**From pets to plates: Network analysis of trafficking in tortoises and freshwater turtles representing different types of demand**

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Supplementary Table 1 Description of network terms.

**Term Description Further details/references**

Node Nodes represent locations at districts-scale for locations within India or city-scale

 for locations outside India

Links/Edges Directed connections between nodes in the network

Network size Number of nodes in the network

Link density Proportion of number of observed links to the number of possible links. In directed networks, possible number of

 Link density ranges from 0 (no links) to 1, where all possible links links is equal to N\*(N-1)

 between nodes in the network are observed. (Wasserman & Faust, 1994)

Degree Freeman, 1978

 In-degree Number of incoming trafficking links directly associated with a node

 Out-degree Number of outgoing trafficking links directly associated with a node

 Total-degree Total number of trafficking links directly associated with a node

 Mean-degree Average number of trafficking links directly associated with a node

 in the network

Strength

 In-strength Number of individuals (volume) of tortoises/hard-shell turtles or

 soft-shell turtles being trafficked into a node

 Out-strength Number of individuals (volume) of tortoises/hard-shell turtles or

 soft-shell turtles being trafficked out of a node

Betweenness Number of times a node falls along the shortest possible paths $Betweenness\_{v}=\sum\_{i}^{}g\_{ivj}/g\_{ij}$

 between other nodes in the network. Nodes with high betweenness where, betweennessv represents betweenness are considered to have greater influence or control over the flow of node v, givj: number of shortest paths of trade within the network between nodes i and j containing node v and

 gij: total number of shortest paths

 between nodes i and j (Freeman, 1978)

Centralization Centralization measures the variation in centrality score of individual $Centralization=\frac{\sum\_{i=1}^{n} [C\_{max}-C\_{i}]}{max\sum\_{i=1}^{n} [C\_{max}-C\_{i}]}$

 nodes to the maximum observed centrality score in the network. $ $

 Values of this score ranges from 0 (where the centrality scores of

 all nodes are equal) to 1 (where only a single node with the maximum where, Cmax is the maximum observed

 centrality completely dominates the network with respect to centrality) centrality score in the network and Ci is the

 centrality score of node i, the denominator

 is the theoretical maximum possible sum of

 differences in node centrality and n refers to

 the number of nodes in the network

 (Freeman, 1978)

Fragmentation index Fragmentation measures the reciprocal sum of distances between $Fragmentation=1-(\frac{2\sum\_{i>j}^{}\frac{1}{dij}}{n\left(n-1\right)})$

 remaining nodes in the network, after optimal set of nodes called where, dij refers to the distance between

 ‘key players’ are removed. Values of this index range from 0 remaining nodes in the network after

 (completely connected network) to 1 (networks composed entirely of key players are removed. n refers to

 isolated nodes). number of nodes in the network

 (Borgatti, 2006)

Supplementary Table 2 Of the 75 unique trafficking links/routes in the tortoise/hard-shell turtle trafficking network, 28 % (n = 21) were traversed using rail, 24 % (n = 18) using air, 22.67 % (n = 17) using road and 2.67 % (n = 2) using sea. Mode of transportation for 22.67 % of routes (n = 17) were unknown. The table summarizes the unique trafficking links recorded in this network and the corresponding mode of transportation used, along with species seized along that link/route.

|  |  |  |  |
| --- | --- | --- | --- |
| from | to | Transport | Documented species |
| Agra | Chennai | Road | Red-crowned roofed turtle, Spotted black terrapin |
| Agra | Delhi | Road | *Batagur* sp. |
| Agra | Tirupati | Rail | Red-crowned roofed turtle |
| Allahabad | Unspecified-West Bengal  | Rail | Spotted black terrapin |
| Allahabad | Rohtas | Rail | Indian star tortoise |
| Anantapur | Mumbai | Rail | Indian star tortoise |
| Anantapur | Krishna | Unknown | Indian star tortoise |
| Anantapur | Pune | Unknown | Indian star tortoise |
| Bangkok | Macau | Air | Spotted black terrapin |
| Bareilly | Kolkata | Road | Tricarinate hill turtle |
| Bengaluru | Chennai | Road | Indian star tortoise, Tricarinate hill turtle, Indian tent turtle |
| Bengaluru | Thane | Rail | Indian star tortoise |
| Bengaluru | Kuala Lumpur | Air | Indian star tortoise , Spotted black terrapin  |
| Chennai | Bangkok | Air | Indian star tortoise, Spotted black terrapin |
| Chennai | Unspecified-China  | Air | Indian star tortoise, Tricarinate hill turtle, Indian tent turtle |
| Chennai | Kuala Lumpur | Air | Indian star tortoise |
| Chennai | Howrah | Rail | Indian star tortoise |
| Chennai | Unspecified-Malaysia  | Air | Indian star tortoise |
| Chennai | Madurai | Unknown | Indian star tortoise |
| Chennai | Bengaluru | Unknown | Indian star tortoise , Spotted black terrapin  |
| Chennai | Colombo | Air | Spotted black terrapin |
| Chennai | Surat | Rail | Indian star tortoise |
| Chennai | Delhi | Rail | Indian star tortoise |
| Chennai | Thoothukudi | Road | Red-crowned roofed turtle, Spotted black terrapin |
| Chikkaballapur | Delhi | Unknown | Indian star tortoise |
| Chittoor | Chikkaballapur | Road | Indian star tortoise |
| Coimbatore | Thiruvananthapuram | Rail | Indian star tortoise |
| Colombo | Kuala Lumpur | Air | Spotted black terrapin |
| Delhi | Dimapur | Rail | Indian star tortoise |
| Delhi | Meerut | Unknown | Indian star tortoise |
| Dewas | Indore | Unknown | Indian tent turtle  |
| Etawah | Udham Singh Nagar | Road | Spotted black terrapin |
| Howrah | Unspecified-Bangladesh  | Unknown | Indian star tortoise |
| Howrah | North 24 Parganas | Road | Indian star tortoise |
| Jhansi | Nagpur | Rail  | Spotted black terrapin |
| Jhansi | Mumbai | Rail | Indian star tortoise |
| Kanpur Nagar | Kolkata | Rail | Indian tent turtle, Indian roofed turtle  |
| Khordha | Unspecified-Bangladesh  | Unknown | Indian star tortoise |
| Kochi | Kuala Lumpur | Air | Indian star tortoise, Spotted black terrapin |
| Kolkata | Bangkok | Air | Spotted black terrapin |
| Kolkata | Gaya | Unknown | Indian star tortoise |
| Kolkata | Chennai | Sea | Spotted black terrapin |
| Krishna | Ahmedabad | Rail | Indian star tortoise |
| Krishna | Khordha | Rail | Indian star tortoise |
| Kuala Lumpur | Jakarta | Unknown | Indian star tortoise |
| Kuala Lumpur | Phuket | Unknown | Spotted black terrapin |
| Lucknow | Firozabad | Road | *Pangshura* sp. |
| Macau | Hong Kong | Unknown | Spotted black terrapin |
| Madurai | Unspecified-Sri Lanka  | Air | Indian star tortoise |
| Mumbai | Kuala Lumpur | Air | Spotted black terrapin |
| Mumbai | Dubai | Air | Indian star tortoise , Spotted black terrapin  |
| Mumbai | Bangkok | Air | Spotted black terrapin , Tricarinate hill turtle , Indian eyed turtle, *Pangshura* sp.  |
| Mumbai | Ahmedabad | Unknown | Indian star tortoise |
| Mumbai | Vadodara | Unknown | Indian star tortoise |
| Nagpur | Tirupati | Rail  | Spotted black terrapin |
| North 24 Parganas | Unspecified-Bangladesh  | Road | Indian star tortoise, Spotted black terrapin |
| Patna | Kolkata | Rail | *Pangshura* sp. |
| Pune | Mumbai | Road | Indian star tortoise |
| Raebareli | Varanasi | Road | *Pangshura* sp. |
| Rohtas | Paschim Burdwan | Rail | Indian star tortoise |
| Sultanpur | Allahabad | Unknown | Spotted black terrapin |
| Thiruvananthapuram | Unspecified-Sri Lanka  | Air | Indian star tortoise |
| Thoothukudi | Unspecified-Sri Lanka  | Sea | Red-crowned roofed turtle, Spotted black terrapin |
| Tiruchirappalli | Bangkok | Air | Spotted black terrapin |
| Unspecified-Andhra Pradesh  | Chennai | Road | Indian star tortoise |
| Unspecified-Andhra Pradesh  | Chikkaballapur | Unknown | Indian star tortoise |
| Unspecified-Karnataka  | Kozhikode | Road | Indian star tortoise |
| Unspecified-Sri Lanka  | Bangkok | Air | Indian star tortoise |
| Unspecified-Sri Lanka  | Kuala Lumpur | Air | Indian star tortoise |
| Unspecified-Uttar Pradesh  | Mumbai | Rail | Indian tent turtle |
| Unspecified-West Bengal  | Jessore | Road | Indian star tortoise, Tricarinate hill turtle, Spotted black terrapin  |
| Unspecified-West Bengal  | Dhaka | Road | Spotted black terrapin |
| Varanasi | Patna | Rail | *Pangshura* sp. |
| Varanasi | Unspecified-West Bengal  | Road | *Pangshura* sp. |
| Visakhapatnam | Howrah | Rail | Indian star tortoise |
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1We attempted to confirm the species for all seizures through cross-verification with data from Mendiratta et al., 2017 and expert help. However, given that tortoises, hard-shell and soft-shell turtles are not easily distinguishable in the field and are not often identified to the species level by the law enforcement agencies in India or reported to the species level in the media, there may have been additional species trafficked along these routes that are not recorded here.

SUPPLEMENTARY TABLE 3 Of the 69 unique trafficking links/routes in the soft-shell turtle trafficking network, 39.13 % (n = 27) were traversed using rail, 37.68 % (n = 26) using road and 1.45 % (n = 1) using air. Mode of transportation for 23.19 % of routes (n = 16) were unknown. Soft-shell turtle species seized along these routes, comprised Indian flapshell turtle, Indian softshell turtle, Indian peacock softshell turtle and Indian narrow-headed softshell turtle. The table summarizes the unique trafficking links recorded in this network, and the corresponding mode of transportation used.

|  |  |  |
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| From  | To | Mode of transportation |
| Agra | Delhi | Road |
| Allahabad | Unspecified-West Bengal | Rail |
| Ambedkar Nagar | Kolkata | Road |
| Amethi | Kolkata | Unknown |
| Amethi | Dhanbad | Road |
| Auraiya | Udham Singh Nagar | Road |
| Balasore | Unspecified-West Bengal  | Rail |
| Balasore | Paschim Medinipur | Rail |
| Bangkok | Macau | Air |
| Bareilly | Kolkata | Unknown |
| Bareilly | Unspecified-West Bengal  | Unknown |
| Chandauli | Kolkata | Rail |
| Cuttack | Kolkata | Unknown |
| Dhanbad | Hooghly | Rail |
| Dhanbad | Unspecified-West Bengal  | Road |
| Dumka | Unspecified-West Bengal  | Road |
| East Godavari | Malkangiri | Road |
| Etawah | Udham Singh Nagar | Road |
| Faizabad | Jaunpur | Rail |
| Fatehpur | Unspecified-West Bengal  | Road |
| Gonda | Unspecified-Bihar  | Unknown |
| Hooghly | Howrah | Rail |
| Howrah | North 24 Parganas | Road |
| Jaunpur | Varanasi | Rail |
| Jaunpur | Malda | Rail |
| Jaunpur | Unspecified-West Bengal  | Rail |
| Jaunpur | Dhanbad | Rail |
| Khordha | Kolkata | Rail |
| Khordha | Howrah | Road |
| Kolkata | Unspecified-Bangladesh  | Unknown |
| Krishna | Unspecified-Odisha  | Unknown |
| Lucknow | Nadia | Road |
| Lucknow | Kolkata | Road |
| Macau | Hong Kong | Unknown |
| Mainpuri | Kolkata | Unknown |
| Nadia | North 24 Parganas | Road |
| North 24 Parganas | Unspecified-Bangladesh  | Road |
| North 24 Parganas | Kolkata | Unknown |
| Paschim Bardhaman | Hooghly | Unknown |
| Patna | Kolkata | Rail |
| Patna | Howrah | Rail |
| Pratapgarh | Kolkata | Rail |
| Pratapgarh | Malda | Rail |
| Pratapgarh | Howrah | Rail |
| Pratapgarh | Unspecified-West Bengal  | Rail |
| Purba Bardhaman | Kolkata | Road |
| Puri | Khordha | Rail |
| Puri | Balasore | Rail |
| Raebareli | Varanasi | Road |
| Sahibganj | Malda | Rail |
| Sambalpur | Kolkata | Unknown |
| Sultanpur | Allahabad | Unknown |
| Sultanpur | Chandauli | Road |
| Sultanpur | Purba Bardhaman | Road |
| Sultanpur | Patna | Rail |
| Udham Singh Nagar | Nainital | Road |
| Unspecified-Andhra Pradesh  | North 24 Parganas | Road |
| Unspecified-Bangladesh  | West Tripura | Road |
| Unspecified-Odisha  | Unspecified-Bihar  | Unknown |
| Unspecified-Rajasthan  | Delhi | Road |
| Unspecified-Uttar Pradesh  | Dumka | Road |
| Unspecified-Uttar Pradesh  | Purba Bardhaman | Road |
| Varanasi | Unspecified-West Bengal  | Road, Rail |
| Varanasi | Patna | Rail |
| Varanasi | Sahibganj | Rail |
| Varanasi | Purba Burdwan | Rail |
| Varanasi | Hooghly | Rail |
| Visakhapatnam | North 24 Parganas | Unknown |
| Visakhapatnam | Unspecified-Odisha  | Unknown |

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Supplementary Fig. 1 Map of nodes (at district scale for locations within India or city scale for locations outside India) documented in the tortoise/hard-shell turtle trafficking network.



Supplementary Fig. 2 Map of nodes (at district scale for locations within India or city scale for locations outside India) documented in the soft-shell turtle trafficking network. A single incident involving trafficking of soft-shell turtles from India to Bangkok and further to Macau and Hong Kong was not included in this map for clarity of scale.

Supplementary Material 1 Media reports that mention sale/consumption/seizure of softshell turtles in the following markets and villages of North 24 Parganas.

* Chandpara market:

- Adak, 2017: As quoted in the article: “The turtle meat is eaten as a delicacy by both Hindus and Muslims, mostly in the villages of Bongaon, Barasat, Chandpara, Gobordanga and Basirhat that fall along the Indo-Bangladesh border.”

- WCCB, 2021a: In a joint operation of WCCB (ER) and 24 Parganas (North) Division of Directorate of Forest, West Bengal, 1231 Indian Flapshelled / Softshelled turtles were seized on 22-01-2019 with the arrest of 1 accused from Chandpara, West Bengal.

* Thakurnagar market:

- WCCB, 2021b: On 14th March, 2021, a joint operation was conducted by Wildlife Crime Control Bureau (WCCB) & West Bengal Forest Department at Thakurnagar Fish Market, North-24 Parganas, West Bengal, in which huge quantity of wildlife articles including 21 Indian softshell turtles, 08 Ganges softshell turtles, 01 Indian tent turtle, 06 dead Indian softshell turtle & 02 turtle-shell. 03 persons were arrested in the operation.

* Bongaon market:

- Adak, 2017: As mentioned in the article: “The turtle meat is eaten as a delicacy by both Hindus and Muslims, mostly in the villages of Bongaon, Barasat, Chandpara, Gobordanga and Basirhat that fall along the Indo-Bangladesh border.”

- Chatterjee, 2020: As mentioned in the article: “Wildlife Crime Control Bureau (Eastern Region) of the Union ministry of environment, forest and climate change and West Bengal forest department personnel, seized 983 Indian flapshell turtles and two Indian peacock softshell turtles from a Bongaon market.”

Supplementary Material 2 Unverified media reports that mention the potential presence of illegal hatcheries or captive breeding facilities of Indian star tortoises in different locations of Southern India.

1. Oppili & Selvaraj, 2016:

Seizure of 500 Indian star tortoises at Chennai international airport. As quoted in the article: “This tortoise species is being bred in captivity especially in places such as Kolathur and Red Hills.”

2. TNN, 2014:

Seizure of 450 Indian star tortoises at Trivandrum international airport. As quoted in the article: “From initial inspection, it appears that the tortoises were not poached but grown in a hatchery for the specific purpose of illegal trade as they are of the same weight, height, etc.," said the official”

3. Reddy, 2018:

As quoted in the article: “Sleuths of the Directorate of Revenue Intelligence (DRI), investigating the illegal trade of star tortoises, have found that smugglers have been operating small-time illegal hatcheries in AP and Karnataka.”

4. Oppili, 2005:

As quoted in the article: “Authorities note that most of the seized star tortoises were collected from the wild. But, one consignment of star tortoises recently seized by them led to the suspicion that the reptiles could have been hand-reared, as their shells were softer than the ones from the wild.”

**References**

Adak, B. (2017) Khokon Saha, big fish of turtle trade, in West Bengal police net. *India Today*. New Delhi, India.

Borgatti, S.P. (2006) Identifying sets of key players in a social network. *Computational and Mathematical Organization Theory*, 12, 21–34.

Chatterjee, T. (2020) Operation Turtshield: Thousand endangered turtles seized from Bengal market. *Hindustan Times*. Kolkata, West Bengal, India.

Freeman, L.C. (1978) Centrality in social networks conceptual clarification. *Social Networks*, 1, 215–239.

Mendiratta, U., Sheel, V. & Singh, S. (2017) Enforcement seizures reveal large-scale illegal trade in India’s tortoises and freshwater turtles. *Biological Conservation*, 207, 100–105. Elsevier Ltd.

Oppili, P. (2005) Star tortoise smuggling has declined, authorities claim. *The Hindu*. Chennai, Tamil Nadu, India.

Oppili, P. & Selvaraj, A. (2016) 500 live star tortoises seized at Chennai airport. *The Times of India*. Chennai, Tamil Nadu, India.

Reddy, S.U. (2018) Illegal trade flourishes, smugglers breeding star tortoises in small hatcheries in AP, Karnataka. *The Times of India*. Hyderabad, Telangana, India.

TNN (2014) Man caught with 450 star back tortoises at Trivandrum International Airport. *The Times of India*. Thiruvananthapuram, Kerala, India.

Wasserman, S. & Faust, K. (1994) Social Network Analysis: Methods and Applications.

WCCB (2021a) Seizures of WCCB. Http://wccb.gov.in/Content/SeizuresofWCCB.aspx [accessed 24 December 2021].

WCCB (2021b) Turtles seized from North-24 Parganas West Bengal. Http://wccb.gov.in/NewsDetail.aspx?news\_id=11302 [accessed 24 December 2021].