Indonesian Journal of Contemporary Multidisciplinary Research (MODERN)
Vol. 5, No. 2, 2026: 421-440

Alien Fish Invasions in Indonesian Inland Waters: Ecological Consequences and Biodiversity Implications

Faqih Baihaqi[1]*, Shafira Bilqis Annida[2]
[1]Department of Fisheries, faculty of Fisheries and Marine Sciences, Jatinangor Padjadjaran University, [2]Marine Tourism Study Program, Vocational School, Padjadjaran University
Corresponding Author: Faqih Baihaqi faqih.baihaqi@unpad.ac.id

A R T I C L E I N F O

Keywords: Alien Fish, Invasive Species, Freshwater Biodiversity, Inland Waters, Indonesia

Received : 10 January
Revised : 15 February
Accepted: 30 March

A B S T R A C T

Alien fish introductions have become an increasingly significant ecological issue in Indonesian inland waters, largely driven by aquaculture development, fisheries enhancement, and ornamental fish trade. While non-native species contribute to food security and economic growth, their establishment in natural freshwater ecosystems raises concerns for native biodiversity. This study systematically reviews existing literature on alien fish invasions in Indonesia, focusing on their ecological consequences and biodiversity implications. Using a structured review approach across major academic databases, relevant peer-reviewed studies were identified and synthesized. The findings indicate that widely introduced species such as *Oreochromis niloticus* and *Clarias gariepinus* are associated with competition, predation, habitat modification, and trophic restructuring. These impacts may alter native fish community composition and contribute to biotic homogenization, particularly in high-endemism freshwater systems. The review highlights the need for strengthened risk assessment, biosecurity measures, and ecosystem-based management to balance fisheries development with long-term biodiversity conservation

DOI: https://doi.org/10.55927/modern.v5i2.37
E-ISSN: 2985-6108
https://journalmodern.my.id/index.php/MODERN/index

INTRODUCTION

Freshwater ecosystems are among the most biologically diverse yet highly threatened ecosystems on the planet. Although they cover less than 1% of Earth's surface, inland waters support a disproportionately high number of species, particularly fish (Dudgeon et al., 2006a; Sayer et al., 2025). Indonesia, as one of the world's megabiodiversity countries, harbors an exceptionally rich freshwater ichthyofauna characterized by high levels of endemism across its archipelagic river basins, lakes, and wetlands. This unique biogeographical setting makes Indonesian inland waters both ecologically invaluable and inherently vulnerable to biological invasions (Haryono et al., 2023; Medrano, 2023; Salsabila et al., 2024).

The introduction of alien fish species, whether deliberate or accidental, has become increasingly common over the past decades. Globally, species introductions are primarily driven by aquaculture expansion, ornamental fish trade, recreational fisheries, and stock enhancement programs (Adha et al., 2013; Haubrock et al., 2022; Hedianto et al., 2014). In Indonesia, economically valuable species such as *Oreochromis niloticus*, *Clarias gariepinus*, and *Cyprinus carpio* have been widely introduced to enhance food security and rural livelihoods. While these introductions have contributed significantly to aquaculture production and economic development, their ecological consequences remain a growing concern (Henriksson et al., 2017; Mujahid et al., 2025; Sulistiono et al., 2022).

Biological invasions are recognized as one of the leading drivers of global biodiversity loss, alongside habitat degradation, pollution, overexploitation, and climate change. Once established, alien fish species may compete with native species for food and habitat, predate upon endemic fauna, introduce novel pathogens, alter trophic structures, and modify physical habitats. In tropical freshwater systems, where ecological interactions are often complex and endemism is high, such disturbances can lead to irreversible declines in biodiversity and biotic homogenization. The ecological sensitivity of island ecosystems further amplifies these risks, making Indonesia particularly susceptible to the impacts of invasions (Blanchard et al., 2023; Christian, 2023; Erarto & Getahun, 2020).

Despite the increasing documentation of alien fish occurrences in various Indonesian water bodies, existing studies are often fragmented, geographically limited, or species-specific. Most research focuses on distribution records, aquaculture performance, or localized ecological effects, with limited attempts to synthesize findings at a national scale. Consequently, there remains a critical knowledge gap in understanding the cumulative ecological consequences and broader biodiversity implications of alien fish invasions across Indonesian inland waters.

A comprehensive literature review is therefore urgently needed to consolidate existing scientific evidence, identify consistent patterns of impact, and assess the extent to which alien fish species threaten native biodiversity in Indonesia. Such synthesis is essential not only for advancing scientific understanding within invasion ecology but also for informing evidence-based

management strategies, conservation planning, and policy formulation. In the context of sustainable fisheries development and biodiversity conservation, balancing economic benefits against ecological risks requires an integrated, well-documented knowledge base.

Accordingly, this study aims to systematically review and synthesize published research on alien fish invasions in Indonesian inland waters. Specifically, this review seeks to: (1) identify the major alien fish species introduced and established in Indonesia; (2) examine the documented ecological impacts on native fish communities and aquatic ecosystems; (3) assess the broader implications for freshwater biodiversity; and (4) highlight research gaps and management challenges that require future attention. By providing a structured synthesis of available knowledge, this paper intends to contribute to a more comprehensive understanding of invasion dynamics in tropical archipelagic freshwater systems and to support sustainable biodiversity management in Indonesia.

LITERATURE REVIEW

Concept of Alien and Invasive Species in Freshwater Ecosystems

The terms *alien species*, *non-native species*, *exotic species*, and *invasive species* are often used interchangeably, although they represent distinct ecological concepts. An alien (or non-native) species refers to a species introduced outside its natural distribution range through human activities, either intentionally or unintentionally. However, not all alien species become invasive. An invasive species is generally defined as a non-native organism that establishes, spreads, and causes ecological, economic, or social harm in the introduced environment (Dali et al., 2023; Dina et al., 2022).

In freshwater ecosystems, fish introductions have historically been motivated by aquaculture development, food security enhancement, recreational fisheries, and biological control programs. Once introduced, alien fish may undergo a series of stages commonly described in invasion ecology: transport, introduction, establishment, and spread. The transition from introduction to successful invasion depends on propagule pressure, environmental suitability, species life-history traits, and ecosystem resistance (Dali et al., 2023; Gozlan et al., 2024; Kiruba-Sankar et al., 2018).

Understanding these conceptual distinctions is crucial in the Indonesian context, where many economically valuable species, such as *Oreochromis niloticus* and *Clarias gariepinus,* are widely cultivated and socially accepted, yet may exhibit invasive characteristics under certain ecological conditions (Chakraborty, 2024; Haryono & Wahyudewantoro, 2020; Shuai et al., 2023; Sulistiono et al., 2022). Other species, such as the red devilfish (*Amphilopus* spp.), were initially introduced into freshwater ecosystems to increase local fisheries productivity, but instead have actively dominated, invaded, and caused high local species losses (Ohee et al., 2018; Umar et al., 2015).

Theoretical Foundations of Invasion Ecology

Invasion ecology provides the primary theoretical framework for understanding the dynamics and impacts of alien species. Several key concepts are particularly relevant to freshwater fish invasions.

First, the biotic resistance hypothesis suggests that ecosystems with high native biodiversity may be more resistant to invasion due to niche saturation and strong interspecific interactions. However, empirical evidence remains mixed, especially in tropical freshwater systems where disturbance and habitat modification may reduce ecological resistance (Beaury et al., 2020).

Second, the enemy release hypothesis posits that alien species may become successful invaders because they escape natural predators, parasites, or competitors from their native range. In newly colonized environments, this release from biological constraints may enhance their growth, reproduction, and competitive dominance (Colautti et al., 2004).

Third, the concept of ecological niche theory explains invasion success through niche overlap and resource competition. When alien fish occupy trophic or habitat niches similar to those of native species, competitive exclusion may occur, potentially leading to local population declines or displacement (Li et al., 2022).

Finally, invasion processes are often linked to disturbance theory, which suggests that anthropogenic disturbances, such as habitat alteration, pollution, dam construction, and overfishing, create ecological opportunities that facilitate the establishment of alien species. In rapidly developing regions such as Indonesia, these disturbances may interact synergistically with species introductions (Blanchard et al., 2023).

Ecological Impacts on Native Fish Communities

The ecological consequences of alien fish invasions can be categorized into direct and indirect effects. Direct effects include predation on native species, competition for food and spawning grounds, and hybridization that may lead to genetic introgression. Hybridization is particularly concerning in systems with closely related endemic taxa, as it can lead to genetic erosion and the loss of unique evolutionary lineages (Banyal & Bains, 2025; Carosi et al., 2023).

Indirect effects involve alterations to trophic structure, nutrient cycling, and habitat characteristics. For example, benthic-feeding invasive species such as *Pterygoplichthys pardalis* can increase turbidity and modify substrate composition, thereby affecting spawning habitats and primary productivity. These cascading ecological effects may extend beyond fish communities, influencing broader aquatic biodiversity (Elfidasari et al., 2020).

Over time, such impacts may result in biotic homogenization, a process in which distinct local assemblages become increasingly similar due to the widespread establishment of common non-native species and the decline of endemic taxa (Chien, 2025).

Biodiversity Implications in Archipelagic and Tropical Contexts

Indonesia's freshwater biodiversity is shaped by its archipelagic geography, complex geological history, and varied climatic conditions. Many river basins and lakes harbor endemic species with restricted distributions, making them particularly vulnerable to ecological perturbations (Hutama et al., 2016; Lohman et al., 2011).

Island biogeography theory suggests that isolated ecosystems often exhibit high endemism but lower resilience to biological invasions. In such systems, native species may lack evolutionary adaptations to cope with novel predators or competitors. Consequently, the introduction of alien fish may disproportionately affect endemic and specialist species compared to widespread generalists (Rios et al., 2024).

In tropical freshwater ecosystems, where ecological interactions are often tightly structured and species richness is high, the loss of native fish can have cascading implications for ecosystem functioning, food web stability, and local livelihoods. Therefore, understanding the theoretical links between invasion processes and biodiversity outcomes is essential for developing effective conservation and management strategies (Cooke et al., 2024).

METHODOLOGY

Research Design

This study adopted a literature review approach to synthesize and critically evaluate existing scientific evidence on alien fish invasions in Indonesian inland waters and their ecological consequences on native biodiversity. A systematic review design was chosen to ensure methodological transparency, replicability, and analytical rigor in identifying and interpreting relevant publications. By implementing a structured and sequential review protocol, this study sought to minimize subjectivity in article selection while enabling a comprehensive synthesis of available knowledge.

The scope of the review was limited to freshwater inland ecosystems within the Indonesian territory, including rivers, lakes, reservoirs, wetlands, and associated floodplain systems. Marine and brackish-water environments were intentionally excluded to maintain ecological consistency and to ensure that the synthesis remained focused on freshwater invasion dynamics. The overall review process followed four main stages: identification of relevant publications, screening and eligibility assessment, systematic data extraction, and thematic synthesis.

Data Sources and Search Strategy

Scientific publications were retrieved from major academic databases, including Scopus, Web of Science, and Google Scholar, in order to ensure broad coverage of peer-reviewed international and national literature. These databases were selected because they index high-quality scientific outputs across ecological and environmental disciplines and provide sufficient search flexibility for systematic reviews (Gusenbauer & Haddaway, 2020).

The search strategy employed structured keyword combinations using Boolean operators to capture variations in terminology related to alien species

and ecological impacts. Core search strings included combinations of "alien fish," "non-native fish," "exotic fish," and "invasive fish" together with "Indonesia" and terms such as "freshwater," "river," "lake," or "inland waters," as well as "biodiversity" and "ecological impact." Searches were conducted for publications released between 2000 and 2025 to ensure that the review reflected contemporary invasion patterns and recent ecological findings.

To reduce the risk of omitting relevant studies, a backward reference search (snowballing technique) was conducted by examining the reference lists of selected articles. This step allowed the identification of additional relevant publications that were not captured during the initial database search (Wohlin et al., 2022).

Study Selection Criteria

Following the identification stage, all retrieved records underwent a two-step screening process. First, titles and abstracts were examined to determine their relevance to the research objectives. Articles that appeared to address occurrences of alien fish, ecological impacts, or biodiversity implications in Indonesian inland waters were retained for full-text evaluation. In the second stage, full-text articles were assessed for eligibility based on predefined inclusion and exclusion criteria.

Only peer-reviewed journal articles were included to ensure scientific credibility and methodological clarity. Studies were required to explicitly focus on alien or non-native fish species in Indonesian freshwater ecosystems and to report ecological impacts, biodiversity effects, distributional patterns, or management implications. Publications written in English or Bahasa Indonesia were considered eligible. Conversely, studies that focused exclusively on aquaculture production performance without ecological assessment were excluded, as were studies conducted outside Indonesia and grey literature lacking sufficient methodological transparency. Marine ecosystem studies were also excluded to maintain analytical focus.

This structured selection process ensured that the final dataset comprised scientifically robust, contextually relevant studies aligned with the review's objectives.

Data Extraction and Thematic Classification

Eligible articles were systematically examined, and relevant information was extracted and compiled into a structured data matrix. Extracted data included publication details, geographic study location, alien fish species reported, documented introduction pathways where available, types of ecological impacts identified, biodiversity indicators assessed, and any management or policy recommendations proposed by the authors.

To facilitate comparative analysis, ecological impacts reported across studies were categorized into major thematic groups based on recurring patterns observed in the literature. These themes included interspecific competition, predation, hybridization and genetic introgression, habitat alteration, disease transmission, and modifications to trophic structure. The use of thematic classification allowed the identification of dominant impact

pathways and provided a consistent analytical framework for synthesizing findings across geographically and methodologically diverse studies.

Data Analysis and Synthesis

Given the heterogeneity of study designs, ecological indicators, and methodological approaches among the reviewed articles, a quantitative meta-analysis was deemed inappropriate. Instead, this study employed a qualitative narrative synthesis supported by frequency-based pattern analysis. Recurring species, commonly reported impact mechanisms, and geographically concentrated invasion cases were identified and interpreted to reveal broader ecological trends (Popay et al., 2006).

The analysis focused on identifying consistent patterns in species dominance, ecological interactions, and biodiversity responses across freshwater systems. Particular attention was paid to evidence of declines in native species, shifts in community composition, and indications of biotic homogenization. The synthesized findings were subsequently interpreted in light of established invasion ecology theories presented in the theoretical review section, thereby connecting empirical observations to broader ecological principles.

Through this integrative analytical approach, the review aimed not merely to summarize previous studies but to provide a structured understanding of invasion dynamics and their implications for freshwater biodiversity conservation in Indonesia.

Limitations of the Review

This review acknowledges several inherent limitations. Publication bias may influence the availability of documented ecological impacts, as studies reporting significant or negative effects are more likely to be published. Additionally, variations in sampling design, ecological indicators, and temporal scales across primary studies limit direct comparability and preclude statistical aggregation. These limitations were carefully considered during interpretation to avoid overgeneralization and to ensure balanced conclusions.

RESEARCH AND DISCUSSION

Overview of Alien Fish Introductions in Indonesian Inland Waters

The synthesis of reviewed studies indicates that alien fish introductions in Indonesian inland waters are neither recent nor incidental phenomena. Rather, they represent a long-standing and cumulative process closely linked to aquaculture development, fisheries enhancement programs, and the ornamental fish trade. Over the past several decades, Indonesia has actively introduced economically valuable freshwater fish species to support food security and rural livelihoods. While these initiatives have contributed significantly to national fish production, they have also facilitated the establishment of non-native species in natural ecosystems (de Silva, 2012; FAO, 2010; Haubrock, Novello, et al., 2025).

Several species recur consistently across multiple regions and studies. Among the most widely reported are *Oreochromis niloticus*, *Clarias gariepinus*,

and *Cyprinus carpio*, all of which were intentionally introduced for aquaculture purposes (Ainy et al., 2024; Muchlisin, 2012; Yanuarita et al., 2020). Benthic armored catfish such as *Pterygoplichthys pardalis* have been documented in several Indonesian rivers, often associated with releases from the ornamental fish trade (Elfidasari et al., 2020; Patoka et al., 2020). Another example often found is the red devil fish (*Amphilopus* spp.), which is known to have been introduced into lakes, reservoirs, and rivers in Indonesia to increase the productivity of local regional fisheries, with a lack of comprehensive initial studies and potential as an invasive species (Dadiono, 2023; Ohee et al., 2018; Umar et al., 2015). On the other hand, several foreign species, such as *Hypophthalmichthys molit,* were deliberately introduced as biological controls to counter plankton dominance (Herawati et al., 2017). Once established, many of these species demonstrate high environmental tolerance, rapid growth rates, and broad dietary niches, traits commonly associated with invasion success (Dina et al., 2022).

Indonesia's archipelagic geography and fragmented river systems create both ecological opportunity and vulnerability. In many cases, introductions that began in controlled aquaculture settings expanded into open freshwater systems through flooding events, cage aquaculture escape, or deliberate stocking. Over time, repeated propagule pressure has increased the likelihood of establishment and spread (Dina et al., 2022; Haryono et al., 2023; Husnah & Aida, 2005; Salsabila et al., 2024).

Patterns of Ecological Impacts

Across the reviewed literature, ecological impacts of alien fish in Indonesia can be grouped into several recurring mechanisms: competition, predation, habitat modification, and trophic alteration (Dina et al., 2022; Haryani et al., 2025; Hedianto & Sentosa, 2019; Robin et al., 2023).

Competition for food and spawning habitats is one of the most frequently reported interactions. Species such as Nile tilapia and red devil fish are characterized by dietary plasticity and efficient reproductive strategies, enabling them to exploit a wide range of trophic resources (Adjie et al., 2015; Nurfadillah et al., 2025; Pavlov & Kasumyan, 2002; Subekti et al., 2025). In lakes and reservoirs, their dominance has been associated with shifts in native fish abundance, particularly among species occupying similar ecological niches. Although direct causality is often difficult to isolate due to concurrent environmental degradation, multiple studies indicate consistent patterns of native species decline following the prolonged establishment of non-native fish populations (Insani et al., 2020; Umar et al., 2015).

Predatory impacts are especially significant in systems containing endemic species with restricted distributions. In smaller lakes or isolated river basins, introduced predatory or omnivorous species may exert disproportionate pressure on native juveniles and eggs. For example, the presence of alligator gar in the family Lepisosteidae (*Lepisosteus* spp. & *Atractosteus* spp.) poses a potential threat to native freshwater fishes in Indonesia due to their position as top predators (Hadiaty, 2007). Tropical island ecosystems, where many species

evolved in relative isolation, often lack evolutionary exposure to novel predators, reducing adaptive resilience (Achmad et al., 2018; Dina et al., 2022; Salsabila et al., 2024).

Habitat modification represents another critical yet sometimes overlooked pathway. Bottom-feeding invasive catfish, particularly species in the genus *Pterygoplichthys*, disturb sediment during foraging and burrowing. This behavior can increase turbidity, alter substrate composition, and disrupt spawning grounds of native fishes. Such physical ecosystem alterations may trigger cascading effects extending beyond fish assemblages, influencing aquatic vegetation and invertebrate communities (Elfidasari et al., 2020; Jeff et al., 2014; Patoka et al., 2020).

At the ecosystem level, several studies suggest evidence of trophic restructuring following biological invasions. The introduction of highly adaptable omnivores or generalist predators can simplify food webs by disrupting established trophic interactions and reducing specialist species. Consequently, invaded ecosystems often become dominated by generalist assemblages with lower structural complexity. This process is consistent with broader global patterns linking biological invasions to the functional homogenization of freshwater communities (David et al., 2017; Wainright et al., 2021).

Biodiversity Implications and Biotic Homogenization

One of the most significant long-term implications identified in the literature is the gradual erosion of freshwater biodiversity. Indonesia is globally recognized for its high freshwater fish endemism, particularly in ancient lakes and geographically isolated drainage basins. Geological complexity and long-term habitat isolation have promoted extensive speciation, resulting in numerous taxa restricted to single lakes or river systems. However, the introduction of widespread non-native species may erode the ecological distinctiveness of these systems by altering native community composition and threatening locally endemic taxa (Hutama et al., 2016; Parenti, 2011)

Biotic homogenization, the increasing similarity of species composition across geographically distinct ecosystems, emerges as a recurring theme. As widely distributed alien species establish populations in multiple river basins, locally unique assemblages may be replaced or diluted by a common set of generalist species. While total species richness may not decline immediately, the replacement of endemic taxa by cosmopolitan invaders reduces beta diversity and evolutionary uniqueness (Olden et al., 2004; Rahel, 2002).

Hybridization poses an additional, more subtle threat. Although less frequently documented, genetic introgression between introduced and native congeners can lead to genetic dilution and long-term evolutionary consequences. Such impacts are difficult to detect without molecular analyses, suggesting that current assessments may underestimate the true scale of biodiversity loss (Bradbeer et al., 2019; Scribner et al., 2001).

Importantly, the review indicates that biodiversity impacts often interact with other anthropogenic stressors, including habitat fragmentation, pollution,

and hydrological alteration. Invasion effects rarely occur in isolation; instead, they compound existing ecological pressures, amplifying vulnerability in already stressed freshwater systems (Dudgeon et al., 2006b; Johnson et al., 2008; Strayer, 2010).

Drivers and Synergistic Pressures

The literature consistently highlights aquaculture expansion as the dominant driver of fish introductions in Indonesia. Cage culture in lakes and reservoirs increases the likelihood of escape events, particularly during extreme weather or infrastructure failure. Government-supported stocking programs, historically aimed at enhancing fisheries productivity, have also contributed to the widespread distribution of certain species (Casal, 2006).

The ornamental fish trade represents a secondary but increasingly relevant pathway. Releases of aquarium species, intentional or accidental, have resulted in the establishment of several non-native taxa in urban rivers. Once introduced, high reproductive capacity and absence of natural predators may facilitate rapid population growth (Casal, 2006; Rachmatika et al., 2006; Widjaja et al., 2014).

Crucially, invasion success appears closely linked to ecosystem disturbance. Systems experiencing nutrient enrichment, shoreline modification, or hydrological change often provide ecological opportunities that favor adaptable non-native species. This interaction between disturbance and invasion reinforces theoretical expectations from invasion ecology and underscores the importance of integrated watershed management (Bunn & Arthington, 2002; Haubrock, Tarkan, et al., 2025; Ricciardi et al., 2021).

Implications for Conservation and Management

The cumulative findings suggest that alien fish invasions in Indonesian inland waters represent not merely isolated ecological events but systemic biodiversity challenges. While introduced species contribute to food production and economic resilience, unmanaged spread into natural ecosystems may compromise long-term ecological stability (Dina et al., 2022; Salsabila et al., 2024).

The review highlights the need for strengthened biosecurity protocols, risk assessments prior to species introduction, and post-introduction monitoring programs. Additionally, improved integration between fisheries development policies and biodiversity conservation frameworks is essential. Without proactive management, the gradual homogenization of freshwater ecosystems may undermine Indonesia's globally significant freshwater biodiversity heritage (Alfiandi et al., 2025; Liu et al., 2026; Taryono et al., 2021).

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This review demonstrates that alien fish invasions in Indonesian inland waters constitute a persistent ecological issue closely intertwined with aquaculture expansion, fisheries enhancement, and ornamental fish trade. While introduced species contribute significantly to food security and economic development, their establishment in natural freshwater systems has generated consistent ecological consequences, including competition with native species, predation, habitat alteration, and trophic restructuring. In ecologically isolated and high-endemism freshwater systems, these impacts may disproportionately affect endemic taxa.

The synthesis further indicates that invasion effects rarely occur in isolation but interact with broader anthropogenic pressures such as habitat degradation and hydrological modification. Over time, these cumulative processes may contribute to shifts in community composition and gradual biotic homogenization, thereby reducing the ecological distinctiveness of Indonesia's freshwater ecosystems. Balancing fisheries productivity with biodiversity conservation, therefore, emerges as a central sustainability challenge.

Recommendations

To address these challenges, stronger pre-introduction ecological risk assessments should be institutionalized prior to the deliberate release of non-native fish species, particularly in ecologically sensitive regions. Post-introduction monitoring systems, including long-term ecological and genetic surveillance, are essential for early detection of invasive spread and biodiversity impacts. Enhanced biosecurity protocols in aquaculture operations, especially in open-water cage systems, are equally critical to minimizing escape events.

At the policy level, closer integration between fisheries development and biodiversity conservation frameworks is required to ensure ecosystem-based management of inland waters. Future research should prioritize long-term, cross-basin comparative studies and functional diversity assessments to better quantify cumulative ecological impacts. Through precautionary and evidence-based management, Indonesia can better safeguard its freshwater biodiversity while sustaining the socioeconomic benefits derived from aquatic resource development.

ADVANCED RESEARCH

Despite the growing body of research on the occurrence of alien fish in Indonesian inland waters, significant knowledge gaps remain. Future studies should prioritize long-term ecological monitoring to quantify the cumulative impacts of invasions across multiple river basins and lake systems. In particular, there is a need for standardized methodologies to assess changes in community structure, functional diversity, and ecosystem resilience over time. Molecular and population genetic approaches are also essential to detect hybridization, cryptic invasions, and genetic erosion among endemic taxa, processes that are often underestimated in conventional ecological surveys.

Moreover, interdisciplinary research integrating ecological assessment with socio-economic and governance analysis is urgently required. Understanding how aquaculture expansion, stocking policies, and ornamental fish trade interact with local livelihoods and regulatory frameworks will provide a more comprehensive socio-ecological perspective on invasion dynamics. Comparative cross-basin studies and predictive modeling under climate change scenarios would further strengthen risk assessment and management strategies, ensuring that freshwater biodiversity conservation in Indonesia is informed by robust, forward-looking scientific evidence.

REFERENCES

Achmad, H., Martini, L., Aris Wibowo, S., & Nugroho, L. (2018). Harmful/invasive and potentially invasive fishes in Yogyakarta and surrounding: Spread,introduction potentials and control measures. *Jurnal Penelitian Perikanan Indonesia*, *24*(1), 61–72.

Adha, K., Rahim, A., Esa, Y., & Arshad, A. (2013). The Influence of Alien Fish Species on Native Fish Community Structure in Malaysian Waters. *Kuroshio Science*, *7*(1), 81–93.

Adjie, S., Khoirul, D., Balai, F., Perikanan, P., Umum, P., & Palembang, M.-. (2015). *R (Amphilopus labiatus) and (Ampheproductive biology of red devililopus citrinellus) IN KEDUNG OMBO RESERVOIR, CENTRAL JAVA* (Vol. 7, Number 1).

Ainy, N. S., Mujadid, I., Hadi, N., & Sjahfirdi, L. (2024). Increase in the Abundance of Invasive Fish Species in the Ciliwung River, DKI Jakarta and West Java Provinces. *ADI Journal on Recent Innovation (AJRI)*, *6*(1), 17–31. https://doi.org/10.34306/ajri.v6i1.1060

Banyal, H. S., & Bains, N. (2025). Impacts of Invasive Fish Species on Native Fish Species: Mechanisms, Evidence, and Management. *BioThink E-Magazine*, (4), 135–141. https://doi.org/10.5281/zenodo.17332225

Beaury, E. M., Finn, J. T., Corbin, J. D., Barr, V., & Bradley, B. A. (2020). Biotic resistance to invasion is ubiquitous across ecosystems of the United States. *Ecology Letters*, *23*(3), 476–482. https://doi.org/10.1111/ele.13446

Blanchard, R., Camacho-Cervantes, M., Herrera Ecuador, I., Koyama, A., Morales, C. L., & Munishi, L. K. (2023). Drivers Affecting Biological Invasions. In H. E. Roy, A. Pauchard, P. Stoett, & Truong R T (Eds.), *Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES Secretariat. https://doi.org/10.5281/zenodo.7430727

Bradbeer, S. J., Harrington, J., Watson, H., Warraich, A., Shechonge, A., Smith, A., Tamatamah, R., Ngatunga, B. P., Turner, G. F., & Genner, M. J. (2019). Limited hybridization between introduced and Critically Endangered indigenous tilapia fishes in northern Tanzania. *Hydrobiologia*, *832*(1), 257–268. https://doi.org/10.1007/s10750-018-3572-5

Bunn, S. E., & Arthington, A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management*, *30*(4), 492–507. https://doi.org/10.1007/s00267-002-2737-0

Carosi, A., Lorenzoni, F., & Lorenzoni, M. (2023). Synergistic Effects of Climate Change and Alien Fish Invasions in Freshwater Ecosystems: A Review. *Fishes*, *8*(10), 1–20. https://doi.org/10.3390/fishes8100486

Casal, C. M. V. (2006). Global documentation of fish introductions: The growing crisis and recommendations for action. *Biological Invasions*, *8*(1), 3–11. https://doi.org/10.1007/s10530-005-0231-3

Chakraborty, B. (2024). Clarias gariepinus Summary Datasheet Type(s). *CABI*, *16*, 1–24.

Chien, S. C. (2025). Ecological homogenization and convergence in urban ecosystems: A global synthesis of biotic, abiotic, and ecosystem dimensions. In *Environmental and Sustainability Indicators* (Vol. 28). Elsevier B.V. https://doi.org/10.1016/j.indic.2025.100954

Christian, H.-M. (2023). The Main Drivers of Biodiversity Loss: A Brief Overview. *Journal of Ecology & Natural Resources*, *7*(3), 1–7. https://doi.org/10.23880/jenr-16000346

Colautti, R. I., Ricciardi, A., Grigorovich, I. A., & MacIsaac, H. J. (2004). Is invasion success explained by the enemy release hypothesis? *Ecology Letters*, *7*(8), 721–733. https://doi.org/10.1111/j.1461-0248.2004.00616.x

Cooke, S. J., Piczak, M. L., Nyboer, E. A., Michalski, F., Bennett, A., Koning, A. A., Hughes, K. A., Chen, Y., Wu, J., Cowx, I. G., Koehnken, L., Raghavan, R., Pompeu, P. S., Phang, S., Valbo-Jørgensen, J., Bendixen, M., Torres, A., Getahun, A., Kondolf, G. M., … Taylor, W. W. (2024). Managing exploitation of freshwater species and aggregates to protect and restore freshwater biodiversity. *Environmental Reviews*, *32*(3), 414–437. https://doi.org/10.1139/er-2022-0118

Dadiono, Muh. S. (2023). Invasi Spesies Amphilophus citrinellus Terhadap Ikan Lokal di Perairan Waduk Sanguling. *Nekton*, *3*(2), 116–121. https://doi.org/10.47767/nekton.v3i2.498

Dali, M. Z. M., Umar, R., Ismail, N., Juahir, H., Nasir, M. S. A. M., Khaleel, A. G., Madiran, N. A., Kari, Z. A., Wei, L. S., Tahiluddin, A. B., Téllez-Isaías, G., & Kamarudin, A. S. (2023). Detection and Management of Freshwater Invasive Alien Species through Environmental DNA Analysis and Geographic Information Systems: A Review. *Sustainability (Switzerland)*, *15*(12), 1–25. https://doi.org/10.3390/su15129497

David, P., Thébault, E., Anneville, O., Duyck, P. F., Chapuis, E., & Loeuille, N. (2017). Impacts of Invasive Species on Food Webs: A Review of Empirical Data. In *Advances in Ecological Research* (Vol. 56, pp. 1–60). Academic Press Inc. https://doi.org/10.1016/bs.aecr.2016.10.001

De Silva, S. S. (2012). Aquaculture: A newly emergent food production sector-and perspectives of its impacts on biodiversity and conservation. *Biodiversity and Conservation*, *21*(12), 3187–3220. https://doi.org/10.1007/s10531-012-0360-9

Dina, R., Wahyudewantoro, G., Larashati, S., Aisyah, S., Lukman, Sulastri, Imroatushshoolikhah, & Sauri, S. (2022). Distributional Mapping and Impacts of Invasive Alien Fish in Indonesia: An Alert to Inland Waters Sustainability. *Sains Malaysiana*, *51*(8), 2377–2401. https://doi.org/10.17576/jsm-2022-5108-04

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D., Stiassny, M. L. J., & Sullivan, C. A. (2006a). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society*, *81*(2), 163–182. https://doi.org/10.1017/S1464793105006950

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D., Stiassny, M. L. J., & Sullivan, C. A. (2006b). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society*, *81*(2), 163–182. https://doi.org/10.1017/S1464793105006950

Elfidasari, D., Wijayanti, F., & Sholihah, A. (2020). Trophic level and position of pterygoplichthys pardalis in ciliwung river (Jakarta, indonesia) ecosystem based on the gut content analysis. *Biodiversitas*, *21*(6), 2862–2870. https://doi.org/10.13057/biodiv/d210665

Erarto, F., & Getahun, A. (2020). Impacts of introductions of alien species with emphasis on fishes. *International Journal of Fisheries and Aquatic Studies*, *8*(5), 207–216. http://www.fisheriesjournal.com

Alfiandi, M. F., Rokhim, A., & isnaeni, D. (2025). Ownership of invasive fish under positive law in Indonesia. *International Journal of Cultural and Social Science*, *6*(2), 660–667.

FAO. (2010). *Inland fisheries resource enhancement and conservation in Asia* (M. Weimin, S. De Sliva, & B. Davy, Eds.). Food and Agriculture Organization of the United Nations.

Gozlan, R. E., Bommarito, C., Caballero-Huertas, M., Givens, J., Mortillaro, J. M., Pepey, E., Ralaiarison, R. P., Senff, P., & Combe, M. (2024). A one-health approach to non-native species, aquaculture, and food security. *Water Biology and Security*, *3*(2), 100250. https://doi.org/10.1016/j.watbs.2024.100250

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods*, *11*(2), 181–217. https://doi.org/10.1002/jrsm.1378

Hadiaty, R. K. (2007). Kajian ilmiah ikangar, Famili Lepisosteidae (Lepisosteus spp. & Atractosteus spp.): spesies ancaman bagi ikan asli Indonesia. *Zoo Indonesia*, *16*(2), 87–96.

Haryani, G. S., Gustiano, R., Arthana, I. W., Noegroho, T., Aisyah, S., Kartika, G. R. A., & Sulawesty, F. (2025). Optimizing Fisheries Management for Invasive Fish Control in Lake Batur, Bali Island. *BIO Web of Conferences*, *196*. https://doi.org/10.1051/bioconf/202519605001

Haryono, H., Gustiano, R., & Wahyudewantoro, G. (2023). Sustainable Development: The Case for Aquatic Biodiversity in Indonesia's Peatland Areas. In G. Shukla, J. A. Bhat, S. Chakravarty, A. W. Almutairi, & M. Li (Eds.), *Floristic Diversity – Biology and Conservation*. IntechOpen. https://doi.org/10.5772/intechopen.105919

Haryono, & Wahyudewantoro, G. (2020). The alien freshwater fish of Mount Galunggung, West Java, Indonesia. *BIODIVERSITAS*, *21*(4), 1407–1414. https://smujo.id/biodiv/about/submissions

Haubrock, P. J., Bernery, C., Cuthbert, R. N., Liu, C., Kourantidou, M., Leroy, B., Turbelin, A. J., Kramer, A. M., Verbrugge, L. N. H., Diagne, C., Courchamp, F., & Gozlan, R. E. (2022). Knowledge gaps in economic costs of invasive alien fish worldwide. *Science of the Total Environment*, *803*, 149875. https://doi.org/10.1016/j.scitotenv.2021.149875

Haubrock, P. J., Novello, M., Abreo, N. A., Błońska, D., Sampaio Franco, A. C., Soto, I., Castaldelli, G., Katsanevakis, S., Kouba, A., Balzani, P., Kurtul, I., Tarkan, A. S., Briski, E., & Britton, R. (2025). A Global Account of Established Non-Native Fish Species. *Global Change Biology*, *31*(8), 1–16. https://doi.org/10.1111/gcb.70451

Haubrock, P. J., Tarkan, A. S., Martín-Forés, I., Katsanevakis, S., Sousa, R., Soto, I., Green, A. J., Kouba, A., Everts, T., Dominguez Almela, V., Belouard, N., Hui, C., Bojko, J., Deklerck, V., Boeraeve, M., Essl, F., & Britton, J. R. (2025). The spread of non-native species. *Biological Reviews*, 1–38. https://doi.org/10.1002/brv.70121

Hedianto, D. A., Purnomo, K., Kartamihardja, E. S., & Warsa, A. (2014). Population parameters of three spot cichlid (Cichlasoma trimaculatum, Günther 1867) in sempor reservoir, Central Java. *Jurnal Penelitian Perikanan Indonesia*, *20*(2), 81–88.

Hedianto, D. A., & Sentosa, A. A. (2019). Trophic interactions of fish community in Lake Matano, South Sulawesi post-development of invasive alien fish species. *Jurnal Penelitian Perikanan Indonesia*, *25*(2), 117–133. https://doi.org/10.15578/jppi.25.2.2019.117-133

Henriksson, P. J. G., Tran, N., Mohan, C. V., Chan, C. Y., Rodriguez, U. P., Suri, S., Mateos, L. D., Utomo, N. B. P., Hall, S., & Phillips, M. J. (2017). Indonesian aquaculture futures – Evaluating environmental and socioeconomic potentials and limitations. *Journal of Cleaner Production*, *162*, 1482–1490. https://doi.org/10.1016/j.jclepro.2017.06.133

Herawati, H., Dhahiyat, Y., & Raya Bandung-Sumedang, Z. J. (2017). Restocking Ikan Mola (Hypophthalmichthys molit,Valenciennes 1844) Di Waduk Cirata Sebagai Upaya Pengendalian Kelimpahan Plankton. *Jurnal Akuatika Indonesia*, *2*(1), 95–101.

Husnah, & Aida, S. N. (2005). Jenis, jumlah, dan distribusi ikan budi daya terlepas di Sungai Kampar, Provinsi Riau. *Jurnal Penelitian Perikanan Indonesia*, *11*(6), 1–10.

Hutama, A. A., Hadiaty, R. K., & Hubert, N. (2016). Biogeography of Indonesian freshwater fishes: Current progress. *Treubia*, *43*, 17–30.

Insani, L., Hasan, V., Sil Valen, F., Pratama, S., Widodo, M. S., Faqih, A. R., Islamy, A., Mukti, A. T., & Isroni, W. (2020). Presence of the invasive nile Tilapia Oreochromis niloticus Linnaeus, 1758 (Perciformes, Cichlidae) in the Yamdena Island, Indonesia. *Eco. Env. & Cons.*, *26*(3), 1115–1118.

Jeff, J., Hoover, R., Murphy, C. E., & Killgore, J. (2014). Aquatic Nuisance Species Research Program Ecological Impacts of Suckermouth Catfi shes (Loricariidae) in North America: A Conceptual Model. *ANSRP Bulletin Volume*, *14*, 1–20.

Johnson, P. T. J., Olden, J. D., & Vander Zanden, M. J. (2008). Dam invaders: Impoundments facilitate biological invasions into freshwaters. *Frontiers in Ecology and the Environment*, *6*(7), 357–363. https://doi.org/10.1890/070156

Kiruba-Sankar, R., Praveen Raj, J., Saravanan, K., Lohith Kumar, K., Raymond, J., Angel, J., Velmurugan, A., & Dam Roy, S. (2018). Invasive species in freshwater ecosystems-threats to ecosystem services. In *Biodiversity and Climate Change Adaptation in Tropical Islands* (pp. 257–296). Elsevier. https://doi.org/10.1016/B978-0-12-813064-3.00009-0

Li, Q. S., Xiong, Z. P., Lu, B., Pu, Y. W., Li, Y., Zhang, Y. J., & Duan, Y. B. (2022). Trophic niche differentiation between invasive and native frog species in urban wetlands of Kunming, China. *Global Ecology and Conservation*, *40*, e02318. https://doi.org/10.1016/j.gecco.2022.e02318

Liu, Y., Hewitt, C. L., McKirdy, S. J., & Thomas, M. L. (2026). Safeguarding islands: A systematic review of global island biosecurity plans. *Global Ecology and Conservation*, *66*, e04107. https://doi.org/10.1016/j.gecco.2026.e04107

Lohman, D. J., De Bruyn, M., Page, T., Von Rintelen, K., Hall, R., Ng, P. K. L., Shih, H. Te, Carvalho, G. C., & Von Rintelen, T. (2011). Beyond Wallaces line: Genes and biology inform historical biogeographical insights in the Indo-Australian archipelago. *Annual Review of Ecology, Evolution, and Systematics*, *42*, 205–226. https://doi.org/10.1146/annurev-ecolsys-102710-145001

Medrano, A. D. (2023). Fish, Freshwater, and the Promise of Biodiversity History for Indonesian Studies. *Forest and Society*, *7*(2), 435–449. https://doi.org/10.24259/fs.v7i2.18877

Muchlisin, Z. (2012). First report on introduced freshwater fishes in the waters of Aceh, Indonesia. *Archives of Polish Fisheries*, *20*(2), 129–135. https://doi.org/10.2478/v10086-012-0015-1

Mujahid, M., Adlan, Q., Diatin, I., Hadiroseyani, Y., & Matangaran, J. R. (2025). Utilizing settling ponds in reclaimed mine sites in Indonesia: Linking georesources and fish culture. *Journal of Degraded and Mining Lands Management*, *12*(5), 8583–8592. https://doi.org/10.15243/jdmlm.2025.125.8583

Nurfadillah, N., Fadli, N., Jalil, Z., & Akib, N. A. M. (2025). Food Habits and Growth Patterns of Native and Invasive Fish in Lake Aneuk Laot Sabang, Indonesia. *International Journal of Design and Nature and Ecodynamics*, *20*(4), 933–944. https://doi.org/10.18280/ijdne.200422

Ohee, H. L., Sujarta, P., Surbakti, S. B., & Barclay, H. (2018). Rapid expansion and biodiversity impacts of the red devil cichlid (Amphilophus labiatus, Günther 1864) in Lake Sentani, Papua, Indonesia. *Biodiversitas*, *19*(6), 2096–2103. https://doi.org/10.13057/biodiv/d190615

Olden, J. D., Poff, N. L. R., Douglas, M. R., Douglas, M. E., & Fausch, K. D. (2004). Ecological and evolutionary consequences of biotic homogenization. *Trends in Ecology and Evolution*, *19*(1), 18–24. https://doi.org/10.1016/j.tree.2003.09.010

Parenti, L. R. (2011). Endemism and conservation of the native freshwater fish fauna of Sulawesi, Indonesia. *Prosiding SeminarNasional Ikan V!*, 1–10.

Patoka, J., Takdir, M., Yonvitner, Aryadi, H., Jerikho, R., Nilawati, J., Tantu, F. Y., Bohatá, L., Aulia, A., Kamal, M. M., Wardiatno, Y., & Petrtýl, M. (2020). Two species of illegal South American sailfin catfish of the genus Pterygoplichthys well-established in Indonesia. *Knowledge and Management of Aquatic Ecosystems*, *2020-January*(421), 1–5. https://doi.org/10.1051/kmae/2020021

Pavlov, D. S., & Kasumyan, A. O. (2002). Feeding Diversity in Fishes: Trophic Classification of Fish. *Journal of Ichthyology*, *42*(2), S137–S159.

Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Britten, N., Roen, K., & Duffy, S. (2006). *Guidance on the Conduct of Narrative Synthesis in Systematic Reviews*. Lancaster University.

Rachmatika, I., Wahyudewantoro, G., Zoologi, B., Raya, J., Bogor, J., & 46 Cibinong, K. (2006). Introduced Fishes to Inland Waters in West Java and Ban ten: Some Notes on its Taxonomic and Distribution. *Jurna/ Iktiologi Indonesia*, *6*(2), 93–97.

Rahel, F. J. (2002). Homogenization of freshwater faunas. *Annual Review of Ecology and Systematics*, *33*, 291–315. https://doi.org/10.1146/annurev.ecolsys.33.010802.150429

Ricciardi, A., Iacarella, J. C., Aldridge, D. C., Blackburn, T. M., Carlton, J. T., Catford, J. A., Dick, J. T. A., Hulme, P. E., Jeschke, J. M., Liebhold, A. M., Lockwood, J. L., Macisaac, H. J., Meyerson, L. A., Pyšek, P., Richardson, D. M., Ruiz, G. M., Simberloff, D., Vilà, M., & Wardle, D. A. (2021). Four priority areas to advance invasion science in the face of rapid environmental change. *Environmental Reviews*, *29*(2), 119–141. https://doi.org/10.1139/er-2020-0088

Rios, E. B., Sadler, J., Graham, L., & Matthews, T. J. (2024). Species distribution models and island biogeography: Challenges and prospects. *Global Ecology and Conservation*, *51*. https://doi.org/10.1016/j.gecco.2024.e02943

Robin, Valen, F. S., Nomleni, A., Turnip, G., Yermias Luhulima, M., & Insani, L. (2023). Presence of non-native freshwater fish in Indonesia: A review - Risk and ecological impacts. *AACL Bioflux*, *16*(1), 66–79. http://www.bioflux.com.ro/aacl

Salsabila, S., Putri, V. Y. N., Bagaskara, R. D., Putri, N. P., Khoirinisa, F., Margaretha, A., Vauzcika, A. N., Ero, S. T. Y., Wiranti, D. D. P., Syabani, F. R., Rahayu, S. M., Sanjayasari, D., & Hutabarat, P. (2024). Invasive Aquatic Animal Species in Indonesia: A Review. *MAIYAH*, *3*(4), 287. https://doi.org/10.20884/1.maiyah.2024.3.4.13946

Sayer, C. A., Fernando, E., Jimenez, R. R., Macfarlane, N. B. W., Rapacciuolo, G., Böhm, M., Brooks, T. M., Contreras-MacBeath, T., Cox, N. A., Harrison, I., Hoffmann, M., Jenkins, R., Smith, K. G., Vié, J. C., Abbott, J. C., Allen, D. J., Allen, G. R., Barrios, V., Boudot, J. P., … Darwall, W. R. T. (2025). One-quarter of freshwater fauna threatened with extinction. *Nature*, *638*(8049), 138–145. https://doi.org/10.1038/s41586-024-08375-z

Scribner, K. T., Page, K. S., & Bartron, M. L. (2001). Hybridization in freshwater fishes: a review of case studies and cytonuclear methods of biological inference. *Reviews in Fish Biology and Fisheries*, *10*, 293–323.

Shuai, F., Li, J., & Lek, S. (2023). Nile tilapia (Oreochromis niloticus) invasion impacts trophic position and resource use of commercially harvested piscivorous fishes in a large subtropical river. *Ecological Processes*, *12*(1), 1–17. https://doi.org/10.1186/s13717-023-00430-3

Strayer, D. L. (2010). Alien species in fresh waters: Ecological effects, interactions with other stressors, and prospects for the future. *Freshwater Biology*, *55*(1), 152–174. https://doi.org/10.1111/j.1365-2427.2009.02380.x

Subekti, N. M., Kartika, I. W. D., & Restu, I. W. (2025). Reproductive Aspects of Red Devil Fish (Amphilophus citrinellus) in Lake Batur Area, Bali. *Advances in Tropical Biodiversity and Environmental Sciences*, *9*(2), 135–139. https://doi.org/10.24843/atbes.2025.v09.i02.p10

Sulistiono, S., Wildan, D. M., Ervinia, A., Rohim, N., Hedianto, D. A., Baihaqi, F., Abdillah, D., Yoga Parawangsa, I. N., Wahyudewantoro, G., & Yokota, M. (2022). Diversity, distribution, and species status of the fish in Banten Bay, Indonesia. *E3S Web of Conferences*, *339*. https://doi.org/10.1051/e3sconf/202233903003

Taryono, Mashar, A., & Aryasa, S. (2021). Management policy of invasive species red claw crayfish (Cherax quadricarinatus) at Lido Lake, Bogor Regency. *IOP Conference Series: Earth and Environmental Science*, *744*(1). https://doi.org/10.1088/1755-1315/744/1/012090

Umar, C., Kartamihardja, E. S., & Aisyah. (2015). Invasive impact of red devil fish (Amphilophus citrinellus) to fish diversity in inland water in Indonesia. *Jurnal Kebijakan Perikanan Indonesia*, *7*(1), 55–61.

Wainright, C. A., Muhlfeld, C. C., Elser, J. J., Bourret, S. L., & Devlin, S. P. (2021). Species invasion progressively disrupts the trophic structure of native food webs. *Proceedings of the National Academy of Sciences*. https://doi.org/10.1073/pnas.2102179118/-/DCSupplemental

Widjaja, E. A., Rahayuningsih, Y., Rahajoe, Y. S., Ubaidillah, R., Maryanto, I., Walujo, E. B., & Semiadi, G. (2014). *Kekinian Keanekaragaman Hayati Indonesia*. LIPI Press.

Wohlin, C., Kalinowski, M., Romero Felizardo, K., & Mendes, E. (2022). Successful combination of database search and snowballing for identification of primary studies in systematic literature studies. *Information and Software Technology*, *147*, 106908. https://doi.org/10.1016/j.infsof.2022.106908

Yanuarita, D., Inaku, D. F., Nurdin, N., Rahim, S. W., Kudsiah, H., Parawansa, B. S., Rukminasari, N., Irmawati, & Moka, W. (2020). Aquatic invasive species distribution within Wallace region: A preliminary review. *IOP Conference Series: Earth and Environmental Science*, *564*(1). https://doi.org/10.1088/1755-1315/564/1/012038