Patch dynamics in the Javan Hawk-Eagle (Nisaetus bartelsi) habitat of East Java

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Abstract. Javan Hawk-Eagle (JHE, Nisaetus bartelsi) is an endemic species in Java Island and an important biological indicator of ecosystem health. The government has issued regulations to protect this species and increase the population by 10% from 2015 until 2019. East Java has the largest JHE potential habitat in Java Island based on a previous study using satellite images of 2002. Therefore, the current habitat distribution of JHE’s is essential for getting knowledge about patch dynamics in JHE’s habitat. This study’s objective was to analyze patch dynamics of JHE’s habitat from 2002 until 2015 and validate habitat distribution. Previously predicted probability map (2002) of JHE’s were updated using Landsat 8 satellite images of 2015 and was validated through ground-truth checked. Results showed that the distribution of JHE’s habitat after validation is 28 patches, which is covered 4766.26 km². The dynamics that occur in the JHE’s patch are patch lost (1 patch), patch area decreased (5 patches), patch area increased (13 patches), new patch (4 patches), and merged patch. After validation, there are six newly identified patches, and one patch area increased. The total area increased by 2156.14 km² or 82.61% of the total area occupied by JHE’s in 2002. About 39.89% of total habitat patches were located inside the protected area. This study recommends continuing monitoring activities on habitat patches, including potential habitat patches in lowland areas, and proposing conservation activities based on habitat patch dynamics that occurred from 2002 to 2015.

Keywords: habitat distribution, habitat validation, patch, Javan Hawk-Eagle

1. Introduction
Javan Hawk-Eagle (Nisaetus bartelsi) is an endemic raptor in Java Island, an indicator species for natural landscapes due to their role as top-level predators in the food chain [1]. JHE is one of the non-migratory birds of prey with a narrow distribution so that the function of ecosystem indicators is only on a local scale. In its natural habitat, JHE plays a role in controlling the animals’ population that become its prey. This bird is susceptible to environmental changes that cause its population to be disturbed if the environment’s quality is disturbed [2]. The small population size coupled with the destruction and fragmentation of natural forests and illegal trade and hunting caused JHE by the IUCN to be granted rare status [3,4]. The Director of Forest Protection and Nature Conservation (PHKA), through the Decree of the Director-General of Layoffs No. 200/IV/KKH/2015 to establish JHE as an endangered species that is prioritized to increase its population by 10% in 2015-2019 following biological conditions and habitat availability—supported by Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.58/Menhut-II/2013 on Strategy and Action Plan of JHE Conservation (Spizaetus bartelsi) in 2013-2022.

East Java is the largest location on the island of Java, which is a habitat for JHE because of the high quality of its natural landscape [5]. Based on the probability model of habitat suitability of JHE using satellite imagery in 2002 conducted [5], there are an estimated 189 pairs of JHE in East Java. Currently, there are several locations of JHE encounters outside of the existing model. Based on several locations where there is the presence of JHE, it
assumes that the population of this species in Java is increasing, and its distribution is also widespread, especially in East Java [6]. Hence, it is necessary to evaluate the current distribution of JHE’s habitat in East Java.

This study aimed to analyze the patch dynamics in the current condition of the JHE habitat distribution using Landsat 8 imagery in 2015 compared with previous research using 2002 satellite imageries [1,5]. This study also validates the patch occupancy by JHE through ground truth-checked activities to determine the actual JHE’s habitat distribution. The results of current conditions, dynamics, and validation of habitat distribution are used to provide recommendations for JHE’s habitat management based on patch dynamics in East Java.

2. Method of analysis

2.1. The study area
This study focused on the East Java province (figure 1), and Madura Island was excluded from this research. The area of 42,406 km² with a geographical location of 111.0°-114.3 BT and 7.0°-8.30°LS.

![Study Area: East Java province (Source: Landsat 8 OLI/TIRS)](image)

2.2. Analysis
At this stage, data updates are carried out to produce the current conditions of JHE habitat distribution using the habitat suitability model of the JHE’s that has been formulated previously [1] using logistic regression model as follows:

\[
P_i = \frac{1}{1 + \exp[-(0.3804SLP + 0.0148ELV - 0.1229NDVI - 19.6518)]}
\]
Slope (SLP) and Elevation (ELV) derived from the ASTER GDEM data of 2015. Normalized Difference Vegetation Index (NDVI) obtained from Landsat 8 OLI/TIRS scene (path/row) 119/66, 119/65, 118/66, 118/65, 117/66, 117/65 taken in May-June 2015. Furthermore, a habitat suitability map is obtained by using a modeler in ERDAS Imagine 2014 software. The habitat suitability model contains probability values ranging from 0 (not suitable) to 1 (suitable). In this process, the threshold value used is 0.5; it is intended to identify a habitat patch. This stage’s result is the current habitat distribution of the JHE. All environmental variables used in this study have a spatial resolution of 30 m. The current habitat distribution has re-sampled to a resolution of 250m to compare with the previous habitat distribution of 2002.

Two types of errors identify at the validation stage, omission error, where the model is predicted as an inappropriate habitat. Still, the species can be found at that location, and a commission error in the model is predicted as suitable habitat, but the species cannot be found there [7]. Data of JHE encounters from local researchers, and related agency reports are used to validate the current habitat conditions of JHE. Then ground truth-checked activities are carried out for further validation and observed the land cover in the patch area and the habitat threats. Based on the validation results, the condition of distribution of JHE’s habitat is obtained. Map of habitat distribution of JHE is then superimposed (overlay) with a map of land cover and protected areas.

3. Results and discussions
The update of the probability model of the suitability of JHE’s habitat in East Java resulted in 22 patches in 2015. The patch area varies from 4.01 km² to 936.95 km², with a total patch area of JHE habitat in East Java of 3744.13 km². Compared with 2002, the total area of JHE’s habitat patch in East Java has increased by 1134.01 km² (43.45%). The dynamics that occur in the JHE’s patch are patch lost (1 patch), patch area decreased (5 patches), patch area increased (13 patches), new patch (4 patches), and merged patch (Table 1, Figure 2).

| Patch Number | Location Name                     | Patch Area (km²) | Change (km²) | Patch Dynamics      |
|--------------|-----------------------------------|------------------|--------------|---------------------|
| 1            | Mt. Lawu                          | 194.32           | 271.22       | 76.90               |
|              |                                   |                  |              | Patch area increased|
| 2            | Mt. Liman - Wilis                 | 221.01           | 347.06       | 126.05              |
|              |                                   |                  |              | Patch area increased|
| 3            | Namangan                          | 4.70             | 21.36        | 16.66               |
|              |                                   |                  |              | Patch area increased|
| 4            | Badengan                          | 9.47             | 6.71         | -2.76               |
|              |                                   |                  |              | Patch area decreased|
| 5            | Slangu                            | 4.72             | 0            | 0.00                |
|              |                                   |                  |              | Patch lost          |
| 6            | Sambit                            | 4.61             | 4.01         | -0.60               |
|              |                                   |                  |              | Patch area decreased|
| 7            | Karangan                          | 12.31            | 7.18         | -5.13               |
|              |                                   |                  |              | Patch area decreased|
| 8            | Mt. Kelud                         | 35.73            | 52.11        | 16.38               |
|              |                                   |                  |              | Patch area increased|
| 9            | Kasembon                          | 5.92             | 7.73         | 1.81                |
|              |                                   |                  |              | Patch area increased|
| 10           | Mt. Kawi - Arjuna - Welirang      | 472.13           | 658.34       | 186.21              |
|              |                                   |                  |              | Patch area increased|
| 11           | Mt. Penanggungan                  | 12.25            | 12.57        | 0.32                |
|              |                                   |                  |              | Patch area increased|
| 12           | Tutor*                            | 15.75            | 0            | 0.00                |
|              |                                   |                  |              | Patch merged to 13  |
| 13           | Bromo Tengger Semeru National Park*| 663.65          | 936.95       | 273.30              |
|              |                                   |                  |              | Patch area increased|
| 14           | Candipuro                         | 7.67             | 5.22         | -2.45               |
|              |                                   |                  |              | Patch area decreased|
| 15           | Tiris                             | 13.49            | 12.71        | -0.78               |
|              |                                   |                  |              | Patch area decreased|
| 16           | Pakuniran                         | 5.02             | 6.72         | 1.70                |
|              |                                   |                  |              | Patch area increased|
| 17           | Yang Plateau - Mt. Argapura       | 435.94           | 587.86       | 151.92              |
|              |                                   |                  |              | Patch area increased|
| 18           | Tegalampel                        | 6.24             | 18.99        | 12.75               |
|              |                                   |                  |              | Patch area increased|
### Patch Dynamics from 2002 to 2015 in East Java

| Patch Number | Location Name                     | Patch Area (km²) | Change (km²) | Patch Dynamics                  |
|--------------|-----------------------------------|------------------|--------------|---------------------------------|
| 19           | Meru Betiri National Park         | 5.16 19.35       | 14.19        | Patch area increased            |
| 20           | Alabang*                         | 5.60 0           | 0            | Patch merged to 22              |
| 21           | Arjuna*                          | 8.61 0           | 0            | Patch merged to 22              |
| 22           | Mt. Raung – Ijen*                | 465.82 722.19    | 256.37       | Patch area increased            |
| 23           | Bandar                            | 0.00 15.75       | 15.75        | New patch                       |
| 24           | Pule                              | 0.00 7.26        | 7.26         | New patch                       |
| 25           | Bunga                             | 0.00 9.31        | 9.31         | New patch                       |
| 26           | Mt. Baluran                       | 0.00 13.53       | 13.53        | New patch                       |
| Total        |                                   | 2610.12 3744.13  |              |                                 |

Note: The marked location (*) is habitat merged

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**Figure 2** Patch dynamics from 2002 to 2015 in East Java
Among the three environmental variables (SLP, ELV, NDVI) in the predicted probability model, NDVI becomes a factor that tends to make the dynamic patch results. The slope and elevation tend not to change unless there is a natural disaster that can change the landform. This study's NDVI was transformed from MODIS NDVI 250 m [5] to Landsat 8, 30m resolution. Differences in the resolution of imagery are thought to be one influencer for increasing suitable habitat areas in 2015. Higher image resolution used will produce a more precise calculation of NDVI [8]. Meanwhile, environmental quality changes are suspected of causing the natural forest area to increase in Java Island, especially in protected areas.

Ground truth-check was carried out at nine locations: Mount Kelud, Mount Budeg, Jolosutro Beach, Ngeliyep Beach, Kondang Merak, Sempu Island Nature Reserve, Mount Arjuna-Wellirang, Baluran National Park, and Alas Purwo National Park. The JHE was found in two patches from ground truth-checked (patch 2, patch 28), and the JHE nests were found in patches 28 and 30. All validation patches are located in the southern part of the study site (Figure 3).

![Figure 3 Patch validation sites](image)

Based on the validation results, six newly identified patches (patch 27 to patch 32) and one patch area increased (patch 19). The total area of the habitat patches increased by 1022.13 km² after the validation. The total number of patches after validation became 28 patches, which is covered 4766.26 km². The total area increased after validation became 2156.14 km² or 82.61% of the total area occupied by JHE’s in 2002 (Table 2) (Figure 4). At the validation stage, 15 patches (48.39%) were detected by the model, ten patches (32.26%) are commission errors, and six patches (19.35%) are omission errors. Commission error is an unavoidable error because JHE not occupies all potential habitats. Therefore, commission errors are considered patches that can become the habitat of JHE in this study. So that the patch detected correctly has the potential as a habitat of JHE is 80.65%.

JHE is known can live from 0 to 3000 meters above sea level [9]. The patch omission error sites are located at an altitude of 0-500 meters above sea level and characterize a tropical lowland rainforest [10]. JHE is also explicitly referred to as slope specialist because
of its dependence on varied topography [11],[12]. This steep slope is related to protection against humans or other predators [1]. However, ground truth-check results show that the nest trees in Alas Purwo National Park (patch 29) are on a flat area, and shrubs overgrow the surroundings and are located below 100m above sea level. The previous probability model of JHE was developed based on JHE nest in Mount Gede Pangrango National Park in West Java, a highland tropical rainforest ecosystem [1]. Alas Purwo National Park (patch 29) is an omission error in the previous study [5]. The probability model of JHE's did not predict Alas Purwo National Park as a potential habitat for JHE. Therefore, the model does not correctly identify the habitat of JHE in the lowlands. This study recommends conducting intensive observations on the potential patches of JHE in lowland forests in East Java and Central Java, and West Java.

Table 2 Habitat distribution validation in 2015

| Patch Number | Location Name                      | Area (km²) | Description               |
|--------------|------------------------------------|------------|---------------------------|
| 1            | Mt. Lawu                           | 271.22     | √                         |
| 2            | Mt. Liman - Wilis                  | 347.06     | √                         |
| 3            | Namangan                           | 21.36      | Commission Error          |
| 4            | Badengan                           | 6.71       | Commission Error          |
| 5            | Slangu                             | -          | Patch lost                |
| 6            | Sambit                             | 4.01       | Commission Error          |
| 7            | Karangan                           | 7.18       | Commission Error          |
| 8            | Mt. Kelud                           | 52.11      | √                         |
| 9            | Kasembon                           | 7.73       | Commission Error          |
| 10           | Mt. Kawi - Arjuna - Welirang       | 658.34     | √                         |
| 11           | Mt. Penanggungan                   | 12.57      | √                         |
| 12           | Tutor                              | -          | Merged to patch 13         |
| 13           | Bromo Tengger Semeru National      | 936.95     | √                         |
| 14           | Candipuro                          | 5.22       | Commission Error          |
| 15           | Tiris                              | 12.71      | Commission Error          |
| 16           | Pakuniran                          | 6.72       | √                         |
| 17           | Yang Plateu - Mt. Argapura         | 587.86     | √                         |
| 18           | Tegalampel                         | 18.99      | √                         |
| 19           | Meru Betri National Park*          | 19.35      | √                         |
| 20           | Alabang                            | Merged to patch 22 |
| 21           | Arjuna                             | Merged to patch 22 |
| 22           | Mt. Raung - Ijen                   | 722.19     | √                         |
| 23           | Bandar                             | 15.75      | Commission Error          |
| 24           | Pule                               | 7.26       | Commission Error          |
| 25           | Bunga                              | 9.31       | Commission Error          |
| 26           | Mt. Baluran                         | 13.53      | √                         |
| 27           | Sangria Beach                      | -          | 20.72                     |
| 28           | Kondang Merak –Ngeliyep Beach      | -          | 25.98                     |
| 29           | Alas Purwo National Park            | -          | 437.84                    |
| 30           | Sempu Island Nature Reserve        | -          | 9.87                      |
| 31           | Mt. Budeg                          | -          | 9.49                      |
| 32           | Jolosutro Beach                    | -          | 10.02                     |
| Total        |                                    | 3744.13    | 4766.26                   |

Note: - The marked location (*) is a patch that has increased in one area
- (√) is a patch detected by the model
Based on the overlay results with a map of protected areas, there are ten patches (1901.08 km² or 39.89% of JHE area) located inside the protected areas. Ten patches of JHE’s habitat in protected areas are Mount Lawu (patch 1), Mount Liman-Wilis (patch 2), Mount Kawi-Arjuna-Welirang (patch 10), Bromo Tengger Semeru National Park (patch 13), Yang Plateau-Mount Argapura (patch 17), Meru Betiri National Park (patch 19), Mount Raung-Ijen (patch 22), Mount Baluran (patch 26), Alas Purwo National Park (patch 29), and Sempu Island Nature Reserve (patch 30). The natural tourism area contained in JHE’s habitat patch area, Mount Lawu (patch 1), Mount Kawi-Arjuna-Welirang (patch 10), Mount Penanggungan (patch 11), Bromo Tengger Semeru National Park (patch 13), and Kondang Merak-Ngeliyep Beach (patch 28). JHE’s habitat patches outside the protected area as much as 18 patches with an area of 2865.18 km² or 60.11%.

The results showed that the habitat patches are dominantly located in forests (71,62%) and followed by plantations and shrubs. The forest land, especially natural forests, is the nesting place of JHE, while other land covers, i.e., plantations, shrubs, agricultural areas, become essential hunting areas for JHE. A large and healthy forest can provide a home range area for JHE [13], including natural forests and secondary forests [14]. The forest can provide the prey for JH e.g. reptiles, small mammals (bats, squirrels, rats, infant) [13]. Characteristics of JHE’s nest tree in lowland forest, which is found in this study and Ujung Kulon National Park [15], have a height between 25-50 m with a diameter between 60-230 cm and have the tree architecture of “rauh.” The tree canopy should be open with horizontal branches and have a broad view.

This study recommends continuing monitoring activities on habitat patches, including potential habitat patches in lowland areas, and proposing conservation activities based on
habitat patch dynamics that occur especially for the patch area decrease over the 2002-2015 period. Perform landscape restoration on patch habitat lost and preserving landscapes on patches that have decreased of area.

4. Conclusion

This study successfully updated the distribution of JHE’s habitat patches based on 2015 data and validated them through ground truth-checked activities in 2016. East Java has 22 patches with a total patch area of JHE’s habitat in East Java of 3744.13 km² or an increase of 1134.01 km² (43.45%) of the total patch area the JHE’s habitat in 2002. The dynamics that occur in the JHE’s patch are patch lost (1 patch), patch area decreased (5 patches), patch area increased (13 patches), new patch (4 patches), and merged patch. After validation, the number of patches becomes 28 patches. There are six newly identified patches, and one patch has increased area (patch 19). The total area of JHE’s patch habitat in 2015 after validation became 4766.26 km², where 2156.14 km² increased or 82.61% of the total area occupied by JHE’s in 2002. The patch detected correctly has the potential as a habitat of JHE is 80.65%. This study’s results will be useful for habitat management activities based on patch dynamic occurred from 2002-2015.

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