Bengen, D. G., & Prasetyo, L. B. (2016). Patterns of landscape change on small islands: A case of Gili Matra Islands, Marine Tourism Park, Indonesia. *Procedia-Social and Behavioral Sciences*, *227*, 553-559. DOI: https://doi.org/10.1016/j.sbspro.2016.06.114

Kurniawan, F., Adrianto, L., Bengen, D. G., & Prasetyo, L. B. (2022). Hypothetical effects assessment of tourism on coastal water quality in the Marine Tourism Park of the Gili Matra Islands, Indonesia. *Environment, Development and Sustainability*, 1-27. DOI: https://doi.org/10.1007/s10668-022-02382-8

León, Y. M., & Bjorndal, K. A. (2002). Selective feeding in the hawksbill turtle, an important predator in coral reef ecosystems. *Marine Ecology Progress Series*, *245*, 249-258. DOI: https://doi.org/10.3354/meps245249

Limpus, C. J., & Fien, L. (2009). *A biological review of Australian marine turtles* (p. 324). Brisbane, Australia: Environmental Protection Agency.

Limpus, C., & Nicholls, N. (2000). ENSO regulation of Indo-Pacific green turtle populations. *Applications of seasonal climate forecasting in agricultural and natural ecosystems*, 399-408. DOI: https://doi.org/10.1007/978-94-015-9351-9_24

Lloyd, J. R., Maldonado, M. A., & Stafford, R. (2012). Methods of developing user-friendly keys to identify green sea turtles (Chelonia mydas L.) from photographs. *International Journal of Zoology*, *2012*. DOI: https://doi.org/10.1155/2012/317568

Luna, S., Gold, M., Albert, A., Ceccaroni, L., Claramunt, B., Danylo, O., Haklay, M., Kottmann, R., Kyba, C., Piera, J., Radicchi, A., Schade, S., & Sturm, U. (2018). Developing mobile applications for environmental and biodiversity citizen science: considerations and recommendations. *Multimedia tools and applications for environmental & biodiversity informatics*, 9-30. DOI: https://doi.org/10.1007/978-3-319-76445-0_2

Makowski, C., Seminoff, J. A., & Salmon, M. (2006). Home range and habitat use of juvenile Atlantic green turtles (Chelonia mydas L.) on shallow reef habitats in Palm Beach, Florida, USA. *Marine Biology*, *148*, 1167-1179. DOI: https://doi.org/10.1007/s00227-005-0150-y

Milani Chaloupka, P. D., & Nakano, H. (2004). Status of sea turtle stocks in the Pacific. *Papers Presented at the Expert Consultation on Interactions Between Sea Turtles and Fisheries Within an Ecosystem Context: Rome, 9-12 March 2004*, (738), 135-164.

Ministry of Marine Affairs and Fisheries. (2014). Rencana Pengelolaan dan Zonasi Taman Wisata Perairan Pulau Gili Ayer, Gili Meno dan Gili Trawangan di Provinsi Nusa Tengara Barat Tahun 2014–2034. In Keputusan Menteri Kelautan dan Perikanan Republik Indonesia No.57/2014. Jakarta, Indonesia: Ministry of Marine Affairs and Fisheries. Retrieved from: https://peraturan.bpk.go.id/Home/Details/159957/kepmen-kkp-no-57kepmen-kp2014-tahun-2014

Monk, K., & De Fretes, Y. (2012). *Ecology of Nusa Tenggara*. Indonesia: Tuttle Publishing.

Nuitja. I.N.S. (1992). Biologi dan Ekologi Pelestarian Penyu Laut. Bogor; Institut Pertanian Bogor Press.

Nurhayati, A., Putra, P. K. D. N. Y., & Supriatna, A. K. (2022). The Role of Sea Turtle Conservation Education for Sustainable Marine Tourism Based on Bio-Ecoregion (Case Study in Bali, Indonesia). *Geo Journal of Tourism and Geosites*, *41*(2), 477-484. DOI: https://doi.org/10.30892/gtg.41219-853

Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment*, *10*(6), 314-317. DOI: https://doi.org/10.1890/120007

Papafitsoros, K., Panagopoulou, A., & Schofield, G. (2021). Social media reveals consistently disproportionate tourism pressure on a threatened marine vertebrate. *Animal Conservation*, *24*(4), 568-579. DOI: https://doi.org/10.1111/acv.12656

Partelow, S., & Nelson, K. (2020). Social networks, collective action and the evolution of governance for sustainable tourism on the Gili Islands, Indonesia. *Marine Policy*, *112*. DOI: https://doi.org/10.1016/j.marpol.2018.08.004

Pauwelussen, A., & Swanson, S. S. (2022). Good Human–Turtle Relationships in Indonesia: Exploring Intersecting Legalities in Sea Turtle Conservation. In *Laws of the Sea* (pp. 258-281). Routledge. DOI: https://doi.org/10.4324/9781003205173-13

Rahmadyani, R. F., Dargusch, P., & Adrianto, L. (2022). Assessment of Stakeholder's Perceptions of the Value of Coral Reef Ecosystem Services: The Case of Gili Matra Marine Tourism Park. *International Journal of Environmental Research and Public Health*, *20*(1), 89. DOI: https://doi.org/10.3390/ijerph20010089

Read, T. C., Wantiez, L., Werry, J. M., Farman, R., Petro, G., & Limpus, C. J. (2014). Migrations of green turtles (Chelonia mydas) between nesting and foraging grounds across the Coral Sea. *PLoS One*, *9*(6), e100083. DOI: https://doi.org/10.1371/journal.pone.0100083

Read, T., & Jean, C. (2021). Using social media and photo-identification for sea turtles of new caledonia. *Marine Turtle Newsletter*, *162*, 25-29. Retrieved from: http://www.seaturtle.org/mtn/archives/mtn162/mtn162-8.shtml

Reisser, J., Proietti, M., Kinas, P., & Sazima, I. (2008). Photographic identification of sea turtles: method description and validation, with an estimation of tag loss. *Endangered Species Research*, *5*(1), 73-82. DOI: DOI: https://doi.org/10.3354/esr00113

Rodríguez-Zárate, C. J., Sandoval-Castillo, J., van Sebille, E., Keane, R. G., Rocha-Olivares, A., Urteaga, J., & Beheregaray, L. B. (2018). Isolation by environment in the highly mobile olive ridley turtle (Lepidochelys olivacea) in the eastern Pacific. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1878), 20180264.DOI: https://doi.org/10.1098/rspb.2018.0264

Ruchimat, T., Basuki, R., & Welly, M. (2013). Nusa Penida marine protected area (MPA) Bali-Indonesia: Why need to be protected?.*Transylvanian Review of Systematical and Ecological Research*, *15*(1), 193-202. DOI: https://doi.org/10.2478/trser-2013-0016

Saputra, I. G. N. P. W. E. The Roles of Dive Centers in Conserving Coral Reefs to Support Tourism Industry in Gili Trawangan. *Gadjah Mada Journal of Tourism Studies*, *2*(1), 19-32. DOI: https://doi.org/10.22146/gamajts.v2i1.56845

Schofield, G., Katselidis, K. A., Dimopoulos, P., & Pantis, J. D. (2008). Investigating the viability of photo-identification as an objective tool to study endangered sea turtle populations. *Journal of experimental marine biology and ecology*, *360*(2), 103-108. DOI: https://doi.org/10.1016/j.jembe.2008.04.005

Shanker, K., & Pilcher, N. J. (2003). Marine turtle conservation in South and Southeast Asia: hopeless cause or cause for hope. *Marine Turtle Newsletter*, *100*, 43-51. Retrieved from: http://www.seaturtle.org/mtn/archives/mtn100/mtn100p43.shtml

Silvertown, J., Buesching, C. D., Jacobson, S. K., & Rebelo, T. (2013). Citizen science and nature conservation. *Key topics in conservation biology 2*, 127-142. DOI: https://doi.org/10.1002/9781118520178.ch8

Sims, M., Bjorkland, R., Mason, P., & Crowder, L. B. (2008). Statistical power and sea turtle nesting beach surveys: How long and when?, *Biological Conservation*, *141*(12), 2921-2931. DOI: https://doi.org/10.1016/j.biocon.2008.07.021

Solihin, L., Kusumastanto, T., Fauzi, A., & Yulianda, F. (2021). Spacial Economic Model of Sustainability Scuba Diving Tourism at Gili Matra Conservation Area, Indonesia. ECSOFiM (Economic and Social

of Fisheries and Marine Journal), 9(1), 45-59. DOI: https://doi.org/10.21776/ub.ecsofim.2021.009.01.04

Suana, I. W., & Ahyadi, H. (2012). Mapping of ecosystem management problems in Gili Meno, Gili Air, and Gili Trawangan (Gili Matra) through participative approach. *Coastal Development*, *16*(1), 94-101. Retrieved from: https://ejournal.undip.ac.id/index.php/coastdev/article/view/4943

Susiloningtyas, D., Handayani, T., & Amalia, A. N. (2018). The impact of coral reefs destruction and climate change in Nusa Dua and Nusa Penida, Bali, Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 145, No. 1, p. 012054). Bristol, UK: IOP Publishing.

Syaputra, M., Wahyuningsih, E. W., Aji, I. M. L. A., Suparyana, P. K. S., & Lestari, A. T. L. (2023). Zonation of Nipah Beach Ecosystem in North Lombok District to Support Sea Turtle Conservation Efforts. *Jurnal Multidisiplin Madani*, *3*(5), 994-1009. DOI: https://doi.org/10.55927/mudima.v3i5.4094

Tapilatu, R. F. (2017). Status of sea turtle populations and its conservation at Bird's Head Seascape, Western Papua, Indonesia. *Biodiversitas Journal of Biological Diversity*, *18*(1), 129-136. DOI: https://doi.org/10.13057/biodiv/d180119

Tapilatu, R. F., Wona, H., Mofu, B., Kolibongso, D., Alzair, N., Erdmann, M., & Maruanaya, B. (2022). Foraging habitat characterisation of green sea turtles, Chelonia mydas, in the Cenderawasih Bay, Papua, Indonesia: Insights from satellite tag tracking and seagrass survey. *Biodiversitas Journal of Biological Diversity*, *23*(6), 2783-2789. DOI: https://doi.org/10.13057/biodiv/d230601

van Noordwijk, T., Bishop, I., Staunton-Lamb, S., Oldfield, A., Loiselle, S., Geoghegan, H., & Ceccaroni, L. (2021). Creating positive environmental impact through citizen science. *The science of citizen science*, 373-395. DOI: https://doi.org/10.1007/978-3-030-58278-4_19

Vargas, S. M., Jensen, M. P., Ho, S. Y., Mobaraki, A., Broderick, D., Mortimer, J. A., Whiting, S. D., Miller, J., Prince, R. I. T., Bell, I. P., Hoenner, X., Limpus, C. J., Santons, F. R., & FitzSimmons, N. N. (2016). Phylogeography, genetic diversity, and management units of hawksbill turtles in the Indo-Pacific. *Journal of Heredity*, *107*(3), 199-213. DOI: https://doi.org/10.1093/jhered/esv091

Williams, J. L., Pierce, S. J., Fuentes, M. M., & Hamann, M. (2015). Effectiveness of recreational divers for monitoring sea turtle populations. *Endangered Species Research*, *26*(3), 209-219. DOI: DOI: https://doi.org/10.3354/esr00647