The Status and Recent Management of the Fisheries and Aquaculture Sector in the Fisheries Management Area of 711, part of the South China Sea

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Abstract

The South China Sea sub-region of Indonesia (FMA 711) represents a major contributor to national fisheries production, supporting both industrial and small-scale sectors and sustaining significant marine biodiversity. This report provides a comprehensive assessment of capture fisheries, aquaculture, stock status, fishing effort, and emerging environmental pressures across the region. Findings reveal long-term increases in reported capture production since the 1950s, driven by fleet modernization and expanded fishing capacity. At the same time, unreported catches remain comparatively low but still pose uncertainties for stock assessment. Several key species groups, including large pelagic, demersal, cephalopods, shrimp, and crab, show signs of overexploitation, exacerbated by destructive gear use, habitat degradation, and IUU fishing. Environmental variability and climate change further influence species distribution, productivity, and catch potential, with models indicating an approximate 12% decline in maximum catch potential from 1990 to 2025. Aquaculture production displays substantial regional disparity, dominated by East Java, Jakarta, and West Java, while smaller provinces exhibit limited growth due to regulatory and infrastructural constraints. Collectively, these findings highlight the urgent need for science-based fisheries management, strengthened monitoring and enforcement, and adaptive strategies to enhance the resilience of both capture fisheries and aquaculture under increasing anthropogenic and climatic pressures.

Keywords: aquaculture, fisheries, South China Sea.

1. Introduction

The fisheries sector in Indonesia plays a vital role both economically and socially, serving as one of the main pillars of national food security and a source of livelihood for millions of coastal communities. The contribution of the capture fisheries sub-sector to the national Gross Domestic Product (GDP) reached around 2.7% in 2023, with an average growth of 5–6% per year (MMAF, 2024). The high national consumption of fish, which has increased to around 57 kg per capita per year, reflects the importance of this sector in supporting the nutrition of the Indonesian people. One of the strategic fisheries areas that supports this contribution is the South China Sea (SCS) sub-region, also known as the Indonesian Fisheries Management Area (FMA) 711, which covers the northern waters of the Natuna Islands, Anambas, and surrounding areas in the Riau Islands Province.

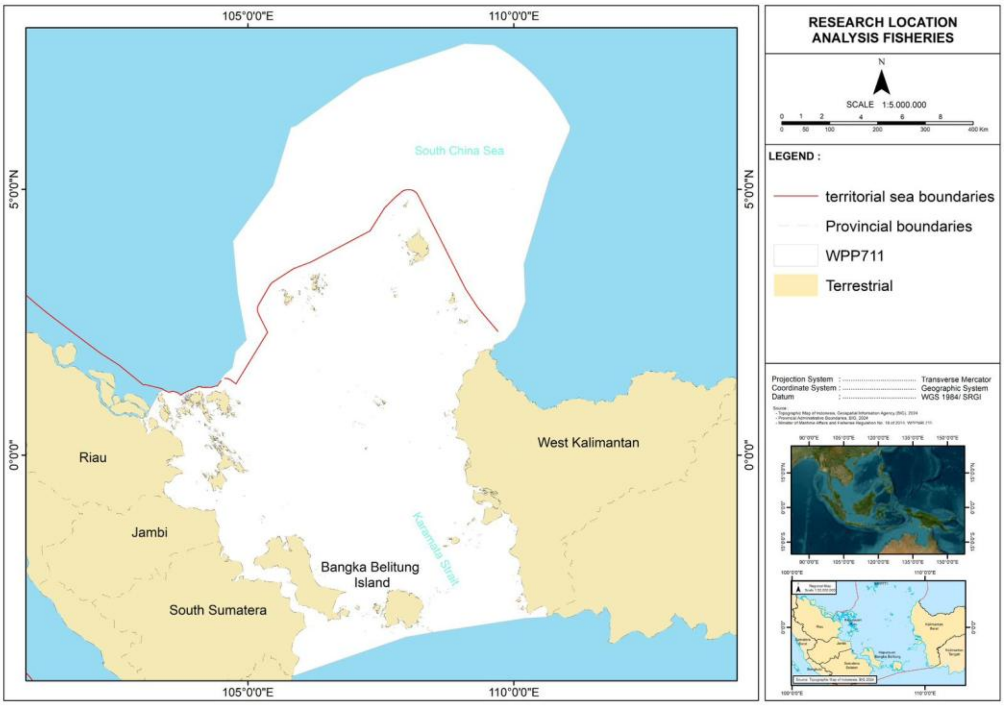

Figure 1 Coverage of the SCS sub-area that is part of WPPNRI 711

The Indonesian sub-region of the South China Sea (WPPNRI 711) is a biodiverse tropical ecosystem and key migration route for large pelagic fish, contributing 11–13% of national capture fisheries production with high MSY potential for pelagic and demersal resources. Despite this significance, the area faces significant challenges, including overexploitation, IUU fishing, habitat degradation, and climate-driven shifts in temperature and currents that affect species distribution and productivity. These pressures highlight the need for adaptive, science-based, and collaborative management approaches, as NTDA findings indicate notable overexploitation of high-value pelagic and demersal stocks. This paper, therefore, assesses the fisheries and aquaculture status of WPPNRI 711 and provides strategic recommendations intended to guide sustainable resource and pollution management in the region.

This paper aims to comprehensively examine the status of fisheries and aquaculture in the WPPNRI 711 of the South China Sea (SCS) region (Figure 1). The paper concludes with a set of recommendations in the form of a strategic action plan, which is expected to serve as a reference for pollution management in Indonesia, particularly within the SCS region.

2. Overexploitation of Living Aquatic Resources

2.1.1. Production Required by Reporting Status

Fisheries in the South China Sea under WPPNRI 711 form a key component of regional marine productivity, requiring an indicator-based framework to assess resource potential amid rising anthropogenic and climatic pressures. Five core indicators, biomass, reproductive dynamics, mortality, habitat condition, and environmental parameters, collectively support comprehensive stock evaluation. Biomass estimation, derived from trawl surveys, CPUE, and stock assessment models, provides the primary metric for determining MSY and assessing exploitation levels, a critical function in this transboundary and migratory species–dominated region. Studies show that declines in biomass can amplify the effects of climate variability and fishing intensity on population trajectories.

Habitat quality, particularly within coral reefs, mangroves, and seagrass systems, underpins recruitment and trophic stability. Degradation from sedimentation, pollution, and destructive fishing has reduced habitat complexity and carrying capacity, diminishing biodiversity and coastal fishery productivity. Environmental conditions, including SST, salinity, dissolved oxygen, and nutrient dynamics, further shape species physiology, distribution, and recruitment. Climate-driven anomalies and changing monsoon patterns in WPPNRI 711 have been linked to shifts in species composition and poleward migration, underscoring the need for continuous monitoring to inform ecosystem-based fisheries management.

Analysis of capture fisheries production from 1950 to 2019 shows a persistent dominance of reported over unreported catches. Reported production increased steadily, peaking near 900,000 tonnes in the late 2010s, reflecting fleet modernization, improved reporting systems, and stronger governance. Unreported catches remained comparatively low and stable, though this may indicate both effective monitoring and ongoing challenges in detecting IUU fishing, particularly in remote or disputed areas (Figure 1).

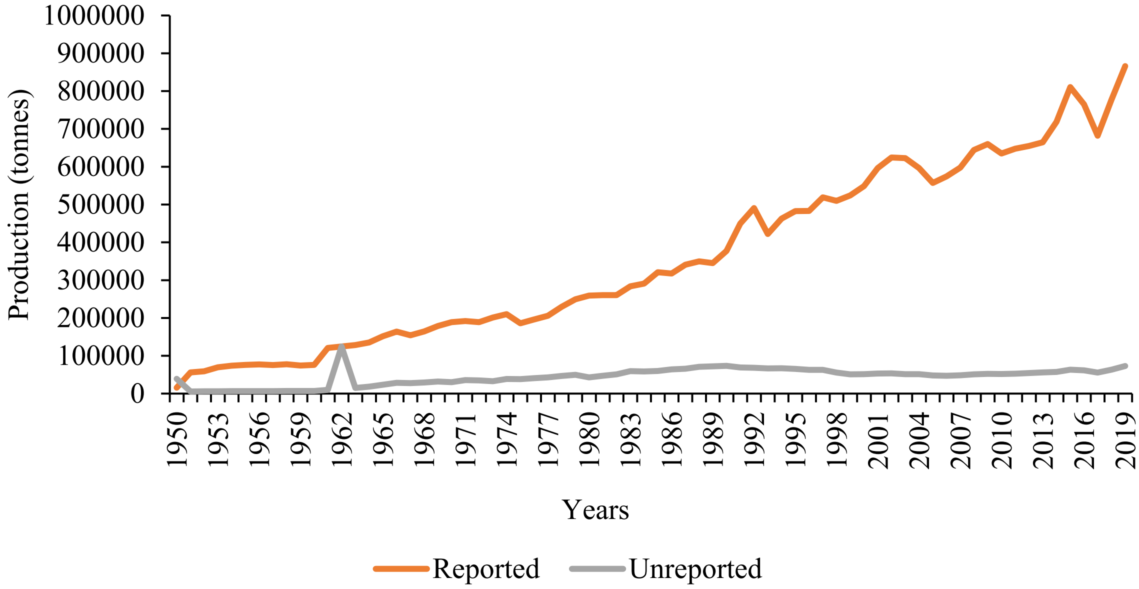

Figure 2 Capture fisheries production in the South China Sea from 1950 to 2019 (FAO, 2022)

From a scientific and management perspective, the significant disparity between reported and unreported catches carries important implications for sustainable fisheries governance in the South China Sea. The predominance of reported data provides a strong foundation for conducting stock assessments, setting quotas, and formulating science-based policy decisions. However, even a small proportion of unreported catch can introduce significant uncertainty into biomass estimates, especially when it involves high-value or ecologically important species. Unreported fishing may occur due to small-scale artisanal operations outside the formal monitoring system, cross-border fishing in disputed territories, or deliberate underreporting to evade regulations and taxes. This underestimation of total catch can lead to overly optimistic assessments of stock health, inadvertently increasing the risk of overexploitation and long-term stock depletion. To address this, it is essential to strengthen catch documentation schemes, expand the use of electronic monitoring and vessel tracking systems, and promote regional cooperation among South China Sea nations.

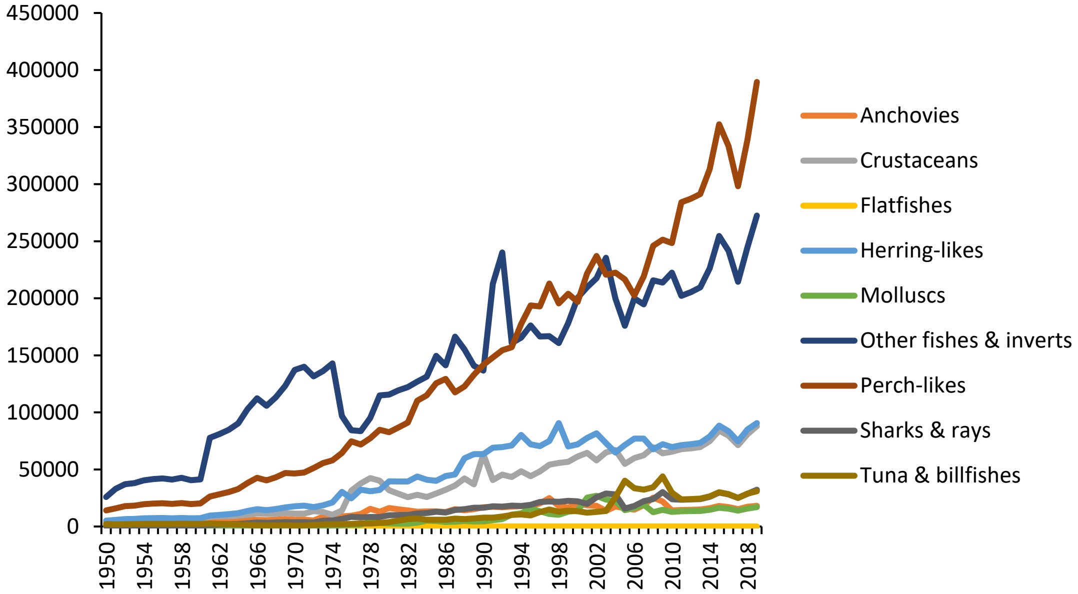

Figure 3 Capture fisheries by species group production in the South China Sea from 1950-2019 (FAO, 2022)

The artisanal fisheries sector in the South China Sea is essential for coastal livelihoods and food security, with catches dominated by anchovies, herring-like species, and other small pelagics that have grown steadily, especially since the late 1990s. Molluscs, crustaceans, and perch-like species also contribute significantly, reflecting the region's ecological richness and the reliance of small-scale fishers on nearshore resources. Although some high-value species such as sharks, rays, and tuna are caught in smaller volumes, they provide important economic benefits. However, the expanding fishing range of artisanal fleets driven by market demand and technological improvements, combined with pressure from industrial fisheries, raises growing concerns about overfishing and long-term resource sustainability.

2.1.2. Fisheries Production Potential

The capture fisheries production potential in freshwater areas of the South China Sea region demonstrates distinct trends when viewed over the period from 1960 to 2020 (Figure 4). Freshwater fishes (nei) have consistently dominated production, showing peaks in the mid-1960s and early 1970s before experiencing fluctuations and a gradual decline after 2005. Despite these variations, they remain the most significant contributor to freshwater capture production, indicating that fish species still hold significant economic and nutritional value in the region's inland fisheries.

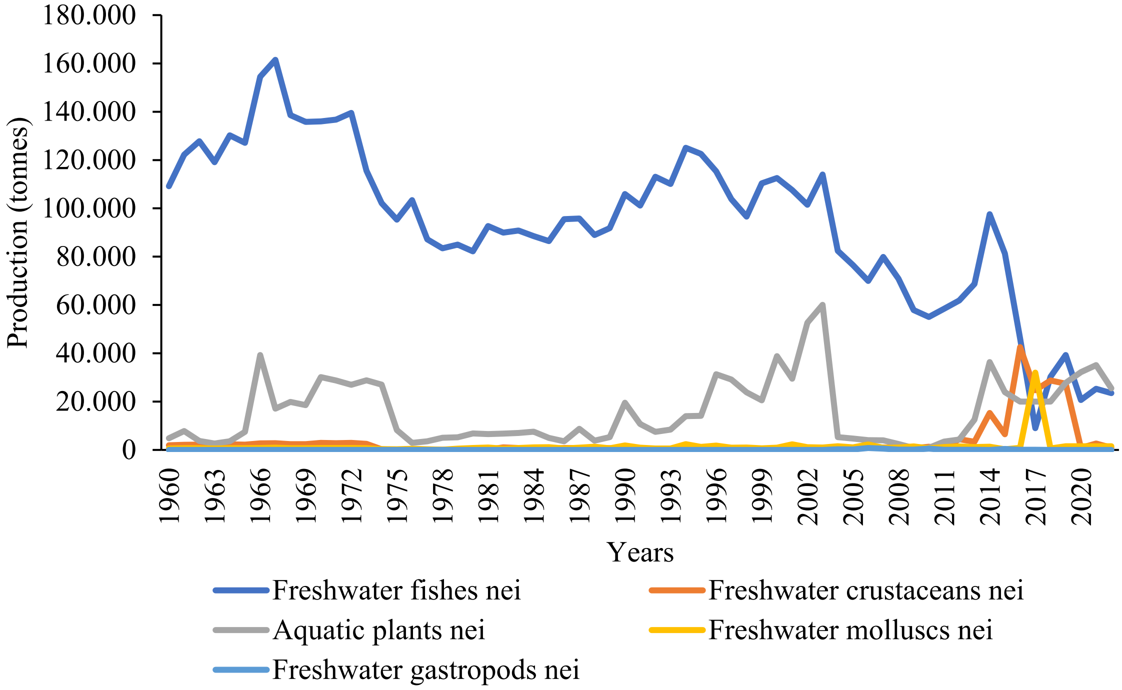

Figure 4 Freshwater production potential from 1960 to 2020 (FAO, 2022)

Aquatic plants in the region have shown intermittent but notable production spikes, particularly in the late 1960s and early 2000s, likely driven by seasonal harvests and shifting market demand, while freshwater crustaceans and molluscs have become more prominent since 2010, though their volumes remain modest. These groups hold niche market potential and could be strengthened through targeted management, improved harvesting methods, and integration with aquaculture. Freshwater gastropods remain minimal, reflecting low availability or demand, yet they indicate untapped biodiversity. Overall, freshwater capture fisheries in the South China Sea region offer opportunities for diversification and economic enhancement, provided that sustainable management and habitat conservation measures are implemented.

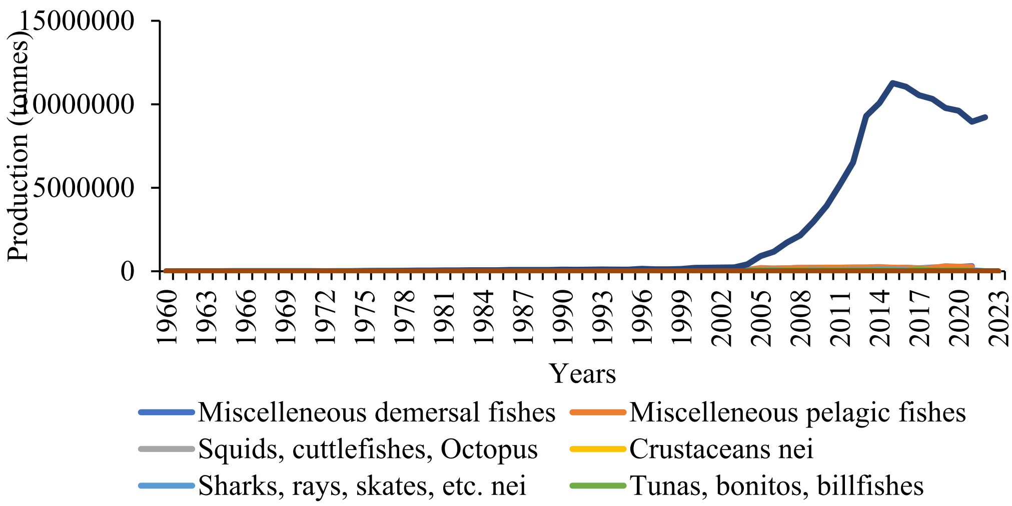

Figure 5 Production potential (FAO, 2022)

Capture fisheries in the South China Sea are dominated by miscellaneous demersal fishes, which surged dramatically in the early 2000s and peaked in 2014–2015 at over 11 million tonnes, reflecting intensified fishing pressure and technological improvements. Although production has slightly declined since then, demersal catches remain far higher than those of other groups. Pelagic fishes, tunas, billfishes, sharks, and rays contribute much smaller volumes, with pelagics and tunas maintaining steady commercial importance, while low shark and ray catches likely reflect conservation limits or declining stocks. Cephalopods and crustaceans, though modest in volume, are economically valuable and show stable trends that could support targeted fishery expansion. In contrast, seaweed and sea cucumbers appear only minimally in capture data. The strong dependence on demersal resources raises sustainability concerns due to their slower life histories, highlighting the need for diversified fishing targets, spatial management, selective gear use, and better utilization of underexploited species to strengthen long-term fisheries resilience.

2.1.3. Fishing Effort

Table 1 Number of fleets by fishing boats and gears

Country/ Sub Regions	**Number of fleets by type of fishing boats**				**Number of fleets by type of fishing gear**				
	Inboard	**Outboard**	**Non-motorized**	**Total**	**Trawlers**	**Purse Seiners**	**Hook & Lines**	**Gillnet**	**Total**
Indonesia									
Riau-Batam	19,783	6,794	11,612	38,189	-	-	-	-	-
Bangka-Belitung and South Sumatra	2,350	757	418	3,525	-	-	-	-	-
Jakarta and West Java	6,766	11,425	20	18,211	-	-	-	-	-
East Java	27,224	26,365	3,654	57,243	-	-	-	-	-
South Kalimantan	5,901	68	68	6,037	-	-	-	-	-
West Kalimantan	7,777	3,536	4,591	15,904	-	-	-	-	-
Subtotal	69,801	48,945	20,363	139,109	-	-	-	-	-

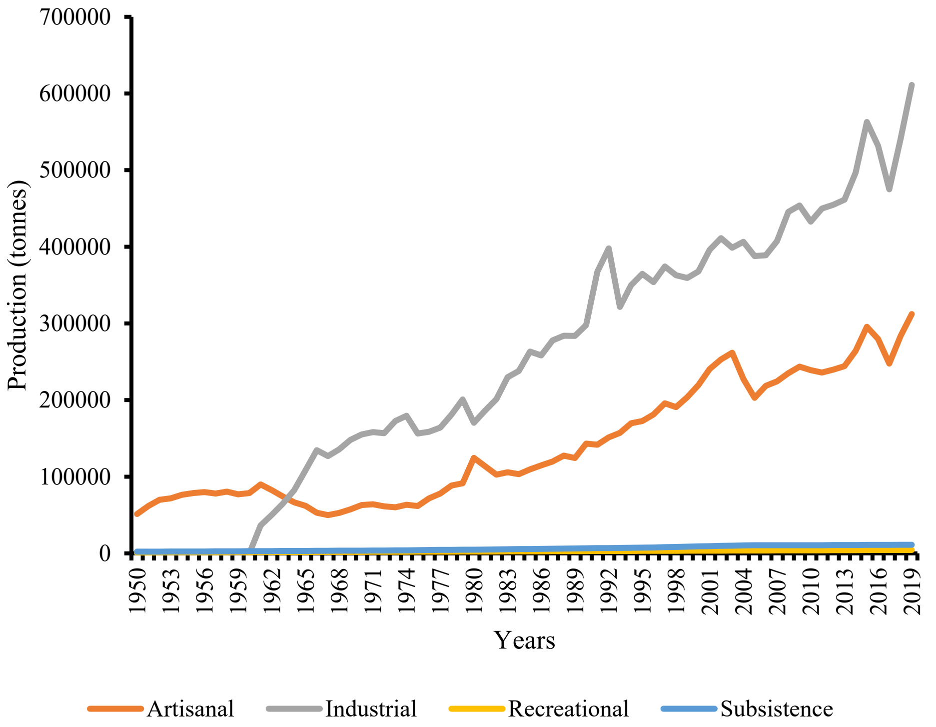

Figure 6 Fish production (tonnes) by fisheries sector in the South China Sea from 1950 to 2019

The fishing effort in the Indonesian regions bordering the South China Sea is characterized by a significant number of fleets, with a mix of inboard, outboard, and non-motorized vessels. According to the table, East Java has the largest total fleet with 57,243 boats, followed by Riau-Batam with 38,189 vessels. The prevalence of non-motorized boats in areas like Riau-Batam (11,612 units) highlights the importance of small-scale artisanal fisheries, which rely heavily on traditional fishing methods and nearshore resources. However, the large numbers of inboard and outboard motorized vessels in key provinces suggest a growing fishing capacity that can exert considerable pressure on fish stocks.

Figure 6 illustrates the long-term production trend of two main fisheries sectors, artisanal (traditional) and industrial fisheries, which together represent the dominant fishing activities within Indonesia's South China Sea sub-region. From the 1950s to 2019, industrial fisheries production increased exponentially, reaching nearly 600,000 tonnes, while artisanal fisheries showed a steadier but consistent growth, rising from less than 50,000 tonnes in the 1950s to over 300,000 tonnes by 2019. The continuous upward trend in both sectors reflects the expansion of fishing capacity, technological advancement, and market-driven demand for export-oriented species such as tuna, mackerel, and anchovy.

Figure 6 and Table 2 reveal a structural dualism in Indonesia's fishing economy, a coexistence between the rapidly modernizing industrial sector, supported by motorized fleets and advanced gear such as purse seiners and hook-and-line systems, and the traditional artisanal sector, which remains vital for coastal livelihoods and local food security. The expansion of industrial fleets correlates with the sharp rise in production after the 1980s, whereas artisanal fisheries growth is constrained by limited vessel capacity and spatial competition in nearshore waters. This dual-sector dynamic underscores the need for differentiated management strategies ensuring industrial efficiency while safeguarding artisanal sustainability, particularly in the WPPNRI 711 region, where both sectors play complementary but increasingly competitive roles.

2.1.4. Stock Numbers and Catch Biomass

Capture fisheries production in the South China Sea has risen steadily from 1950 to the late 2010s, driven by fleet mechanization, technological advancements, expanded fishing grounds, and improved reporting. Production reached its highest levels in the late 2010s, nearly one million tonnes, before dropping sharply in the most recent year, a decline that may reflect stricter management, reporting changes, or reduced resource availability. While the long-term growth trend highlights the sector's expansion, the recent downturn signals ecological limits and increasing pressure on stocks, emphasizing the need for science-based management, stronger monitoring, and ecosystem-based approaches to maintain sustainability and safeguard coastal livelihoods.

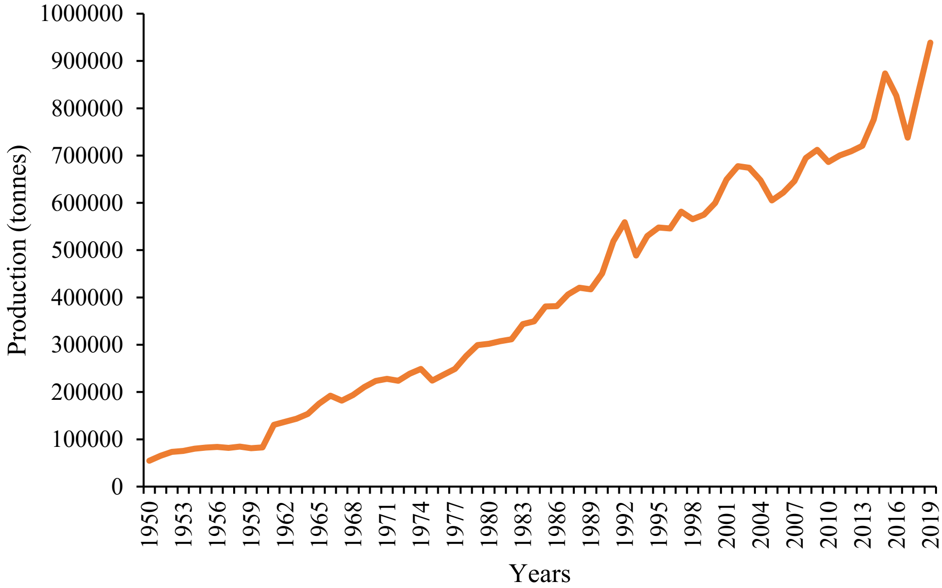

Figure 7 Fish production (tonnes) in the South China Sea from 1950-2019 (FAO, 2022)

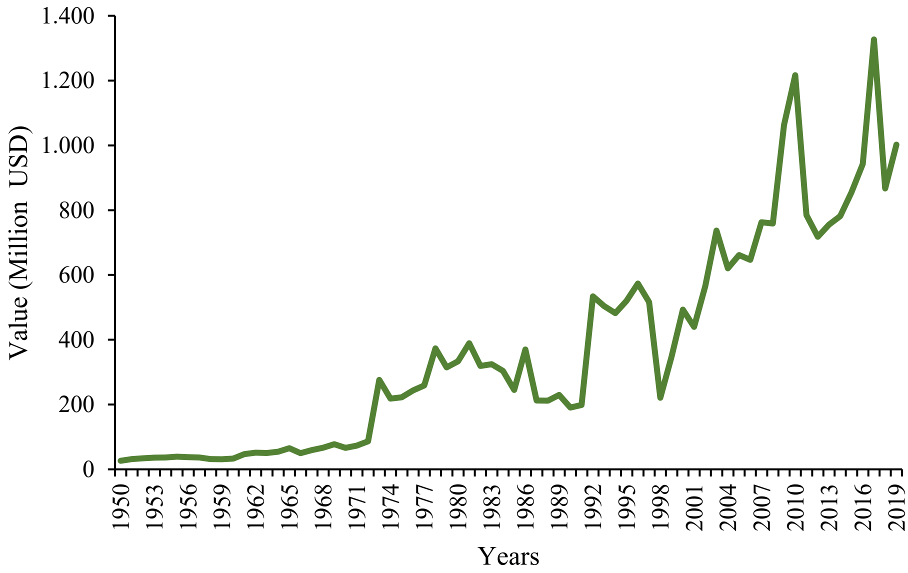

Figure 8 Fish production value in the South China Sea from 1950-2019 (FAO, 2022)

The economic value of capture fisheries in the South China Sea has grown substantially from 1950 to the late 2010s, rising gradually in the early decades and then sharply from the 1970s onward due to improved technology, offshore expansion, and stronger market integration. After fluctuating through the 1980s and early 2000s, the sector experienced its steepest growth in the mid-2000s, peaking above one trillion rupiah in the early–mid 2010s as demand and prices for high-value species increased. The abrupt decline in the most recent year parallels drops in production, indicating possible reductions in catch, market disruptions, or reporting changes. This trend demonstrates the economic vulnerability of fisheries-dependent regions and reinforces the need for sustainable management to stabilize both biomass and long-term economic returns.

Table 2 Exploitation level in the South China Sea from 1950 to 2019

Country /Sub-Regions or coastal provinces	**Resource Categories (Fish Species Groups)**								
		Miscellaneous demersal fishes	**Miscellaneous pelagic fishes**		**Squids, cuttlefish, and Octopus**	**Crustaceans nei**			
			Small Pelagic	**Big Pelagic**		**Shrimp**	**Lobster**	**Crab**	**Blue Crab**
Indonesia									
Riau-Batam	Potency	131,070	330,284	185,855	23,499	62,342	1,421	2,318	9,711
	TAC	104,856	264,227	148,684	18,799	49,874	1,137	1,854	7,769
	Level of Utilization	0.61	1.41	0.93	1.84	0.53	0.54	1.09	1.18
Bangka-Belitung and South Sumatra	Potency	131,070	330,284	185,855	23,499	62,342	1,421	2,318	9,711
	TAC	104,856	264,227	148,684	18,799	49,874	1,137	1,854	7,769
	Level of Utilization	0.61	1.41	0.93	1.84	0.53	0.54	1.09	1.18
Jakarta and West Java	Potency	657,525	364,663	72,812	126,554	57,965	989	7,664	23,508
	TAC	526,020	291,730	58,250	101,243	46,372	791	6,131	18,806
	Level of Utilization	0.83	0.38	0.63	2.02	1.11	1.36	0.7	0.65
East Java	Potency	657,525	364,663	72,812	126,554	57,965	989	7,664	23,508
	TAC	526,020	291,730	58,250	101,243	46,372	791	6,131	18,806
	Level of Utilization	0.83	0.38	0.63	2.02	1.11	1.36	0.7	0.65
South Kalimantan	Potency	252,869	208,414	645,058	10,519	30,404	927	4,347	5,463
	TAC	202,295	166,731	516,046	8,415	24,323	742	3,478	4,370
	Level of Utilization	0.96	1.23	1.13	1.19	0.52	1.4	0.83	0.73
West Kalimantan	Potency	131,070	330,284	185,855	23,499	62,342	1,421	2,318	9,711
	TAC	104,856	264,227	148,684	18,799	49,874	1,137	1,854	7,769
	Level of Utilization	0.61	1.41	0.93	1.84	0.53	0.54	1.09	1.18

Average Score		1	2	3				
		Under Exploitation	Exploitation	Over exploitation				

The fisheries status of Indonesian waters bordering the South China Sea shows differing levels of resource use across species groups, as summarized in Table 2. Indonesia's marine resources in WPPNRI 711 are categorized into demersal fishes, pelagic fishes (small and large), cephalopods, and crustaceans. Key species include small pelagics such as *Decapterus* spp., *Sardinella* spp., and *Rastrelliger* spp. Large pelagics such as *Thunnus tonggol, Thunnus albacares*, and *Scomberomorus commerson*. Demersal species such as *Lutjanus* spp., *Epinephelus* spp., and *Nemipterus* spp., and crustaceans including *Penaeus merguiensis, Panulirus* spp., *Portunus pelagicus*, and *Scylla serrata.*

The term "potential" refers to Maximum Sustainable Yield (MSY) or Total Allowable Catch (TAC) estimates derived from biomass assessments by the Ministry of Marine Affairs and Fisheries. These values represent the biological capacity for sustainable harvest rather than recorded catches, emphasizing the need for science-based management in WPPNRI 711 through catch limits, gear controls, and habitat protection. Overexploitation in several sub-regions, particularly Jakarta and West Java, East Java, South Kalimantan, and West Kalimantan, indicate fishing pressure exceeding TAC. High utilization of cephalopods, shrimp, and crab is driven by the expansion of industrial and artisanal vessels, especially purse seines and trawls. East Java alone operates over 57,000 vessels, intensifying spatial and operational pressure on shared resources.

Key drivers of overexploitation include technological advancements that boost fishing efficiency, weak enforcement of quotas and spatial regulations, and strong market demand for export-oriented species such as Penaeus merguiensis, Portunus pelagicus, and various cephalopods. Habitat degradation, particularly coral reef and mangrove loss, further reduces ecosystem resilience, while climate-driven shifts in temperature and productivity alter distribution and recruitment.

2.1.5. Catch from Bottom Impacting Gear Types

The types of gear used in Indonesia are diverse, ranging from simple fishing gear to modern fishing gear that uses certain types of machinery. The type of fishing gear used can have an impact on the number of fish caught. The following graph shows the types of fishing gear used and the number of fish caught.

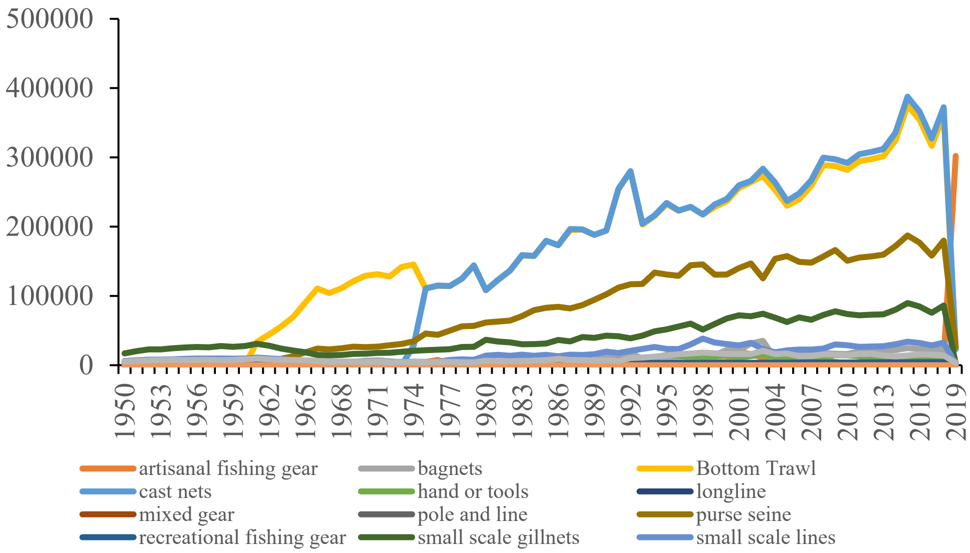

Figure 9 Number of fleets in the South China Sea from 1950 to 2019

Purse seine is the dominant gear in the South China Sea, expanding rapidly since the 1970s and peaking at over 400,000 units in 2010–2016, driving pelagic fisheries but raising concerns over juvenile bycatch and stock decline. Bottom trawls, the second primary gear type, have increased since the 1980s and remain highly productive for demersal species, though they cause severe habitat damage and high bycatch. Longlines, while fewer, contribute significantly to high-value tuna and billfish markets, reflecting a gradual shift toward selective, premium fisheries. Traditional small-scale gears show modest, stable contributions mainly supporting local food security. Overall, data from 1950–2019 indicate substantial industrial intensification, with purse seines and trawls dominating production but amplifying sustainability risks; in WPP 711 and 718, bottom seine nets add further pressure due to high bycatch, habitat disruption, and conflicts with artisanal fishers.

2.1.6. Change in Catch Potential Under Global Climate Change

The region of WPPNRI 711, located in the southern part of the South China Sea, exhibits significant variability in sea surface temperature (SST) and ocean circulation driven by monsoon systems and regional currents. For example, studies report that SST in the area fell to as low as 27.1 °C in February and rose to around 30.9 °C in May between 2017 and 2021, with a long-term mean near 29.0 °C. The lowest values typically occur during the West Monsoon season, when colder water masses and stronger winds reduce surface temperatures. In terms of sea surface salinity (SSS), measurements show an average of about 33.3 psu during the West Monsoon (Dec–Feb), with observed ranges between approximately 30.4 psu and 33.6 psu for that seasonal period. At depth in the upper ~54 m layer of the sea, salinity ranges from about 33.3 psu to 34.2 psu, indicating variability due to dynamic processes and mixing.

Table 3 Environmental data of the South China Sea

Variable	Observed Values	Sources
Sea Surface Temperature (SST)	• Lowest record for 2017-2021 in North Natuna: 27,1 °C (February)	Debiyanti *et al*. 2025

	• Highest recorded for 2017-2021 in North Natuna: 30.9 °C (May) • Long-term (2011-2020) mean 29.0 °C	
Sea Surface Salinity (SSS)	• Average salinity ~ 33,3 psu during West Monsoon (Dec-Feb) • 30,4 psu to 33,6 psu for Dec-Feb period • In the upper ~54 m depth of SCS: salinity range ~ 33,3 psu to 34,2 psu (for the SCS upper layer)	Debiyanti *et al*. 2025, Xie *et al*. 2023
SST Anomaly/Variation	Seasonal maximum SST in SCS > 29,8ºC (summer) and minimum in winter < ~ 27ºC	Tan *et al.* 2016, Belkin&Shen 2025
Salinity vertical variability	Maximum horizontal difference at depth ~54 m in SCS 2,1 psu, and at depth >500 m, difference ~ 0,3 psu	Xie *et al*. 2022

Three-dimensional salinity patterns in WPPNRI 711 reveal substantial variability in the upper water column, with horizontal differences reaching 2.1 psu at ~54 m but narrowing to about 0.3 psu below 500 m, indicating that surface and subsurface layers are far more dynamic than deeper waters. These conditions, shaped by monsoons, circulation, mixing, and river inputs, underscore the region's highly variable oceanographic environment—an important factor for understanding ecosystem behavior and informing resource management.

Climate change is projected to further reshape this system by reducing catch potential through warming, acidification, and declining primary productivity, which drive species to cooler or deeper habitats and disrupt food webs. Long-term assessments show an estimated 12% decline in maximum catch potential from 1990 to 2025, with many pelagic and demersal species shifting poleward or into less suitable environments. These changes pose significant challenges for fisheries governance, highlighting the need for ecosystem-based management, regional cooperation, habitat protection, and adaptive strategies to maintain resource sustainability and support vulnerable coastal communities.

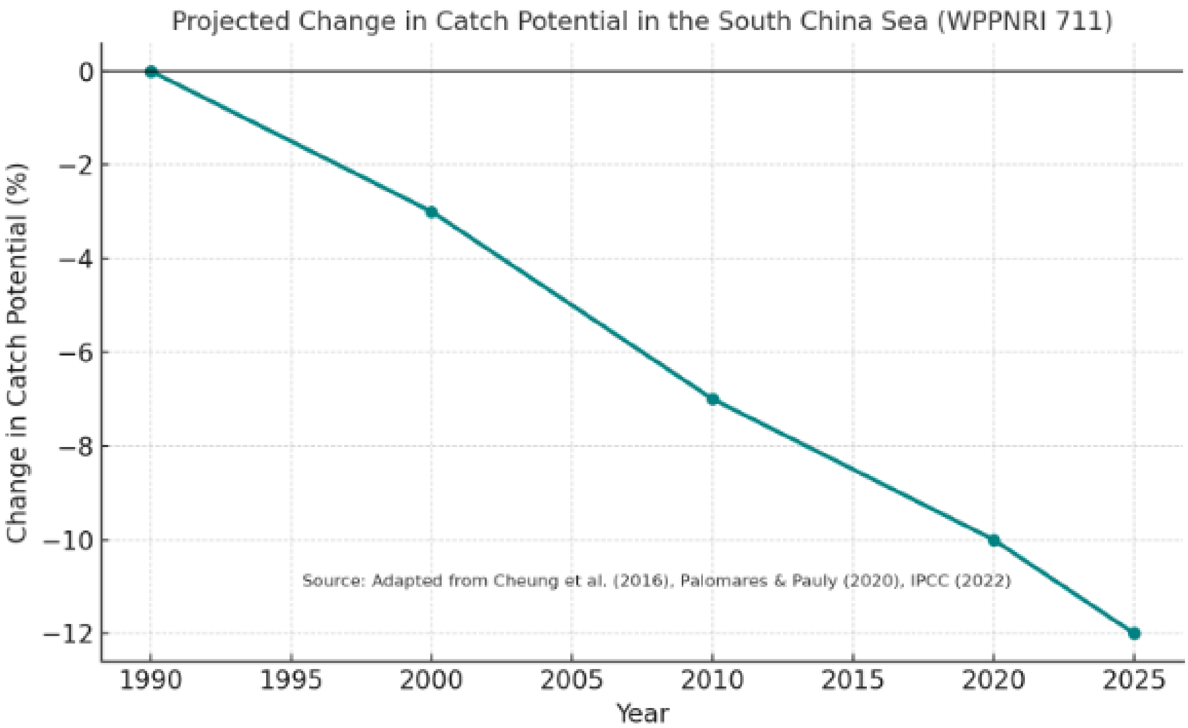

Figure 10 Projected change in fisheries catch potential in the South China Sea (WPPNRI 711) from 1990 to 2025, adapted from Cheung et al. (2016), Palomares & Pauly (2020), and IPCC (2022).

Risk Assessment

The projected decline in catch potential presents multiple risks to fish stocks, fisheries, and coastal livelihoods. Under moderate to severe warming scenarios, key pelagic species such as mackerel (*Rastrelliger spp*.), tuna (*Thunnus* spp.), and anchovy (*Stolephorus* spp.) are expected to lose 10–20% of their biomass due to altered thermal regimes and disrupted spawning patterns. These biological impacts cascade into socioeconomic vulnerabilities, particularly in nations bordering the South China Sea, Indonesia, Vietnam, and the Philippines, where a high proportion of protein intake and employment depend on marine resources. Studies by Sumaila *et al. (2019)* suggest that without adaptive measures, climate-induced changes in fish stocks could exacerbate income inequality, reduce food security, and drive overexploitation in nearshore ecosystems as communities seek to compensate for declining yields.

Reporting and Communication

To manage and mitigate these impacts, systematic monitoring and transparent communication are essential. Regional initiatives such as the Southeast Asian Fisheries Development Center (SEAFDEC) and the ASEAN-SEAFDEC Strategic Partnership play a crucial role in coordinating research and sharing data. Regular reports integrating satellite-based environmental observations, catch statistics, and species distribution models should be disseminated to policymakers, fishery managers, and local communities. These reports serve to inform evidence-based decision-making and promote the implementation of adaptive strategies such as climate-resilient fisheries management, spatial zoning, and ecosystem-based approaches to enhance sustainability in the region's fisheries sector.

3. Status of Coastal Aquaculture

3.1. Aquaculture Production

Aquaculture production in the South China Sea region varies significantly across different provinces over the observed period from 1998 to 2024 (Figure 11). In the early years, production levels were generally low, with sporadic increases in Riau-Batam and East Java. Before 2012, most regions maintained relatively modest outputs, reflecting either limited aquaculture development or data availability. However, East Java began showing a steady increase in production from 2010 onward, becoming a notable contributor to the overall output.

From 2013 to 2016, production trends shifted dramatically. Jakarta and West Java experienced a sharp spike, peaking at around 1.5 million units in 2015 before rapidly declining. In the same period, East Java also saw a substantial surge, reaching its highest levels around 2016, before stabilizing at a high output range through the following years. West Kalimantan, while less dominant, showed a gradual upward trend starting in the mid-2010s, contributing steadily to total production.

In contrast, South Kalimantan and Bangka-Belitung, with South Sumatra, maintained consistently low production throughout the period, indicating smaller-scale aquaculture activities. By 2018 onward, production from East Java and Jakarta–West Java dominated the regional aquaculture output, despite fluctuations. This pattern suggests a regional concentration of aquaculture capacity in these provinces, likely due to better infrastructure, market access, and technological investment compared to other areas in the South China Sea region (Table 3)

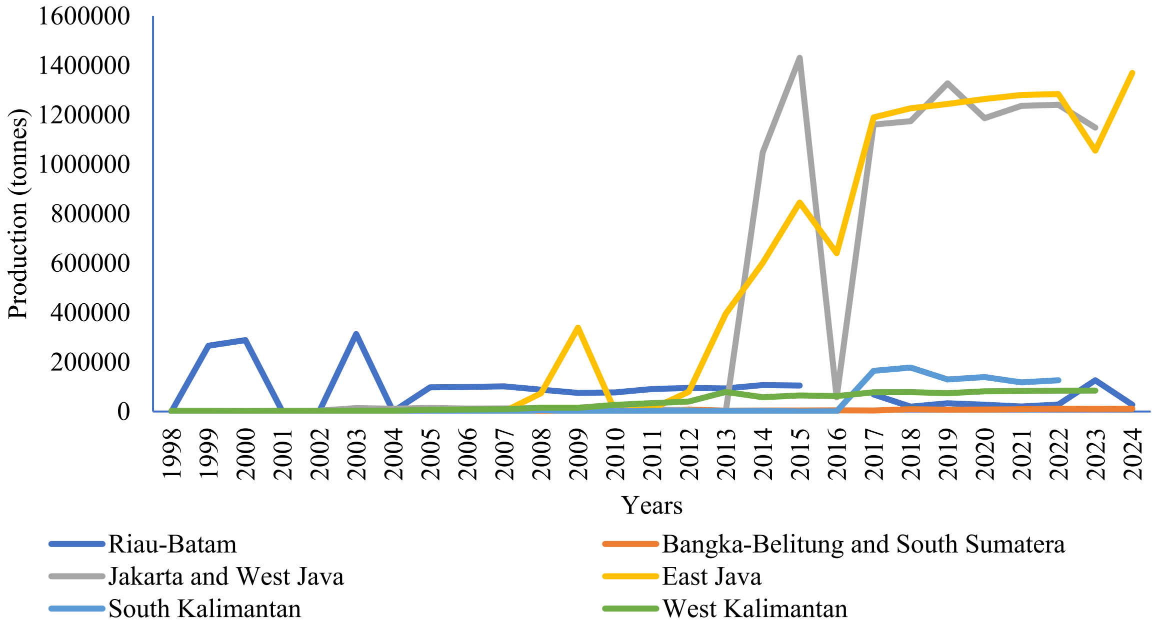

Figure 11 Aquaculture production by province from 1998 to 2024

Table 4: Aquaculture production of the seven provinces in the South China Sea

Years	Riau-Batam	Bangka-Belitung and South Sumatra	Jakarta and West Java	East Java	South Kalimantan	West Kalimantan
1998	-	-	-	-	-	3,006.70
1999	265,843.10	-	-	-	-	2,684.90
2000	288,473.30	-	-	-	-	2,347.80
2001	-	-	-	-	-	2,856.70
2002	-	313.99	3,760	-	502.1	2,921.80
2003	313,656.40	626.84	13,760	-	511.3	3,321.70
2004	-	788.74	11,092.60	-	496.2	3,671.70
2005	97,781.80	724.64	14,662.57	-	504.9	6,903.60
2006	99,188.20	935.48	11,774.50	-	316.0	7,757.20
2007	102,090.20	903.12	12,381.69	-	-	9,269.30
2008	87,919.20	1,502.56	12,624.41	73,737.60	5,622	14,888.90
2009	75,517.50	2,076.68	2,676.17	339,487.50	1,833	15,204.80
2010	77,113.50	2,622.27	9,577.84	1,680.30	1,866.90	27,039.10
2011	90,505.30	1,683.05	8,799.88	10,690	3,063.40	33,878.30
2012	96,611	8.107.50	4,505.12	79,610	2,725.90	40,309
2013	93,279.20	3,209.37	211,272.25	395,396	2,426.20	79,154
2014	107,306	4,199	1,048,114	601,413	2,705.60	57,936
2015	105,296.30	4,307	1,430,700	845,862	486	65,267
2016	-	4,623	57,079	640,818.91	675	62,301
2017	68,606	3,845	1,160,748	1,189,443	164,715	77,970
2018	19,686	9,334	1,174,435	1,226,560	177,852	78,349
2019	33,195	7,151	1,327,271	1,243,767	129,442	74,245
2020	27,237	8,164	1,186,738	1,264,159	139,079	81,474
2021	20,235	9,144	1,235,930	1,279,959	118,059	83,149
2022	27,942	11,165	1,240,853	1,284,129	126,468	84,076
2023	126,344.73	10,913.68	1,148,456	1,054,927	-	84,717.32
2024	27,421	11,165	-	1,369,571	-	-

3.2. Climate Change Impacts

Climate change poses significant challenges to the marine aquaculture sector through its influence on ocean temperature, chemistry, and circulation patterns. Rising sea surface temperatures can alter the growth rates, metabolism, and reproductive cycles of cultured species, often leading to reduced productivity or increased mortality. Warm-water stress may also create conditions that favor harmful algal blooms (HABs), which release toxins that can contaminate shellfish and disrupt fish farming operations. Additionally, changes in ocean currents and stratification can affect nutrient availability and water exchange in aquaculture sites, further impacting the health and yield of farmed stocks.

Extreme weather events, including storms, floods, and prolonged heatwaves, are expected to increase in frequency and intensity under climate change, posing direct physical threats to aquaculture infrastructure. Storm surges and strong waves can damage cages, nets, and mooring systems, leading to stock losses and economic setbacks. Salinity fluctuations from heavy rainfall or drought can stress farmed species, especially those with narrow tolerance ranges. These combined impacts not only threaten production stability but also increase operational costs due to the need for adaptive measures, such as selective breeding for climate-resilient species, improved farm design, and strategic relocation of aquaculture facilities to less vulnerable areas.

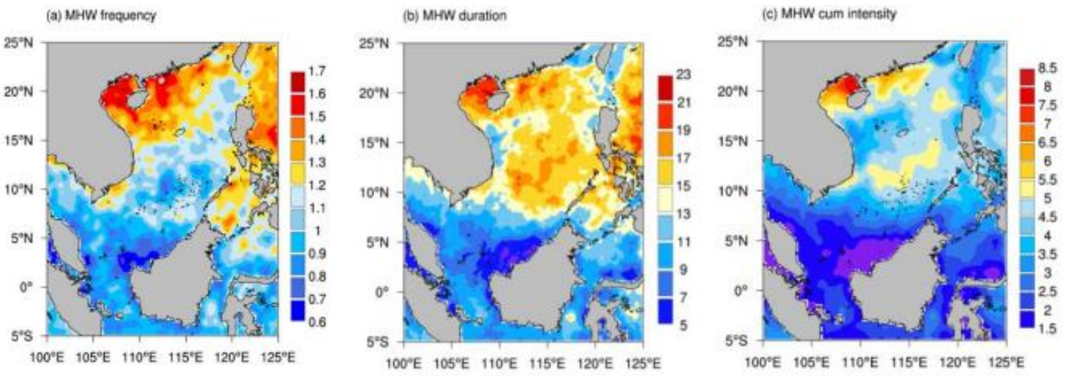

Figure 12 Spatial distribution of multiyear warm season (1982-2020) in the SCS (Li *et al.*, 2022)

In the South China Sea, climate change has already shown tangible impacts on marine aquaculture, particularly in coastal provinces such as Guangdong, Hainan, and the Gulf of Thailand region. Rising sea surface temperatures have led to more frequent outbreaks of fish diseases, including viral nervous necrosis (VNN) in groupers and streptococcosis in tilapia, which thrive in warmer and more stagnant waters. Farmers have reported reduced growth rates and increased mortality in high-value species like shrimp, as higher temperatures and lower dissolved oxygen levels stress the animals. In shellfish farming areas, such as oyster and mussel beds, shifts in seasonal temperature cycles have disrupted spawning periods, affecting seed availability and production timing. These biological changes, compounded by unpredictable monsoon patterns, have made it more difficult for farmers to plan stocking and harvesting schedules.

Ocean acidification in the South China Sea has further exacerbated challenges, particularly for calcifying organisms such as pearl oysters in Hainan and scallops in northern Vietnam. Lower pH levels have been linked to weaker shell formation and higher larval mortality, reducing yields and threatening the economic viability of hatcheries. Additionally, stronger typhoons, which have increased in intensity over the past two decades, have caused significant physical damage to fish cages, seaweed lines, and other infrastructure, resulting in both stock loss and environmental degradation from escaped non-native species. These climate-driven impacts highlight the urgent need for adaptive strategies in the region, including selective breeding for heat- and acidification-resistant strains, the use of deeper or more sheltered farming sites, and the integration of climate forecasting into aquaculture management.

Climate change has measurably affected fisheries in Indonesia's South China Sea sub-region (WPPNRI 711), encompassing the Natuna and Anambas waters. Satellite observations show that sea surface temperatures have increased by 0.2–0.4 °C per decade since the early 2000s, while marine heatwaves occur up to four times annually, lasting 8–18 days with temperature anomalies reaching +1.6 °C (Zandika *et al.,* 2024). These thermal shifts disrupt plankton productivity—chlorophyll-a concentrations fluctuate between 0.1–5 mg/m³—and drive habitat shifts in pelagic fish such as mackerel (*Scomberomorus commerson*), yellowfin tuna (*Thunnus albacares*), and skipjack tuna (*Katsuwonus pelamis*). The area of potential fishing grounds has declined by about 30% during transitional monsoon seasons, causing reduced catch efficiency and up to 20–25% higher fuel costs for local fleets (Untan, 2023). Socioeconomic surveys in Natuna indicate that over 60% of small-scale fishers have experienced declining income due to changing fishing patterns. These findings highlight that without adaptive, data-driven management and improved resilience of coastal communities, climate-related stressors could significantly reduce fishery productivity in Indonesia's portion of the South China Sea.

4. Problems and Issues

4.1.Fisheries Issues

The waters around Bintan within WPPNRI 711 (Natuna and the South China Sea) are highly strategic but face significant ecological and governance pressures. IUU fishing remains a major issue, with violations by Vietnamese vessels increasing despite reductions in Thai incursions, placing heavy pressure on demersal and pelagic stocks and creating economic disadvantages for local fishers. Bottom seine vessels from Java—along with continued use of bouke ami, seine nets, and other bottom-contact gears—frequently violate spatial regulations and damage benthic habitats, particularly in areas such as Tambelan and Anambas where destructive practices like blast fishing, cyanide use, and compressor-assisted capture persist.

Harmful traditional gears, including Muroami and coral-placed fish traps, further degrade reef structures, reduce habitat complexity, and weaken fish recruitment. Spatial conflicts between fishing and marine tourism have intensified in Bintan and Anambas due to overlapping use zones, underscoring the need for clearer zoning and stronger enforcement under RZWP3K. Additional concerns include abandoned and lost fishing gear (ALDFG), which accumulates in coral and dive sites, posing entanglement risks and contributing to marine debris. Cross-border trade challenges persist for high-value or protected species such as Napoleon wrasse, sharks, and sea cucumbers, with recent export restrictions from China affecting local livelihoods. Illegal harvest of protected fauna, including dugongs and sea turtles, continues in remote areas, despite the region’s role as a migratory corridor for many ETP species. Overall, these issues highlight the need for enhanced monitoring, stricter compliance mechanisms, and the development of sustainable livelihood alternatives for coastal communities.

4.2. Aquaculture Issues

In addition to captured fisheries, aquaculture activities in Bintan and Pontianak face several regulatory and environmental challenges that hinder their sustainable development. One major issue is the absence of clear regulations for limited aquaculture activities within the designated aquaculture utilization zones in Pontianak. This regulatory gap often leads to overlapping spatial use, unmonitored farm expansion, and potential conflicts with other coastal activities such as capture fisheries and tourism. The lack of formal governance mechanisms also weakens law enforcement, making it difficult to control environmental impacts and ensure that aquaculture practices comply with sustainability principles.

Environmental concerns are also evident in both regions. Uncontrolled feed input, poor waste management, and weak water quality monitoring contribute to nutrient accumulation and eutrophication in coastal waters, particularly around floating net cages and pond systems.

Inadequate biosecurity and disease surveillance further exacerbate production risks, leading to periodic losses that affect small-scale farmers. Moreover, limited access to high-quality seed stock, feed, and technology remains a constraint for many aquaculture operators. Dependence on wild-caught juveniles, especially for species like grouper and lobster, not only reduces natural stock populations but also threatens ecosystem balance. Without sufficient hatchery development and local government support, reliance on natural seed sources is likely to persist.

From a socioeconomic perspective, small-scale aquaculture producers also struggle to meet market demands and international export standards. The lack of certification schemes, product traceability, and stable market access, especially for live reef fish such as Napoleon wrasse and groupers, makes the sector vulnerable to fluctuating trade policies and demand, such as China's recent import restrictions. To ensure long-term sustainability, the aquaculture sector in Bintan and Pontianak require stronger spatial planning, clear regulatory frameworks, and enhanced capacity-building programs that promote environmentally responsible and economically viable aquaculture development.

5. Conclusion

The fisheries and aquaculture systems of Indonesia's South China Sea sub-region are at a critical juncture, balancing high productivity with mounting ecological and governance challenges. Analysis of historical production trends demonstrates substantial growth supported by technological advancement and expanded fishing capacity; however, several major species groups now face overexploitation and habitat pressures. IUU fishing, destructive and bottom-impacting gears, and weak enforcement continue to undermine resource sustainability, particularly in ecologically sensitive areas such as Bintan, Natuna, and Anambas. Climate-driven changes, including rising sea surface temperatures, altered salinity structure, and shifting species distributions further reduce catch potential and increase socioeconomic vulnerability among coastal communities.

Aquaculture presents a growing but unevenly distributed sector, with substantial development concentrated in East Java and Jakarta, West Java. At the same time, other provinces face regulatory gaps, environmental constraints, and limited access to technology and quality seed. Strengthening spatial planning, improving biosecurity, and promoting environmentally responsible practices are essential to support sustainable aquaculture growth.

Overall, ensuring the long-term viability of fisheries in WPPNRI 711 requires integrated, ecosystem-based management that incorporates accurate stock assessments, improved catch documentation, habitat protection, and climate adaptation measures. Enhanced regional cooperation, transparent reporting, and community-focused livelihood diversification will be critical to maintaining food security, economic stability, and ecological resilience in Indonesia’s portion of the South China Sea.

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References

Allen, M.S. (2014). Fish Population Dynamics: Mortality, Growth, Reproduction. *American Fisheries Society.* https://fisheries.org/docs/books/55060C/2.pdf

Belkin IM, Shen C. (2025). *Long-term variability of surface temperature in the South China Sea*. NOAA AOML Technical Report. Retrieved from https://www.aoml.noaa.gov/phod/docs/jcli-d-15-0338.1.pdf

Cheung WWL, Reygondeau G, Frölicher TL. (2016). *Large benefits to marine fisheries of meeting the 1.5°C global warming target. Science.* 345(6319): 1591–1594. https://doi.org/10.1126/science.aag2331

Debiyanti N, Alfiansyah S, Hidayat M. 2025. Cycle of potential fishing area of WPP-NRI 711 (2011–2020). *Journal of Regional Science and Sustainable Fisheries Development.* 12(3): 115–124.

Degnbol P, Jarre A. (2004). Review of indicators in fisheries management. *African Journal of Marine Science,* 26(1), 303–313. https://doi.org/10.2989/18142320409504063

Durant JM, Holt RE, Langangen. (2024). Large biomass reduction effects on the relative role of climate, fishing, and recruitment on fish population dynamics. *Scientific Reports.* 14: 15469. https://doi.org/10.1038/s41598-024-59569-4

FAO. 2018. *The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals.* Rome: Food and Agriculture Organization of the United Nations.

FAO. 2020. *Fishery and Aquaculture Country Profiles – Southeast Asian Region.* Rome: Food and Agriculture Organization.

FAO. 2021. *Global Capture Production Database (1950–2019).* Rome: Food and Agriculture Organization.

Friedland KD, Tanaka KR, Smolinski S, Wang Y, Hodgdon C, Mazur M, Wiedenmann J, Goetscg C, Pendleton DE. 2023. Trends in the area of occurrence and biomass of fish and macroinvertebrates. *Marine and Coastal Fisheries,* 15(2), e210235. https://doi.org/10.1002/mcf2.210235

IPCC. (2022). *Sixth Assessment Report: Impacts, Adaptation and Vulnerability – Chapter 18: Climate Change Impacts on Fisheries and Aquaculture.* Intergovernmental Panel on Climate Change.

Li Y, Ren G, Wang Q, Mu L, Niu Q. 2022. Marine heatwaves in the South China Sea: temporal-spatial pattern and its association with large-scale circulation. *Remote Sens*. 14: 1-19

Nash, K. L., et al. (2016). Habitat structure and the resilience of reef fish communities. *Ecosphere,* 7(8), e01362. https://doi.org/10.1002/ecs2.1362

Nilsson JA, Johnson CR, Fulton EA, Haward M. (2019). Fisheries sustainability relies on biological understanding. *ICES Journal of Marine Science,* 76(6), 1436–1447. https://doi.org/10.1093/icesjms/fsz058

Palomares MLD, Pauly D. 2020. On the creeping increase of marine fisheries catches in the South China Sea: A basin-wide analysis, 1950–2016. *Frontiers in Marine Science.* 7: 309. https://doi.org/10.3389/fmars.2020.00309

SEAFDEC. (2019). *Regional Catch and Effort Data Compilation for the South China Sea Area.* Southeast Asian Fisheries Development Center.

SEAFDEC. (2021). *Status and Trends of Fisheries and Aquaculture in the ASEAN Region.* Bangkok: SEAFDEC.

SEAFDEC. (2022). *Fishing Capacity and Resource Utilization in the South China Sea Sub-region.* Southeast Asian Fisheries Development Center.

Su C, Shan X, Jin X, Han Q, Chen W, Gorfine H. 2024. Simulated reproductive allocation to fisheries-induced evolution. *Ecological Indicators,* 160, 112257. https://doi.org/10.1016/j.ecolind.2024.112257

Sumaila UR, Tai TC, Lam VWY. 2019. Benefits of the Paris Agreement to ocean life, economies, and people. *Science Advances, 5*(2): 38-55. https://doi.org/10.1126/sciadv.aau3855

Tan W, Wang C, Zhang L. (2016). Sea surface temperature variability and monsoon influence in the South China Sea. *Journal of Climate*. 29(4), 1423–1438. https://doi.org/10.1175/JCLI-D-15-0338.1

Xie Q, Wang G, Qiu Y. (2023). Seasonal variability and salinity structure in the South China Sea based on long-term observation. *Frontiers in Marine Science.* 10: 1168486. https://doi.org/10.3389/fmars.2023.1168486

Zandika R, Ismunarti DH, Kunarso, Hatmaja RB, Ayubi MAA. 2024. Variabilitas thermal front dan keterkaitan dengan klorofil-a di wilayah pengelolaan perikanan Negara Republik Indonesia 711. *Buletin Oseanografi Marina*. 13(2): 250-260