



Actor-Network Dynamics in the Use of *Carettochelys insculpta* Eggs in South Papua: A Social Network Analysis Approach

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ABSTRACT

Carettochelys insculpta, a freshwater turtle with ecological importance in riverine systems and cultural value for local populations in South Papua, Indonesia, is the only remaining member of the Carettochelyidae family. Despite its protected status, egg collection is unsustainable and illegal due to poor governance ability and fragmented stakeholder cooperation. This study employed social network analysis to evaluate the interactions between egg harvesting and trade actors and suggest potential intervention locations. Egg collectors had the highest degree centrality, indicating extensive direct linkages; government players had strong proximity and betweenness centrality, uniting otherwise disparate groups; and brokers with high eigenvector centrality-controlled trade indirectly via links with other major actors. Modularity analysis revealed three actor clusters with stronger internal than external relationships, whereas MR-QAP results indicated non-random patterns driven by institutional linkages. Limitations include the extent of actor coverage, since peripheral stakeholders may not be fully represented, despite confirmation through literature and focus group discussions. Technical assistance for egg collectors, increased collaboration among actor groups, and regulatory measures that are consistent with traditional practices are among the recommendations made. The approach establishes a framework for integrating social and spatial data to detect governance gaps and prioritize solutions in species use management.

Keywords: centrality metrics, conservation strategy, ranching initiatives, turtle egg harvesting, wildlife use

INTRODUCTION

Carettochelys insculpta Ramsay, 1886, is a freshwater turtle found in Papua New Guinea and the southern area of Papua, Indonesia. It is the only living member of the Carettochelyidae family, which has a fossil record reaching back to the Mesozoic period (Joyce 2014; Vitt and Caldwell 2014). In addition to its evolutionary uniqueness, the species serves an important ecological role in freshwater ecosystems as an omnivore, contributing to nutrient cycling (Eisemberg *et al.* 2018), and has cultural significance, such as its use as a traditional dowry in indigenous communities (Triantoro *et al.* 2017). The species can be found in major river systems throughout Indonesia,

notably the Digoel and Kao Rivers in South Papua, where it contributes to residents' livelihoods. This species' eggs have long been used as a food source and are culturally significant in some locations (Eisemberg *et al.* 2018; Triantoro *et al.* 2017).

Despite its ecological importance and legal protection under Indonesian regulation Permen LHK No. P.106/MenLHK/Setjen/KUM.1/12/2018 (Permen LHK 2018), *C. insculpta* is still threatened due to unsustainable harvesting techniques. The species is also classified in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), indicating global concern over trade-related pressures (Triantoro *et al.* 2017). Pressures on wild populations in Indonesia have persisted, owing in part to the limited geographical scope of formal ranching quotas and inconsistencies in law enforcement, such as a lack of monitoring in areas outside authorized ranching zones (Shepherd *et al.* 2020; Kusri *et al.* 2024; Graha *et al.* 2024).

While spatial models have helped to identify high-risk exploitation zones (Graha *et al.* 2024), this study uses Social Network Analysis (SNA) to map both formal and informal relationships, revealing hidden power structures, information flows, and influence patterns that are critical for wildlife governance (Costa 2021). Several parties interact within loosely regulated networks, including local egg collectors, intermediaries,

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government organizations, and private-sector interests. Previous research has found loopholes in quota allocation mechanisms and inconsistent enforcement at the local level, illustrating similar governance difficulties (Graha *et al.* 2024). Understanding these connections is critical to developing effective and context-appropriate conservation methods.

This study investigates the actor-network dynamics of *C. insculpta* eggs in South Papua, using SNA to identify key actors, relational structures, and leverage points within the governance system. By mapping actor affiliations and identifying critical roles within the network, this approach sheds light on governance dynamics and potential leverage points for better species management. The study combines conservation social science and ecological factors, adding to larger global conversations about controlling community-based wildlife use and combating illegal wildlife trade (IPBES 2022). This study's findings may potentially have implications for broader animal conservation governance frameworks in regions with similar socio-legal complexities.

METHODS

Materials and Study Areas

This research was conducted in South Papua Province, specifically in Boven Digoel Regency. The Digoel and Kao Rivers are important habitats for *C. insculpta*. The landscape consists of lowland tropical rainforest and riverine ecosystems, where local communities have been observed gathering eggs (Figure 1). During field visits, a variety of ecological observations were made, including nesting site condition, evidence of recent harvesting, and signs of human disturbance. These findings offered contextual information for connecting social dynamics to biological conservation concerns.

Data Collecting

Data for this study were gathered through unstructured interviews, field surveys, focus group discussions (FGD), and a literature review. The investigation was carried out in Boven Digoel Regency, South Papua Province, namely along the Digoel and Kao Rivers.

Unstructured interviews were used to gather extensive information on *C. insculpta* use practices, interactions between important actors, and community perspectives of the species' management and sustainability. This qualitative method enabled a thorough examination of local narratives and indigenous knowledge relevant to the context of species utilization (Costa 2021). The interview approach was divided into five major themes: (1)

species location and usage; (2) use and trade patterns; (3) local and customary rules; (4) stakeholders and inter-actor relationships; and (5) perceptions and difficulties related to sustainability. Respondents included egg collectors, local mediators, customary authorities, and community members who were actively involved in egg gathering or distribution (Table 1). Participants were chosen specifically based on their direct engagement in the use (Manan 2021).

Previous geographical and literature-based studies found 720 use points, including predicted nesting site distribution and documented collecting sites (Graha *et al.* 2024). Following recognized nonprobability sample methods for network and ethnographic research, 33 respondents were purposefully chosen to represent players actively involved in harvesting, transporting, regulating, or trading activities (Moser & Kalton 1979; Manan 2021). The selection of 33 respondents supplemented the existing literature study and spatial data with primary field evidence, assuring the inclusion of actors in key positions in the network and capturing both formal and informal relationship patterns. The respondent selection procedure was further validated through FGD consensus to ensure actor relevance in local government.

Field surveys were undertaken between October 28 and November 21, 2023, in six locations: Iwot, Tanah Tinggi, Muara Mandobo, Tutainom, Mindiptana, and Anggamburan villages. The surveys sought to document active nesting sites and observe egg harvesting procedures *in situ*. On November 14, 2024, an online FGD was held with representatives from the Papua Natural Resources Conservation Agency (BKSDA), including the Merauke Resort, Agats Section, and Timika Section; civil society organizations (Yasa in Agats); private sector actors (Korindo Group); and academic experts from IPB University. FGD discussions provided cross-verification of interview findings, clarified institutional roles, and added insight into regulatory enforcement challenges.

Secondary data were gathered through a thorough examination of legal documents, institutional reports, and relevant scientific and technical literature. Unstructured interview transcripts and field notes were analyzed using Miles and Huberman's 1994 interactive methodology, which included iterative data reduction, thematic classification, and data display. Coding validity was improved by triangulating secondary data, testing inter-coder reliability, and checking patterns using FGD outputs. During the data presentation phase, information was structured methodically into topic tables, actor affiliation matrices, and social network representations. The goal of this technique was to better understand the structure of actor interactions within *C. insculpta*'s use practices. Furthermore, spatial data on nesting site distribution and use likelihood were merged using previously reported modeling results (Graha *et al.* 2024). These

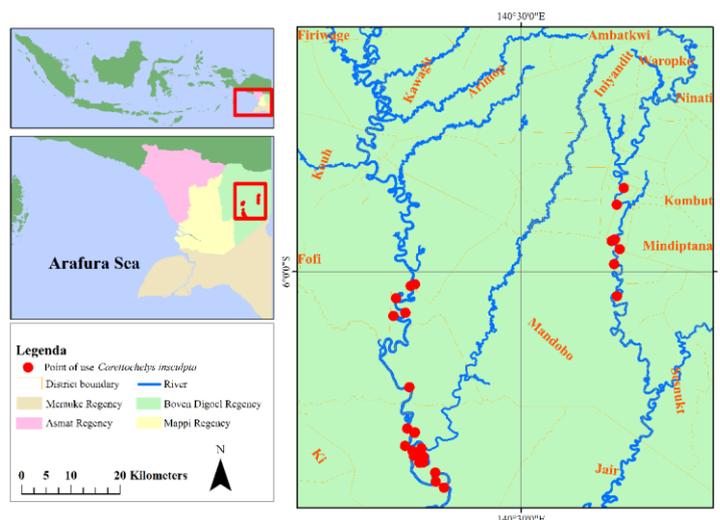


Figure 1 Nesting sites used for the collection and use of *C. insculpta* eggs, based on 2023 field visits to Boven Digoel Regency.

Table 1 Respondents of the field survey conducted in Boven Digoel Regency

Respondents	Number of respondents	District
Egg collectors of <i>C. insculpta</i>	8	Jair, Sesnukt, Mandobo, Mindiptana
Small-scale broker	5	Jair, Mindiptana
Consumers from the local community	18	Jair, Mandobo, Mindiptana
Local area management company	1	Jair
Unregistered <i>C. insculpta</i> users	1	Jair

spatial insights aided in the discovery of usage patterns and social connectivity among stakeholders. The final phase of study entailed synthesizing prominent patterns within the use network, assessing conservation risks based on activity intensity, establishing central actors' responsibilities, and assessing environmental factors influencing sustainability of species. The data was then used to provide evidence-based management guidelines for *C. insculpta* in the research region.

All data gathering procedures were carried out without official ethical approval from an established ethics committee or institutional review board. However, moral norms were upheld by instituting informed consent processes, ensuring participant anonymity, and protecting sensitive information. The study used non-invasive qualitative data gathering methods to focus on social dynamics and actor interactions using animal resources, rather than collecting biological data or conducting interventions or studies on human participants. Before each interview, verbally informed consent was sought in accordance with local customs, as written consent processes are not often used. Participants were told of the study's goal, the voluntary nature of their participation, and their right to withdraw at any time. No personally identifiable information was collected, and all responses were anonymized during data processing to maintain confidentiality. To avoid identifying vulnerable people or groups, discussions about possibly unlawful behaviors were depicted in network visualizations with

pseudonyms and aggregated actor types. The study followed Free, Prior, and Informed Consent (FPIC) standards, particularly in interactions with indigenous and local populations, and was conducted with cultural sensitivity and academic integrity to limit any harm.

Actor Identification and Network Mapping

Actors using *C. insculpta* were identified based on their reported involvement in egg-related activities (Table 2). Actor relationships were mapped to construct an affiliation matrix based on interview and observation data. These matrices represented direct linkages between actors, reflecting both the frequency and direction of interactions. Graha *et al.* (2024) used spatial data to analyze nesting site accessibility, shedding light on how physical closeness and geographic reachability affect where actors operate. Spatial data from the published models Graha *et al.* (2024) were georeferenced and linked with respondent activity data to contextualize network interactions. Spatial information was interpreted rather than used directly for metric calculation in the SNA. These spatial insights influenced the contextual perception of the social network.

Social Network Analysis (SNA) Techniques

Social Network study (SNA) was used to investigate the structure and dynamics of relationships between individuals participating in the visualization and study of *C. insculpta* using Gephi software. Each node in the network represents an actor, either an individual (e.g.,

Table 2 Interactions among different actors involved in the management of *C. insculpta* use in South Papua Province

Interactions	Definition	Types of interaction
Use of <i>C. insculpta</i>	This function covers the use of <i>C. insculpta</i> as well as the distribution of eggs to end consumers or through illicit markets	a. Collection of eggs in the wild b. Acting as brokers for eggs c. Buying eggs d. Selling eggs
Operational capital for the egg collection activities of <i>C. insculpta</i>	This function includes providing operational capital for the activities related to the collection of <i>C. insculpta</i> eggs	a. Recipients of capital for egg collection b. Providers of capital for egg collection
Authorization of indigenous land rights	This function encompasses the issuance of permits for <i>C. insculpta</i> egg collection within indigenous customary areas	a. Recipients of permits for egg collection in indigenous customary areas b. Authorities granting permits for egg collection in indigenous customary areas
National quota permit	This function includes the application for and issuance of permits for the use of <i>C. insculpta</i> eggs through the national quota system	a. Application for permits to use eggs under the national quota b. Receiving applications for permits to use eggs under the national quota c. Receiving permits for the use of eggs under the national quota d. Assessing permits related to the use of eggs under the national quota e. Approving permits for the use of eggs under the national quota
Monitoring population and use of <i>C. insculpta</i>	This function encompasses activities related to monitoring the use of <i>C. insculpta</i>	a. Reporting of outcomes and use b. Monitoring the population and use
Research and investigation of <i>C. insculpta</i>	This function involves conducting research on <i>C. insculpta</i>	a. Research activities

egg collector) or a group (e.g., firm), and links reflect relational ties such as trade, information exchange, or collaboration. These linkages have two fundamental characteristics: direction, which indicates the flow of interaction from one actor to another, and weight, which reflects the intensity or frequency of interaction, as shown by the thickness of the line. These structural features are critical for understanding actor connectedness and influence in the network (Borgatti *et al.* 2018).

The data for the network were gathered from interview replies, field observations, and literature sources. Actor relations were captured in an affiliation matrix, which was then translated into a bipartite activity matrix and fed into Gephi. Network visualization enabled the calculation of numerous centrality measures to identify major actors and their structural relevance. The centrality measurements included Degree Centrality, which indicated the number of connections each actor has; Weighted Degree, indicating the overall strength of relationships; Closeness Centrality measures one actor's proximity to

others in the network, while Betweenness Centrality identifies actors who function as bridges or brokers. Modularity Class finds subgroups or clusters within the network, while Eigenvector Centrality assesses influence based on the connectedness of surrounding nodes (Borgatti *et al.* 2018; Clifton and Webster 2017). These specific metrics were chosen based on established SNA applications in conservation governance (Costa 2021; Borgatti *et al.* 2018; Clifton & Webster 2017), as they allow for the identification of actors with high direct connectivity, strong cumulative ties, strategic positional advantages, brokerage roles, influence through well-connected neighbors, and subgroup clustering for targeted interventions. These measures identified actor prominence and possible leverage areas for collaborative conservation efforts. The combination of SNA and spatial modeling of use likelihood allows a focused assessment of high-risk zones and relevant stakeholders. This approach establishes a framework for spatially explicit and socially informed conservation planning (Costa 2021).

To improve analytical rigor, this work used the Multiple Regression Quadratic Assignment Procedure (MR-QAP) with the SNA and Statne packages in R Studio, as described by Borgatti *et al.* (2018). The MR-QAP method was used to statistically test the relationship between various types of interaction matrices while accounting for the autocorrelated structure of network data. The dependent matrix represented the operational linkages between actors, whereas the independent matrices indicated the co-occurrence of interactions connected to national policy and quota utilization.

Permutation tests with 10,000 iterations were conducted to compute *p*-values and confidence intervals for each regression coefficient. This procedure provides a robust method to assess whether the presence or strength of operational ties is significantly associated with other types of institutional or regulatory interactions, rather than occurring by random chance. Following Borgatti *et al.* (2018), the analysis focused on relational structures rather than testing the statistical significance of individual centrality scores, as no established null model exists for

evaluating centrality values independently of the network's structural context.

RESULTS AND DISCUSSION

Social Network Structure in Egg Use

Egg collectors emerged as the most central actors in the network, with a Degree Centrality of 12 and a Weighted Degree of 16, the highest of any stakeholder. A social network analysis conducted on *C. insculpta* eggs in South Papua Province highlighted the critical role of egg collectors as major actors in the distribution network. The study used Degree Centrality and Weighted Degree metrics to show that egg collectors had the most connectedness and interaction intensity with other key stakeholders, such as small-scale brokers, local consumers, and customary landowners (Table 3). Their network position allows them to communicate directly with many operational actors from various collection areas.

The network representation (Figure 2) clearly depicts the directionality and strength of interactions

Table 3 Social network centrality metrics for actors or stakeholders involved in the use of *C. insculpta*

Actor	Degree of centrality	Weighted degree	Closeness centrality	Betweenness centrality	Eigenvector centrality	Modularity class
National management authority	2	3	0.35	0	0.11	2
Registered company authorized to use <i>C. insculpta</i>	7	8	0.58	0.18	0.35	1
National scientific authority	9	9	0.58	0.03	0.34	2
Subsidiary company involved in the use of <i>C. insculpta</i>	7	7	0.54	0.15	0.39	1
Local area management company	9	9	0.56	0.01	0.42	2
Unregistered <i>C. insculpta</i> users	8	8	0.45	0.02	0.61	0
Local government	12	12	0.61	0.10	0.49	2
Consumers from the local community	10	10	0.50	0.13	0.78	0
Non-Governmental Organization	9	9	0.50	0.02	0.51	2
Small-scale broker	10	12	0.40	0.03	0.84	0
Academics	10	10	0.52	0.03	0.51	2
High-level broker	11	12	0.47	0.12	0.90	0
National government	11	13	0.52	0.30	0.47	2
Clan leader (traditional landowner)	7	12	0.35	0.01	0.69	0
Egg collectors of <i>C. insculpta</i>	12	16	0.39	0.16	1	0

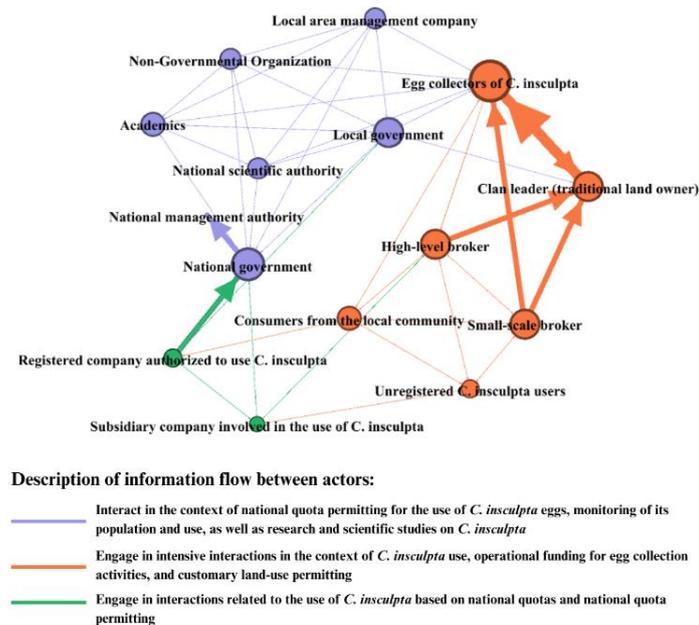


Figure 2 Information network connectivity among actors or stakeholders involved in the use of *C. insculpta*

between the participants. The thickness of the arrows shows the intensity of the relationships, whilst the direction of the arrows represents the flow of information or impact. This graphic reinforces the importance of egg collectors as nodes that mediate the majority of network interactions. The concentration of connections surrounding egg collectors represents their ability to rapidly transport information or resources across the network.

Furthermore, the central government is shown to have the greatest Betweenness Centrality value (0.30), showing its strategic role as a crucial mediator between operational actors and regulatory agencies. The regional government also plays an important role in the network, as indicated by its high Closeness Centrality, which reflects its ability to easily acquire and transmit information to multiple parties. These bridging functions can assist connecting previously isolated clusters in the network, hence facilitating conservation management cooperation. An MR-QAP was performed to assist with the statistical interpretation of network patterns. The findings ($F(2, 207) = 3.08, p = 0.048$) show a strong association between operational ties and other institutional interactions, particularly national policy and quota use. This supports the structural relevance and non-random nature of the patterns identified through SNA.

Actor Groups Based on Modularity

The network analysis classified actors into three modularity classes depending on their level of internal connectedness. The first category (Modularity Class 0) includes direct users such as egg collectors, small brokers, local communities, and traditional landowners.

The second group (Modularity Class 1) consists of formally registered user companies. The third category (Modularity Class 2) consists of government agencies, scientific authorities, academia, and non-governmental organizations (NGOs) dedicated to conservation and regulation (Table 4). These three groupings have significant internal linkages but relatively weak exterior connections. Connectivity inside clusters was significantly higher than between clusters, indicating that most exchanges take place among actors in the same group.

The FGD findings show that these groups have different perceptions and levels of responsibility. Actors in Modularity Class 0 prioritized economic and traditional advantages. At the same time, Modularity Class 2 participants emphasized the necessity of population statistics and adherence to laws such as the CITES Non-Detrimental Finding (NDF). The disparities in operational focus and priorities help to explain the limited cross-cluster interaction, which may impede the transmission of conservation-related information to local players. The FGD findings help to explain the modularity structure's fragmentation pattern, which is characterized by restricted cross-cluster connectedness due to varying values and institutional mandates. Integrating qualitative perceptions into the network pattern improves the understanding of actor group dynamics. A more in-depth explanation is available in the explanation section, specifically under Strategic Interventions Based on Actor Positions. This section stresses policy-based strategic actions as an important outcome of the investigation.

Table 4 Actors with diverse interests in the use of *C. insculpta*

Actor	Description	Role
Egg collectors of <i>C. insculpta</i>	Local or indigenous communities in South Papua Province	Users of <i>C. insculpta</i> or egg collectors, and wild individuals of <i>C. insculpta</i>
Clan leader (traditional landowner)	Customary landowners / holders of customary land rights around the <i>C. insculpta</i> nesting rivers in South Papua Province	Users of <i>C. insculpta</i> , providers of operational funding for <i>C. insculpta</i> use activities, and permit issuers for the collection of eggs or individuals within the relevant customary land rights
Small-scale broker	Village-level egg middlemen from South Papua Province	Users of <i>C. insculpta</i> and providers of operational funding for <i>C. insculpta</i> use activities
High-level broker	Regency-level egg middlemen from South Papua Province	Users of <i>C. insculpta</i> and providers of operational funding for <i>C. insculpta</i> use activities
Subsidiary company involved in the use of <i>C. insculpta</i>	Subsidiaries holding concessions to sell <i>C. insculpta</i> based on national quotas in Merauke and other cities in Papua, Indonesia	Users of <i>C. insculpta</i> and applicants for national quota permits for <i>C. insculpta</i> use
Registered company authorized to use <i>C. insculpta</i>	Registered companies holding national quotas for the utilization of <i>C. insculpta</i>	Users of <i>C. insculpta</i> , applicants and recipients of national quota permits for <i>C. insculpta</i> use, and reporters of <i>C. insculpta</i> use
Unregistered <i>C. insculpta</i> users	Unregistered entities without national quotas involved in the use of <i>C. insculpta</i>	Users of <i>C. insculpta</i> who are not registered under the national quota permit system for <i>C. insculpta</i> use
Local government	BKSDA SKW I and II in South Papua Province	Monitoring of <i>C. insculpta</i> population and use, and reporting of monitoring results
National government	BKSDA	Reporting the results of monitoring <i>C. insculpta</i> population and use, and reviewing national quota permits for <i>C. insculpta</i> use
National management authority	Ministry of Environment and Forestry (KLHK)	Reviewing monitoring reports on the population and use of <i>C. insculpta</i> and granting utilization permits to registered companies under the National Quota system
National scientific authority	BRIN	Reporting the results of monitoring <i>C. insculpta</i> population and use, reviewing these monitoring reports, and conducting research related to the population and use of <i>C. insculpta</i>
Consumers from the local community		Users of <i>C. insculpta</i>
Non-Governmental Organization (NGOs)	Yasa Papua, WWF, and other NGOs	Reviewing monitoring reports on the population and use of <i>C. insculpta</i> and conducting research related to the population and use of <i>C. insculpta</i>
Academics	Cenderawasih University, IPB University, local researchers, and researchers from outside South Papua Province	Reviewing monitoring reports on the population and use of <i>C. insculpta</i> and conducting research related to the population and use of <i>C. insculpta</i>
Local area management company	Palm oil companies, forestry companies, and mining companies	Reporting the results of monitoring the population and use of <i>C. insculpta</i> , and conducting research related to its population and use

The Role of Brokers and Government in the Distribution Network

The analysis results show that high-level brokers have the greatest Eigenvector Centrality ratings. This shows that, despite having few direct ties, they are related to performers who play pivotal roles. In other words, they have an indirect but important influence on

the network, particularly in commercialization and market control.

Figure 2 and Table 3 support this idea by depicting the relative positions of high-level brokers within the network structure. These findings underline the necessity for stringent control of distribution routes involving powerful entities whose operations are

opaque. Field observations show that brokers frequently influence the price and volume of *C. insculpta* eggs and hatchlings, including through unofficial trade routes at local ports.

Findings from Field Visits and FGD

Field visits undertaken in Boven Digoel Regency revealed 27 active nesting sites used by local populations to retrieve *C. insculpta* eggs. These nesting sites are generally located on sandy riverbanks without rocky substrate, away from densely populated settlements, ports, and industrial facilities, and are characterized by minimal disturbance from boat traffic. The average nest elevation was 19.56 m (19.56 to 44.01 m) (Figure 3).

Harvesting took place from August to early November, with a peak between August and September due to water level variations at the start of the wet season. Egg collectors employed both non-powered and motorized boats (Figure 4 a-b), identified tracks to find nests (Figure 4 part e), and confirmed egg existence by probing the sand (Figure 4 d).

Nests immersed in rising water were frequently left unharvested, and eggs carried away by flooding did not hatch. Late-season nests were left uncollected because yields were insufficient to justify costs. Harvesting was conducted under customary permissions, with quotas and benefit-sharing determined by local customary law. Violations such as collecting outside permitted places may result in typical fines. The season saw the establishment of temporary bivouacs (Figure 4 f-j) and incubation sites (Figure 4 k-m). Incubation lasted around three months and occurred near nesting places and broker premises.

The FGD findings showed several internal issues associated with the conservation and utilization of *C. insculpta*. One of the most pressing difficulties was the

lack of credible data, particularly for creating the NDF document required by CITES, because wild population and dispersion data are inadequate. The discussion also focused on the species' use history and applicable legislation, noting that the first formal decree in 2016 allowed egg harvesting in Asmat, which was later expanded to Timika in 2021, while unregulated operations continue in other regions. Another barrier included breeding permissions, as only one firm presently holds a valid ranching permit, and future applicants must meet stringent environmental and administrative standards under the One Single Submission (OSS) system. Furthermore, the absence of integrated customary land mapping was noted as an impediment to the coordinated management of egg collecting activities.

External challenges were also addressed. These included variations in market trade and pricing, with albino morphs commanding IDR 50–100 million per individual and ordinary egg costs falling below IDR 20,000 in 2023, which can influence harvesting intensity. Geographic constraints, such as the remoteness and limited accessibility of nesting places, limit activities while also potentially reducing hunting pressure. In terms of habitat characteristics, some nesting locations are relatively protected due to their remote location and limited accessibility. Finally, participants proposed alternate livelihood possibilities, such as ecotourism or the sale of non-wildlife items that do not contain *C. insculpta*, as potential solutions to lessen reliance on its collection and promote long-term conservation efforts.

After harvest, eggs were sold to brokers who ran independent hatcheries. Observations revealed that *C. insculpta* was present in their holding ponds among other turtle species such as *Eiseya rhodini* and *Emydura subglobosa*. These eggs and turtles were



Figure 3 Nesting sites of *C. insculpta* in Boven Digoel Regency.



Figure 4 Boats, harvesting methods, temporary bivouacs, and independent incubation facilities for *C. insculpta* in Boven Digoel, South Papua. (a): non-motorized boat; (b): motorized boat; (c): temporary egg placement site; (d): egg-searching activity; (e): *C. insculpta* track; (f-j): bivouacs used by egg collectors; (k): temporary incubation area for eggs; and (l) and (m): independent incubation areas at egg collector facilities.

sold in traditional markets, port markets, and pet shops. According to interviews, cargo reaching Surabaya or Jakarta via commercial or business ports take between seven and nine days. Boat traffic, neighboring industrial facilities, and adjacent communities have all been observed to cause disturbance in nesting locations.

These issues were consistent with the modularity study, which classified actors into discrete clusters with strong internal relationships but weak exterior linkages. Community-based actors (e.g., egg collectors, traditional landowners) and formal institutions (e.g., government agencies, NGOs) were classified as independent modularity classes, with few inter-group relationships. This structural isolation was also apparent in the network visualization, which revealed few direct connections between community and regulatory actors. FGD participants also emphasized the necessity of multi-stakeholder collaboration, improved population monitoring, increased local capacity, and complete customary land mapping as a foundation for long-term management initiatives.

DISCUSSION

Spatial-Social Convergence in Exploitation Risk

The results of the social network analysis are compatible with the spatial modeling of the usage likelihood for *C. insculpta* in South Papua, Indonesia, which was done by Graha *et al.* (2024) using the Ecological Niche Modelling technique created at the MetaLand Ecology Lab. Areas with a high exploitation likelihood, such as Boven Digoel and Asmat

Regencies, are also distinguished by the prevalence of egg collectors in the distribution network. This reveals a link between ecological pressure and the social effect of actors in specific regions.

The Random Forest (RDF)-based probability model of *C. insculpta* use across forest function zones in South Papua, Graha *et al.* (2024) demonstrates that high probability areas are concentrated in Permanent Production Forests, Limited Production Forests, and Other Land Use Areas (Figure 5), many of which coincide with river systems used as egg collection and trade routes. Easy access to non-protected zones encourages unmonitored harvesting, but conservation-designated zones such as Wildlife Sanctuaries and Nature Reserves have lower likelihood values. The overlap between high ecological appropriateness and significant actor connectedness emphasizes the need of intervening in convergent zones.

According to Graha *et al.*'s (2024) spatial exploitation model, sites with limited accessibility but suitable nesting habitats serve as focal points for *C. insculpta* egg harvesting. Similarly, Eisemberg *et al.* (2011) discovered that low-human-disturbance areas are crucial for freshwater turtle conservation. Burgess and Lilley (2014) found that increased river transportation contributes significantly to exploitation pressure in riparian environments. Bennett and Robinson (2000) complement these findings, stating that access closeness, social connections, and local economic mechanisms all have a substantial influence on wildlife exploitation.

Eisemberg *et al.* (2018) found that the usage of *C. insculpta* eggs has become incorporated into local

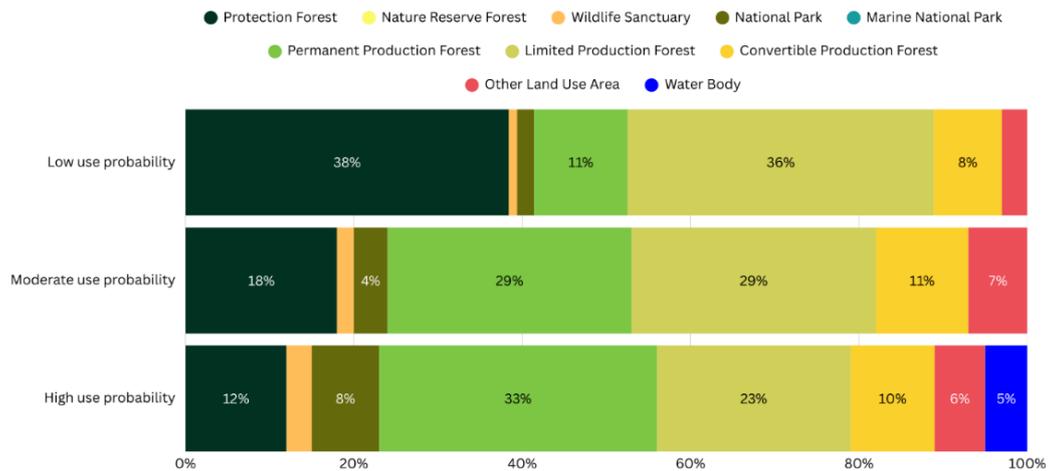


Figure 5 RDF-based probability model of *C. insculpta* use across Forest Function Zones in South Papua, Indonesia.

populations' livelihoods, with harvesting practices ingrained in customary norms and complex social structures. Kusriani *et al.* (2024) highlighted that providing quotas and exploiting areas has the potential for development as part of community-based conservation methods. Given the spatial-social overlap shown in both network and probability models, conservation zoning should be planned to account for actor influence as well as ecological sensitivity. Because significant actors are also active in environmentally valuable places, these areas should be prioritized for conservation actions that incorporate social and geographic data.

Governance Implications from Network Fragmentation

The network analysis revealed three modularity classes: direct resource consumers (Module 0), legally registered commercial actors (Module 1), and regulatory or conservation-oriented parties (Module 2). These structural divisions reflect distinctions in actor function and legal standing. The limited linkages between these groupings point to fragmented coordinating pathways.

Previous research has found that institutional separation can diminish policy efficacy in conservation situations involving many actor types, which is consistent with IPBES (2022). The spatial probability model developed by Graha *et al.* (2024) demonstrates that exploitation risk extends across multiple administrative areas, including Boven Digoel, Asmat, Mappi, and Merauke, implying that conservation actions limited to one regency may leave high-risk zones in other jurisdictions unmanaged. Although formal egg ranching activities are primarily concentrated in Asmat, network and spatial data suggest that harvesting happens in other regencies with varying levels of institutional commitment. This

demonstrates a mismatch between ecological pressure and present policy scope.

Egg ranching has been linked to a variety of management outcomes, including harvest intensity regulation, improved monitoring systems, and economic incentives for local stakeholders (Siroski *et al.* 2024). Given the observed fragmentation of actor groups in the network, extending regulatory tools like licensing procedures and quota access to different regencies may help to expand institutional coverage and improve coordination.

FGD data revealed disparities in players' access to legislative frameworks and quota systems. These findings are consistent with the network's limited inter-modular connections. Participants in Modularity 0 reported little involvement in formal governance structures, but institutions in Modularity 2 had challenges expressing compliance expectations to decentralized users. These results are consistent with IPBES (2022), which identifies numerous enabling elements for community-based conservation, including as clear legislative frameworks, certified market access, economic incentives, and stakeholder participation in decision-making processes.

Strategic Interventions Based on Actor Positions

Table 5, adapted from Lemieux *et al.* (2022), lists situational offense prevention measures that apply to *C. insculpta* egg harvesting. The approaches are described in terms of actor locations and identified intervention points, which include high-centrality actors and access routes such as river systems and isolated nesting areas.

Actors in low-centrality but strategic positions, such as national scientific authorities or traditional leaders, may fulfill monitoring and regulatory communication functions. According to Lemieux *et al.* (2022), interventions that consider each actor's individual role

Table 5 Situational offense prevention techniques in the context of local harvesting of turtle eggs (advanced)

Step	No.	Situational offense prevention technique	Egg harvesting
Reduce provocations that encourage the problem	16	Reduce frustrations and stress: Find ways to remove stressors that lead to offending	Provide seasonal alternative livelihood opportunities for harvesters
	17	Avoid disputes: Find ways to reduce the likelihood of disputes or ways to resolve them quickly	Not applicable. The problem is not caused by disputes
	18	Reduce temptation and arousal: Eliminate situations that expose motivated offenders to easy offense opportunities	Create an incentive scheme that rewards communities based on a proportion of eggs hatched
	19	Neutralize peer pressure: Find ways to encourage social norms that are against offending	Social media campaign to show the destructive nature of egg harvesting on the local ecosystem
	20	Discourage imitation: Find ways to reduce opportunities to learn offending behavior as well as the benefits of imitating it	Not applicable
Remove excuses for non-compliance	21	Set rules: Define a clear set of regulations and make them known	Define formal harvesting guidelines
	22	Post instructions: Use signs and display boards to clearly communicate rules at a location	Post signs at entrances or at harvesting areas indicating which species can be harvested and when
	23	Alert conscience: Find ways to remind offenders their behavior is not allowed and punishment may be possible	Install discreet markers at turtle nesting sites to remind harvesters that egg collection is illegal and the area is under monitoring
	24	Assist compliance: Find ways to make it easier for people to follow the agreed-upon rules	Create a legal and sustainable offtake scheme
	25	Control drugs and alcohol: Find ways to limit the availability and use of substances driving offender behavior	Not applicable. This problem is not related to or facilitated by drugs and alcohol

might improve deterrent and policy efficacy in decentralized wildlife use scenarios. The central government, which has the highest betweenness centrality in the network, serves as a bridge entity and is structurally linked to several actor groupings. This post enables policy harmonization and cross-sector coordination. Actor roles in the network correlate to specific leverage points in the distribution chain. Brokers with strong eigenvector centrality but limited direct connectivity, for example, might be targeted via transaction monitoring and control at large trade hubs. In contrast, egg collectors with a high degree of centrality can be engaged through capacity-building initiatives and quota-based incentives in high-probability harvesting zones suggested by the RDF model. Intervention techniques, such as increasing legal access, giving technical support, and communicating quota-related information, can be tailored to certain actor characteristics and levels of connectivity.

Policy and Implementation Considerations

Several conservation implementation objectives were discovered by combining social network and geographic data. These include providing legal recognition and technical assistance to local actors involved in egg incubation methods, establishing coordination platforms among actor groups, and designing policy instruments that incorporate customary norms into quota management. Spatial risk mapping from Graha *et al.* (2024) adds another tool for focusing actions, notably in Permanent Production Forests and Other Land Use Areas where access and lax regulation allow for unmonitored harvesting. Integrating this spatial layer with network measurements allows for the prioritization of zones with high actor influence and high ecological appropriateness. The observed modularity structure and spatial distribution of use risk provide support for conservation zoning techniques that consider actor roles and ecological fragility. Recommendations may

be directed by institutional membership, network position, and access to legal frameworks rather than broad demands for improved collaboration.

This study considers numerous methodological considerations. Purposive sampling, as advised for relational studies by Borgatti *et al.* (2018), was used to identify key participants in the South Papuan *C. insculpta* egg usage network. In addition to interview data, focus group discussions and previous literature, such as Kusriani *et al.* (2024), aided in the validation of actor roles beyond direct observation. While this approach may not have captured all peripheral participants, it did allow for a focused analysis of the primary social structure.

The network data describe relationships as they existed during fieldwork. Although interaction dynamics may change over time, data collection took place during the *C. insculpta* nesting season, which occurs once a year. As a result, the timing reflects peak egg use activity, and the reported interactions are representative of that active period. Relational data were derived from self-reported information and may be subject to interpretation bias. These factors should be considered while determining the scope and applicability of the final network structure.

The findings emphasize the importance of combining geographical and relational data in species management, especially in decentralized systems with many actor levels. Alignment of observed use patterns, institutional frameworks, and governance structures could lead to more adaptive and context-relevant conservation initiatives.

CONCLUSION

This study used Social Network Analysis to look at the relationships between the people involved in using *C. insculpta* eggs in South Papua. The findings suggest that egg collectors hold dominant positions in the network, as evidenced by the highest degree centrality and weighted degree values. Regional and central government actors have significant proximity and betweenness centrality, indicating a structural role as connections between actor levels. High-level brokers had the highest eigenvector centrality, indicating indirect influence through relationships with other central actors.

The modularity class analysis divided actors into three clusters, with stronger internal linkages than external ones. This structural segmentation is consistent with actor functions and institutional connections, and it can help inspire coordination tactics that take network structure into consideration. Several

recommendations have been developed as a result of the investigation. These include technical assistance for egg collectors in managing incubation activities, facilitating collaboration among identified actor groups, and aligning regulatory processes with community-based practices. This includes revising legal procedures to increase access to formal markets and clarify operating guidelines.

Integrating actor connections and spatial distribution patterns contributes to a better understanding of use dynamics in decentralized systems. These findings can help with conservation planning by connecting actor roles to ecological circumstances. Pilot initiatives, such as community-based ranching schemes, should be investigated to determine the possibility of formalizing local practices inside regulated frameworks. Future research should involve longitudinal analyses to track temporal changes in actor interactions and their impact on conservation outcomes. The technique described here provides a framework for connecting social and spatial data to detect governance weaknesses and prioritize solutions in species use management.

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