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Research Article

Analyses of Vegetation Used by Long-tailed Macaque (*Macaca fascicularis* Raffles 1821) in Tinjil Island

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ABSTRACT
Tinjil Island is a semi-natural breeding facility for long-tailed macaques (*Macaca fascicularis*) managed by Primate Research Center, IPB University, located at the southern of Java Island and surrounded by the Indian Ocean. Long-tailed macaques are considered frugivorous even though they are well-known for their flexible diet. This study aims to analyse the vegetation supporting the population of long-tailed macaques. Data were collected from six tracks using square sampling plots with the size of 20 m x 20 m for trees as the main plot, inside the main plot were square subplots consisting of 10 m x 10 m for poles, 5 m x 5 m for saplings, and 2 m x 2 m for seedlings. The Important Value Index (IVI) was calculated for each level of vegetation. Hanjuang (*Dracaena elliptica*) dominated the seedlings with 29.35%, followed by Kampis (*Hernandia peltata*) with 18.73%, and Kalapari (*Pongamia pinnata*) with 13.73%. Hanjuang (*Dracaena elliptica*) also dominated the saplings with 26.83%, followed by Pancal (*Syzygium antisepticum*) with 19.19%, and Laban (*Vitex pubescens*) with 12.30%. The poles were dominated by Ki Cau (*Dolichandrone spathacea*) as high as 59.28%, while Waru (*Thespesia populnea*) and Ki Ciat (*Ficus septica*) dominated at 40.47% and 36.15%, respectively. Kampis (*Hernandia peltata*) dominated the trees with 39.28%, followed by Ki Ara (*Ficus glomerata*) with 35.56%, and Ki Langir (*Dysoxylum amooroides*) with 28.70%. Species found on Tinjil Island are mostly Moraceae (9.84%) and Fabaceae (9.84%), followed by Malvaceae (8.20%), Euphorbiaceae (4.92%), Myrtaceae (4.92%), and Anacardiaceae (4.92%). The vegetation in Tinjil Island supports the livelihood of long-tailed macaques on the island because they have an abundance of food and staple food such as figs to help them fulfil the energy needed to survive and reproduce.

INTRODUCTION
Long-tailed macaques (*Macaca fascicularis* Raffles 1821) are primates from the Cercopithecoidea family and are widely distributed in Asia, including Indonesia (Hansen et al. 2022). Based on the IUCN Red List of Threat-

ened Species, long-tailed macaques are considered Endangered (EN) species because of concerns regarding excessive hunting and persecution that have led to the trend of the species' population being decreased (Eudey et al. 2021; Hansen et al. 2022). The distribution of long-tailed macaques includes Laos, Vietnam, Cambodia, Thailand, Indonesia, the Philippines, and Vietnam (Roos et al. 2014). Long-tailed macaques are known to live in a wide range of habitats, including lowland and beach forests (Matsumura 2001), such as Tinjil Island. Tinjil Island is a semi-natural breeding facility managed by the Primate Research Center IPB University, located at the southern of Java Island and surrounded by the Indian Ocean. Since its introduction in 1988, long-tailed macaques have been bred multiple times and, since then, have been harvested regularly.

Long-tailed macaques are considered frugivorous, even though they can feed on insects, young stems, mature leaves, flowers, seeds, grass, mushrooms, lichens, invertebrates, bird eggs, clay, and bark (Thierry 2007; Tsuji et al. 2013; Kassim et al. 2017). Even though long-tailed macaques are well-known for their flexible diet (Aldrich-Blake 1980; Chivers & Raemakers 1980; MacKinnon & MacKinnon 1980), the availability of food in their habitat is an essential factor for their survival. Research regarding vegetation on the island has been done multiple times in 1992 (Santoso 1996), 2001 (Fadilah 2003), and 2009 (Yusuf 2010). Vegetation structure and composition in Tinjil Island is the association of *Dysoxylum amorooides* - *Intsia amboinensis* and influences the population distribution of long-tailed macaques (Santoso 1996). Numerous amounts of species have been used by long-tailed macaques as part of their diets, such as *Antidesma montanum*, *Melanorrhoea wallichii*, and *Barringtonia asiatica* (Santoso 1996).

The current vegetation status in Tinjil Island has to be determined, and further action is needed to support the long-tailed macaque population on the island. Thus, current data regarding vegetation on the island and its potential food is needed to assess the island's current condition. The information obtained from this study will be further used by the government and Primate Research Center IPB University to manage the semi-natural breeding facility.

MATERIALS AND METHODS

Study Area

The study was conducted on Tinjil Island, Banten Province, Indonesia. Located at 6°57′44″S and 105°47′0″E, the island is surrounded by the Indian Ocean with an area of approximately 5.65 km^2. The topography of the island is mostly flat, with no extreme height difference. Comprised of beach and lowland forest, the island is mainly covered by vegetation.

Long-tailed macaque was first introduced to the island in 1988, then the island became a semi-natural breeding facility managed by Primate Research Center IPB University. To simplify the process of observing the long-tailed macaques, multiple tracks have been made throughout the island. Each track was named after the acronym of a significant person who has contributed largely to the well-being of the island.

Procedures

This study has been approved by the Animal Care and Use Committee Protocol Assessment (IPB PRC-21-E006). The observation of vegetation was conducted on the tracks on Tinjil Island. Due to extreme obstacles and time-constraint, only six tracks could be observed (DS, HW, JK, RK, OS, and KO). Data were collected using square sampling plots (Figure 1) with the size of 20 m x 20 m for trees as the main plot, inside the main plot were square subplots consisting of 10 m x 10 m for poles, 5 m x 5 m for saplings, and 2 m x 2 m for seedlings.

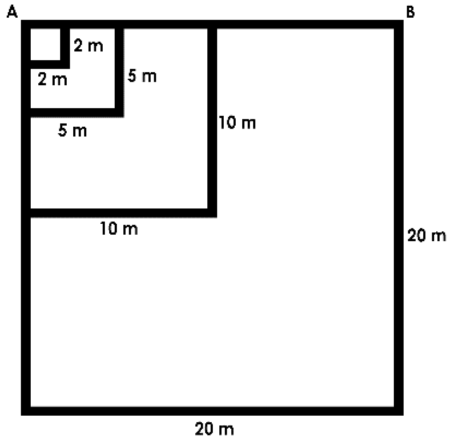

Figure 1. Square sampling plot of vegetation analysis, where A is the initial point, and A-B is parallel to the tracks.

Three main plots were placed on each track, resulting in 18 plots in total (Figure 2). The vegetation was classified into four levels: 1) Tree, woody species with a diameter above 20 cm, 2) Poles, woody species with a diameter between 10 cm-20 cm, 3) Saplings, small trees taller than 1.5 m and diameter less than 10 cm, and 4) Seedlings, small trees with height less than 1.5 m. The vegetation parameters, such as species, number of species, number of individuals per species, and the diameter of trees and poles, were collected. The name of the species was determined by identifying the characteristics of the vegetation and the local name, and then we cross-checked them using literature. Tree and pole heights were measured using a haga hypsometer. The crown width of trees and poles was measured with a meter tape using vertical crown projection to ground level. Tree and pole positions were written down by referring to the X and Y-axis of the main plot pointing to the same azimuth. Based on the notes taken on the field, the final forest profile diagram was constructed to scale. Observation of the environment and special findings are written when needed to be used as additional observation data.

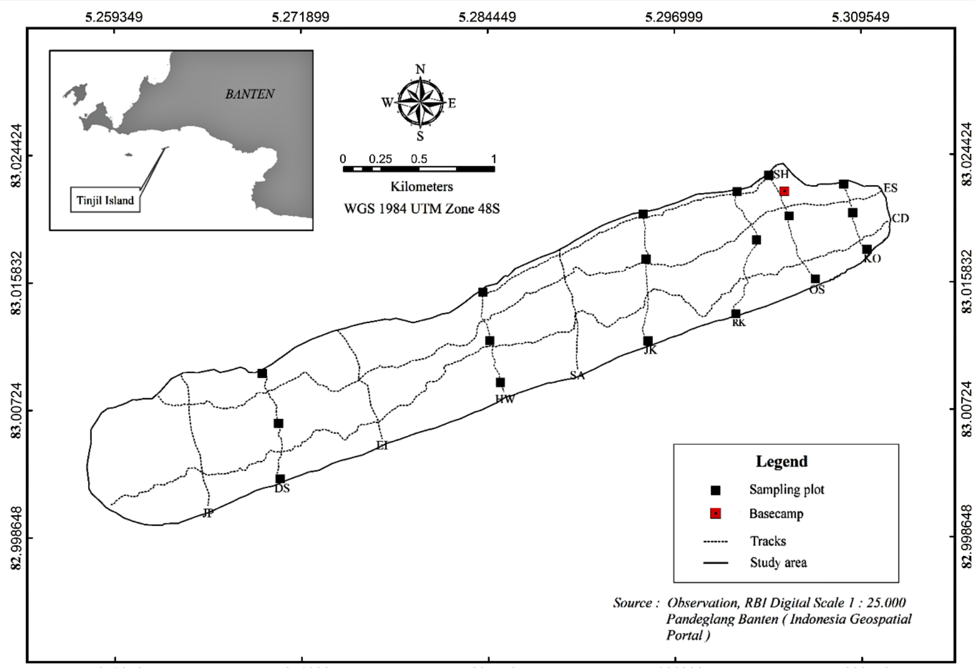

Figure 2. Sampling plot locations for vegetation analysis.

Data Analysis

Vegetation analysis was done to identify the composition of species on Tinjil Island. The dominancy of species was calculated using the Important Value Index (IVI). The following are the equations used to acquire the data (Kusmana 2017):

Species Density = Number of individuals per species/Area of plot

Relative Density = (Species Density/Total Species Density) x 100%

Species Frequency = Number of plots where the species was found/ Total number of plots

Relative Frequency = (Species Frequency/Total Species Frequency) x 100%

Species Dominance = Basal area of a species/Area of plot

Relative Dominance = (Species Dominance/Total Species Dominance) x 100%

Important Value Index (IVI) for trees and poles = Relative Density + Relative Frequency + Relative Dominance

Important Value Index (IVI) for seedlings and saplings = Relative Density + Relative Frequency

RESULTS AND DISCUSSION

Vegetation Composition

The Important Value Index (IVI) for each level of vegetation was calculated, resulting in different percentages of IVI. Hanjuang (*Dracaena elliptica*) dominated the seedlings with 29.35%, followed by Kampis (*Hernandia peltata*) with 18.73% and Kalapari (*Pongamia pinnata*) with 13.73%. Hanjuang (*Dracaena elliptica*) also dominated the saplings with 26.83%, followed by Pancal (*Syzygium antisepticum*) with 19.19% and Laban (*Vitex pubescens*) with 12.30%. The poles were dominated by Ki Cau (*Dolichandrone spathacea*) as high as 59.28%, while Waru (*Thespesia populnea*) and Ki Ciat (*Ficus septica*) dominated at 40.47% and 36.15%, respectively. Kampis (*Hernandia peltata*) dominated the trees with 39.28%, followed by Ki Ara (*Ficus glomerata*) with 35.56% and Ki Langir (*Dysoxylum amooroides*) with 28.70%.

The previous study conducted by Fadilah (2003) in 2001 concluded that there were no significant differences in vegetation dominancy for seedlings, saplings, and poles from 1991 until 2001, while there was a difference in vegetation dominancy at tree level from 1991 until 2001. Seventy-two species were found in 2001 (Fadilah 2003), while Santoso (1996) stated that the structure and composition of vegetation on Tinjil Island is an association of *Dysoxylum amooroides-Intsia amboinensis* (Table 1). Based on both previous studies, there is a significant difference in vegetation dominancy with the result obtained from this study.

The factor that may influence the result is the time difference of each study. The contributing factor that may influence the difference in results, from year 1996, 2001, and 2021 besides the time difference is 1) The survey area of each research may be different because there's no permanent area in which an inter-yearly study is conducted to observe the vegetation composition difference each year, 2) The skill of the researchers in every research is different and no training has been done before to make sure that the standard skillsets needed to conduct this research successfully is acquired by every person involved in the research, 3) The succession of forest in Tinjil Island that is influenced by many elements, such as weather, soil, and seed dispersal by wild animals living in the island. Since the interval from the previous study is 20 years, dynamism in vegetation is inevitable. Succession contributes to the change and promotes the progressive dominance of the most competitive species (Loidi

Table 1. Vegetation dominancy based on previous research.

Vegetation Level	2001*		1992**	
	Vegetation Level	IVI (%)	Vegetation Level	IVI (%)
Seedlings	*Piper retrofractum*	39.47	*Piper retrofractum*	37.85
	Dracaena elliptica	38.34	*Dracaena elliptica*	29.04
Saplings	*Antidesma montanum*	21.26	*Antidesma montanum*	35.24
			Alphania montana	20.63
Poles	Bamboo	27.91	*Gnetum gnemon*	38.13
	Gnetum gnemon	27.30	*Dysoxylum amooroides*	24.43
Trees	Cotton	30.14	*Dysoxylum amooroides*	49.32
			Intsia amboinensis	37.15
			Ficus glomerata	28.46

* Fadilah 2003; ** Santoso 1996

2017).

Potential Food

The number of species found on Tinjil Island (Table 2) is 61 species, comprised of mostly Moraceae (9.84%) and Fabaceae (9.84%), followed by Malvaceae (8.20%), Euphorbiaceae (4.92%), Myrtaceae (4.92%), and Anacardiaceae (4.92%). Moraceae is known to be the family of figs, breadfruit, and mulberry (Naira et al. 2013), and most of the species found in the Moraceae family were figs. Figs are considered keystone species because of their important role in frugivorous tropical vertebrates, especially primates and birds (Kinnaird & O'Brien 2005). The availability of figs becomes essential when there are limited fruits available because they provide enough energy for frugivores (Foster 1982; Leighton & Leighton 1983; Terborgh 1983; Lambert 1991; Lambert & Marshall 1991). The fact that Tinjil Island is 5.65 km^2 and is surrounded by the Indian Ocean means that there is a limited foraging area for the long-tailed macaques. The presence of figs can provide the energy for long-tailed macaques to survive when other fruits are scarce.

Fabaceae is the third-largest land plant family, with 730 genera and over 19,400 species (Rahman & Parvin 2015). Both families have vital roles in the diet of primates, where Moraceae was mainly consumed as fruit and Fabaceae as non-fruit parts (Lim et al. 2021), which shows the diversity of plant species that could provide necessary nutrients for the long-tailed macaques, which could sustain the livelihood of long-tailed macaques. Macaques are known to be able to survive anywhere and can exploit a variety of food sources (Karuppannan et al. 2014). The ability of long-tailed macaques to adapt and the availability of food resources can support the chance for population increase in the future.

Studies regarding potential food for long-tailed macaques in Tinjil Island were conducted in 1992 (Santoso 1996) and 2001 (Fadilah 2003). Based on previous studies, the number of species that are considered potential food for long-tailed macaques is presented in Table 3. Twenty-three species are considered as potential food where fruits, leaves, and flowers are the potentially eaten parts of the plant. Long-tailed macaques in Telaga Warna showed similar preferences where they consumed flowers, stems, fruits, and seeds (Nila et al. 2014), while long-tailed macaques in Cikakak Monkey Park ate plant parts such as leaves, fruits, seeds, and flowers (Hadi et al. 2007).

Vegetation Density

The diameter breast high (DBH) of poles and trees ranges from 0.11 m to 2.04 m while the height ranges from 1-50 m (Figure 3). The spatial area

Table 2. Plant species found on Tinjil Island.

No.	Family	Species	Local Name
1	Amaryllidaceae	*Crinum asiaticum* L.	Bakung
2	Anacardiaceae	*Gluta renghas* L.	Renghas
3	Anacardiaceae	Undetermined	Renghas Kuning
4	Anacardiaceae	*Semecarpus heterophylla* Blume	Renghas Putih
5	Apocynaceae	*Cerbera manghas* Boiteau, Pierre L	Bintaro
6	Apocynaceae	*Alstonia angustiloba* Miq.	Lame
7	Araceae	*Cocos nucifera* Linn.	Kelapa
8	Asparagaceae	*Dracaena elliptica* Thunb. & Dalm.	Hanjuang
9	Bignoniaceae	*Dolichandrone spathacea* (L.f.) Seem.	Ki Cau
10	Boraginaceae	*Heliotropium arboreum* (Blanco) Mabb.	Babakoan
11	Calophyllaceae	*Calophyllum inophyllum* Linn.	Nyamplung
12	Clusiaceae	*Gracinia celebica* Linn.	Manggu
13	Combretaceae	*Terminalia catappa* L.	Ketapang
14	Commelinaceae	*Commelina oblique* Ham.	Ki Sepet
15	Dilleniaceae	*Dillenia indica*	Simpeureum
16	Dipterocarpaceae	*Shorea javanica*	Meranti Putih
17	Euphorbiaceae	*Bridelia glauca* Blume.	Ki Hoe
18	Euphorbiaceae	*Macaranga tanarius*L.	Mara
19	Euphorbiaceae	*Drypetes sumatrana*	Taritih
20	Fabaceae	*Pongamia pinnata* (L.) Pierre.	Kalapari
21	Fabaceae	*Millettia sericea* (Vent.)Benth.	Kawao
22	Fabaceae	*Cynometra ramiflora* L.	Ki Batok
23	Fabaceae	*Leucaena leucocephala* (Lam.) de W.	Lamtoro
24	Fabaceae	*Intsia bijuga* (Colebr.) O.K.	Merbau
25	Fabaceae	*Albizia chinensis* (Osbeck.) Merr.	Sengon
26	Gnetaceae	*Gnetum gnemon* Linn.	Melinjo
27	Hernandiaceae	*Hernandia peltata* Meisn.	Kampis
28	Lamiaceae	*Vitex pubescens* Vahl.	Laban
29	Lauraceae	*Litsea cordata* (Jack) Hook.f.	Huru
30	Lauraceae	*Cinnamomum iners* Reinw. Ex Bl.	Ki Teja
31	Lecythidaceae	*Barringtonia asiatica* (L.) Kurz.	Butun
32	Lecythidaceae	*Barringtonia macrocarpa* Hassk.	Songgom
33	Malvaceae	*Pterospermum javanicum* Jungh.	Bayur
34	Malvaceae	*Heritiera littoralis* Aiton	Carlang
35	Malvaceae	*Microcos tomentosa* Sm.	Darewak
36	Malvaceae	*Ceiba pentandra* L.Gaertn.	Kapas
37	Malvaceae	*Thespesia populnea* L.	Waru
38	Marantaceae	*Donax canniformis* K.Schum.	Bangban (Bemban)
39	Melastomataceae	*Pternandra azurea* (DC.) Burkill.	Ki Besi/Tulang
40	Meliaceae	*Dysoxylum amooroides* Miq.	Ki Langir
41	Meliaceae	*Swietenia macrophylla* King.	Mahoni
42	Moraceae	*Ficus hispida* L.f.	Bisoro
43	Moraceae	*Ficus glomerata* Roxb.	Ki Ara
44	Moraceae	*Ficus septica* Burm. F.	Ki Ciat
45	Moraceae	*Ficus ampelas* Burm. F.	Ki Hampelas
46	Moraceae	*Ficus variegata* Blume.	Kopeng
47	Moraceae	*Artocarpus elasticus* Reinw. ex Blume.	Teureub
48	Myrtaceae	*Eugenia cymosa* Lamk.	Jambu Kopo
49	Myrtaceae	*Eugenia* sp.	Jambu Lalai
50	Myrtaceae	*Syzygium antisepticum* (Blume.) Merr.	Pancal
51	Pandanaceae	*Pandanus odorifer* (Forssk.) Kuntze.	Pandan laut
52	Phyllanthaceae	*Bischofia javanica* Blume.	Gadog
53	Phyllanthaceae	*Antidesma montanum* Blume.	Peuris
54	Primulaceae	*Ardisia humilis* Vahl.	Lampeni
55	Rubiaceae	*Morinda citrifolia* L.	Mengkudu
56	Rubiaceae	*Randia patula* (Horsf. ex Schult.)Miq.	Wareng
57	Sapindaceae	*Lepisanthes tetraphylla* (Vahl.) Radik.	Ki Lalayu
58	Sapotaceae	*Manilkara kauki* (L.) Dubard.	Sawo Kecik

Table 2. Contd.

No.	Family	Species	Local Name
59	Undetermined	Undetermined	Pangku
60	Undetermined	Undetermined	Paranje
61	Undetermined	Undetermined	Pitako

Table 3. Potential food and eaten parts.

No.	Family	Species	Local Name	Potentially Eaten Parts
1	Asparagaceae	*Dracaena elliptica* Thunb. & Dalm.	Hanjuang	Leaves, fruit
2	Bignoniaceae	*Dolichandrone spathacea* (L.f.) Seem.	Ki Cau	Fruit
3	Combretaceae	*Terminalia catappa* L.	Ketapang	Leaves, fruit
4	Fabaceae	*Pongamia pinnata* (L.) Pierre.	Kalapari	Fruit
5	Fabaceae	*Intsia bijuga* (Colebr.) O.K.	Merbau	Fruit
6	Gnetaceae	*Gnetum gnemon* Linn.	Melinjo	Leaves, fruit
7	Hernandiaceae	*Hernandia peltata* Meisn.	Kampis	Fruit
8	Lecythidaceae	*Barringtonia asiatica* (L.) Kurz.	Butun	Leaves
9	Lecythidaceae	*Barringtonia macrocarpa* Hassk.	Songgom	Fruit
10	Malvaceae	*Pterospermum javanicum* Jungh.	Bayur	Fruit
11	Malvaceae	*Thespesia populnea* L.	Waru	Leaves, flowers
12	Meliaceae	*Dysoxylum amooroides* Miq.	Ki Langir	Fruit
13	Moraceae	*Ficus hispida* L.f.	Bisoro	Fruit, leaves
14	Moraceae	*Ficus glomerata* Roxb.	Ki Ara	Fruit, leaves
15	Moraceae	*Ficus septica* Burm. F.	Ki Ciat	Leaves, fruit
16	Moraceae	*Ficus ampelas* Burm. F.	Ki Hampelas	Leaves, fruit
17	Moraceae	*Ficus variegata* Blume.	Kopeng	Fruit, leaves
18	Myrtaceae	*Eugenia cymosa* Lamk.	Jambu Kopo	Leaves, fruit
19	Myrtaceae	*Eugenia* sp.	Jambu Lalai	Fruit, leaves
20	Phyllanthaceae	*Antidesma montanum* Blume.	Peuris	Fruit
21	Primulaceae	*Ardisia humilis* Vahl.	Lampeni	Leaves
22	Rubiaceae	*Morinda citrifolia* L.	Mengkudu	Fruit
23	Sapotaceae	*Manilkara kauki* (L.) Dubard.	Sawo Kecik	Fruit

of trees usually used by long-tailed macaques on the island is between 4-20 m (Santoso 1996). The forest profile diagram was sketched roughly, showing that the vegetation is quite dense. The density of poles for some species from Santoso (1996) was 20.83 plants/ha (*Antidesma montanum*), 16.67 plants/ha (*Ficus ampelas*), 12.50 plants/ha (*Terminalia catappa*), 12.50 plants/ha (*Ficus variegata*), 8.33 plants/ha (*Ficus glomerata*), and 4.17 plants/ha (*Barringtonia asiatica*). The density of trees in 1992 (Santoso 1996) for some species were 9.38 plants/ha (*Ficus glomerata*), 3.13 plants/ha (*Ficus variegata*), 3.13 plants/ha (*Terminalia catappa*), 3.13 plants/ha (*Barringtonia macrocarpa*), 2.08 plants/ha (*Ficus ampelas*), and 1.04 plants/ha (*Barringtonia asiatica* and *Eugenia cymosa*).

Additional Observation

Besides the four levels of vegetation mentioned earlier, there were other plants found on the island that weren't included in the calculation. Those plants were pandan laut (*Pandanus odorifer* (Forssk.) Kuntze.), bakung (*Crinum asiaticum* L.), and kelapa (*Cocos nucifera* Linn.). Ninety-seven *Pandanus odorifer* were found during the observation, while 64 individuals of *Crinum asiaticum* were found and only one individual of *Cocos nucifera* was found during the sampling. Those plants were found near the beach. Goeltenboth et al. (2006) stated that the species diversity in beach forests is usually low with only scarce representatives of conifers, lianas, and plants showing cauliflory, with abundant Pandanus sp. as well as epiphytes. *Cocos nucifera* develops a fruit or nut that can withstand seawater

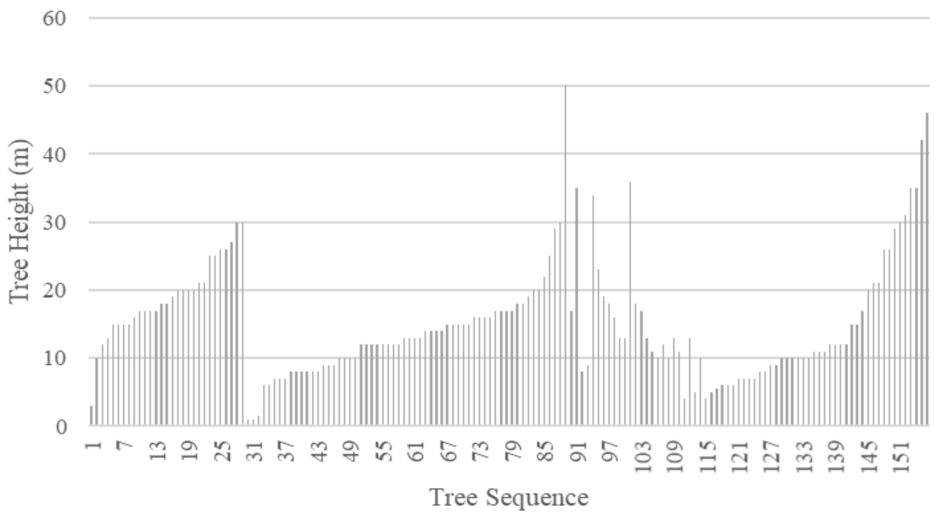

Figure 3. Tree height in meters (Y-axis) and tree sequence based on the observation (X-axis).

for months (Goeltenboth et al. 2006) which explains why they are only found on the beach and not in the lowland forest. Based on the information obtained from the local guides, long-tailed macaques have been spotted consuming young *Pandanus odorifer* when other food might seem unavailable. Long-tailed macaques also drink water from the tips of the plants, where water from the rain was unintentionally collected by the plants. The flexible drinking behavior of long-tailed macaques has been spotted in the Northeast of Thailand (Schurer et al. 2019), in Malaysia (Hambali et al. 2012; Hassim et al. 2018), and in Indonesia (Nila et al. 2014).

CONCLUSION

Tinjil Island can be considered an isolated location for long-tailed macaques where the potential for them to naturally move outside the island is almost impossible, implicating the limited foraging area for the long-tailed macaques. Based on the results of this research, the presence of figs can provide the energy for long-tailed macaques to survive when other fruits are scarce. The result shows the diversity of plant species in Tinjil Island that could provide necessary nutrients for the long-tailed macaques, which could sustain their livelihood by supporting their ability to survive and reproduce. Considering that macaques can survive anywhere and exploit various food sources, the ability of long-tailed macaques to adapt and the availability of food resources can support the chance for population increase in the future. Future studies regarding the population and habitat use of long-tailed macaques in Tinjil island might be necessary as part of a bi-annual monitoring plan between the stakeholders involved in the maintenance of the island.

AUTHORS CONTRIBUTION

D.P. reviewed the manuscript, H.I.S. collected and analysed the data and wrote the manuscript, S.T. collected the data, T.LA. created the map, E.I. reviewed the manuscript, H.S.D. supported the research.

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CONFLICT OF INTEREST

There's no conflict of interest regarding the research or the research funding.

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