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REVIEW

# Climate change vulnerability, adaptation and ecosystem services in different fisheries and aquaculture in Asia: a review

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**ABSTRACT.** This review aimed to discuss the vulnerability and climate change impacts on tropical fisheries in Asia using a systematic literature review. The study applied the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to evaluate literature from 1990-2020. The results showed clustering of texts, keywords, and titles based on search terms like climate change, fisheries, and adaptation. High-scoring links revealed clusters: 1) climate change and food security, 2) biodiversity and environment protection, 3) conservation of resource, 4) climate change impacts in Asia, 5) fisheries. Abstracts and titles produced clusters on: 1) livelihood and food security, 2) fisheries catch, 3) stakeholder approaches, 4) Ecosystem services. While climate change dominated vulnerability and adaptation studies, it is only one of many stressors affecting fisheries and aquaculture. Adaptation is suggested as a solution for reducing vulnerability and increasing resilience in fishing communities. However, our findings indicate that the social and economic factors contributing to climate-induced vulnerability are still relatively neglected. Enhancing biodiversity and environmental protection can lead to a more productive and food-secure environment for farmers and fishers. It is crucial that interventions focus on adaptation and establishing science-based 'adaptive fisheries co-management' to engage fishing communities and address their broader vulnerabilities and aspirations.

**Key words:** Systematic literature review, PRISMA, fisheries management, food security.



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**Vulnerabilidad al cambio climático, adaptación y servicios ecosistémicos en diferentes pesquerías y acuiculturas en Asia: una revisión**

**RESUMEN.** Esta revisión tuvo como objetivo discutir la vulnerabilidad y los impactos del cambio climático en las pesquerías tropicales en Asia mediante una revisión sistemática de la literatura. El estudio aplicó los elementos del Ítems Preferidos para Revisiones Sistemáticas y Metaanálisis (PRISMA) para evaluar la literatura entre 1990 y 2020. Los resultados mostraron agrupaciones de textos, palabras clave y títulos según términos de búsqueda como cambio climático, pesca y adaptación. Los enlaces con puntajes altos revelaron las agrupaciones: 1) cambio climático y seguridad alimentaria, 2) biodiversidad y protección del medio ambiente, 3) conservación de recursos, 4) impactos del cambio climático en Asia, 5) pesca. Los resúmenes y títulos produjeron agrupaciones sobre: 1) medios de vida y seguridad alimentaria, 2) captura pesquera, 3) enfoques de las partes interesadas, 4) servicios ecosistémicos. Si bien el cambio climático dominó los estudios de vulnerabilidad y adaptación, es solo uno de los muchos factores de estrés que afectan a la pesca y la acuicultura. Se sugiere la adaptación como una solución para reducir la vulnerabilidad y aumentar la resiliencia en las comunidades pesqueras. Sin embargo, nuestros hallazgos indican que los factores sociales y económicos

que contribuyen a la vulnerabilidad inducida por el clima aún están relativamente desatendidos. Mejorar la biodiversidad y la protección del medio ambiente puede conducir a un entorno más productivo y con mayor seguridad alimentaria para los agricultores y pescadores. Las intervenciones deben centrarse en la adaptación, y el establecimiento de una "cogestión pesquera adaptativa" basada en la ciencia es crucial para involucrar a las comunidades pesqueras y abordar sus vulnerabilidades y aspiraciones más amplias.

**Palabras clave:** Revisión sistemática de literatura, PRISMA, manejo pesquero, seguridad alimentaria.

## INTRODUCTION

Fishing is a crucial economic activity contributing significantly to poverty reduction, food security, job creation, and the health of marine ecosystems, aligning with the SDG 2030 agenda (Ojeda-Ruiz et al. 2022). Small-scale fisheries and aquaculture are the primary livelihoods for millions, especially in developing countries (Islam et al. 2020; Chhetri 2021). However, this sector faces substantial risks from climate change, threatening the livelihoods, food security, and economies of coastal communities worldwide (Barange et al. 2018; Hoang et al. 2020). Climate change exacerbates overfishing, habitat degradation, and pollution, reducing future fish catch potential and impacting fish prices, income, and well-being (Macusi et al. 2021a; Nabuurs et al. 2022).

The Intergovernmental Panel on Climate Change (IPCC) highlighted the vulnerability of low-income countries more dependent on fisheries (Grubb et al. 2022). Fish migration patterns are already shifting as marine biodiversity responds to rising sea temperatures and habitat degradation (Pachauri et al. 2014). Understanding the effects of climate change on fisheries and aquaculture is critical, particularly in tropical regions where biodiversity and marine ecosystems are highly sensitive (Worm and Lotze 2021).

Southeast Asia is home to rich biodiversity and many coastal communities reliant on fisheries and aquaculture for livelihoods (Nong 2019). This coastal ecosystems share common vulnerabilities, such as low-lying deltas and dependence on monsoon seasons, which make them particularly susceptible to climate change (Feist et al. 2021). Across this region, fish populations are projected to decline due to changing ocean temperatures and salinity levels, as well as habitat destruction and overfishing (Macusi et al. 2021b). In the Philippines, impacts of climate change are already evident (Jacinto et al. 2015). Local fish populations, including key species like green bumphead parrotfish, humphead wrasse, African pompano, giant groupers, mangrove snapper, spanish mackerel and anchovies, are expected to decline significantly by the 2050s (Lavides et al. 2016; Macusi et al. 2021b). This would have serious consequences for food security and the livelihood of coastal communities. Similarly, Bangladesh faces heightened risks due to rising sea levels and increasing salinity in the Bay of Bengal, particularly affecting the economically and culturally significant hilsa shad fishery (Mozumder 2020). Fishermen are forced to extend fishing ranges and durations, leading to increased financial and occupational risks while threatening local food security as fish prices rise (Hossain et al. 2023).

In Malaysia, sea level rise (SLR) threatens coastal regions with SLR rates of around 4.22 mm year$^{-1}$ (Hamid et al. 2018). Thailand also faces similar challenges, with Krabi province projected to see an increase in sea levels by 21 cm by 2050 (Markphol et al. 2021). Indonesia is particularly vulnerable, with provinces like Banda Aceh at risk of future SLR, which endangers aquaculture and coastal infrastructure (Meilianda et al. 2019). These challenges mirror those faced by India, where the western coast is impacted by both SLR and habitat degradation (Raj et al. 2021). Climate change adaptation plans in regions like Tamil Nadu, which engage local communities, are crucial for mitigat-

ing these effects (Khan et al. 2022). Pakistan and Myanmar also face substantial threats from climate change. Coastal regions of Pakistan, especially Sindh province, experience tropical cyclones and storm surges that exacerbate SLR (Weeks and Harrison 2020). Similarly, coastal areas of Myanmar are vulnerable to floods during monsoon seasons, with southern regions like Tanintharyi and Ayeyarwady severely impacted (Nguyen-Huy et al. 2022).

The Coral Triangle, which includes Indonesia, faces significant ecological and socioeconomic challenges due to coral bleaching and reef degradation (Veron et al. 2011). These events reduce reef fish populations, such as groupers and snappers, directly affecting coastal communities dependent on reef fisheries for income and food security (McClanahan et al. 2015). The declining health of the Coral Triangle's ecosystems not only diminishes protein sources but also undermines the economic stability of these regions (Muringai et al. 2021). Preserving the Coral Triangle is essential for both global marine biodiversity and local livelihoods. Efforts to address coral bleaching, such as enhancing fisheries management practices, are vital to maintaining ecological balance and socioeconomic resilience (Stephenson et al. 2018).

Countries across the region are adopting various strategies to mitigate the impacts of climate change on fisheries and aquaculture. In Vietnam, adaptation efforts include the development of resilient fish and shrimp species, improved water management, and reinforced infrastructure (Joakim et al. 2015). These measures aim to protect seafood production, coastal communities, and food security against the risks posed by climate change (Weatherdon et al. 2016). China is also vulnerable, particularly its aquaculture sector, which suffers from frequent typhoons. To address this, China is strengthening aquaculture infrastructure, expanding species diversity, and improving early warning systems to enhance resilience to extreme weather events (Fang et al. 2017). They are also currently building offshore facilities that are under controlled conditions. Similarly, India is tackling the challenge of salinity intrusion in coastal aquaculture ponds by promoting saline-tolerant species and enhancing management practices to ensure sustained productivity (Velmurugan et al. 2016).

This paper aimed to explain the vulnerability and impact of climate change on tropical fisheries focused on southeastern Asian countries through a systematic literature review, in order to offer a structured evaluation of the existing knowledge regarding this issue. This approach ensures an objective and thorough analysis of available studies, enabling the identification of significant themes, trends, and gaps in the literature. In particular, we focused on Bangladesh, the Philippines, Indonesia, Malaysia, Vietnam, Thailand, India, Pakistan and Myanmar, as fishery resources and livelihoods of small-scale fisher in these countries are most vulnerable to the impact of climate change.

## MATERIALS AND METHODS

### Search strategy

In this paper, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was carried out for the systematic literature review (Figure 1). This process utilizes four stages, namely identification, screening, eligibility assessment, and inclusion (Moher et al. 2009), and has been utilized in several studies such as climate change (Liu et al. 2021; Macusi et al. 2021a) and aquaculture (Gong et al. 2021; Macusi et al. 2021b, 2022; Suresh et al. 2022). All articles were identified based on the search of terms through the Web of Science and Scopus databases covering the period of 1990-01-01 to 2020-12-31. Web of Science and Scopus were selected for their reliable, good quality control through rigorous peer-reviewed content across disciplines such as environment sciences, fisheries, and climate change, ensuring access to credible sources and citation tracking to identify key studies and trends. The period 1990-

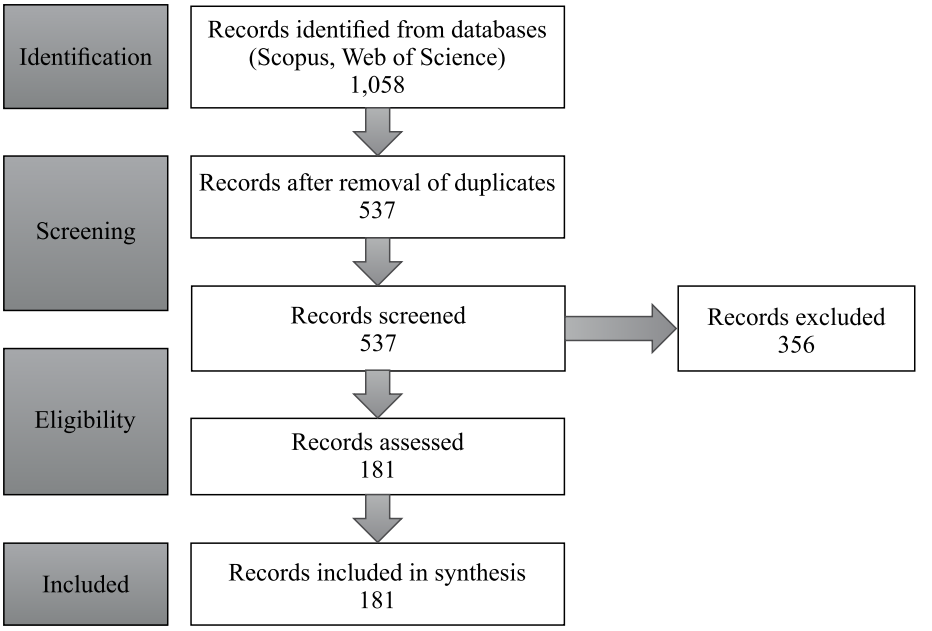


Figure 1. Search process flow from Moher et al. (2009).

2020 captures crucial developments in climate change and fisheries research. These databases also avoid duplication from less rigorous sources and provide advanced search tools for efficient, systematic review and analysis. The combination of phrases and keywords used were 'climate change AND fisheries AND Asia', 'climate change impact AND fisheries AND Asia', 'climate change AND adaptation AND fisheries AND Asia', 'climate change AND fisheries AND Asia AND aquaculture', and 'climate vulnerability AND fisheries AND Asia'. A total of 1,058 records were culled out, and 521 duplicates were then removed. After screening for eligibility, 181 articles were deemed appropriate for the content analysis. Selection criteria included articles written in English, and if the topic relates to climate change, they must be contextualized in Asia. Review articles and book chapters were also excluded from content analysis, so that only original works related to climate change studies were selected. Data extracted were abstract, titles, author's keywords, index keywords, publication year, volume and issue number.

**Data analysis**

A bibliometric analysis was conducted utilizing the VOSviewer (van Eck and Waltman 2010) to analyse the co-occurrences of keywords and indexes, and thematically analyse titles and abstracts of articles. A co-occurrence analysis helped to cluster words based on concordances between words and their number of occurrences (Snilstveit et al. 2012; Bourgeois et al. 2015). The thematic analysis of selected records (n = 181) was then followed by a synthesis approach utilising summaries and main content of articles.

## RESULTS

An upward trend of scientific publications related to climate change in Asia from 1990 to 2020 was detected (Figure 2). The set of publications used have a total of 71 authors and their keywords were extracted, tabulated and then visualized (Table 1).

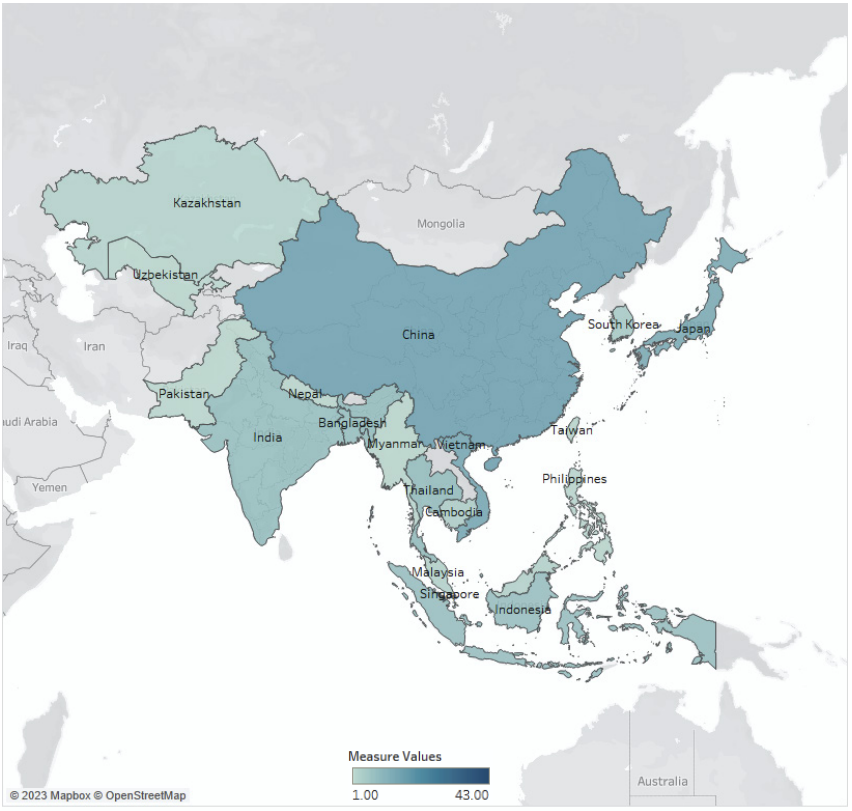


Figure 2. Scientific publications on climate change vulnerability and impacts across Asia from 1990 to 2020.

The cluster analysis revealed five clusters and words under each cluster (Table 1; Figure 3). Under cluster 1, food security, vulnerability, and management had the highest link strength. For cluster 2, biodiversity, environmental protection, aquaculture, and conservation had the highest total linking strength. Then for cluster 3, natural resources conservation and agriculture were included as words with the highest link strength. Cluster 4 included Asia, climate change, and fishery management as keywords with the highest total linking strength. Lastly, cluster 5 included fisheries, fishery, and ecosystem as keywords with the highest total linking strength. Results revealed that climate change adaptation and food security were central subjects in fisheries research across Asia, as evidenced by the prominence of keywords such as food security, vulnerability, and adaptation in cluster 1.

Moreover, Marine Protected Areas (MPAs) appeared as a significant theme in cluster 2, and represent a key strategy for biodiversity conservation and fisheries management. Results further underscore the importance of ecosystem services, as reflected in the frequent occurrence of terms like ecosystem service and biodiversity in clusters 2 and 5.

Regarding the text data, the most common words used were categorized into four clusters (Table 1; Figure 4). Words with highest occurrences included adaptation, livelihood, catch, distribution, approach, and service. Words with highest total linking strength (Table 2) for cluster 1 included food security, framework, livelihood, sector, sustainability, vulnerability, opportunity, and need. In contrast, cluster 2 included catch, distribution, lake, and variation. Cluster 3 included approach, degradation,

Table 1. Occurrence classification for author and index keywords by links, total link strengths and occurrences.

| Clusters | Links | Total link strength | Occurrences |
|---|---|---|---|
| Cluster 1 | | | |
| Adaptive capacity | 14 | 20 | 5 |
| Catch | 11 | 18 | 5 |
| **Climate change** | **41** | **86** | **30** |
| Fisheries management | 18 | 26 | 6 |
| **Food security** | **41** | **76** | **13** |
| Hydropower | 23 | 37 | 6 |
| Impact | 28 | 54 | 14 |
| **Management** | **34** | **72** | **19** |
| Marine | 17 | 22 | 5 |
| Marine protected areas | 14 | 16 | 5 |
| Mekong basin | 23 | 36 | 5 |
| Poverty | 24 | 32 | 5 |
| Resilience | 26 | 51 | 12 |
| River basin | 24 | 39 | 5 |
| Small-scale fisheries | 19 | 34 | 7 |
| Sustainability | 28 | 35 | 9 |
| **Vulnerability** | **42** | **72** | **13** |
| Cluster 2 | | | |
| **Aquaculture** | **39** | **68** | **15** |
| **Biodiversity** | **55** | **116** | **21** |
| Carbon | 35 | 50 | 5 |
| **Conservation** | **39** | **68** | **15** |
| Decision-making | 33 | 50 | 6 |
| Deforestation | 23 | 27 | 5 |
| Dynamics | 21 | 25 | 5 |
| Ecosystem service | 21 | 29 | 6 |
| Ecosystems | 38 | 59 | 8 |
| Environmental management | 30 | 47 | 5 |
| **Environmental protection** | **43** | **78** | **8** |
| Remote sensing | 25 | 30 | 6 |
| Water quality | 17 | 21 | 6 |
| Wetlands | 26 | 37 | 5 |
| Cluster 3 | | | |
| Abundance | 16 | 20 | 5 |
| **Agriculture** | **38** | **59** | **8** |
| Climate change | 20 | 25 | 6 |
| **Conservation of natural resources** | **43** | **84** | **8** |

Table 1. Continued.

| Clusters | Links | Total link strength | Occurrences |
|---|---|---|---|
| Coral reef | 30 | 48 | 8 |
| Environmental impact | 35 | 49 | 6 |
| Global warming | 26 | 39 | 7 |
| Growth | 17 | 23 | 7 |
| **Humans** | **36** | **66** | **6** |
| Salinity | 24 | 36 | 8 |
| Sea surface temperature | 23 | 36 | 7 |
| Temperature | 31 | 44 | 6 |
| Water | 27 | 38 | 6 |
| Water supply | 31 | 47 | 6 |
| Cluster 4 | | | |
| Anthropogenic effect | 19 | 27 | 6 |
| **Asia** | **58** | **181** | **38** |
| Biomass | 23 | 42 | 9 |
| **Climate change** | **70** | **377** | **84** |
| Climate effect | 24 | 56 | 11 |
| Developing world | 17 | 28 | 5 |
| Environmental change | 20 | 21 | 5 |
| **Fishery management** | **40** | **82** | **14** |
| Fishery production | 17 | 36 | 8 |
| Overfishing | 20 | 24 | 6 |
| South Asia | 25 | 38 | 5 |
| Stock assessment | 23 | 35 | 6 |
| Sustainable development | 30 | 44 | 7 |
| Water resource | 12 | 17 | 5 |
| Cluster 5 | | | |
| Adaptation | 31 | 50 | 8 |
| **Ecosystem** | **54** | **130** | **13** |
| Fish | 42 | 92 | 18 |
| **Fisheries** | **63** | **210** | **39** |
| **Fishery** | **49** | **129** | **20** |
| Fishes | 24 | 43 | 6 |
| Fishing | 27 | 42 | 5 |
| Nonhuman | 35 | 57 | 5 |
| Physiology | 22 | 38 | 6 |
| Phytoplankton | 17 | 19 | 5 |
| Population dynamics | 18 | 33 | 7 |
| Sea | 25 | 33 | 6 |

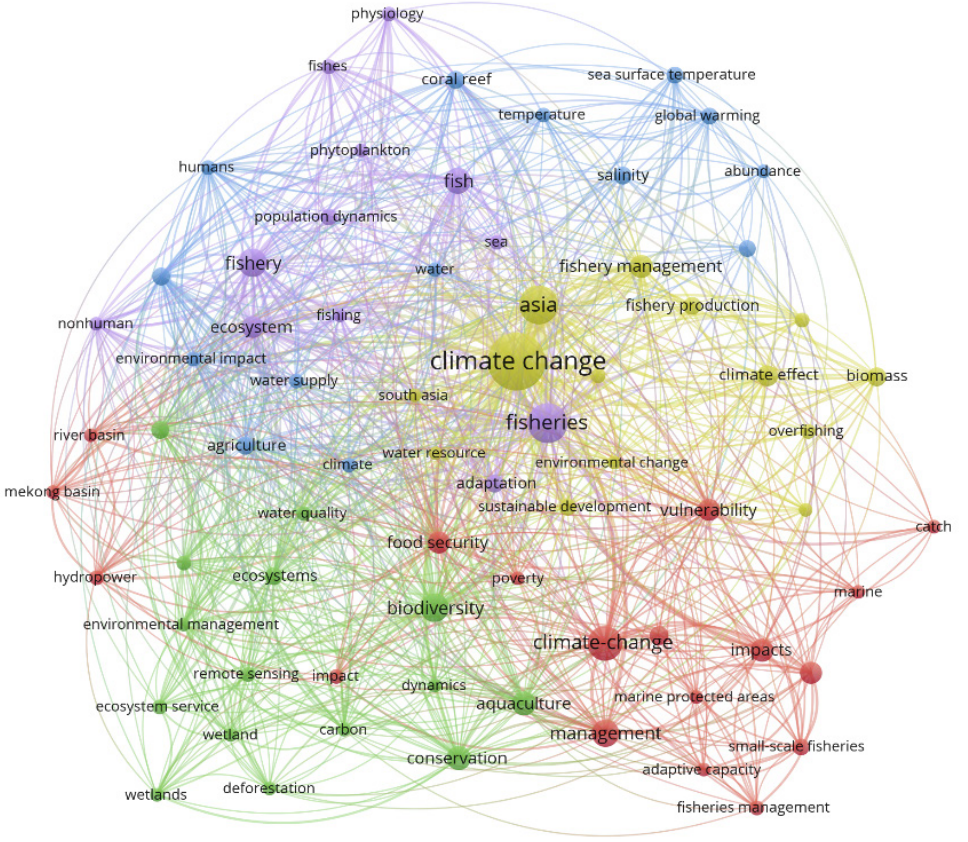


Figure 3. Co-occurrence network map based on keywords.

driver, resilience, and stakeholder as words with the highest total linking strength; while for cluster 4 this had basin, benefit, mitigation, and service as words with the highest total linking strength. Moreover, the analysis of keywords revealed a strong emphasis on livelihood and fisheries management in clusters 1 and 4, where socioeconomic factors affected vulnerability. Co-management, highlighted in cluster 4, offers a more participatory approach to resource management.

The most frequently used keywords and words from titles and abstracts from 1990 to 2020 showed the overall research trend in Asia in the said period concerning climate change (Figures 5 and 6). The most recent research focus included sustainable development, fisheries management, adaptive capacity, food security, vulnerability, and small-scale fisheries. Recent research trends focused on terms like adaptive capacity, small-scale fisheries, and food security, suggesting a growing recognition of the need to build resilience in vulnerable communities (Figure 6).

## DISCUSSION

### Climate change adaptation and food security

Understanding stressors induced to fisheries and aquaculture by climate change that lead to vulnerability is critical for effective adaptation planning, policy development, and the design of strategies to reduce these vulnerabilities (Hjerpe and Glaas

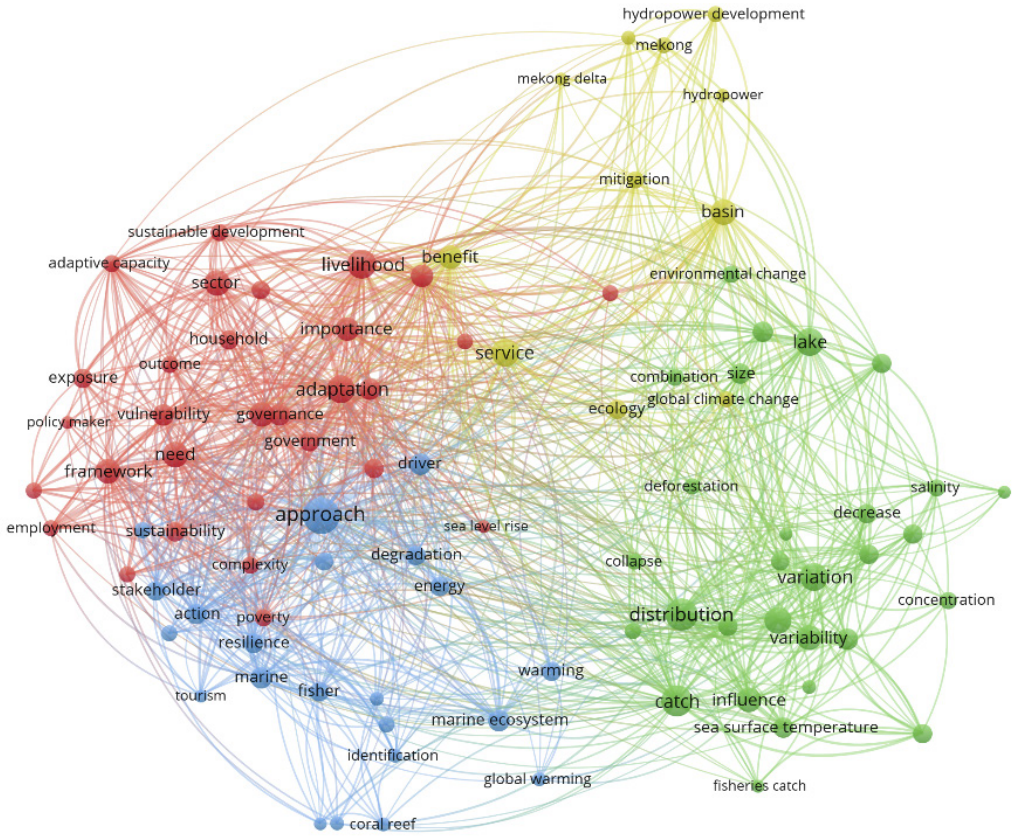


Figure 4. Co-occurrence network map based on titles and abstracts.

2012; Bennett et al. 2015). Findings revealed that vulnerability to climate change in fisheries is influenced by multiple factors including environmental changes, socio-economic dynamics, and institutional frameworks. Disentangling these complex interactions allows for more targeted investments in reducing vulnerability (Ribot 2013), especially in the context of broader global environmental challenges, which are only one part of the equation (O'Brien et al. 2004; Adger 2006; Brulé et al. 2022).

Despite the fact that numerous studies can make fishing communities more resilient, these is an implicit transfer of responsibility from institutions that cause vulnerability to fishermen. Broader reforms in the political economy of fisheries institutions and policies, alongside social hierarchies and practices that influence well-being must be considered (Ribot 2013). Additionally, adaptation is often discussed without adequate exploration of its nuances. Vulnerability and adaptation are context-specific, and successful adaptation is linked to enhanced resilience or transformation, whereas a lack of adaptation increases vulnerability (Joakim et al. 2015). These complexities highlight the need for integrated approaches that combine local adaptations with larger structural changes in governance and policy.

## Adaptation to climate change

Adaptation strategies across Asia vary, reflecting different environmental, economic, and social contexts. For example, Indonesia's community-based

Table 2. Occurrence classifications of texts from record abstracts and titles.

| Clusters | Links | Total link strength | Occurrences |
|---|---|---|---|
| Cluster 1 | | | |
| Adaptation | 65 | 14 | 22 |
| Adaptive capacity | 39 | 62 | 8 |
| Agriculture | 54 | 93 | 14 |
| Coastal Community | 34 | 53 | 7 |
| Complexity | 34 | 46 | 8 |
| Economy | 46 | 76 | 11 |
| Employment | 34 | 55 | 7 |
| Exposure | 36 | 64 | 11 |
| Fisheries management | 38 | 56 | 7 |
| Food production | 29 | 40 | 7 |
| Food security | 56 | 103 | 17 |
| **Framework** | **56** | **126** | **17** |
| Governance | 54 | 97 | 13 |
| Government | 36 | 50 | 10 |
| Household | 40 | 61 | 10 |
| Importance | 53 | 93 | 15 |
| **Livelihood** | **71** | **182** | **24** |
| Migration | 42 | 64 | 8 |
| **Need** | **64** | **130** | **19** |
| Opportunity | 56 | 96 | 13 |
| Outcome | 40 | 64 | 8 |
| Policy maker | 26 | 33 | 5 |
| Poverty | 46 | 69 | 8 |
| Sea level rise | 32 | 37 | 5 |
| Sector | 57 | 125 | 18 |
| Sensitivity | 33 | 50 | 9 |
| Sustainability | 46 | 72 | 10 |
| Sustainable development | 38 | 69 | 8 |
| Vulnerability | 47 | 86 | 13 |
| Water supply | 34 | 46 | 7 |
| Cluster 2 | | | |
| Abundance | 39 | 65 | 11 |
| Biomass | 34 | 47 | 11 |
| **Catch** | **64** | **139** | **26** |
| Collapse | 27 | 37 | 7 |
| Combination | 41 | 55 | 8 |
| Concentration | 28 | 36 | 8 |
| Decrease | 37 | 54 | 11 |

Table 2. Continued.

| Clusters | Links | Total link strength | Occurrences |
|---|---|---|---|
| Deforestation | 29 | 35 | 7 |
| **Distribution** | **63** | **132** | **28** |
| Environmental change | 34 | 40 | 8 |
| Environmental condition | 31 | 39 | 7 |
| Fish species | 33 | 47 | 11 |
| Fisheries catch | 23 | 31 | 5 |
| Human activity | 35 | 63 | 11 |
| Influence | 51 | 99 | 17 |
| Lake | 55 | 121 | 22 |
| Negative impact | 20 | 22 | 5 |
| Phytoplankton | 24 | 28 | 6 |
| Reduction | 50 | 76 | 12 |
| Salinity | 33 | 49 | 8 |
| Sea surface temperature | 42 | 71 | 12 |
| Shift | 39 | 61 | 13 |
| Size | 50 | 76 | 12 |
| Spatial distribution | 17 | 23 | 5 |
| Temperature | 55 | 99 | 20 |
| Variability | 49 | 92 | 17 |
| Variation | 54 | 120 | 22 |
| Water temperature | 27 | 52 | 11 |
| | | | |
| Cluster 3 | | | |
| Action | 56 | 92 | 12 |
| **Approach** | **79** | **248** | **37** |
| Climate change impact | 37 | 48 | 9 |
| Coral reef | 28 | 38 | 6 |
| Degradation | 44 | 72 | 11 |
| **Driver** | **63** | **99** | **13** |
| Energy | 41 | 58 | 11 |
| Fisher | 48 | 75 | 11 |
| Fisheries | 24 | 35 | 7 |
| Global warming | 26 | 29 | 6 |
| Human | 32 | 40 | 7 |
| Identification | 44 | 59 | 6 |
| Marine | 53 | 91 | 13 |
| Marine ecosystem | 46 | 79 | 13 |
| Marine resource | 39 | 49 | 7 |
| Ocean acidification | 30 | 37 | 5 |
| Overfishing | 38 | 45 | 6 |

Table 2. Continued.

| Clusters | Links | Total link strength | Occurrences |
|---|---|---|---|
| Resilience | 52 | 86 | 11 |
| Small scale fishery | 29 | 36 | 6 |
| **Stakeholder** | **57** | **101** | **11** |
| Tourism | 35 | 49 | 5 |
| Warming | 45 | 59 | 11 |
| | | | |
| Cluster 4 | | | |
| **Basin** | **57** | **109** | **19** |
| **Benefit** | **48** | **88** | **15** |
| Ecology | 45 | 61 | 10 |
| Global climate change | 41 | 51 | 7 |
| Hydropower | 21 | 28 | 5 |
| Hydropower development | 20 | 36 | 7 |
| Mekong | 30 | 51 | 7 |
| Mekong Delta | 19 | 24 | 5 |
| Mekong River | 24 | 39 | 6 |
| Mitigation | 45 | 65 | 8 |
| **Service** | **63** | **129** | **22** |

fisheries management fosters local involvement in sustainable practices and regulation enforcement (Glaser et al. 2010). In the meantime, Vietnam prioritizes selective fishing gear and monitoring systems to reduce environmental impacts (Kelly et al. 2012), and the Philippines incorporates ecosystem-based management into its fisheries infrastructure (Santos et al. 2011). These examples, while diverse, share common elements: they emphasize community involvement, technological innovation, and ecosystem preservation as key pillars for adaptation. However, these strategies must also be evaluated in terms of their long-term effectiveness. Are they addressing root vulnerabilities, or are they only mitigating symptoms of deeper systemic issues? The reliance Galician shellfish industry on adaptive strategies, such as diversification of income and more selective harvesting (Villasante et al. 2022) illustrates a broader trend in which communities modify their livelihoods in response to immediate environmental pressures. However, these adaptations can only provide a short-term relief if institutional weaknesses, such as poor governance or lack of knowledge transfer between generations are not addressed. In this regard, adaptation strategies should be seen not just as a response to environmental challenges but as part of a broader, more comprehensive approach that includes social and economic reforms.

## Adaptation to food insecurity

Food security, encompassing availability, access, utilization, and stability, is increasingly under threat due to climate change impacts and anthropogenic pressures (HLPE 2020). These disruptions affect not only agricultural sectors like crops and livestock but also fisheries, which are critical for food security in Asia (Macusi et al. 2023; Pagulayan et al. 2024). Findings of this study align with

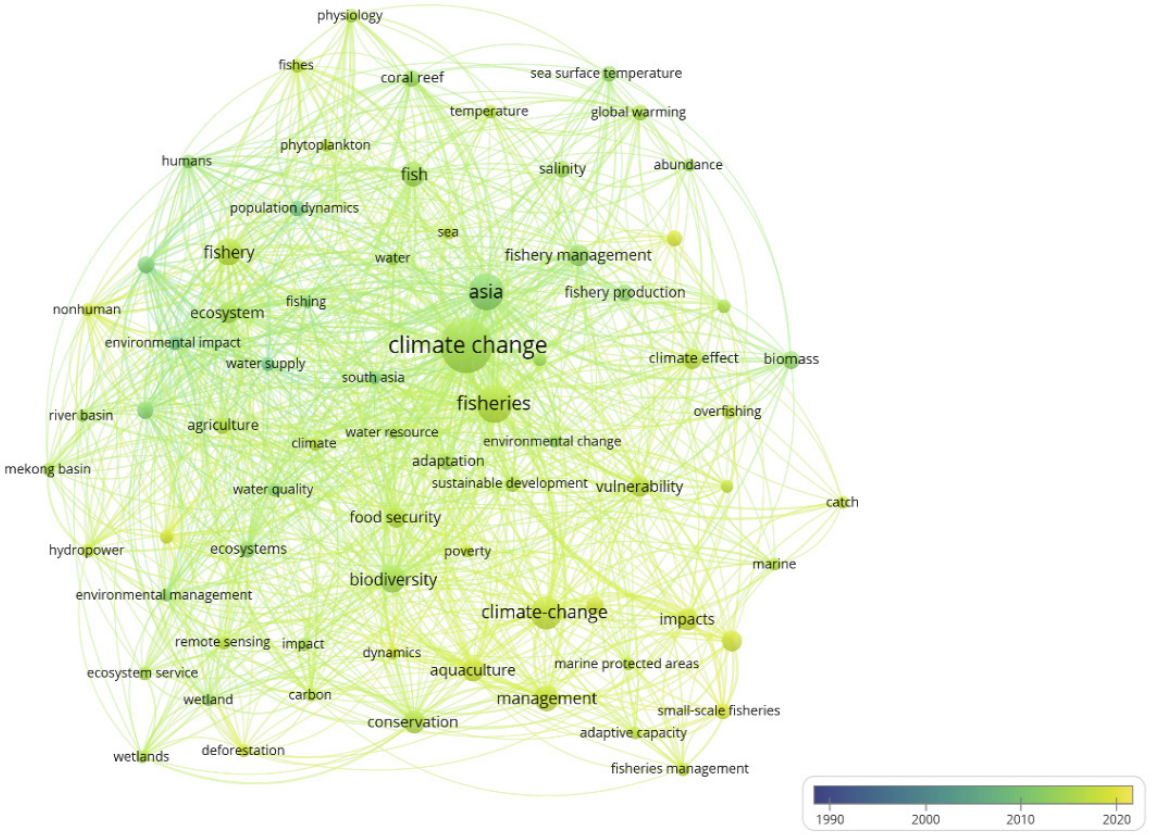


Figure 5. Co-occurrence network map based on keywords linked with climate change.

previous observations (Roy et al. 2022) indicating that climate change exacerbates food insecurity by destabilizing food systems and supply chains, particularly through extreme weather events. Strategies employed by Asian nations to combat food insecurity offer valuable lessons. For instance, the integration of agroforestry and community seed banks in Indonesia enhances both agricultural resilience and food security (Kiss et al. 2018). Similarly, the promotion of climate-resilient crops and integrated pest management in Vietnam reflects an adaptive approach that not only stabilizes yields but reduces reliance on chemical inputs (Sebesvari et al. 2011). These examples demonstrate that adaptation to food insecurity must go beyond mere agricultural production by addressing the entire food system, including supply chains, market dynamics, and policy frameworks (Ziervogel and Ericksen 2010).

## Biodiversity conservation

Biodiversity conservation is essential for sustainable fisheries, particularly in regions such as southeastern Asia, where high biodiversity supports marine ecosystems and crucial fish stocks. Climate change, habitat destruction, and pollution simultaneously threaten both biodiversity and fisheries, as the degradation of ecosystems such as coral reefs and mangroves disrupts the food chain, leading to declining fish population (Coleman et al. 2019; Zhang et al. 2023). Since biodiversity loss has direct influence on fishery productivity and resilience, this relationship is crucial for effective fisheries

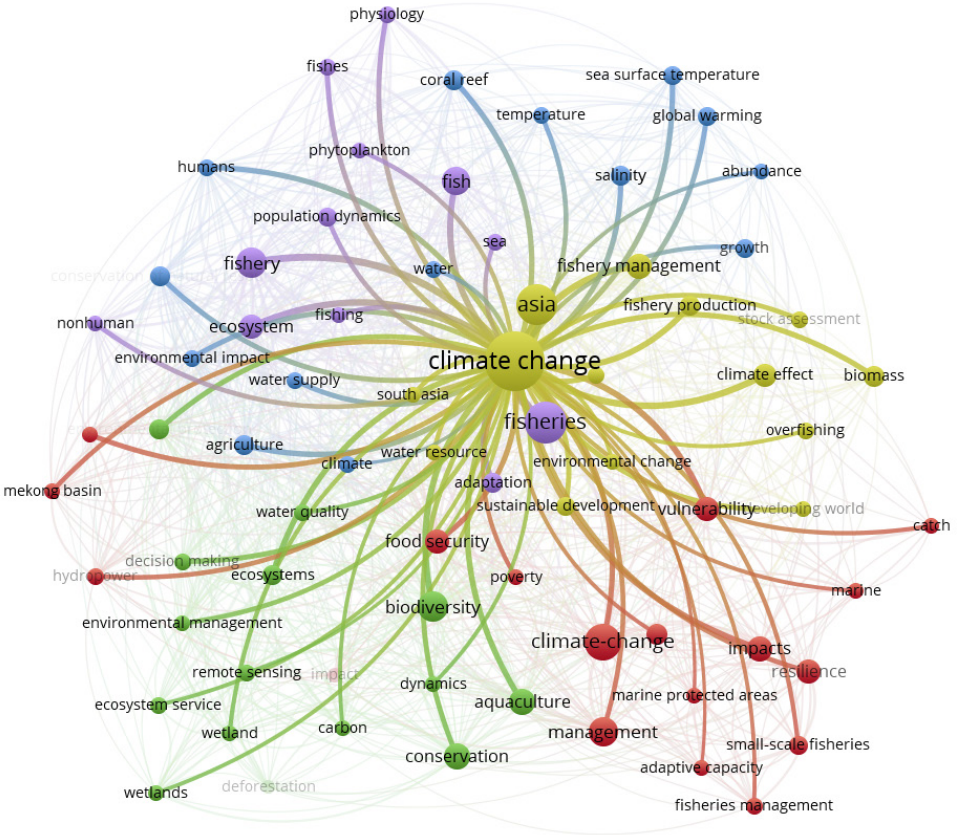


Figure 6. Overlay visualization of most frequently used keywords concerning climate change and fisheries studies in Asia from 1990-2020.

management. Climate change exacerbates biodiversity loss, with rising sea temperatures, acidification, and extreme weather damaging vulnerable ecosystems. The Sixth Assessment Report (AR6) of the IPCC emphasizes how tropical fisheries and dependent communities are at risk due to the combined effect of biodiversity loss and climate change (IPCC 2022). Marine Protected Areas (MPAs) are a proven strategy, protecting critical habitats and enhancing fish stocks through spillover effects (Edwards et al. 2016; D'agata and Maina 2022). Countries like Indonesia and the Philippines have implemented MPAs to safeguard biodiversity while supporting local fisheries (Crawford et al. 2006; White et al. 2006). Similarly, marine conservation efforts and habitat protection in Vietnam are vital for maintaining viable fisheries in a changing climate (Rambaldi et al. 2001). These initiatives demonstrate the importance of aligning biodiversity conservation with fisheries management to secure long-term food security and economic stability. This integrated strategy is crucial for addressing the effects of climate change on fisheries, providing solutions to enhance climate adaptation and protect ecosystems in tropical fisheries across Asia.

## Ecosystem services adaptation

Ecosystem services play a vital role in supporting human well-being, from providing food and fuel to regulating environmental processes (Spaninks and van Beukering 1997). Protecting

these services through ecosystem-based adaptations is essential for building resilience to climate change in many Asian countries. Efforts such as mangrove conservation in Indonesia (Narendra et al. 2021) and coral reef protection in the Philippines (White et al. 2005) demonstrate how safeguarding ecosystems can simultaneously enhance community livelihoods and support biodiversity conservation. Nevertheless, the challenge remains to fully understand and value these services. Ecosystem services often have non-material benefits, such as cultural and spiritual well-being, which are difficult to quantify (Chakraborty et al. 2019). Future adaptation efforts should consider these intangible benefits, ensuring that the full spectrum of ecosystem services is recognized and preserved in the face of climate change.

**Livelihood and fisheries management**

Vulnerabilities faced by fisheries communities due to climate change are shaped by socio-economic and environmental factors. The IPCC (2022) notes that intersecting challenges, including weak governance, inequity, and marginalization, exacerbate these vulnerabilities. In response, co-management, where responsibilities are shared between governments and user groups, has been widely proposed as a more effective model for fisheries management compared to traditional command-and-control approaches (Sen and Nielsen 1996). This model fosters collaboration and encourages sustainable resource use while addressing community needs (Barratt and Allison 2014). However, vulnerability can undermine participatory efforts in fisheries management. Fishers facing immediate risks may discount future benefits, making them less likely to engage in long-term resource stewardship (Kolding et al. 2014). This highlights the need for creating an enabling environment where fishing communities are supported not only in managing resources but also in addressing their broader social and economic challenges.

Findings of this review corroborate those of Ribot (2013) in that anthropogenic processes such as governance, socio-economic dynamics, and institutional weaknesses, are often poorly explored while physical and natural factors of vulnerability are well-described. The reluctance of some fisheries scientists to engage with multidisciplinary approaches that integrate stronger social and economic components may be contributing to this gap (Kolding et al. 2014). By adopting a more integrative perspective, fisheries management can address both environmental and human vulnerabilities ensuring more sustainable outcomes.

## CONCLUSIONS

This systematic review provided a direction for further studies on socioeconomic factors affecting vulnerabilities concerning climate change. This could pave the way for better policies to support fisheries management in Asia. Enabling mechanisms for fishing as an economic activity should be anchored on its socio-economic context to better adapt to climate change. Further studies on adaptation and how it is developed in the context of climate change vulnerability should be explored, considering the interaction of other stressors. This might better aid government agencies in crafting better fishery management policies. Many important programs or initiatives from government and non-government organizations can reduce vulnerability and build adaptive capacity in several ways. For example, contributing funding, advocacy and strengthening national policy on adaptation, improving rural infrastructure, providing climate education and diversifying livelihoods. However, assessing the driving factor of climate-related vulnerability and identifying which are amenable is insufficient for a vulnerability reduction strategy. What is needed is long-term stewardship for better compliance and support for fisheries management. Finally, this review revealed that while

many adaptation strategies have been proposed and implemented, there is still a significant need for a deeper understanding of the socioeconomic and political factors shaping vulnerability. Future research should focus on developing more integrated approaches that account for these complexities, ensuring that vulnerability assessments inform not only climate change adaptation strategies but also broader reforms in governance and social equity. This will enable more effective and equitable fishery management policies, ultimately ensuring that both ecosystems and fishing communities can thrive in the face of climate change.

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### Author contributions

Ahasan Habib: led the writing of the manuscript and analysed the data, conceptualised the topic; contributed to the critical revision of the article. Elaine Q. Borazon: conceptualised the topic; contributed to the critical revision of the article. Ivy M. Nallos: contributed to the writing and revision of the article; contributed to the critical revision of the article. Edison D. Macusi: conceptualised the topic; contributed to the writing and revision of the article; contributed to the critical revision of the article.

### Declaration of competing interest

The authors declare that no competing financial interests or personal relationships could have appeared to influence the work reported in this paper.

### Data availability

Data will be made available on request.

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