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Short Note

Dugong (*Dugong dugon*) Reproductive Behaviour in Koh Libong, Thailand: Observations Using Drones

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The dugong (*Dugong dugon*) is a threatened species which has experienced considerable reductions across many seascapes of the Indo-Pacific region (Marsh et al., 2005) and is listed as "Vulnerable" in the International Union for Conservation of Nature's (IUCN) *Red List of Threatened Species* (Marsh & Sobtzick, 2019). Dugongs are distributed along the coast of the Andaman Sea and Gulf of Thailand. The largest dugong population in Thailand (around 200 individuals in 2018) was found around Libong and Muk Islands where the highest number of dugong strandings was reported (Department of Marine and Coastal Resources [DMCR], 2019b). Yet, data on population status and distribution are still scarce in many regions, though they represent an important part of the current global distribution. As a result, our understanding of the ecology and distribution of dugongs is informed largely from well-studied dugong hotspots in Australia (Marsh et al., 2002). In the Indo-Pacific area, dugong numbers have shown declines and are currently restricted to small, localized populations, the status of which is poorly known (Hines et al., 2005; Marsh et al., 2011). The number of stranded dugongs in Thailand has been gradually increasing and reached the highest number per year in 2019 with 25 individuals stranded. Throughout the last 10 years (2009 to 2019), 142 dugongs were stranded in Thai waters with an average of 14 stranded dugongs per year (DMCR, 2019a). Most dugongs died entangled in fishing gear (50%), such as gillnets, trawlers, and longlines, and the rest of the deaths were caused by illness or accidents (44%) (DMCR, 2019a). This highlights the need for continuous monitoring and adequate management of the existing populations.

Dugong reproductive behaviour has been minimally described due to the difficulty of observing dugongs in the wild. The studies of dugong biology have been based on three basic approaches: (1) analysing specimens collected from carcasses, (2) monitoring the reproductive history of known free-ranging individuals during their life span (longitudinal studies), and (3) studying individuals in captivity (Boyd et al., 1999). All three methods have biases that are important to understand when interpreting their results. For example, dugongs have never been bred in captivity, and using carcasses requires many samples, which might become challenging in locations with low dugong populations. The best strategy to study reproductive activity is in the wild; and remote sensing platforms, such as unmanned aerial vehicles (also known as drones), might be suitable for observing the small population of wild dugongs in Thailand. The aim of this study was to identify if drones could be used as a remote observation platform for (1) the reproductive behaviour of dugongs in Thailand and (2) the identification of individuals using tusk scars.

Surveys were performed around the island of Koh Libong in the Trang Province of Thailand from 6-8 February 2019 and 24-26 February 2020 (Figure 1). A *vocal hotspot* has been identified to the southwest of the island after elevated levels of dugong vocal behavior were identified (Ichikawa et al., 2006, 2011; Tanaka et al., 2017). The survey covered the southeast and northeast sides of the island where intense dugong feeding

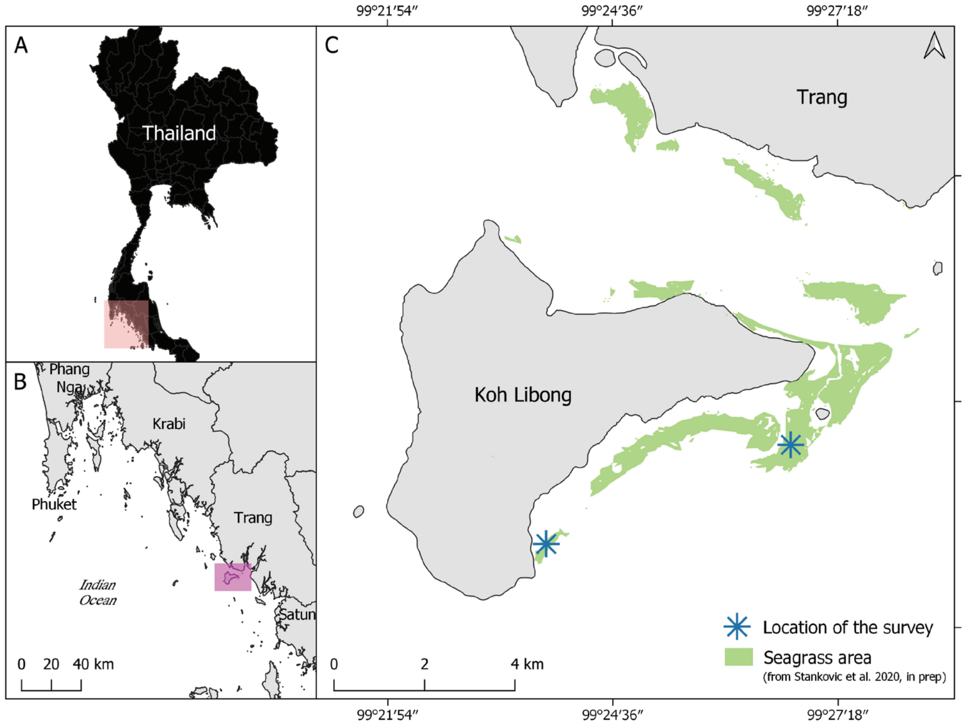

Figure 1. Location of the survey area and seagrass beds at Koh Libong island

trails were present in the seagrass beds. Aerial surveys were performed at an altitude of 100 m, approximately 1 to 3 h before the high tide. To not interfere with dugong mating behaviour, remote aerial observations were made using a ×30 optical zoom camera (Zenmuse Z30; DJI, Nanshan, Shenzhen, China) mounted on a quadcopter drone (Matrice 200, DJI). The optical zoom allowed observers to remain distant from the animals and to obtain a high level of detail from the individuals. The drone streamed live-view images to the pilot and to an assistant observer with First Person View (FPV) goggles (DJI) with a 1,080p/30fps screen definition. This set-up facilitated the location and identification of dugong behaviour since the pilot could safely navigate the drone while the assistant focused on the dugong observations. The image quality of the goggles on sunny days was higher than on the tablet used by the pilot to navigate the drone, which facilitated the observation activities. The resulting images recorded had a 1,920 × 1,080 resolution. In addition, a DJI Phantom 4-Pro was used to perform additional observations during the surveys. All observations were performed at spring tides when the water depth was over 2 m. The level of turbidity of the water was high; therefore, animals that were not at the surface were difficult to track.

Dugongs were scattered throughout the survey area feeding on seagrass beds with no calves observed. Reproductive behaviour was observed in a seagrass meadow at the island of Koh Libong on 26 February 2020 (Figure 1). Three dugongs were observed—two individuals followed by a third dugong (Figure 2a). We estimated the distance between the couple and individual to be approximately 15 to 20 m, calculated by using the length of an adult dugong (1.6 m) as reference. The dugong couple showed a behaviour of approaching and stimulating, where the male was close to the female and used his muzzle to touch the ventral side of the female including her chest and belly (Figure 2b). The male gender was clearly identifiable by its genitalia in the drone images. We assumed the other was female, though sirenians exhibit little sexual dimorphism. Although the asymptotic length of females may be slightly larger than that of males in dugongs (Marsh, 1980), the sex of dugongs cannot be inferred from body size. Our observations were similar to the dugong mating stages previously described by Adulyanukosol et al. (2007). Five stages were observed: (1) *Following* – two dugongs swam

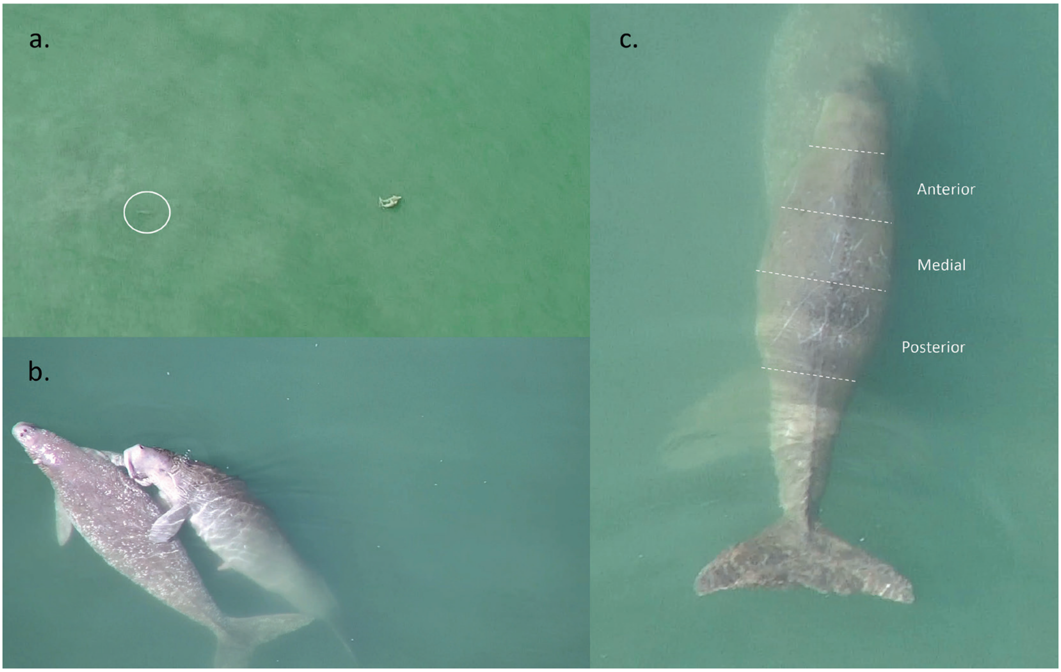

Figure 2. Dugong mating behaviour at Koh Libong, Thailand: (a) two dugongs followed by a third dugong at approximately 15 to 20 m (shown in white circle); (b) two dugongs approaching and stimulating in an early stage of mounting; and (c) tusk marks in the three dorsal regions: (1) anterior (auditory meatus to position caudal of pectoral flipper), (2) medial (pectoral flipper to umbilicus), and (3) posterior (position of umbilicus to anus).

behind the female and one male moved closer to the female (Figure 2a); (2) *Approaching and stimulating* – the male was close to the female and used his muzzle to touch the ventral side of the female, including her chest and belly (Figure 2b); (3) *Pairing* – the male and female swam in parallel, ventral side to ventral side—at this stage, the male genitalia were clearly observed; (4) *Mounting* – the male copulated with the female by moving his genitalia toward the female; and (5) *Separating* – the male and female separated after the mounting and swam away from each other. Of these five stages, video recordings were only captured for the first two stages and one attempt of a pairing (see "Dugong Mating Thailand Libong 26-Feb-2020," a supplementary video recording available on YouTube: https://youtu.be/rPUge_2G7Kw).

Dugong mating behaviour may vary with locations. For example, mating herds have been observed in Queensland and Western Australia (Preen, 1989), while lone pairs mating were observed in Palau (Marsh et al., 2011) and in mating leks in South Cove of Shark Bay, Western Australia (Anderson, 1997). Our observations resemble the reproductive stages described by Adulyanukosol et al. (2007) in Thai waters, thus supporting their findings. Behaviours such as splashing and fighting (Preen, 1989) or rushing at the water surface (Anderson & Birtles, 1978) that were observed in mating herds in Australia were not observed here. Lek mating behaviour has also been described in Shark Bay (Anderson, 1997). Although lek behaviour might exist, it was not observed during our survey in Koh Libong.

Tusk scars were observed on most dugongs (Figure 2c), suggesting that some aggressive behaviour between males associated with mating might have occurred (Preen, 1989; Anderson, 1995; Burgess et al., 2013). This aggressive behaviour was not observed during the survey, but scars suggest it might occur. Dugong scars caused by tusks or other injuries can be used to identify individuals since some marks might remain over time. Identification of dugongs using scars and notches has previously allowed resighting of the same individuals over time in the Andaman Islands (Souza & Patankar, 2009). Shawky et al. (2017) observed that some dugong scars disappeared completely over a period of 4 mo, which indicated that scars cannot be used for the identification of dugongs over a long period of time. In contrast, Anderson (1995) assumed that deeper scars were permanent and could be used to identify individuals over periods of several years or throughout the remaining life of the individual. The tusk injuries observed in the drone images were located mainly in the medial and posterior dorsal regions (Figure 2c) as also observed by Burgess et al. (2013). The dorsal area of dugongs is the ideal location to photograph from the air using a drone. We recommend further studies should focus on the identification of individual dugongs using dorsal tusk scars via drones since they might be useful to track dugong movements over time.

In this study, drones were a cost-efficient tool to document dugong behaviour and to provide video images. For example, multiple observations were needed by Adulyanukosol et al. (2007) to completely observe all stages of mating, while, with drones, we could continue our observations during all of the the mating stages. Drones are increasingly being utilized for wildlife monitoring because of their ability to survey hard-to-reach populations and places (Hodgson et al., 2016; Wich & Koh, 2018). To reduce the noise impact of the drone on dugong behaviour, we maintained a drone altitude of 100 m while using a zoom lens to observe the dugongs. At this altitude, the drone appeared not to disturb the dugongs or to cause mating behaviours to be disrupted, which suggests that this approach could be used in monitoring reproductive behaviour in wild marine mammals. Flying at this altitude also allowed a better perspective of the survey area to locate dugongs, while the zoom enabled a quick focus on the individuals. In contrast, flying below 25 m height showed some disruption on behaviour when individuals were near the surface breathing; in these occurrences, dugongs dove and swam faster. Although noise levels from multi-rotor drones seem to have little effect on aquatic mammals while underwater (Christiansen et al., 2016), bottlenose dolphins experienced behavioural changes when drones flew between 10 to 25 m in height (Fettermann et al., 2019). Since drone technology is increasingly available for the general public, care must be taken that these dugong watcher activities do not disturb the existing wildlife populations with the noise of propellers (Mulero-Pázmány et al., 2016). We also encourage that dugong mating observations should be conducted during spring tides in the summer (February-March) in the Trang Province since our data and previous dugong mating observations were performed with these conditions (Adulyanukosol et al., 2007). For example, while spring tides might increase the suitable space for feeding and mating along the upper zone of the intertidal seagrass beds (Preen, 1989), seasonal breeding may occur due to the high levels of faecal testosterone in spring (September-October) as seen in Moreton Bay, Australia (Burgess et al., 2012).

Overall, the use of drones allowed us to make observations that were not previously possible, revealing details of the reproductive behaviours of dugongs and making it possible to track individuals using dorsal scars. These types of observations are useful for the management of dugong populations to assess their status. Dugongs have a low lifetime fecundity and are highly susceptible to human impacts. The long-term survival of dugongs is dependent on ongoing conservation initiatives. Small quadcopter drones have great potential for documenting dugong behaviour such as mating, counting the number of individuals present in a given location, and identifying individuals. Larger fixed-wing drones have been used to perform dugong surveys that cover large distances, but they are difficult to launch and retrieve (Hodgson et al., 2013). In contrast, smaller quadcopters, like those used in this study, allow more flexibility by being able to be launched and recovered using small boats. In addition, the total body length or the length of tusk marks can be measured using drone images via photogrammetry techniques such as having reference points of known sizes (e.g., boats, piers, and buoys) or by the relationship between image pixel size and drone altitude (Bell et al., 1997; Christiansen et al., 2019; Fearnbach et al., 2020). In this study, the body length could not be determined with the images since the photos were taken using different camera angles and zoom lengths. Ideally, a 90º down-looking camera will provide higher accuracy than images taken at an oblique angle. We encourage future studies to measure dugong body mass index with drone images since this technique is less disruptive and stressful than traditional catch and release methods.

Conservation of seagrass beds is key to sustaining the dugong populations in Thailand. Seagrass beds not only provide very valuable ecological services (Nordlund et al., 2016), but they also act as important mating areas for dugongs as demonstrated in this study, highlighting the importance of seagrass ecosystems in the dugong life cycles. Impacts from floods decimated 1,000 km^2 of seagrass beds in 1992 at Harvey Bay, Australia, where 99 dugongs died 6 to 8 mo after the floods due to a lack of food (Preen & Marsh, 1995). Human impacts in the Trang Province, such as sediment runoff, can bury small seagrass species, such as *Halodule uninervis* and *Halophila ovalis* (Khogkhao et al., 2017), which could potentially affect the dugongs' food source in this area. Drones could potentially be used in the Trang Province to monitor the extent and species composition of seagrass using Red-Green-Blue (RGB) or multispectral cameras (Infantes, pers. obs.). A holistic view is necessary to integrate the conservation and management systems not only of the dugong populations but also in their habitat.

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Literature Cited

Adulyanukosol, K., Thongsukdee, S., Hara, T., Arai, N., & Tsuchiya, M. (2007). Observations of dugong reproductive behavior in Trang Province, Thailand: Further evidence of intraspecific variation in dugong behavior. *Marine Biology*, *151*, 1887-1891. https://doi.org/10.1007/s00227-007-0619-y

Anderson, P. (1995). Scarring and photo identification of dugongs (*Dugong dugon*) in Shark Bay, Western Australia. *Aquatic Mammals*, *21*(3), 205-211.

Anderson, P. (1997). Shark Bay dugongs in summer. I: Lek mating. *Behaviour*, *134*, 433-462. https://doi.org/10.1163/156853997X00629

Anderson, P., & Birtles, A. (1978). Behaviour and ecology of dugong, *Dugong dugon* (Sirenia): Observations in Shoalwater and Cleveland bays, Queensland. *Australian Wildlife Research*, *5*, 1-23. https://doi.org/10.1071/WR9780001

Bell, C. M., Hindell, M. A., & Burton, H. R. (1997). Estimation of body mass in the southern elephant seal, *Mirounga leonina*, by photogrammetry and morphometrics. *Marine Mammal Science*, *13*(4), 669-682. https://doi.org/10.1111/j.1748-7692.1997.tb00090.x

Boyd, I., Lockyer, C., & Marsh, H. (1999). Reproduction in marine mammals. In J. E. Reynolds III & J. R. Twiss, Jr. (Eds.), *Biology of marine mammals* (pp. 218-286). Smithsonian Institution Press.

Burgess, E., Brown, J., & Lanyon, J. (2013). Sex, scarring, and stress: Understanding seasonal costs in a cryptic marine mammal. *Conservation Physiology*, *1*, 1-14. https://doi.org/10.1093/conphys/cot014

Burgess, E. A., Lanyon, J. M., & Keeley, T. (2012). Testosterone and tusks: Maturation and seasonal reproductive patterns of live, free-ranging male dugongs (*Dugong dugon*) in a subtropical population. *Reproduction*, *143*(5), 683-697. https://doi.org/10.1530/REP-11-0434

Christiansen, F., Rojano-Doñate, L., Madsen, P. T., & Bejder, L. (2016). Noise levels of multi-rotor unmanned aerial vehicles with implications for potential underwater impacts on marine mammals. *Frontiers in Marine Science*, *3*. https://doi.org/10.3389/fmars.2016.00277

Christiansen, F., Sironi, M., Moore, M. J., Di Martino, M., Ricciardi, M., Warick, H. A., Irschick, D. J., Gutierrez, R., & Uhart, M. M. (2019). Estimating body mass of free-living whales using aerial photogrammetry and 3D volumetrics. *Methods in Ecology and Evolution*, *10*(12), 2034-2044. https://doi.org/10.1111/2041-210X.13298

Department of Marine and Coastal Resources (DMCR). (2019a). *The causes of dugong strandings in 2019*. Department of Marine and Coastal Resources, Ministry of Natural Resources and Environment.

DMCR. (2019b). *The marine endangered species stranding in Thailand*. Department of Marine and Coastal Resources, Ministry of Natural Resources and Environment.

Fearnbach, H., Durban, J. W., Barrett-Lennard, L. G., Ellifrit, D. K., & Balcomb, K. C. (2020). Evaluating the power of photogrammetry for monitoring killer whale body condition. *Marine Mammal Science*, *36*(1), 359-364. https://doi.org/10.1111/mms.12642

Fettermann, T., Fiori, L., Bader, M., Doshi, A., Breen, D., Stockin, K. A., & Bollard, B. (2019). Behaviour reactions of bottlenose dolphins (*Tursiops truncatus*) to multirotor unmanned aerial vehicles (UAVs). *Scientific Reports*, *9*(1), 8558. https://doi.org/10.1038/s41598-019-44976-9

Hines, E. M., Adulyanukosol, K., & Duffus, D. A. (2005). Dugong (*Dugong dugon*) abundance along the Andaman Coast of Thailand. *Marine Mammal Science*, *21*(3), 536-549. https://doi.org/10.1111/j.1748-7692.2005.tb01247.x

Hodgson, A., Kelly, N., & Peel, D. (2013). Unmanned aerial vehicles (UAVs) for surveying marine fauna: A dugong case study. *PLOS ONE*, *8*(11). https://doi.org/10.1371/journal.pone.0079556

Hodgson, J. C., Baylis, S. M., Mott, R., Herrod, A., & Clarke, R. H. (2016). Precision wildlife monitoring using unmanned aerial vehicles. *Scientific Reports*, *6*, 22574. https://doi.org/10.1038/srep22574

Ichikawa, K., Akamatsu, T., Shinke, T., Adulyanukosol, K., & Arai, N. (2011). Callback response of dugongs to conspecific chirp playbacks. *The Journal of the Acoustical Society of America*, *129*(6), 3623-3629. https://doi.org/10.1121/1.3586791

Ichikawa, K., Tsutsumi, C., Arai, N., Akamatsu, T., Shinke, T., Hara, T., & Adulyanukosol, K. (2006). Dugong (*Dugong dugon*) vocalization patterns recorded by automatic underwater sound monitoring systems. *The Journal of the Acoustical Society of America*, *119*(6), 3726-3733. https://doi.org/10.1121/1.2201468

Khogkhao, C., Hayashizaki, K-i., Tuntiprapas, P., & Prathep, A. (2017). Changes in seagrass communities along the runoff gradient of the Trang River, Thailand. *ScienceAsia*, *43*(6), 339-346. https://doi.org/10.2306/scienceasia1513-1874.2017.43.339

Marsh, H. (1980). Age determination of the dugong (*Dugong dugon* (Müller)) in northern Australia and its biological implications. *Reports of the International Whaling Commission*, Special Issue 3, 181-201.

Marsh, H., & Sobtzick, S. (2019). *Dugong dugon* (amended version of 2015 assessment). In International Union for Conservation of Nature (Ed.), *The IUCN red list of threatened species 2019: e.T6909A160756767*. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T6909A160756767.en

Marsh, H., O'Shea, T. J., & Reynolds III, J. E. (2011). *The ecology and conservation of Sirenia: Dugongs and* *manatees*. Cambridge University Press. 521 pp. https://doi.org/10.1017/CBO9781139013277

Marsh, H., De'Ath, G., Gribble, N., & Lane, B. (2005). Historical marine population estimates: Triggers or targets for conservation? The dugong case study. *Ecological Applications*, *15*, 481-492. https://doi.org/10.1890/04-0673

Marsh, H., Penrose, H., Eros, C., & Hugues, J. (2002). *The dugong (*Dugong dugon*): Status reports and action plans for countries and territories in its range* (Final Report). United Nations Environment Programme.

Mulero-Pázmány, M., Jenni-Eiermann, S., Strebel, N., Sattler, T., Negro, J., & Tablado, Z. (2016). Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review. *PLOS ONE*, *12*(6), e0178448. https://doi.org/10.1371/journal.pone.0178448

Nordlund, L., Koch, E., Barbier, J., & Creed, J. (2016). Seagrass ecosystem services and their variability across genera and geographical regions. *PLOS ONE*, *11*(10), e0163091. https://doi.org/10.1371/journal.pone.0169942

Preen, A. (1989). Observations of mating behavior in dugong (*Dugong dugon*). *Marine Mammal Science*, *54*(4), 382-387. https://doi.org/10.1111/j.1748-7692.1989.tb00350.x

Preen, A., & Marsh, H. (1995). Response of dugongs to large-scale loss of seagrass from Hervey Bay, Queensland, Australia. *Wildlife Research*, *22*(4), 507-519. https://doi.org/10.1071/WR9950507

Shawky, A., Sallam, W., Alwany, M., Mohammad, D., & Mohamed, S. (2017). Photo identification of dugongs in Marsa Alam and Wadi El Gemal National Park, Egyptian coast of the Red Sea. *Al Azhar Bulletin of Science*, *28*(2), 1-10.

Souza, E., & Patankar, V. (2009). First underwater sighting and preliminary behavioural observations of dugongs (*Dugong dugon*) in the wild from Indian waters, Andaman Islands. *Journal of Threatened Taxa*, *1*, 49-53. https://doi.org/10.11609/JoTT.o2002.49-53

Tanaka, K., Ichikawa, K., Nishizawa, H., Kittiwattanawong, K., Arai, N., & Mitamura, H. (2017). Differences in vocalisation patterns of dugongs between fine-scale habitats around Talibong Island, Thailand. *Acoustics Australia*, *45*(2), 243-251. https://doi.org/10.1007/s40857-017-0094-7

Wich, S., & Koh, L. (2018). *Conservation drones, mapping and monitoring biodiversity* (4th ed.). Oxford University Press. https://doi.org/10.1093/oso/9780198787617.001.0001