A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

NeoBiota 100: 257–280 (2025)
DOI: 10.3897/neobiota.100.156371

Research Article

Non-native species in the Philippines and Southeast Asia

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Abstract

Non-native species introductions threaten global biodiversity, ecosystems, and the services they provide. The limited capacity of developing countries to mitigate and manage biological invasions increases their vulnerability to the resulting impacts. Developing countries' lack of comprehensive information on non-native species to help formulate sound management efforts is a key challenge. Here, we provide the most comprehensive national list of established non-native species in the Philippines, along with an update on the Southeast Asian region to aid national and regional efforts in addressing the threats posed by biological invasions. Our assessment indicates that the Philippines currently hosts at least 1,029 established non-native species, the highest number among Southeast Asian countries, amidst a total of 2,528 non-native species established in the region. A taxonomic breakdown showed species of the division Tracheophyta and phylum Chordata to be the majority of established non-native species in the Philippines, most of which are found in terrestrial ecosystems. A network analysis further highlighted a high degree of similarity in the composition of established non-native species among Southeast Asian countries, with the Philippines' non-native species community most closely resembling that of Indonesia, likely due to close socio-economic ties and similar climatic niches and environmental conditions. Finally, we identified 1,499 non-native species established in Southeast Asia but not the Philippines, which may pose potential future threats for the country. We highlight the need for more comprehensive research on established non-native species in the Philippines and the Southeast Asian region, particularly taxonomic studies and research at broader geographic scales, to better understand the distribution and impact of these species and stress the critical need to address this transboundary threat.

Key words: Alien species, biological invasions, ecological impacts, exotic species, invasion ecology

OPEN ACCESS

This article is part of:
Developing lists of alien taxa in the Global South: workflows, protocols, processes, and experiences
Edited by John Wilson, Michele Dechoum, Katelyn Faulkner, Shyama Pagad, Aníbal Pauchard, Hanno Seebens, Tsungai Zengeya, Silvía Ziller

Academic editor: John Ross Wilson
Received: 19 April 2025
Accepted: 23 July 2025
Published: 27 August 2025

Citation: Abreo NA, Kouba A, Briski E, Ahmed DA, Soto I, Haubrock PJ (2025) Non-native species in the Philippines and Southeast Asia. NeoBiota 100: 257–280. https://doi.org/10.3897/neobiota.100.156371

Introduction

Non-native species are organisms that are intentionally or unintentionally transported by human activities to areas beyond their historically known native range (*sensu* Soto et al. 2024). Their introduction and subsequent possible establishment pose a threat to global biodiversity, local and regional economies, and human well-being (Blackburn et al. 2011; Cuthbert et al. 2022; IPBES 2023) by altering ecosystem dynamics (e.g. alter trophic structure, physico-chemical properties), affecting environmental health, and disrupting the provision of ecosystem services (Hulme 2009; Goto et al. 2020; Pathak et al. 2021). The monetary impacts that biological invasions can cause are equally profound, with global cost estimates – due to direct damage or the management of non-native species – totaling billions of dollars and growing indications of conservative cost estimates being larger than currently reported (Diagne et al. 2021; Soto et al. 2025). This problem is expected to increase in the future, exacerbated by the ease of international trade and travel (Costello et al. 2023; IPBES 2023) and possible synergies with other drivers, such as climate change and pollution (Robinson et al. 2020; Mghili et al. 2023).

A lack of foundational information on non-native species and their ecological and economic impacts, as well as introduction pathways, hinders a comprehensive understanding of the full extent of the burden and threat biological invasions present, especially as proposed management solutions often fail (Kappes et al. 2019; Henriksen et al. 2024). Knowledge gaps primarily arise from a lack of long-term monitoring, data recording, reporting efforts, and the quantification of value-based differences in impacts, especially in developing countries, as these activities require substantial financial investment (Diagne et al. 2021; Liu et al. 2021; Jenkins et al. 2024). As limited resources constrain the capacity to respond and manage the impacts of non-native species introductions – particularly in developing countries – negative effects are expected to be more pronounced (Bradshaw et al. 2024). The inability of these countries to correctly gauge impacts using quantifiable metrics also hinders their capacity for better cost-benefit analysis and effective risk assessment (Soto et al. 2023a).

Southeast Asia, a region that hosts a notably high degree of biodiversity and four biodiversity "hotspots" – Indo-Burma, Sundaland, Wallacea, and the Philippines (Tolentino et al. 2020; Verma et al. 2020; Takahashi et al. 2024) – comprises several countries considered emerging economies, which are, by extension, extremely vulnerable and susceptible to the impacts of non-native species introductions. Yet the dangers associated with these introductions remain largely underappreciated (Early et al. 2016; Bradshaw et al. 2024). Recent studies have shown that governments in this region invest insufficient resources into tackling biological invasions leading to sporadic data gathering and reporting on non-native species as well as their impacts, resulting in fragmented information that fails to translate into coordinated (and thus efficient) management actions (IPBES 2023; Kurtul and Haubrock 2024). Biases in non-native species research and misconceptions about short-term economic benefits further complicate the development of effective strategies (Watkins et al. 2021; Carneiro et al. 2024). One prime example is the introduction of the golden apple snail (*Pomacea canaliculata*) to several Southeast Asian countries. Initially considered a potential alternative source of income for marginalized farming communities, it is now listed as part of "100 of the World's Worst Invasive Species" (Lowe et al. 2000), causing billions of dollars in economic costs to the agricultural sector via crop damage and snail population management (Jiang et al. 2022). Ecologically, intense grazing of the golden apple snail on submerged macrophytes can alter ecosystem functions of aquatic habitats (Carlsson et al. 2004).

The Philippines – as an integral part of Southeast Asia – shares intense trade and travel connections with neighboring countries, known predictors for the introduction of non-native species (Duquesne and Fournier 2024). Consequently, it also shares the region's ecological challenges, with several non-native species that have become widespread and are causing ecological and socio-economic effects (Pili et al. 2019; Mendoza et al. 2022). Reported impacts include the displacement of economically important species resulting in damage to agriculture (Singleton et al. 2021), direct threat to endemic species through resource competition and predation (Corpuz 2018; Gersava et al. 2020), decreased biodiversity (Galano and Rodriguez 2021), and, among others, decreased incomes and lower livelihoods (Mendoza et al. 2022). The introduction of non-native species, however, continues unabated, with the first Philippine records of several species published just within the last five years (e.g. Geromo et al. 2019; Barrion-Dupo et al. 2024) and the country's pet and ornamental trade possibly becoming a source of future introductions (Sy 2014, 2015).

Knowledge gaps, such as the lack of a comprehensive list of non-native species and their impacts, limit our ability to detect, monitor, and understand biological invasions. Without knowing which species are present and their distribution, scientists and policymakers fail to accurately assess which non-native species are harmful, the rate at which they are spreading, or what ecosystems are most at risk. This knowledge gap prevents early detection and rapid response, allowing invasive species to establish and spread unchecked. As a result, developing countries – often with limited resources – face more severe ecological damage, higher economic losses, and greater social impacts (Bradshaw et al. 2024).

To effectively address current and future threats posed by non-native species in the Philippines, it is crucial to (*i*) know which non-native species are currently established in the country and (*ii*) which species could be introduced in the foreseeable future, e.g. due to being already established in adjacent regions. Also, information on non-native species introduction pathways is crucial for understanding how these species are introduced and spread, which in turn helps in designing targeted prevention and control measures (Cunningham et al. 2019; Hulme 2020). However, this information, although not totally absent, is limited to a few high-profile non-native species (Abreo et al., unpub.). To advance Philippine non-native species management, we (*i*) compiled and (*ii*) analyzed the most comprehensive dataset of established non-native species in the Philippines to date. Since we recognize that biological invasions are a transboundary problem (Zhang et al. 2024), we extended our analysis to include the neighboring Southeast Asian countries. Finally, we explored (*iii*) how the connectivity of Southeast Asian countries influences the composition of established non-native species; (*iv*) uncovered taxonomic and geographical patterns in non-native species composition; and (*v*) explored the role of human mediated transport pathways in the non-native species composition of the Philippines.

Methods

To produce the most comprehensive list of established non-native species in the Philippines and other Southeast Asian countries, we leveraged the recently published database by Briski et al. (2024), which integrated data from the SInAS (Standardising and Integrating Alien Species) workflow of non-native species occurrences (Seebens et al. 2020) along with several other publicly available databases and non-native species lists (see Briski et al. 2024 for the complete list of publicly available databases). This database was filtered by countries in Southeast Asia. The resulting extracted part of the database contains information on: the taxonomic classification of non-native organisms; habitat type [i.e. terrestrial, fresh water, marine, terrestrial and freshwater (for semi-aquatic species) or freshwater and marine (for euryhaline species)]; and occurrence status (either present or absent in a specific country; for metadata, see Table 1). However, minimal data and available information on non-native species in Southeast Asia make it difficult to determine whether an introduced species is established or not. As a result, we recognize that possible errors could have been transferred from the original databases (i.e. Seebens et al. 2020) to Briski et al. (2024). Consequently, species names were first checked in the "Global Biodiversity Information Facility" (GBIF) (GBIF.org 2025) following the approach of Haubrock et al. (2025) and Tarkan et al. (unpub). If a species was not listed in GBIF, a general internet search was done to confirm its authenticity before correcting misspelled names and removing duplicate entries. We also consulted GBIF for the species' occurrence data in Southeast Asia (Suppl. material 1: table S1). Additionally, it is important to note that many non-native species remain unreported – a critical limitation of biodiversity databases (McGeoch et al. 2012) – which may have resulted in an incomplete list.

Impact of non-native species

To identify which non-native species have impacts, we extracted all available information on reported impacts, i.e., whether an impact was reported in the Philippines and globally, from the "Global Register of Introduced and Invasive Species" (GRIIS; Ries and Pagad 2020). Further, for species listed in the Philippines, an additional information search in the "InvaCost" database, a database that reports monetary impacts of non-native species, was conducted (Diagne et al. 2020). The resulting list was then compared to the recently published "Global Impacts Dataset of Invasive Alien Species" (GIDIAS; Bacher et al. 2025).

Table 1. Metadata of the database used in the study. For the database, see Suppl. material 1: table S1.

Column label	Format	Possible values	Column description
Location	Character	Country Name	The Southeast Asian country where the established non-native species have been recorded.
Taxon	Character	Binomial name	Species name
Scientific Name	Character	Scientific name	Full scientific name including authorship and taxonomic details
Family	Character	Taxonomic rank	Taxonomic rank, rank below Order and above Genus
Class	Character	Taxonomic rank	Taxonomic rank, rank below Phylum and above Order
Phylum	Character	Taxonomic rank	Major taxonomic rank grouping organism level, rank below Kingdom and above Class
Habitat	Character	Habitat Type	Describes the habitat of the identified established non-native species
Occurrence Status	Categorical	Present/absent	Presence of non-native species in each country
OrigDB	Character	Database name	Database where information was initially collected
Our Reference	Character	Database name	The basis of including the non-native species in the list
GIDIAS. Impact	Categorical	Negative/Positive	Impact record based on GIDIAS database
GRIIS. Impact	Categorical	Yes/No	Impact record based on GRIIS database
Impact. Location	Character	Country Name	Combined list of countries from GIDIAS and GRIIS where impact was described
Source	Character	Bibliographic entry / Database name	Combined list of sources in GIDIAS and GRIIS

Pathways of non-native species introduction

Information on non-native species introduction pathways was extracted from the database published by Saul et al. (2017). This database follows the standardized categorization scheme adopted by the "Convention on Biological Diversity" (CBD; Harrower et al. 2018), integrating information from major invasive species databases such as the "Global Invasive Species Database" (GISD; Invasive Species Specialist Group ISSG 2015) and "Delivering Alien Invasive Species Inventories for Europe" database (DAISIE; Roy and Hulme 2008). However, only four pathways are considered in Saul et al. (2017), merging "Transport as Contaminant" and "Transport as Stowaways" into a single category, "Transport – Contaminant & Stowaway", "Release in Nature", "Escape from Confinement" and "Corridor" while discarding the "Unaided" pathway. For each recorded pathway, information was structured into three key components: the main pathway category, a subcategory providing a more specific mode of introduction (Suppl. material 2: table S2), and the intentionality of the introduction (i.e., whether the species was introduced deliberately or arrived unintentionally). This database was then filtered using the species name of the organisms present in the countries of Southeast Asia, as extracted from Briski et al. (2024). For non-native species with multiple recorded pathways of introduction, each unique entry is counted individually. Therefore, if a non-native species is recorded to have two pathways of introduction (e.g. Release in Nature and Escape from confinement), it is tallied twice. A similar rule was applied with the intentionality of introduction.

Network analysis

To explore the relationship of established non-native species in Southeast Asian countries, we used the vegan R package (Oksanen et al. 2025) to create a similarity matrix based on Euclidean distances. Specifically, we used the *vegdist* function within the vegan R package to calculate the Jaccard similarity index, which quantifies the difference between two samples based on their species composition. The metric ranges from 0 to 1, where a value of 0 indicates that the communities have completely different species and a value of 1 indicates that the two communities are identical in species composition.

To visualize, we utilized the igraph R package (Csardi and Nepusz 2006) to create a bipartite network, in which the nodes represent the countries, and the links represent the Jaccard similarity data. We utilized the Fruchterman-Reingold algorithm within the igraph R package in the network layout to highlight clusters of closely related nodes, signifying similarity in non-native species composition of the countries.

Results

Based on the collated data, Southeast Asian countries currently host 2,528 established non-native species (Suppl. material 1: table S1), with the Philippines hosting the highest number of non-native species (n = 1,029), followed by Indonesia (n = 891), and Singapore (n = 781). Meanwhile, Myanmar (n = 180), Cambodia (n = 162), and Brunei Darussalam (n = 140) had the fewest established non-native species reported (Fig. 1). For the entire Southeast Asia region, most of the established non-native species belonged to the division Tracheophyta (n = 1, 820), followed by

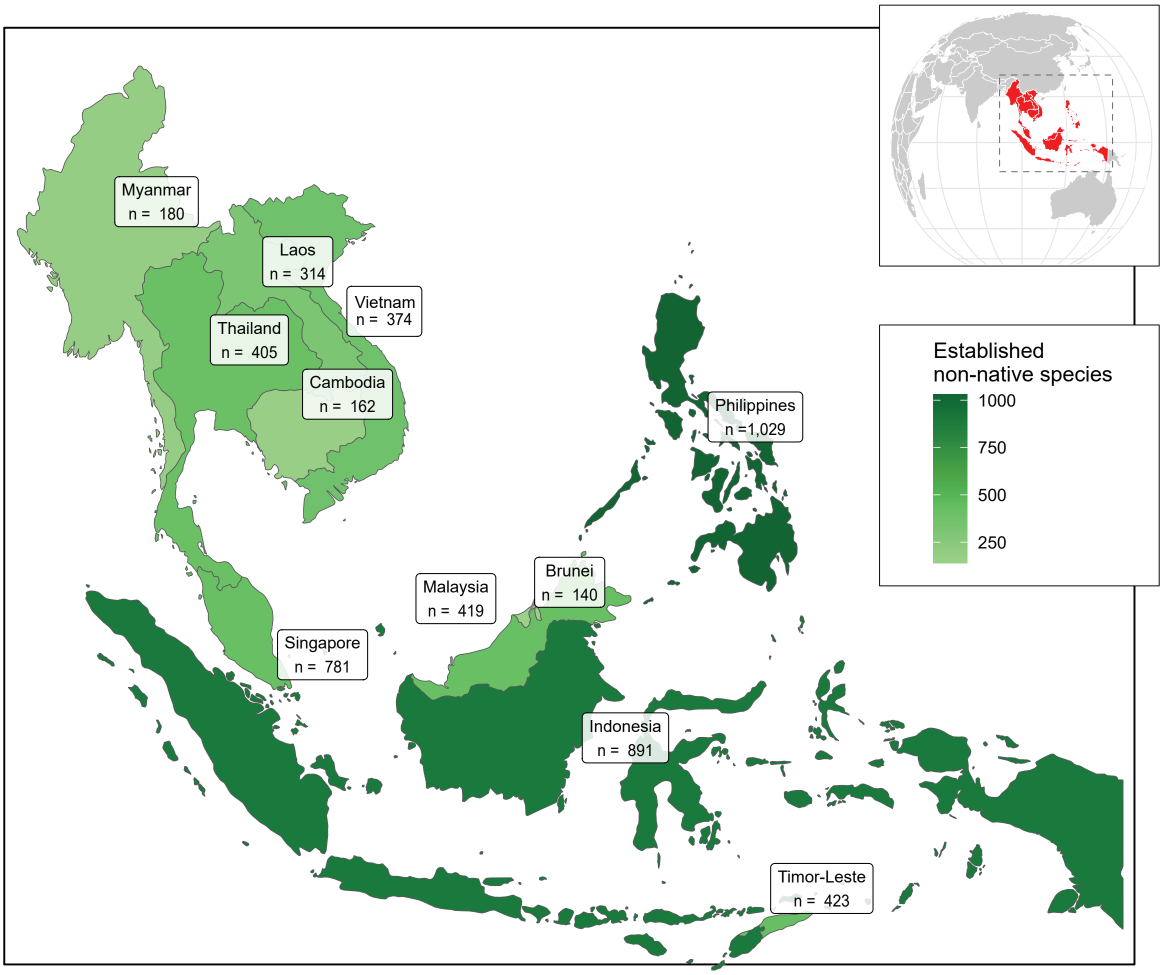

Figure 1. Map of Southeast Asia showing the number of established non-native species reported per country.

phylum Chordata (n = 492) and phylum Arthropoda (n = 127). All other phyla are represented by fewer than 30 species. Similar trends were observed in other Southeast Asian countries, with Tracheophyta having the highest number of species followed by Chordata and Arthropoda – except for Myanmar, where Arthropoda were slightly richer in terms of species than Chordata (see Suppl. material 3: table S3).

In the Philippines, established non-native species (Suppl. material 4: table S4) belonged to 209 families, 24 classes, and 12 phyla (Fig. 2). Tracheophyta was the division with the most species (n = 787; 76.5% of all species), followed by phylum Chordata (n = 181; 17.6%), and phylum Arthropoda (n = 41; 3.9%). Among classes, Magnoliopsida was the most species-rich (n = 624; 60.6%), followed by Liliopsida (n = 153; 14.9%), and Actinopterygii (n = 138; 13.4%) (Fig. 1). Reported non-native species are mostly terrestrial (n = 848; 82.4%), followed by freshwater (n = 105; 10.2%) and marine (n = 17; 1.8%). Semi-aquatic species comprised only n = 21 species (2%) and euryhaline species (n = 38; 3.7%) constituted only a minor role (Fig. 2).

Network analysis

The network analysis revealed a typology indicating a high degree of similarity in the composition of established non-native species among Southeast Asian countries (Fig. 3). The percentage overlap in species between Southeast Asian countries

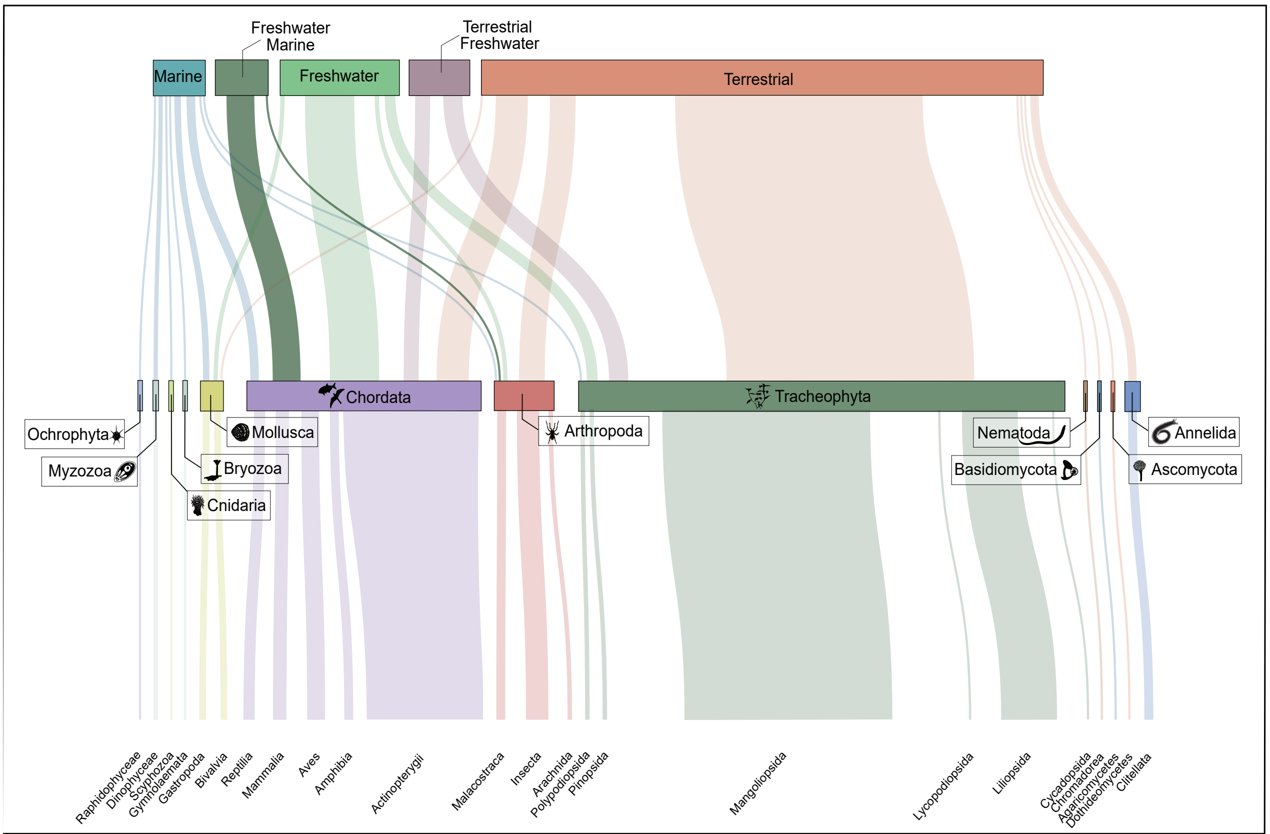

Figure 2. Sankey diagram showing ecosystem (top) of established non-native species in the Philippines by phylum (middle) and class (bottom). For more detailed taxonomic breakdown, see Suppl. material 5: table S5; for other Southeast Asian countries Sankey diagram, please see Suppl. material 10: fig. S1).

ranges from 7.84% to 36.25%, with an average overlap of 16.61% (Suppl. material 6: table S6). Mainland Southeast Asia, which shares land borders, exhibited greater similarities with each other, as seen in cases of Thailand and Malaysia (Jaccard similarity = 0.267), as well as Vietnam and Cambodia (Jaccard similarity = 0.323). The highest similarity was observed between Myanmar and Cambodia (Jaccard similarity = 0.368). The composition of established non-native species of the Philippines most closely resembled that of Indonesia (Jaccard similarity = 0.185), followed by Singapore (Jaccard similarity = 0.169) and Malaysia (Jaccard similarity = 0.167). Meanwhile, Myanmar (Jaccard similarity = 0.082), Cambodia (Jaccard similarity = 0.081), and Brunei Darussalam (Jaccard similarity = 0.079) were the least similar to the Philippines.

Impacts of non-native species in Southeast Asia

Out of the 2,528 established non-native species in the Southeast Asia region, n = 1,631 (65%) are recorded in the GRIIS database. Currently, there are 1,499 non-native species listed as established in other countries of Southeast Asia that are not considered established or are currently not found in the Philippines (Suppl. material 8: table S8). Out of these, n = 638 (43%) of the species are currently not listed in the GRIIS. Of the species listed in the GRIIS database, n = 415 (48%) have recorded impacts in other parts of the globe while the remaining n = 446 (52%) of listed species have no reported impacts. Species with reported impacts in-

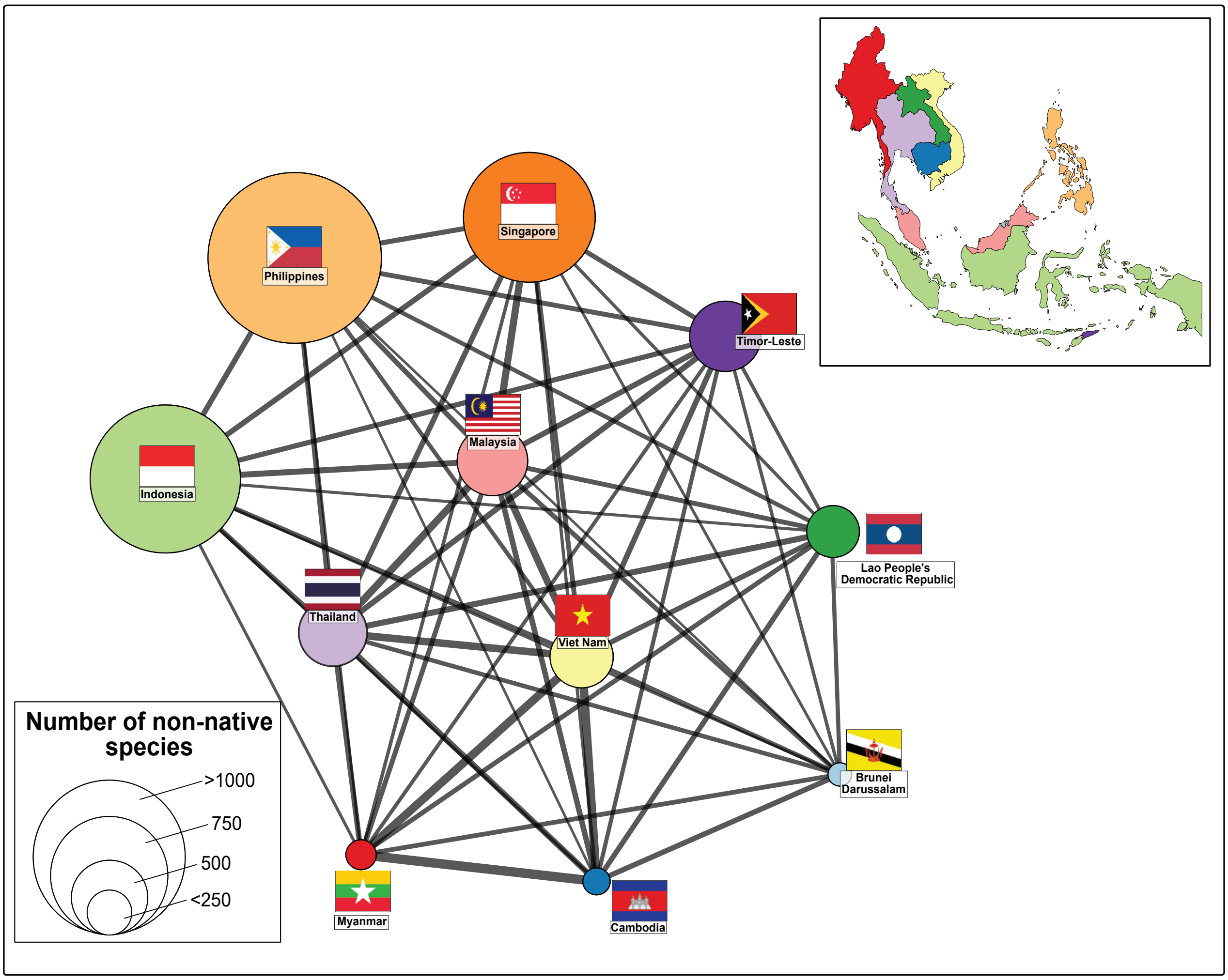

Figure 3. Network analysis based on the similarity in established non-native species compositions of the respective countries. Line widths reflect each respective country's similarity to other countries in Southeast Asia. For exact similarity values see Suppl. material 7: table S7.

cluded 33 listed among the 100 of the World's Worst Invasive Alien Species, such as the soapbush (*Miconia crenata*), Sri Lankan privet (*Ligustrum robustum*) and giant cane (*Arundo donax*) (Table 2). Meanwhile, out of the 1,029 established non-native species in the Philippines, only n = 431 (42%) of the species are reported to have an impact and n = 598 (58%) are listed with no impacts or are not listed in the GRIIS database at all. However, these impacts were records from other countries, and not the Philippines, except for the yellow fever mosquito (*Aedes aegypti*), the golden apple snail and the mango pulp weevil (*Sternochetus frigidus*) (Haubrock et al. 2021).

Further, we found that n = 543 (24%) of the listed non-native species established in the entire Southeast Asia were in GIDIAS. For non-native species established in Southeast Asian countries excluding the Philippines, n = 265 (18%) were listed. For the Philippines, only n = 278 (27%) of established non-native species were included in GIDIAS.

Introduction pathways

Of the 1499 species reported from Southeast Asia that were not identified as established in the Philippines, n = 1,078 (72%) were reported in one and n = 421 (28%) in more than one Southeast Asian country. Additionally, n = 183

Table 2. Non-native species with potential to be introduced in the Philippines and their possible Impacts. See Suppl. material 9: table S9 for the taxonomic checklist in GBIF.

Species	Kingdom	Phylum/Clade	SE Asia	Impact Location	Impact
Ligustrum robustum[b]	Plants	Eudicots	Indonesia, Viet Nam, Thailand	Mauritius	Disrupts primary forest regeneration; Threatens native floral biodiversity
Miconia crenata[a]	Plants	Eudicots	Brunei Darussalam, Indonesia, Malaysia, Singapore, Thailand, Timor-Leste, Viet Nam	Australia, Brunei Darussalam, Comoros, Mauritius, Seychelles, Vanuatu, Kenya, Uganda, United Republic of Tanzania	Resource competition; Weed of natural forests
Parkinsonia aculeata [a]	Plants	Eudicots	Cambodia, Indonesia, Lao People's Democratic Republic, Thailand, Timor-Leste, Viet Nam	Australia, Cuba, Israel, Mozambique, Senegal, Somalia, South Africa, Spain, Ethiopia, Kenya, Uganda, United Republic of Tanzania	Creates dense and impenetrable thickets that make areas inaccessible for both humans and livestock
Stachytarpheta cayennensis [a]	Plants	Eudicots	Malaysia, Singapore, Timor-Leste, Indonesia	Cook Islands, Marshall Islands, Vanuatu	Resource competition
Arundo donax [a]	Plants	Monocots	Indonesia, Thailand, Timor-Leste	Argentina, Australia, Bermuda, Brazil, Chile, Cuba, Ecuador, Portugal, South Africa, Spain, Swaziland, Tunisia, Vanuatu, Zimbabwe, United Republic of Tanzania	Outcompete native species; Alter ecological and successional processes of habitats
Cyperus rotundus [b]	Plants	Monocots	Cambodia, Lao People's Democratic Republic, Malaysia, Myanmar, Singapore, Thailand, Timor-Leste, Viet Nam, Indonesia	Brazil, Cambodia, Chile, Cook Islands, Cote d'Ivoire, Egypt, Israel, Marshall Islands, Mauritius, Mozambique, Myanmar, Nigeria, Sudan, Tunisia, Vanuatu, Vietnam, Zambia, Zimbabwe, Ethiopia, United Republic of Tanzania	Damage to agriculture; Human nuisance
Limnocharis flava [a]	Plants	Monocots	Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Singapore, Thailand, Timor-Leste, Viet Nam	Australia, Ghana, Myanmar	Resource competition; Blockage of irrigation channels
Corvus splendens [a]	Animals	Chordates	Indonesia, Thailand, Malaysia, Singapore, Viet Nam	Mozambique, Saudi Arabia, Seychelles, Singapore, Sudan, United Arab Emirates, Yemen, United Republic of Tanzania, Djibouti, Eritrea, Israel, Jordan, Mauritius	Predation/harassment of native avifauna and livestock
Ctenopharyngodon idella [a]	Animals	Chordates	Cambodia, Indonesia, Thailand, Viet Nam, Brunei Darussalam, Malaysia, Myanmar	Vietnam, Algeria, Bolivia, Cambodia, Japan, Lao People's Democratic Republic, Lithuania, Myanmar, Nepal, Pakistan, Poland, Romania, South Africa, Switzerland	Reduce/removal of aquatic vegetation; Carries parasites
Tapinoma melanocephalum [a]	Animals	Arthropods	Indonesia, Cambodia, Malaysia, Thailand, Viet Nam	Iraq, Marshall Islands, Mauritius, Saudi Arabia, Sierra Leone, Somalia, Spain, United Arab Emirates, Vietnam, United Republic of Tanzania, Cook Islands, Ecuador, Equatorial Guinea, Gabon, Ghana	Agricultural pest; Transport pathogenic microbes

Source of impact information: [a] – CABI | [b] – GISD

species (43%) were found to be established in at least three (3) Southeast Asian countries, many of which have reported impacts (Table 2). Meanwhile, of the 1,209 established non-native species in the Philippines, introduction pathways for the majority of these species (n = 565; 55%) are unknown, with only n = 464 (45%) having known introduction pathways (Fig. 4). Among the available data, n = 307 (66%) pertain to plants, n = 154 (33%) animals, n = 2 (0.43%) algae, and n = 1 (0.21%) Myzozoa. The predominantly recorded introduction

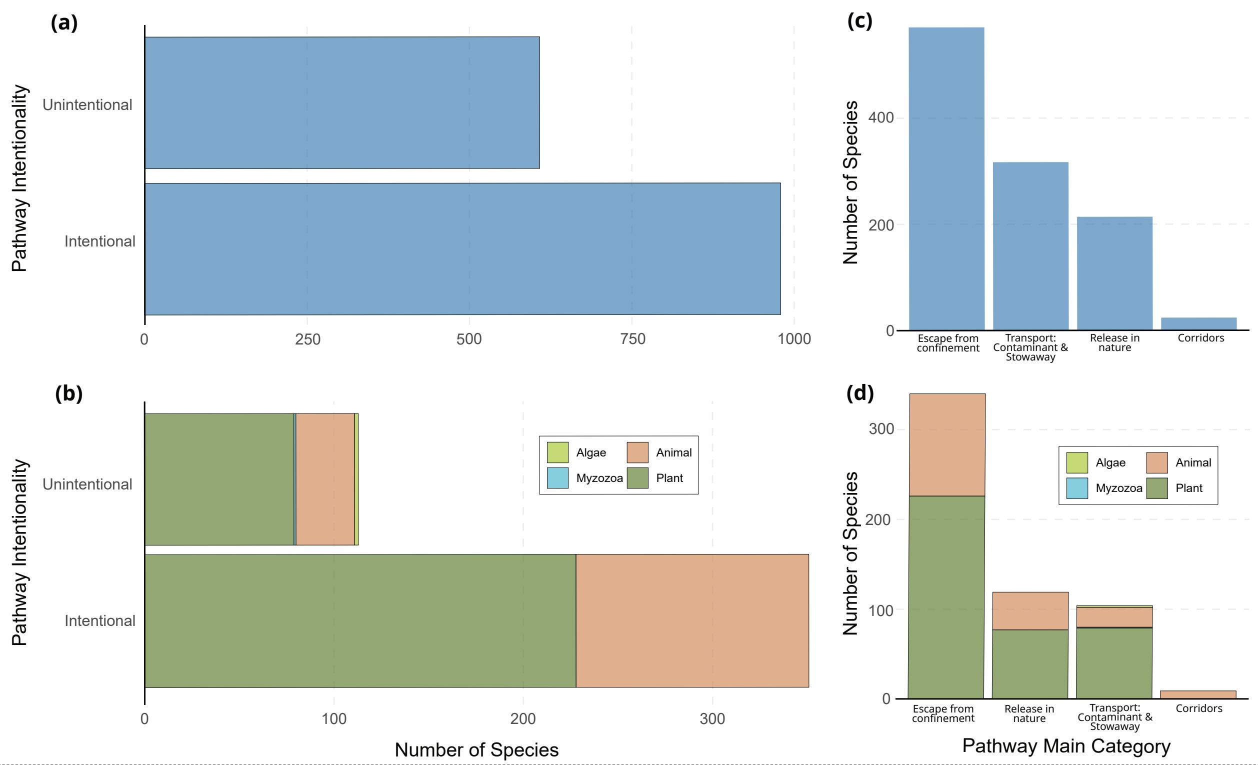

Figure 4. Reasons for introduction of non-native species in (**a**) Southeast Asia and (**b**) the Philippines, showing taxonomic breakdown of established non-native species in the country. (**c**) Recorded pathways for non-native species introduction in Southeast Asia and (**d**) the Philippines, showing taxonomic breakdown.

pathway for both non-native plants (n = 226) and animals (n = 114) is 'Escape from confinement". This is followed by the "Release in nature" pathway (plants = 77 species; animals = 42 species) and Transport – Contaminants & Stowaways (plants = 79 species; animals = 22 species; algae = 2 species; Myzozoa = 1 species). Information on non-native species introduced via "Corridors" is only available for animals (n = 9). Finally, most established non-native species found in the Philippines were introduced intentionally (n = 351), with only 113 species unintentionally introduced.

Discussion

The possible impacts of established non-native species in the Philippines and the Southeast Asia region highlight the need to fill knowledge gaps and provide information that will be useful in addressing the current and future threats. In this study, we identified and compiled the most comprehensive list of established non-native species in the Philippines and Southeast Asia, offering insights into taxonomic diversity, the ecosystems they have invaded, and which of these established species have reported impacts, enhancing our understanding of how biological invasions are reshaping the ecological landscape of the country. Further, our analysis uncovered notable similarities in the composition of established non-native species among Southeast Asian countries, suggesting potential shared introduction pathways and common factors driving invasion success throughout the region (Haubrock et al. 2025).

Potential biases in invasive species research

Global inventories of non-native species show that most of the species that thrive outside their native ranges are plants and arthropods (Briski et al. 2024). In fact, the dominance of these two groups in non-native species inventories has been observed since the 1950s (Elton 1958), but chordates are also a significant group (Turbelin et al. 2017). Comprehensive non-native species inventories conducted in Germany (Haubrock et al. 2025), South Africa (Zengeya et al. 2025) and Chile (Fuentes et al. 2020) demonstrated a similar trend. This pattern was also observed in the established non-native species in the Philippines, with members of these three groups comprising most listed non-native species.

Species from the division Tracheophyta (vascular plants) were the most dominant. Our data showed that species from the class Magnoliopsida (dicots) and Liliopsida (monocots) comprise the majority of non-native Tracheophytes. The role of these plants in the socio-economic development of human societies might have played a major role in their successful introductions in different parts of the globe (Briski et al. 2024). Globally, non-native plants are frequently introduced through horticulture – a major pathway for their introduction and a significant contributor to their spread (Seebens et al. 2022). However, in Southeast Asia, the influence of the traditional Chinese medicinal system, which commonly uses plants in the treatment of diseases (Kuah 2021; Liu 2021) could have facilitated the transport and establishment of some non-native plants in the region. In contrast, the number of non-native arthropods in the Philippines, which is dominated by members of the Insecta class, is not well represented in our dataset. This is surprising, as most non-native arthropods are agricultural pests and human-disease vectors, which are expected to attract significant attention due to their substantial economic impacts, especially in Southeast Asia where these pests cause significant agricultural losses and health issues (Haubrock et al. 2021; Renault et al. 2022; Briski et al. 2024).

An important finding of this study is the high number of non-native species belonging to the phylum Chordata, which is primarily represented by the class Actinopterygii (ray-finned fish). In the Philippines, the perceived socio-economic provisions of non-native species are key factors driving their intentional – or to some extent, unintentional – introduction (Abreo et al., unpub.). Freshwater aquaculture, aquarium and pet trades are all possible pathways that contribute to this high number of non-native chordates (Muyot et al. 2019; Sy et al. 2022). Several fish species, such as the janitor fish (*Pterygoplichthys disjunctivus*) and the clown featherback (*Chitala ornata*), as well as reptiles like the common iguana (*Iguana iguana*) and Chinese soft-shelled turtles (*Pelodiscus sinensis*), have been introduced through the pet and ornamental trade (Sy 2014; Camacho and Taniegra 2021). These species highlight the influence of these pathways in the non-native species composition of the country. Meanwhile, other chordates, such as cane toads, were intentionally introduced as biological control agents (Pili et al. 2019).

Our analyses also indicate a potential bias favoring research on terrestrial non-native species, as reflected in the relatively high number of established terrestrial non-native species reported in the Philippines – a trend consistent with global patterns (Briski et al. 2024; Haubrock et al. 2025). However, this over-representation is influenced by multiple factors. On one hand, it could reflect that susceptibility of terrestrial habitats to non-native species introduction is a consequence of ecological or socio-economic conditions. On the other hand, it may be a result of under-sampling and limited research capacity in other types of taxa and ecosystems. For example, the logistical challenges of studying marine environments and the lack of expertise in aquatic invasions likely contributed to the lower reported numbers (Broderick 2015; Giakoumi et al. 2016). Similarly, soil organisms and microbial taxa are likely underrepresented as a result of methodological limitations and insufficient sampling effort. Even for species belonging to the same taxonomic group (i.e. fungi), studies on microscopic species are far less than their macroscopic counterparts (Desprez-Loustau et al. 2010). Therefore, our findings should not be interpreted as evidence that other ecosystems host fewer non-native species, but rather it highlights the need for a more balanced and comprehensive research effort across taxa and habitat types (Haubrock et al. 2025).

Relationship of non-native species in the Philippines and other Southeast Asian countries

The close proximity of neighboring countries, shared natural vectors, and similar climates, facilitate the dispersal and establishment of non-native species – which together likely contributed to similarities in non-native species composition (Liu et al. 2021; Capinha et al. 2023). Land borders, particularly in Southeast Asia, are high-risk areas for non-native species invasion, acting as “bridgeheads” or sources of propagules, especially where biosecurity measures are weak (Haubrock et al. 2021; Zhang et al. 2024). Transboundary infrastructures, such as road networks and railways, increase connectivity between countries, facilitating the movement of people and goods, both key vectors for spreading non-native species (Zhang et al. 2024). Additionally, natural corridors such as the Mekong River, which spans six countries (China, Myanmar, Lao Peoples’ Democratic Republic, Thailand, Cambodia, and Vietnam), further facilitate species movement and secondary invasions. This can contribute to the similarity of non-native species composition among neighboring countries (Vietnam, Thailand, Cambodia, and Myanmar), comparable to the Danube River in dispersing non-native species across various European countries (Schmid et al. 2023; Soto et al. 2023b). Our results provide further evidence of the susceptibility of contiguous countries to the spread of non-native species. It is important to note, however, that the Jaccard similarity index used in the analysis of this paper is largely influenced by the reporting rate of each country-which is an inherent challenge when utilizing large occurrence data repositories (Maldonado et al. 2015). For example, Brunei Darussalam and Indonesia – having n = 78 similar species-have lower Jaccard similarity (0.083) compared to Brunei Darussalam and Cambodia (0.179) – which only has n = 45 similar species. This discrepancy can be explained because the number of reported non-native species in Indonesia is n = 891 compared to Cambodia which is n = 162. Nevertheless, the use of publicly available species distribution databases remains valuable in addressing knowledge gaps at a macroecological scale (Alhajeri and Fourcade 2019).

In archipelagic nations, where seas serve as natural barriers to species dispersal, long-distance, human-mediated species introductions play a significant role in the spread of non-native species (Pili et al. 2019). In the case between Philippines and Indonesia, socio-cultural connectivity-defined here as the shared traditions, ecological knowledge, and informal exchange networks rooted in a common Austronesian heritage (see Bellwood 1995) – coupled with other socio-economic factors can account for high similarity in non-native species composition. At present, both nations share maritime routes that facilitate legal and illegal wildlife trafficking (Gomez et al. 2022), with Indonesia serving as a primary source of ornamental birds, fish, and reptiles for Philippine markets. Recent studies have uncovered alarming trends in the trade of Indonesian birds in the Philippines (Sy et. al. 2022). The shared heritage which resulted in similar land use practices and domestic cultivation (e.g rice farming, domestication of similar animal species) create conditions that favor the movement and establishment of similar species across both nations.

As our study provided evidence that the problem of non-native species is transboundary (see Briski et al. 2024; Zhang et al. 2024), the number of established non-native species in the Philippines could increase in the foreseeable future as connectivity and economic engagements increase between Southeast Asian nations, through the ASEAN Free Trade Agreement (Nguyen et al. 2024). Although more than 70% of non-native species currently established in other Southeast Asian countries have no known impacts, overcoming methodological limitations in invasive species research or the lag time for the impacts, especially for 'sleeper' species (Spear et al. 2021; Robeck et al. 2024) may prove otherwise and if introduced, would add to the detriment of the Philippine environment and socio-economic landscape. Nevertheless, the more than 400 non-native species established elsewhere in Southeast Asia – some of which have known negative impacts – may be introduced and successfully established in the Philippines. Conversely, the Philippines could serve as a source of non-native species, possibly increasing the number of introductions to other countries in the region. This dual role highlights the Philippines as a critical piece in preventing further spread of non-native species and mitigation of their impacts in Southeast Asia.

Implications

As the Philippines can be considered as both source and sink of non-native species in Southeast Asia, future resource investments will play a crucial role in the detection and reporting of non-native species. Since the Philippines is not known to have significant investments in non-native species research (Liu et al. 2021), it cannot be discounted that having a reported n = 1,029 non-native species is not only an underestimation of the true numbers, but also a persisting regional risk. Additionally, the dataset presented here should be considered conservative, as it excludes recently (≤5 years) detected non-native species whose degree of establishment is unknown. Nevertheless, our study shows more than twice the number of non-native species currently reported in the country-specific list compiled by GRIIS.

The disproportionately high number of non-native species in the Philippines, relative to other Southeast Asian countries, could signal an impending "invasion meltdown" – where interaction between non-native species may facilitate the establishment of other non-native species due to altered attributes of the recipient environment – emphasizing the urgency of addressing this issue. Misinformed decisions by government authorities and the general public, stemming from the lack of comprehensive and long-term monitoring data, may thus exacerbate the non-native species problem (Haubrock et al. 2023). For instance, non-native fish species, such as the Nile tilapia – considered as invasive in nearly all of its non-native range (Canonico et al. 2005) – are distributed by the Philippine government to increase freshwater fisheries production, facilitating their expansion into new areas.

The majority of recorded non-native species in the Philippines are intentionally brought into the country (Fig. 4b) and introduced into the wild through escapes from confinement (Fig. 4d). It is important to note, however, that there are emerging introduction pathways that may have not been captured in the database we utilized during the analysis (e.g. Mghili et al. 2023). Nonetheless, this highlights the role of human perception in viewing benefits, whether emotional and mental health from pets and ornamental organisms (Schmitz et al. 2022) or economic gains, as seen with the golden apple snail in Southeast Asia (Jiang et al. 2022) play a crucial role in non-native species introduction. However, studies show that their negative impacts often outweigh any potential benefits (Carneiro et al. 2024). In general, the complex interplay among geographical, ecological, and socio-cultural/economic factors that drive the dispersal, spread, and establishment of non-native species underscores the need for stronger border biosecurity measures and transboundary cooperation among Southeast Asian countries (IPBES 2023), including joint monitoring and coordinated response strategies, to minimize the threat of non-native species in the region (Magliozzi et al. 2024). Furthermore, it is important to recognize the interconnections between biological invasions and broader environmental and socio-economic challenges. For instance, as global trade and urbanization increases, the frequency and scale of non-native species introductions are likely to rise, with profound implications for global biodiversity and food security (Essl et al. 2020; Diagne et al. 2021). The resulting costs associated with managing non-native species can place an overwhelming strain on already limited resources, particularly in developing regions (Mendoza et al. 2022). Therefore, by positioning our findings within a regional context, we highlight the critical need for managing non-native species – especially in biodiversity-rich areas like Southeast Asia (IPBES 2023) – and pave the way for advancing non-native species research and management in the region.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

Funding

PJH: Marie Skłodowska-Curie Postdoctoral Fellow, European Commission Project: DIRECT (Grant No. 101203662).

Author contributions

Conceptualization: NASA, IS, PJJH. Data curation: IS, EB. Formal analysis: NASA. Resources: AK. Supervision: PJJH, AK, IS. Visualization: NASA, PJJH. Writing – original draft: IS, NASA, PJJH, AK. Writing – review and editing: DA, PJJH, IS, NASA, AK, EB.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Non-native species breakdown for SE Asia

Authors: Neil Angelo Abreo, Antonín Kouba, Elizabeta Briski, Danish Ahmed, Ismael Soto, Phillip J. Haubrock

Data type: csv

Link: https://doi.org/10.3897/neobiota.100.156371.suppl1

Supplementary material 2

Pathways of non-native species according to Saul et al. 2017

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Data type: xlsx

Link: https://doi.org/10.3897/neobiota.100.156371.suppl2

Supplementary material 3

Non-native species breakdown for Southeast Asian countries

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Data type: xlsx

Link: https://doi.org/10.3897/neobiota.100.156371.suppl3

Supplementary material 4

List of established non-native species in the Philippines

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Data type: xlsx

Link: https://doi.org/10.3897/neobiota.100.156371.suppl4

Supplementary material 5

Breakdown of non-native species established in the Philippines

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Data type: xlsx

Link: https://doi.org/10.3897/neobiota.100.156371.suppl5

Supplementary material 6

Species similarity among SE Asian countries

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Data type: pdf

Link: https://doi.org/10.3897/neobiota.100.156371.suppl16

Supplementary material 7

Jaccar similarity index values used in Network Analysis

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Data type: pdf

Link: https://doi.org/10.3897/neobiota.100.156371.suppl7

Supplementary material 8

List of non-native species established in the neighboring countries on the Philippines

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Data type: Data type: xlsx

Link: https://doi.org/10.3897/neobiota.100.156371.suppl8

Supplementary material 9

Taxonomic checklist in GBIF

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Data type: Data type: xlsx

Link: https://doi.org/10.3897/neobiota.100.156371.suppl9

Supplementary material 10

Supplementary figure

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Data type: pdf

Link: https://doi.org/10.3897/neobiota.100.156371.suppl10