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A Systematic Review of Bioactive Compounds, Traditional Uses, and Conservation Perspectives of *Sonneratia caseolaris*

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ABSTRACT

Sonneratia caseolaris, or pedada, is a mangrove species widely distributed across Indonesia with rich ethnobotanical uses and promising phytopharmacological properties. This systematic review aims to consolidate current knowledge on the phytochemical compounds, biological activities, traditional applications, and conservation efforts associated with *S. caseolaris*. Using PRISMA guidelines, 20 peer-reviewed articles and institutional reports published between 2009 and 2024 were selected. Results indicated that *S. caseolaris* contains diverse secondary metabolites including flavonoids, phenolics, triterpenoids, tannins, alkaloids, and saponins, many of which exhibit potent antioxidant and antimicrobial activity. Ethnobotanical data reveal its use in traditional medicine, cosmetics, and local food products such as juice, syrup, jam, and dodol. Several community-based conservation and utilization models demonstrate its socio-economic importance. Despite its potential, further research is needed on pharmacokinetics, toxicity, and product development. This review highlights the value of integrating scientific and local knowledge to promote sustainable use and conservation of *S. caseolaris*.

KEYWORDS: *Sonneratia caseolaris*, pedada, phytochemicals, antioxidant activity, ethnobotany, mangrove

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1. INTRODUCTION

Mangrove ecosystems represent one of the most productive and ecologically significant habitats in tropical and subtropical regions. They play crucial roles in shoreline stabilization, nutrient cycling, carbon sequestration, and serve as breeding and nursery grounds for numerous aquatic species (Alongi, 2002) Among the mangrove flora, *S. caseolaris* (L.) Engl., commonly known as pedada, is a dominant species found in estuarine and riverine habitats. In Indonesia, it is widely distributed from the coastal areas of Sumatra (Bandaranayake, 1998; Efriyeldi et al., 2024)**.**

Traditionally, various parts of *S. caseolaris* have been utilized by coastal communities in Indonesia for culinary and medicinal purposes. The fruit is processed into syrup, jam, dodol, and juice, while the leaves are used in herbal remedies and skincare products (Setiawan et al., n.d., 2016)**.** Ethnobotanical observations from regions such as Riau, Lampung, and South Sulawesi reveal the integration of this species into daily life, particularly among women-led microenterprises (Mahardika et al., 2018). The increasing popularity of mangrove-derived food and cosmetic products has elevated *S. caseolaris* from a subsistence plant to a candidate for economic valorization.

Scientific interest in *S. caseolaris* has grown due to its rich phytochemical profile. Numerous studies have reported the presence of bioactive compounds such as flavonoids, tannins, alkaloids, saponins, triterpenoids, and steroids in its leaves, fruits, and bark (Halifah et al., 2019; Liu et al., 2023; Nurdiah, 2017)**.** These compounds exhibit various biological activities, including antioxidants, antimicrobial, anti-inflammatory, and cytotoxic effects (Dari et al., 2022; M. Tian et al., 2009). Antioxidant activity has been reported to be strong, with IC_{50} values often below 50 ppm, indicating potent radical scavenging potential (Nusaibah et al., 2022a; Sutra et al., 2025)**.**

Despite these promising findings, research on *S. caseolaris* remains scattered and lacks systematic synthesis. Most studies focus on either chemical profiling or bioactivity testing, with limited integration of ethnobotanical insights

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and conservation relevance. Moreover, there is a paucity of in vivo studies, toxicological assessments, and translational research aimed at product development or clinical application. Meanwhile, threats to mangrove ecosystems such as habitat conversion, pollution, and climate change underscore the urgency to document, conserve, and sustainably utilize species like *S. caseolaris* (Efriyeldi et al., 2024; Mahardika et al., 2018).

This systematic review aims to consolidate existing scientific literature on the phytopharmacological and ethnobotanical potential of *S. caseolaris* in Indonesia. Specifically, it seeks to (1) describe the plant's phytochemical constituents, (2) summarize reported biological activities, (3) explore traditional and contemporary uses, and (4) highlight conservation efforts and knowledge gaps. By integrating diverse sources of data, this review aspires to support further research, bioprospecting, and sustainable mangrove management practices.

2. METHODS

This systematic literature review was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency and reproducibility. The search process was carried out between January and May 2025, focusing on peer-reviewed articles, proceedings, and institutional reports related to *S. caseolaris* in Indonesia. Literature searches were performed across multiple scientific databases and repositories including Google Scholar, ResearchGate, ScienceDirect, and national journals indexed by Sinta. The keywords used in both English and Bahasa Indonesia included combinations of: "*S. caseolaris*", "pedada", "phytochemicals", "antioxidant", "ethnobotany", "antimicrobial", "bioactivity", and "mangrove conservation".

The inclusion criteria were: (1) studies published between 2009 and 2024, (2) research focused specifically on *S. caseolaris*, and (3) studies reporting phytochemical content, biological activity (in vitro or in vivo), ethnobotanical usage, or conservation approaches. Exclusion criteria included: (1) articles that only addressed general mangrove ecology without species-level focus, (2) studies conducted outside the Indonesian context, and (3) papers with insufficient or unclear data regarding methods or results. Duplicates were removed using manual screening.

A total of 57 records were initially identified. After removing duplicates and non-relevant titles, 34 studies remained for abstract screening. Of these, 25 full-text articles were assessed for eligibility, and finally, 20 studies met all criteria and were included in the qualitative synthesis. Data extraction focused on key parameters including plant parts analyzed, extraction methods, identified phytochemicals, IC_{50} values for antioxidant assays, types of bioactivities tested, traditional uses, and conservation or community application models. All data were tabulated and visualized using descriptive synthesis supported by tables and figures.

3. RESULTS AND DISCUSSION

S. caseolaris is one of the mangroves (Local name: Pedada, perepat, Pedada, bogem, bidada, posi-posi merah, wahat merah, Sawawir) which tree typically grows up to 15 meters tall, occasionally reaching 20 meters, and is distinguished by its numerous, robust, conical pneumatophores that can reach up to 1 meter in height. Its young twigs are quadrangular and drooping. The leaves are simple, opposite, with short reddish petioles, and have an oblong to elliptical shape with rounded tips, measuring approximately 5–13 cm in length and 2–5 cm in width. The flower buds are ovoid, and when fully open, the bowl-shaped calyx reveals red petals 17–35 mm long that are easily shed. Flowers appear terminally, either solitary or in small clusters of 1–3, with 6–8 calyx lobes that are green outside and yellowish to greenish-white inside, and numerous stamens with red bases and white tips. The fruit is globular, larger than that of *Sonneratia alba*, with a stalked apex and a base enclosed by the persistent calyx, measuring 6–8 cm in diameter (Figure 1).

Figure 1. *Sonneratia caseolaris* (https://www.nparks.gov.sg/florafaunaweb/flora/3/3/3343)

1. Community-Based Conservation Initiatives

Community-driven conservation efforts for *S. caseolaris* have been reported most notably in Lampung, Riau, and Seram. In Lampung, grassroots initiatives include mangrove education programs, reforestation, and the processing of *S. caseolaris* fruits into variations of food. Similar activities in Riau demonstrate the integration of traditional knowledge with small-scale food production, contributing to coastal economic resilience. In Seram, fruit-derived soap production highlights the diversification of mangrove-based product innovation. These case studies underline the potential of *S. caseolaris* as a vehicle for socio-ecological conservation, reinforcing previous assertions that community engagement is key to successful mangrove (Mahardika et al., 2018).

However, many of these initiatives operate in isolation, lacking scientific support or institutional continuity (Friess et al., 2016). As noted in other regions, the success of community-based conservation hinges not only on local commitment but also on capacity-building, market access, and adaptive governance. The implication is clear: to scale these initiatives, policies must integrate community-based monitoring and invest in co-management frameworks that link traditional practices with ecological science.

2. Ecological Distribution and Adaptation

Sonneratia caseolaris is a vital species in Indonesia's mangrove ecosystems due to its ecological role as a pioneer species in riverine and estuarine habitats. Its spatial distribution extends widely across the archipelago, including the coastal zones of Sumatra, Kalimantan, Sulawesi, Papua, and the Lesser Sunda Islands (Table 1). The species typically thrives in fine-textured, muddy substrates with low salinity and high nutrient inputs, forming dense stands along tidal creeks and river mouths. As a landward mangrove species, *S. caseolaris* is known for its tolerance to freshwater influx and fluctuating hydrological conditions. In Indonesia, observations from North Sumatera, Jambi, and Pekanbaru also point to broad habitat tolerance, from freshwater-influenced upstream zones to brackish downstream estuaries. These findings are consistent with global reports emphasizing *S. caseolaris* as a pioneer species in marginal mangrove zones, capable of recolonizing disturbed sites. Spatial analyses using remote sensing and GIS tools have identified that *S. caseolaris* occurs in fragmented patches, particularly in areas facing anthropogenic pressures such as aquaculture expansion, urbanization, and infrastructural development. Nevertheless, regions like East Kalimantan and West Papua still maintain relatively intact stands that exhibit better structural integrity and species composition (Friess et al., 2016; Kalor et al., 2018; Loan et al., 2020).

Population density of *S. caseolaris* varies significantly depending on ecological conditions and human impact. In Central Java's Segara Anakan Lagoon, densities of saplings range from 1.67 to 2.67 individuals per 100 m², while mature trees range from 3.67 to 18.67 individuals per 100 m². In contrast, studies conducted in Tahura Ngurah Rai, Bali, report much higher densities—ranging from 177 to 1,397 individuals per hectare—primarily influenced by physicochemical parameters such as soil type, water salinity, and organic matter content. These findings highlight *S. caseolaris* adaptive capabilities in diverse ecological settings. Therefore, integrating spatial distribution analysis with population ecology is critical for informing mangrove rehabilitation programs, especially within the framework of Indonesia's National Mangrove Restoration Strategy (Kalor et al., 2018).

The combined evidence affirms *S. caseolaris* as a species of high ecological, economic, and ethnobotanical value. It demonstrates resilience to abiotic stress, high content of bioactive compounds, and strong cultural integration in community livelihoods. However, its management remains fragmented, with limited cross-sectoral coordination, absence of in vivo validations, and inconsistent monitoring practices. These limitations echo broader challenges in mangrove conservation across the Indo-Pacific (Friess et al., 2016).

To realize its full potential, an integrated policy-science-practice approach is necessary. This includes conducting long-term ecological studies on population dynamics and biomass, investing in pharmacological validation of its bioactivity, and enhancing local enterprise development through market-linked value chains. With the right enabling environment, *S. caseolaris* could serve as both a keystone species in ecological restoration and a flagship species for bioprospecting and community empowerment in Indonesia's coastal zones.

Tabel 1. Dominant Ecological and Socioeconomic Features in different regions

Region	Dominant Ecological and Socioeconomic Features	Ref.
Lampung	Active community conservation and high population density [Putri et al., 2018]	(Mahardika et al., 2018)
Pekanbaru	Adaptive ecological distribution in tidal gradient zones	(Efriyeldi et al., 2024)
Seram, Riau	Local economic-based conservation through product innovation [Zikri et al., 2022; Patty et al., 2024]	(Adelia et al., 2023)
Vietnam	Physiological adaptation to salinity levels [Loan et al., 2019]	(Ade Syafitri et al., 2024)
North Sumatra	Extensive upstream-downstream riverine distribution (Loan et al., 2020)	(Loan et al., 2020)
Mimika	Extensive upstream-downstream riverine distribution	(Kalor et al., 2018)

3. Phytochemical Profiling of *S. caseolaris*: A Structured Discussion

1. Diverse Plant Parts Used in Phytochemical Research.

Various anatomical parts of *S. caseolaris*—including leaves, fruits, stems, branches, roots, and bark—have been used for phytochemical screening. Leaves and fruits were the most analyzed parts across studies, reflecting their high accessibility and traditional usage in both medicinal and food contexts. For instance, Nurdiah (2017) and Nusaibah et al. (2022) reported significant amounts of flavonoids and phenolics in leaf extracts (Nurdiah, 2017; Nusaibah et al., 2022a), while Dari et al. (2022) confirmed the presence of vitamins and carbohydrates in fruit juice preparations. Such diversity in sampled plant parts is important, as different tissues often harbor different classes of bioactive compounds with distinct pharmacological potential (Dari et al., 2022).

2. Extraction Solvents and Methodological Variation

Ethanol was the most frequently employed solvent across reviewed literature, largely due to its polarity, safety profile, and efficiency in extracting phenolics and flavonoids (Halifah et al., 2019; Nusaibah et al., 2022a). Other solvents used include methanol, ethyl acetate (EtOAc), n-hexane, and n-butanol, either individually or in combination, depending on the target compounds. Tian et al. (2009) used a polarity-gradient approach (methanol → EtOAc → n-BuOH) to isolate triterpenoids, steroids, and flavonoids from stems and branches. However, methodological inconsistency remains a major issue, with several studies omitting details on solvent type or extraction protocol, thus reducing replicability and limiting comparative interpretation (Dari et al., 2022).

3. Major Phytochemical Groups Identified

Across different plant parts and extraction methods, *S. caseolaris* consistently yields a diverse array of phytochemicals with known pharmacological potential. Flavonoids and phenolics are the most frequently reported compounds, especially in leaf and fruit extracts (Table 2). These molecules are well-recognized for their strong antioxidant and anti-inflammatory effects, supporting their use in therapeutic and cosmetic applications (Sutra et al., 2025). Meanwhile, triterpenoids and steroids have been identified primarily in the stems, bark, and roots. These compounds contribute to antimicrobial and cytotoxic activities, suggesting their role in defending the plant against environmental stressors and pathogens (Srinengri et al., 2019; M. Tian et al., 2009).

In addition, alkaloids have been found in root and bark tissues, which may indicate analgesic or antimicrobial properties—an area worth exploring for drug discovery (Srinengri et al., 2019). Tannins and polyphenols, often isolated through ethyl acetate extraction, were noted in both leaves and fruits, and are widely recognized for their astringent effects and ability to neutralize free radicals. Finally, fruit-based samples were rich in vitamins and essential minerals, including vitamins A, C, B1, and B2, as well as sodium and potassium ions, reinforcing the plant's potential as a natural source of nutrients in functional food development (Dari et al., 2022; Loan et al., 2020).

This wide spectrum of phytochemical classes reflects the multi-functional potential of *S. caseolaris*, especially in pharmacognosy, natural antioxidant formulations, and nutraceutical development. Nevertheless, about one-third of the entries reviewed did not specify solvent types or compound categories, highlighting a major gap in reporting standards. Future studies should adopt more rigorous extraction protocols (e.g., Soxhlet, maceration with specified polarity gradients) and employ analytical quantification (HPLC, GC-MS, LC-MS) to standardize findings and facilitate industrial application. In addition, most studies remain in vitro and lack toxicological validation or pharmacokinetic exploration, which are critical for clinical development.

Table 2. Phytochemical Constituents, Extraction Methods, and Biological Activities of *S. caseolaris*: A Literature-Based Summary (2009–2025)

Sample Used	Extraction Solvent	Identified Compounds	Activities	Ref.
Fruit	-	Pectin, Carbohydrate	-	(Setiawan et al., 2016)
Fruit	Ethanol, Ethyl Acetate	Phenolic	Antioxidant, Antimicrobial	(Halifah et al., 2019)
Fruit	Ethanol, Sugar	Vitamin A, C, B1, B2, Carbohydrate	Antioxidant	(Dari et al., 2022)
Leaf	Ethanol, n-hexane, ethyl acetate	Flavonoid	Antioxidant	(Nurdiah, 2017)
Leaf	-	Phenolic, K, Na	-	(Loan et al., 2020; Nurdiah, 2017)
Leaf	Ethanol	Flavonoid, Phenol, Tannin	Antioxidant	(Nusaibah et al., 2022b)
Leaf	-	Stomata type and density	-	(Ade Syafitri et al., 2024)
Leaf	Ethanol	Polyphenol	Antioxidant	
Leaf, Fruit	-	Flavonoid, Phenol	Antioxidant, Antimicrobial	(Abdurachim Audah & Siti Anisa, n.d.)
Leaf, Fruit	Ethanol	Phenolic, Flavonoid	Antioxidant	(Sutra et al., 2025)
Root, Leaf, Bark	-	Steroid, Triterpenoid, Alkaloid	-	(Srinengri et al., 2019)
Stem, Branch	Methanol, EtOAc, n-BuOH	Flavonoid, Triterpenoid, Steroid	Sitotoksik	(M. Tian et al., 2009)

4. Bioactivities

Different plant parts yielded distinct phytochemical profiles. For instance, the stem and branches, extracted using methanol, ethyl acetate (EtOAc), and n-butanol, were rich in flavonoids, triterpenoids, and steroids, which showed cytotoxic activity, suggesting applications in anticancer research (M. Tian et al., 2009). Meanwhile, leaves consistently yielded flavonoids, phenolics, and tannins, especially with ethanol-based extraction, exhibiting strong antioxidant activities (Nusaibah et al., 2022a; Sutra et al., 2025). Fruits, on the other hand, were a rich source of pectin, carbohydrates, vitamins (A, C, B1, B2), and phenolic compounds, supporting both antioxidant effects and nutritional applications (Loan et al., 2020).

Antioxidant activity was reported in more than half of the reviewed studies, primarily using the DPPH radical scavenging assay. IC_{50} values reported ranged from 12.01 ppm (leaf shoot extract) to 45.85 ppm (isolated flavonoids), which places the antioxidant strength in the "very strong" category. Fruit extracts using ethyl acetate reached 0.38% inhibition, while leaf-based formulations such as face mist showed significant scavenging capability. These results correlate with the high flavonoid and phenolic content identified in phytochemical analyses (Nurdiah, 2017; Nusaibah et al., 2022a; Sutra et al., 2025).

Multiple studies demonstrated the antimicrobial effects of *S. caseolaris* extracts, particularly ethanolic and ethyl acetate extracts against *E. coli*, *S. aureus*, and *C. albicans*. Flavonoids, tannins, and alkaloids are presumed to play central roles in these activities. In a cytotoxicity screening, Tian et al. (2009) reported that 3′,4′,5,7-tetrahydroxyflavone exhibited cytotoxic effects against human hepatoma cells (SMMC-7721) with an IC_{50} of 2.8 μg/mL (Halifah et al., 2019; H. Tian et al., 2021; M. Tian et al., 2009; N. Tian et al., 2017).

1. Influence of Plant Part and Extraction Solvent on Bioactivity

The bioactivity of *S. caseolaris* is closely linked to the specific plant part used and the choice of extraction solvent, which determine the range and concentration of bioactive compounds. For example, the stem and branches, when extracted using a gradient of polar and semi-polar solvents (methanol, ethyl acetate, n-butanol), yielded flavonoids, triterpenoids, and steroids, which exhibited cytotoxic activity. This suggests that more complex metabolites associated with cell toxicity are concentrated in woody tissues and require diverse solvent systems for efficient extraction (Halifah et al., 2019; H. Tian et al., 2021; M. Tian et al., 2009; N. Tian et al., 2017).

In contrast, leaf extracts prepared using ethanol or its combinations (e.g., with n-hexane or ethyl acetate) consistently revealed the presence of flavonoids and phenolics, correlating with strong antioxidant activity. Ethanol is known to effectively extract polar compounds such as phenolics and flavonoids, which act as radical scavengers and contribute to oxidative stress modulation (Sutra et al., 2025).

2. Fruits as Sources of Nutritional and Antioxidant Agents

The fruits of *S. caseolaris* were found to contain pectin, carbohydrates, and a wide range of vitamins (A, B1, B2, C), especially when extracted with ethanol and processed with sugar (Dari et al., 2022). These nutritional constituents explain the antioxidant properties detected in some fruit samples, although most reports did not focus on detailed bioassays. This underscores the fruit's functional food potential, particularly in the development of natural antioxidant beverages and nutraceuticals.

3. Compound Classes and Their Corresponding Activities

The data reveals a consistent relationship between specific phytochemical classes and their corresponding biological effects in *S. caseolaris*. Flavonoids and phenolics, commonly found in leaf and fruit extracts, are strongly associated with antioxidant and antimicrobial activities, supporting their role in preventing oxidative stress and pathogen growth. Triterpenoids and steroids, predominantly extracted from stems, bark, and roots, are linked to cytotoxic and anti-inflammatory effects, suggesting their potential in cancer therapy and inflammation control. Tannins, often extracted using ethyl acetate, exhibit antioxidant and astringent properties, contributing to tissue contraction and free radical scavenging. In addition, alkaloids, particularly from root and bark tissues, are suspected to possess antimicrobial and analgesic activities, although these functions remain to be fully characterized (Halifah et al., 2019; Srinengri et al., 2019; M. Tian et al., 2009).

Despite these clear correlations, the dataset also highlights methodological gaps. Several studies lack essential information such as the type of extraction solvent or the specific phytochemicals analyzed, leading to incomplete or non-reproducible findings. This underscores the urgent need for standardized extraction protocols, particularly those based on solvent polarity gradients, to ensure consistency in compound isolation. Additionally, there is a need for comprehensive compound profiling using advanced spectroscopic tools such as LC-MS or GC-MS, and for integrated bioassays that can directly link specific compounds to their biological effects, such as cytotoxicity or antimicrobial activity (M. Tian et al., 2009).

To move beyond descriptive phytochemical analysis, future research should focus on in vivo validation and clinical evaluation of the identified compounds, especially those with promising cytotoxic or antimicrobial properties. Such translational studies are essential to confirm efficacy and safety, paving the way for the development of natural therapeutic agents from *S. caseolaris* (H. Tian et al., 2021; M. Tian et al., 2009; N. Tian et al., 2017).

5. Ethnobotanical Practices and Local Innovation

Traditional uses of *S. caseolaris* are widespread in coastal Indonesia. Communities in Riau, Lampung, and South Sulawesi utilize its fruit for producing juice, syrup, jam, and dodol, while leaves are used in face masks and herbal remedies. In Lampung's Mangrove Center, women-led initiatives such as Kelompok Cinta Bahari have integrated pedada-based products into ecotourism and sustainable livelihoods. These practices are not only culturally embedded but also align with SDG goals on biodiversity conservation and local economy empowerment (Nusaibah et al., 2022a; Setiawan et al., 2016).

This phytochemical and biological diversity has translated into practical product innovation, especially in coastal communities. Fruits are widely used to produce syrup, jam, juice (jus pedada), and dodol, showing the species' value in functional food development (Table 3). Notably, leaves are used in cosmetic products, such as antioxidant face mist, while other efforts in Seram and Riau have explored the use of *S. caseolaris* in antiseptic soap and face masks. The use of ethanol and sugar in fruit processing for beverages also improves both palatability and stability while preserving bioactive content (Nusaibah et al., 2022a).

Some innovations are purely traditional, whereas others show signs of commercial scaling, especially where conservation initiatives are aligned with livelihood programs. The data also indicates that some studies omitted compound identification yet still applied the raw materials for product development, reflecting a practice-before-science trend in community settings.

Table 3. Product Innovations Derived from Different Plant Parts of *S. caseolaris*

Grouped Plant Part	Product Innovations
Leaf	Antioxidant face mist, Jam, Soap
Fruit	Antiseptic soap, Jam, Dodol, Jam, Soap, Pedada fruit jam, Pedada juice, Syrup, Syrup, Dodol, Syrup, Dodol, Mask
Leaf & Fruit	Jam, Soap
Root, Stem, Bark	None
Mixed/Various	None

The analysis confirms that *S. caseolaris* is a highly versatile mangrove species, offering substantial potential across pharmacological, nutritional, and cosmetic applications. Its rich phytochemical profile—comprising flavonoids, phenolics, tannins, triterpenoids, and essential vitamins—supports a wide range of biological activities, including antioxidants, antimicrobial, and cytotoxic effects. These attributes have driven both traditional and modern innovations, from herbal extracts and nutraceuticals to skincare products and functional foods. However, the dataset also reveals inconsistencies in compound identification and a notable lack of biological validation in some studies, which limits the scientific rigor and scalability of these applications. To address these challenges, it is essential to establish standardized phytochemical screening protocols, particularly for community-based and small-scale producers who often rely on empirical knowledge. Moreover, the development of *S. caseolaris*-based therapeutic products, especially those with cytotoxic potential, must be complemented by toxicity and safety evaluations to ensure efficacy and consumer protection. Finally, there is an urgent need for value-chain research that links ethnobotanical knowledge to structured commercial pathways. This includes product formulation, regulatory alignment, marketing strategies, and ecosystem-based resource management. Bridging these gaps will be critical to unlock the full potential of *S. caseolaris* as a sustainable bioresource for tropical coastal regions. Overall, the convergence of traditional knowledge, scientific validation, and product innovation around *S. caseolaris* presents a compelling case for its integration into sustainable mangrove management and coastal bioeconomy strategies.

6. Future Directions

Despite the promising results, several research gaps limit the full utilization of *S. caseolaris*. Most studies focus on in vitro assays without extending to toxicity assessments, pharmacokinetic analysis, or in vivo confirmation (Tian et al., 2009; Liu et al., 2023). No standardized dosage formulations or clinical validations have been conducted. Furthermore, ecological studies addressing the impact of harvesting and seasonal variations of active compounds are absent. Moving forward, multidisciplinary research integrating ethnobotany, pharmacology, and environmental science is essential to elevate *S. caseolaris* from a traditional resource to a standardized functional product.

4. CONCLUSION

This systematic review highlights the considerable phytopharmacological and ethnobotanical potential of *S. caseolaris*, a mangrove species endemic to Indonesia. The synthesis of 20 studies affirms that the plant is rich in secondary metabolites such as flavonoids, tannins, triterpenoids, alkaloids, saponins, and steroids—compounds that underlie its significant antioxidant, antimicrobial, and anti-inflammatory properties. In vitro data, particularly DPPH assays, consistently show strong radical scavenging capacity across leaf and fruit extracts. Antimicrobial efficacy against various human pathogens further supports its potential as a source of natural therapeutic agents.

Beyond laboratory findings, the plant plays an integral role in local communities, particularly among coastal populations in Riau, Lampung, and Sulawesi. Its fruits and leaves are not only used in traditional medicine and skincare, but also transformed into value-added food products such as jam, syrup, dodol, and juice. Community-based conservation programs demonstrate that ethnobotanical use of *S. caseolaris* can align with biodiversity preservation and socio-economic development.

Despite its promising applications, current research on *S. caseolaris* remains predominantly descriptive and laboratory bound. Future work should prioritize toxicological assessments, pharmacodynamic and pharmacokinetic studies, and clinical validation. Furthermore, standardized extraction protocols and sustainable harvesting strategies are urgently needed to ensure both scientific reliability and ecological integrity. The integration of scientific knowledge with indigenous practices is key to unlocking the full potential of *S. caseolaris* as a functional mangrove species for Indonesia's health, economic, and environmental sectors.

REFERENCES

I. Abdurachim Audah, K., & Siti Anisa, A. (n.d.). *The Potential of Sonneratia caseolaris Mangrove Plant as Functional Food and Medicine*. https://journal.sgu.ac.id/jffn

II. Ade Syafitri, Etti Sartina Siregar, & Elimasni. (2024). KERAGAMAN JENIS TUMBUHAN MANGROVE FAMILI LYTHRACEAE DI BELAWAN PULAU SICANANG, SUMATERA UTARA. *Berita Biologi*, *23*(1), 115–128. https://doi.org/10.55981/beritabiologi.2024.3901

III. Adelia, M., Setiawansyah, A., & Sitindaon, R. S. (2023). Potential activity of Stevia rebaudiana Bert. in Inhibiting Cyclooxygenase and Lipooxygenase Enzymes as Anti-inflammatory Candidates: A Molecular Docking Study and ADMET Prediction. *Journal of Drug Delivery and Therapeutics*, *13*(7), 75–86. https://doi.org/10.22270/jddt.v13i7.6137

IV. Alongi, D. M. (2002). Present state and future of the world's mangrove forests. In *Environmental Conservation* (Vol. 29, Issue 3, pp. 331–349). https://doi.org/10.1017/S0376892902000231

V. Bandaranayake, W. M. (1998). Traditional and medicinal uses of mangroves. *Mangroves and Salt Marshes*, *2*, 133–148.

VI. Dari, D., Dini. Junita, Yusra. Arsita, Mila, M., & Vita, M. (2022). Chemical characteristics of juice of mangrove apple (Sonneratia caseolaris) added with sugar. *International Journal of Frontiers in Life Science Research*, *2*(1), 018–028. https://doi.org/10.53294/ijflsr.2022.2.1.0023

VII. Efriyeldi, E., Mulyadi, A., & Mubarak, M. (2024). Distribution and Condition of Sonneratia caseolaris Mangroves in the Siak River Tidal Area, Pekanbaru City. *BIO Web of Conferences*, *136*. https://doi.org/10.1051/bioconf/202413604008

VIII. Friess, D. A., Thompson, B. S., Brown, B., Amir, A. A., Cameron, C., Koldewey, H. J., Sasmito, S. D., & Sidik, F. (2016). Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia. *Conservation Biology : The Journal of the Society for Conservation Biology*, *30*(5), 933–949. https://doi.org/10.1111/cobi.12784

IX. Halifah, P., Hartati, Rachmawaty, Yusminah, H., & Roshanida, A. R. (2019). Phytochemical screening and antimicrobial activity from sonneratia caseolaris fruit extract. *Materials Science Forum*, *967 MSF*, 28–33. https://doi.org/10.4028/www.scientific.net/MSF.967.28

X. Kalor, J. D., Tanjung, R. H. R., Indrayani, E., & Rumbiak, K. (2018). Analisis Tingkat Kerusakan dan Kondisi Ekologi Ekosistem Mangrove, Mimika, Papua. *ACROPORA: Jurnal Ilmu Kelautan Dan Perikanan Papua*, *1*(1). https://doi.org/10.31957/.v1i1.502

XI. Liu, B., Wang, X., Wang, Y., Chen, X., Jin, X., & Luo, X. (2023). Review of compounds and activities from mangrove Sonneratia genus and their endophytes. *Journal of Holistic Integrative Pharmacy*, *4*(3), 218–227. https://doi.org/10.1016/j.jhip.2023.11.003

XII. Loan, N. T. N., Tan, D. Van, Huyen, T. T. T., Quang, N. H., Hue, L. T. Van, Nga, P. T. T., Quinn, C., Carrie, R., Stringer, L., & Hackney, C. (2020). Comparision of several secondary metabolite and elemental ion contents of leaves from *Kandelia obovata* and *Sonneratia caseolaris* forests located in the Red River delta. *Academia Journal of Biology*, *42*(4). https://doi.org/10.15625/2615-9023/v42n4.15068

XIII. Mahardika, A., Sari Dewi, B., Hilmanto Jurusan Kehutanan Fakultas Pertanian Universitas Lampung Jl Sumantri Brojonegoro no, R., & Lampung, B. (2018). Upaya Konservasi Sonneratia caseolaris di Lampung Mangrove Center Conservation

Effort of Sonneratia caseolaris in Lampung Mangrove Center. *Jurnal Sylva Lestari ISSN*, *6*(2), 77–83.

XIV. Nurdiah. (2017). *Isolation and Identificication Pepada*.

XV. Nusaibah, Sari, R. M., & Widianto, D. I. (2022a). Utilization of Mangrove Apple (Sonneratia caseolaris) and Bayhops (Ipomoea pes-caprae) Leaf Extracts as Antioxidants Agents in The Formulation of Face Mist. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *25*(3), 441–456. https://doi.org/10.17844/jphpi.v25i3.42563

XVI. Nusaibah, Sari, R. M., & Widianto, D. I. (2022b). Utilization of Mangrove Apple (Sonneratia caseolaris) and Bayhops (Ipomoea pes-caprae) Leaf Extracts as Antioxidants Agents in The Formulation of Face Mist. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *25*(3), 441–456. https://doi.org/10.17844/jphpi.v25i3.42563

XVII. Setiawan, E., Efendi, R., & Herawati, N. (2016). PEMANFAATAN BUAH PEDADA (Sonneratia caseolaris) DALAM PEMBUATAN SELAI UTILIZATION OF PEDADA (Sonneratia caseolaris) FOR MAKING JAM. *Jom Faperta*, *3*(1).

XVIII. Setiawan, E., Efendi, R., Herawati, N., Pertanian, J. T., & Pertanian, F. (n.d.). *PEMANFAATAN BUAH PEDADA (Sonneratia caseolaris) DALAM PEMBUATAN SELAI UTILIZATION OF PEDADA (Sonneratia caseolaris) FOR MAKING JAM*.

XIX. Srinengri, L., Arryati, H., Yuniarti, D., & Kehutanan, J. (2019). IDENTIFIKASI KANDUNGAN FITOKIMIA TUMBUHAN PIDADA (Sonneratia Caseolaris) DARI HUTAN MANGROVE Identification of Phytochemical Content of Pidada Plants from Mangrove Forests. In *Jurnal Sylva Scienteae* (Vol. 02, Issue 4).

XX. Sutra, I., Yanti, S. P., Alvi, A., Ihsan, M., & Wahyuni, F. (2025). Comparison of Antioxidant Activities of Red Pedada (Sonneratia caseolaris L.) Mangrove Forest Area, Jambi Province. *Jurnal Biologi Tropis*, *25*(1), 814–820. https://doi.org/10.29303/jbt.v25i1.8554

XXI. Tian, H., Wei, L., Yao, Y., Zeng, Z., Liang, X., & Zhu, H. (2021). Analysis of the Anti-Inflammatory and Analgesic Mechanism of Shiyifang Vinum Based on Network Pharmacology. *Evidence-Based Complementary and Alternative Medicine*, *2021*. https://doi.org/10.1155/2021/8871276

XXII. Tian, M., Dai, H., Li, X., & Wang, B. (2009). Chemical constituents of marine medicinal mangrove plant Sonneratia caseolaris. *Chinese Journal of Oceanology and Limnology*, *27*(2), 288–296. https://doi.org/10.1007/s00343-009-9138-7

XXIII. Tian, N., Liu, F., Wang, P., Zhang, X., Li, X., & Wu, G. (2017). The molecular basis of glandular trichome development and secondary metabolism in plants. In *Plant Gene* (Vol. 12, pp. 1–12). Elsevier B.V. https://doi.org/10.1016/j.plgene.2017.05.010