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THE MODERNIZATIONS OF CAPTURE FISHERIES AND FISHERS' WELFARE LEVEL IN PANGANDARAN REGENCY

MODERNISASI PERIKANAN TANGKAP DAN TINGKAT KESEJAHTERAAN NELAYAN DI KABUPATEN PANGANDARAN

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ABSTRACT

Fisheries modernization in Indonesia is expected to improve productivity and strengthen the welfare of coastal communities. This study aimed to examine the relationship between the modernization of capture fisheries and fishers' welfare in Pangandaran Regency. A survey of 60 fishers was conducted using snowball sampling, supported by in-depth interviews and a literature review. Modernization was measured through indicators such as capital, engine power, vessel size, and gear price, while welfare was assessed through income, expenditure, education, health, catch volume, and housing conditions. The analysis employed Spearman's Rank correlation, complemented by qualitative evidence. The results indicated that most fishers remained at a low to medium level of modernization, while their welfare is generally in the medium category. A strong positive correlation was confirmed between modernization and welfare ($\rho = 0.530$; $p < 0.01$). These findings suggest that modernization contributes to better welfare, although the benefits are not distributed evenly, with vessel owners gaining more advantages than crew members. Policy implications highlight the importance of phased financing schemes, improved landing infrastructure, and better protection for small-scale fishers.

Keywords: fisheries modernization, fishers' welfare, Pangandaran, capture fisheries.

ABSTRAK

Modernisasi perikanan di Indonesia diharapkan dapat meningkatkan produktivitas sekaligus memperkuat kesejahteraan masyarakat pesisir. Penelitian ini bertujuan mengkaji hubungan antara modernisasi perikanan tangkap dan kesejahteraan nelayan di Kabupaten Pangandaran. Survei dilakukan terhadap 60 nelayan dengan teknik snowball sampling, didukung wawancara mendalam serta studi pustaka. Modernisasi diukur melalui beberapa indikator, di antaranya modal, tenaga mesin, ukuran kapal, dan harga alat tangkap, sedangkan kesejahteraan dilihat dari pendapatan, pengeluaran, pendidikan, kesehatan, volume tangkapan, dan kondisi rumah. Analisis menggunakan korelasi Spearman Rank, diperkaya dengan bukti kualitatif. Hasil penelitian menunjukkan sebagian besar nelayan masih berada pada tingkat modernisasi rendah hingga sedang, sementara tingkat kesejahteraan umumnya berada pada kategori sedang. Terdapat korelasi positif yang kuat antara modernisasi dan kesejahteraan ($\rho = 0{,}530$; $p < 0{,}01$). Temuan ini menegaskan bahwa modernisasi berkontribusi pada peningkatan kesejahteraan, meskipun manfaatnya belum merata dan lebih banyak dirasakan pemilik kapal dibanding awak. Implikasi kebijakan mencakup perlunya skema pembiayaan bertahap, perbaikan infrastruktur pendaratan, serta penguatan perlindungan bagi nelayan kecil.

Kata kunci: modernisasi perikanan, kesejahteraan nelayan, Pangandaran, perikanan tangkap.

INTRODUCTION

The vast ocean, rich in biological resources, is one of the most vital assets for an archipelagic country like Indonesia. The sea is not only an ecological space, but also a primary support system for the livelihoods of millions of coastal communities. Recent figures revise earlier estimates stated

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in the Decree of the Minister of Marine Affairs and Fisheries No. KEP.45/MEN/2011, which emphasized that the sustainable potential of Indonesia's marine fisheries reaches 6.5 million tons per year, with an allowable catch of 5.2 million tons per year. The FAO (2024) has introduced the concept of Blue Transformation, a call for fisheries modernization that not only increases production but also ensures resource sustainability while enhancing the capacity of small-scale fishers. The intended transformation is not merely "mechanization" but rather a comprehensive change that provides space for improving the welfare of coastal communities (FAO, 2024).

Fisheries modernization has been proven to enhance production capacity and fishers' welfare (Quaas & Skonhoft, 2022). Compared to the pre-modernization period, when fleets were dominated by non-motorized boats and simple fishing gear, the introduction of more advanced capture technologies has significantly increased catch volume, which correlates with higher fishers' income. This transformation was evident among fishers in Southeast Sulawesi, as reported by Malihu et al. (2022), where those who initially relied on simple fishing tools and only met subsistence needs became more economically prosperous, including a reduction in exploitative patron–client relationships. A similar pattern occurred in South Sulawesi, where the introduction of fisheries modernization in the 1980s led to a shift toward motorized boats and modern fishing equipment, resulting in substantial increases in both catch volume and fishers' income (Nur et al., 2020).

However, the benefits of modernization are not evenly distributed and are accompanied by several negative effects. The increase in operational needs, such as fuel, engine, and vessel maintenance, and logistics, has created capital demands that small-scale fishers often struggle to meet (Riantini et al., 2024). These differing findings show that the relationship between modernization and fisher welfare remains debatable. Subjective dimensions such as security, satisfaction, and seasonal income stability are often more decisive in determining fisher welfare than catch volumes alone (Putri et al., 2024). Moreover, increased inputs in fishing operations inevitably raise the required capital, which can adversely affect small-scale fishers with limited resources.

Indonesia, an archipelagic nation with substantial sustainable marine fisheries potential, pursues modernization not merely to raise output, but to ensure resource sustainability while strengthening the capacities of small-scale fishers. Pangandaran Regency provides an interesting local example. According to the Department of Marine Affairs, Fisheries, and Food Security of Pangandaran (2021), this southern Java regency has a marine fisheries hub with a network of 13 fish auction sites (TPI) and more than 2,800 active fishers. Capture fisheries production in 2020 reached approximately 1.39 million kilograms (Laporan Kerja Instansi Pemerintah (LAKIP) Dinas Kelautan, Perikanan, Dan Ketahanan Pangan Kabupaten Pangandaran 2021, 2022). Data from BPS (2024) recorded the poverty rate in Pangandaran at 8.75 percent. Although this figure declined slightly from previous years, when it reached 8.98 percent, it still signals serious challenges among fishing households (BPS, 2024). This situation makes Pangandaran a relevant research location. With a combination of small- and medium-scale fleets, both traditional and modern fishing gear, and

the support of TPI infrastructure, Pangandaran represents a compelling case for assessing how variations in fleet modernization correlate significantly with fisher welfare.

From the literature review, at least two research gaps remain. First, much local research focuses on fleet descriptions and productivity, but has not linked these comprehensively to fisher welfare (Krisyawensya et al., 2025). Second, empirical evidence on the impact of new policies, such as Government Regulation No. 11/2023 on Measured Fishery Catch, which sets out a quota and regulated fishing system, on investment behavior and small-scale fishers' technology adoption remains limited, even though this policy has become the national direction. The objectives are: (1) to describe the local process of modernization, (2) to measure and compare fleet modernity using the four indicators, and (3) to profile welfare and test its association with fleet modernity including owner and crew differences; the hypotheses are: (1) higher capital is associated with higher welfare, (2) greater engine power is associated with higher welfare, (3) larger gross tonnage is associated with higher welfare, (4) higher gear value is associated with higher welfare, (5) a higher overall level of fleet modernization is associated with higher welfare, and (6) on average boat owners have higher welfare than crew.

RESEARCH METHODS

This study employs a survey method supported by in-depth interviews to explore information, data, and facts related to fisheries modernization and fishers' welfare. According to Creswell (2014), the survey method involves drawing samples from a population and using a questionnaire as the primary data collection tool. In addition, qualitative data were also collected to obtain deeper insights and to clarify the social context observed (Jason & Glenwick, 2016).

The research was conducted from August to December 2020 at Fish Auction Site or *Tempat Pelelangan Ikan* (TPI), TPI Pangandaran, and TPI Nusawiru in Pangandaran Regency, West Java. The study subjects consisted of respondents, namely fishers working in the two fish auction sites, as well as informants who provided deeper insights into the socio-economic conditions of fishers. The unit of analysis in this study was the individual fisherman. The population consisted of fishers at TPI Pangandaran and TPI Nusawiru, categorized into two groups there are large-scale and small-scale fishers. Respondents were selected using snowball sampling, comprising 25 large-scale fishers and 35 small-scale fishers, for a total of 60 respondents. Informants were selected using purposive sampling, namely based on specific considerations such as their experience in fisheries and knowledge of fishers' social conditions (Sugiyono, 2017). The first respondents were small-scale fishers who were first encountered at the two fisheries trading centers (TPIs). They then provided information on other small-scale fishers working at the TPIs. Snowball sampling was sufficient if the information provided resulted in redundancy.

Snowball sampling was chosen despite its potential to introduce bias that could affect the representativeness of the sample (Gierczyk et al., 2024). This technique was deemed appropriate for several reasons. Although located within the same sites, fishing communities at TPIs often maintain close social networks, enabling researchers to start with one fisher and expand the pool of

respondents through referrals. This approach was particularly effective because many fishers are not formally recorded in official databases or organizational structures (Pratama et al., 2020). Hence, snowball sampling allowed access to otherwise hard-to-reach fishers and enabled the collection of data from diverse groups within the TPIs, both from large- and small-scale fleets.

Two main variables were examined in this study: the level of fisheries modernization and the level of fishers' welfare. Four indicators were used to measure fisheries modernization: (1) capital investment, (2) engine power, (3) vessel size (Gross Tonnage/GT), and (4) gear price. These indicators were synthesized from prior studies. For instance, Rumpa & Najamuddin (2017) emphasized GT size and engine power as modernization indicators that directly improve fishing productivity, while Damayanti et al. (2018) highlighted gear type, size, and technological sophistication. Then, this study also proposes a framework for fishers' welfare with six indicators: (1) income level, (2) expenditure level, (3) education level, (4) health level, (5) fish catch volume, and (6) housing quality. Catch is recorded per trip, income–expenditure per month, while assets/service access are assessed as the current status. This selection draws on and adapts welfare indicators commonly used by Statistics Indonesia (BPS), such as income, expenditure, education/household characteristics, and housing quality (Sugiharto, 2007).

The study analyzed both quantitative and qualitative data. Quantitative data were processed using Microsoft Excel 2010 and SPSS for Windows, with questionnaire responses coded, classified between small- and large-scale fishers, and then analyzed using Spearman's Rank correlation. This test was chosen because the data are ordinal and do not require the assumption of normality (Agresti, 2018). Qualitative data from in-depth interviews were analyzed inductively through reduction, verification, and interpretation to capture deeper meanings within fishers' socio-economic contexts (Sugiyono, 2017). To enhance the validity of findings, the study applied data triangulation by combining quantitative and qualitative results, thereby offering a more comprehensive perspective, minimizing potential bias, and strengthening the credibility of conclusions regarding the relationship between fisheries modernization and fishers' welfare (Tungka, 2020).

RESULT AND DISCUSSION

Process of Modernization of Capture Fisheries in Pangandaran Regency

The modernization of capture fisheries in Pangandaran Regency has significantly affected the social life of fishers. These impacts include changes in work patterns, the shift from simple to more advanced technology, and increasing levels of capital invested in fishing operations. The development of fishing technology has also contributed to a considerable rise in production volume. Fishers in Pangandaran Regency, particularly those operating at the Pangandaran and Nusawiru Fish Auction Sites (TPI), now utilize various types of fleets and fishing gear. In this study, four distinct periods of fisheries modernization in Pangandaran Regency are identified.

In the 1970s, fishers commonly went to sea using small jukung boats (±6 m × 0.5 m) with a capacity of 2–3 people, without any stabilizing outriggers. Operations were still manual, relying on oars or sails, with fishing rods as the main gear; the dominant catches at that time were Tuna and

Jambal. In the 1980s, fishers in Pangandaran began transitioning to wooden boats with outboard "gantar engines" of about 5 HP as an intermediate technology. These engines were relatively inexpensive, easy to maintain, and widely available, making them suitable for small-scale daily operations (Sabiq et al., 2018). Technically, the long-tail configuration (extended shaft to the propeller) allowed the propeller to be lifted when crossing shallow waters or landing on open beaches such as Pangandaran (Tran Tuan et al., 2021). By the 1990s, fishers in Pangandaran shifted to fiberglass boats as replacements for wooden vessels. Fiberglass boats were more durable (up to 20 years) compared to wood, which typically lasted only 5 years and required higher maintenance costs (Utami & Cahyo, 2022). Most boats were 1–2 GT in size, with a capacity of up to four people. Engines became more modern, with outboard engines ranging from 9–15 HP, providing greater safety and allowing longer trips further from shore. During this period, fishers also began to adopt basic gill nets (sprang nets), often bringing 15–20 sets per trip, increasing their potential catch.

Since the early 2000s, the modernization of fisheries in Pangandaran has become more evident. Based on field interviews, this period was marked by the widespread shift from wooden boats to fiberglass vessels of varying sizes, especially 3 GT boats crewed by 2–4 people with 15–40 HP engines, operating 6–12 hours per trip while deploying 20–100 gill nets. Modernization was further supported by government programs, such as the provision of Inka Mina 30 GT vessels (2010), 5–10 GT boats (2015) under the Special Allocation Fund (DAK) managed by local cooperatives (KUD), as well as the distribution of millennium gill nets (2016) and the introduction of liong bun nets targeting high-value species such as red snapper, cabuk, and grouper. At the same time, fishers began adopting modern navigation technologies: GPS (increasingly adopted after 2015 due to its proven efficiency in time and fuel use), fish finders (more effective for hook-and-line fishing than for nets), and radio communication as the main channel for coordination at sea. Overall, this period reflects a diversification of vessel sizes, increased engine capacity, institutional support, and the adoption of modern technology, all of which together enhanced fishing capacity and efficiency, although the high capital requirements remain a challenge for many small-scale fishers.

The Modernity of the Capture Fleet in Pangandaran Regency

The process of modernization of capture fleets in Pangandaran Regency shows a shift from small traditional boats toward vessels with stronger engines, larger GT sizes, and increasingly modern fishing gear and navigation devices. This transformation not only affects how fishers operate at sea but also has implications for work patterns, social structures, and profit-sharing systems. Using four indicators, there are capital, engine power, GT size, and fishing gear value, this study seeks to illustrate the level of modernity among Pangandaran fishers and the factors that drive or hinder this transformation. Table 1 presents the number and percentage of respondents based on the modernity level of capture fleets in Pangandaran Regency.

Table 1. Number and Percentage of Respondents Based on the Modern Level of Fishing Fleets in Pangandaran Regency

Indicator	Frequency (n)*	Percentage (%)
Level of the Modernity of the Capture Fleet**		
Low	27	45.0
Moderate	9	15.0
High	24	40.0
Amount of Capital***		
Low	23	38.3
Moderate	26	43.4
High	11	18.3
Ship Engine Power		
Small (< 23 PK)	34	56.7
Medium (23 – 55 PK)	4	6.6
Large (> 55 HP)	22	36.7
Ship Size		
Small (1-2 GT)	24	40.0
Medium (3-4 GT)	18	30.0
Large (> 5 GT)	18	30.0
Fishing Gear Prices		
Low (< 40 million Rupiah)	19	31.7
Medium (40 – 80 million Rupiah)	9	15.0
Large (> 80 million Rupiah)	32	53.3

* n total = 60 fishers;
** Aggregate scores from the categorization of the four indicators (amount of capital, engine power, ship size, fishing gear price);
*** Aggregate scores from the categorization of four aspects (cost for one sea trip, the price of the fisherman's boat, ownership status, and the price of the engine to go to sea)

Overall, 45 percent of respondents were at a low modernization level, 15 percent medium, and 40 percent high (n=60). This pattern reflects a disparity: most still operate small boats of 1–3 GT for nearshore fishing, while others already use vessels of ≥5 GT equipped with modern technology. The main barriers to modernization include high waves on the southern coast of Java, limited landing infrastructure, fishers' preference for short trips to remain close to family, lack of capital, and social conflicts caused by the presence of larger vessels. Conversely, government support in the form of boats, fishing gear, and training has become an important driver. Such a divided condition is common during technological transition phases, when access to capital, skills, and institutional support remains uneven (Lopulalan, 2023). While modernization can increase efficiency, its benefits often concentrate among fishers with stronger capital and networks (Yasir et al., 2019).

Fishers' Welfare Level in Pangandaran Regency

This subsection assesses the welfare of fishers in Pangandaran through six key indicators: income, expenditure, education, health, catch volume, and housing quality. A multi-indicator approach was chosen because welfare cannot be measured by income alone, given that catches fluctuate due to season, weather, and profit-sharing systems. Using this framework, fishers' household welfare can be understood more comprehensively, covering their ability to meet basic needs, access essential services, and build decent housing assets. Table 2 presents the distribution of respondents based on these six indicators.

Most fishers' households fall into the medium welfare category (61.7%), followed by high (23.3%) and low (15%). This indicates that the majority can meet their basic needs, although a small

portion has exceeded the minimum standard, while others remain left behind. The medium and high groups are generally supported by more stable employment opportunities in the fisheries sector, whereas the low group largely consists of crew members (ABK) with narrow income margins due to the profit-sharing system. Fishers' welfare also includes non-monetary aspects, such as the freedom to regulate their fishing time and a sense of security. This aligns with Yulisti et al. (2024), who emphasize the role of work position and resource access, and Putri et al. (2024), who highlight that satisfaction and safety often matter more than nominal income. Thus, the aggregate picture of welfare in Pangandaran reflects stratification based on work roles, income, and fishers' subjective perceptions.

Table 2. Number and Percentage of Respondents Based on the Welfare Level of Fishers in Pangandaran Regency

Indicator	Frequency (n)*	Percentage (%)
Level of Fisher's Welfare**		
Low	9	15.0
Moderate	37	61.7
High	14	23.3
Income Levels		
Low (<Rp2.300.000)	15	25.0
Moderate (IDR 2,300,000 – IDR 7,000,000)	33	55.0
High (>Rp7.000.000)	12	20.0
Expense Level		
Inappropriate (income < expenses)	11	18.3
Suitable (income ≈ expenses)	29	48.4
Highly Suitable (income > expenses)	20	33.3
Ability to Access Education		
Low (SD)	7	11.7
Moderate (SMP)	6	10.0
High (High School and College)	47	78.0
Ability to Access Health Facilities		
Low	19	31.7
Moderate	9	15.0
High	32	53.3
Fish Catch		
Low (< 20 Kg)	19	31.7
Moderate (20 Kg – 100 Kg)	9	15.0
High (> 100 Kg)	32	53.3
Quality of Residence****		
Low	19	31.7
Moderate	9	15.0
High	32	53.3

* n total = 60 fishers;

** Aggregate scores from the categorization of the six indicators (income level, expenditure level, ability to access education, ability to access health facilities, fish catch level);

*** Aggregate scores from the categorization of two aspects (source of funds for treatment and type of treatment chosen)

**** Aggregate scores from the two-aspect categorization (house ownership status, type of roof of the house, type of wall of the house, type of floor of the house)

Fishers' income was measured as monthly net income from fish sales, after deducting fishing costs and around 14% in levies, then divided between skippers (juragan) and crew (ABK) using a 60:40 ratio or vice versa. The distribution shows that 55% fall into the medium category, 25% into low, and 20% into high. The dominance of the medium category indicates that most fishers can cover routine needs but lack sufficient financial space for savings or investment. The low category, dominated by crew members, is highly vulnerable to bad seasons or falling fish prices. Conversely,

the high category usually operates vessels of 5 GT or more, although they still face fluctuating catches. Interestingly, small-scale fishers may also obtain large catches during peak seasons, highlighting the seasonal nature of income. This finding is consistent with Riantini et al. (2024), who noted that profit-sharing structures increase small fishers' vulnerability, and Yulisti et al. (2024), who emphasized that operational cost efficiency is crucial for fairer net margins.

Household expenditures are divided into food and non-food needs (such as education, health, and recreation), with three categories: fairly adequate (48.4%), very adequate (33.3%), and inadequate (18.3%). The majority of households can cover monthly needs, and one-third even have surplus for savings or additional needs. However, crew households often fall into the inadequate category because their income does not match monthly needs and the number of dependents. They often borrow money from relatives or neighbors to cover living expenses (Sujarwo, 2022). Meanwhile, skippers bear far greater operating costs before sharing profits with crew, so expenditure patterns are strongly shaped by position in the fishing business (Wahidhani & Solihin, 2024).

The ability to finance children's education serves as a long-term investment indicator. A total of 78.3% of households can afford education up to senior high school or the beginning of university, 10% stop at junior high school, and 11.7% only reach the elementary level or did not graduate. The dominance of the high category indicates aspirations for upward social mobility, with many families considering senior high school sufficient for entering the labor market or supporting family fisheries. However, the small portion stopping at elementary school highlights economic barriers that reduce educational investment when income declines. In some cases, families prioritize daily basic needs over education, especially when boys are expected to join fishing activities early. This is consistent with Aminah & Chalid (2023), who found that children who drop out are often recruited as crew members to support household income.

Health access among fishers is relatively good, 53.3% are in the high category, 15% in medium, and 31.7% in low. This assessment is based on financing sources (National Health Insurance or JKN), types of facilities used (health centers, clinics, hospitals), and distance to services. More than half of households already enjoy ease of access, though one-third still face financial and spatial barriers, such as transportation. For communities reliant on physical labor at sea, timely and affordable health services are crucial, both for treating work-related injuries and illnesses and for preventive services such as child immunization and nutrition monitoring. Suhartoyo et al. (2022) confirmed that participation in JKN provides important financial protection for fishers' households, although education about health-seeking behavior still needs strengthening.

Catch performance per fishing trip shows a clear divide: 43.3% of respondents are in the high category (over 100 kg), 40% in low (under 20 kg), and 16.7% in medium (20–100 kg). This variation is closely related to vessel type and trip duration. Fishers using vessels of 5 GT or more can sail for days to distant fishing grounds and tend to achieve high catches. Conversely, small boats or canoes operating for 6–12 hours in a limited radius often record low catches. The medium category usually consists of small boats optimizing results through more varied fishing gear, though still influenced by

weather and season. This aligns with Briton et al. (2020), who noted that catch levels depend not only on vessel size but also on operational strategies, multi-gear use, and weather risk management.

More than half of fishers' households (53.3%) fall into the high housing quality category, 35% in medium, and 11.7% in low. Housing attributes indicate relatively strong asset accumulation; two-thirds own their homes (66.7%), the majority use tile roofs (68.4%), brick walls (68.4%), and ceramic floors (91.7%). Conversely, the low category is characterized by rented or borrowed houses, zinc/asbestos roofing, bamboo walls, and cement floors, indicators of financial constraints. Housing quality serves as a buffer of welfare, as homeownership with better materials enhances comfort, health, and socio-economic stability (Nguyen et al., 2022). In coastal areas with hot and humid climates, materials like tile and brick also directly influence daily living quality. Thus, while fishers households in Pangandaran have achieved significant progress in physical assets, the lowest group still requires targeted support for housing improvements.

Discussion

A strong and statistically significant positive association is observed between fleet modernization and fishers' welfare (overall $\rho = 0.530$, $p < 0.01$, $n = 60$). At the component level, capital ($\rho = 0.456$, $p < 0.01$), engine power ($\rho = 0.374$, $p < 0.01$), gross tonnage ($\rho = 0.444$, $p < 0.01$), and gear value ($\rho = 0.358$, $p < 0.01$) each exhibit positive relationships with welfare, indicating that upgrading along multiple dimensions co-moves with better household outcomes.

This section discusses the correlation between capture fleet modernization and fishers' welfare in Pangandaran by linking quantitative results (Spearman's rank test) with field evidence. The analysis goes beyond asking whether a relationship exists, focusing instead on the mechanisms at play (capital, engine power, gross tonnage, and fishing gear), the local context that may accelerate or hinder adoption, and the groups of fishers who benefit versus those who are left behind. In this way, the discussion interprets the correlation figures more meaningfully and draws practical implications for ensuring equitable benefits from modernization. Table 3 presents the relationship between the level of fleet modernization and fishers' welfare.

Table 3. Correlation Coefficient of The Modern Fishing Fleet with Fishers' Welfare Level

The level of capture fleet modernity in Pangandaran Regency	Welfare Level	
	Correlation Coefficient	Sig. (2-tailed)
Number of capitals	0.456**	0.000
The power of the machine (PK)	0.374**	0.003
Size of Gross Tonnage (GT)	0.444**	0.000
Price of fishing gear	0.358**	0.005
Overall Modernization Level	0.530**	0.000

note:
n total = 60 fishers
** significant at 95% confidence level

The Spearman Rank test shows a strong and significant correlation between fleet modernization and fishers' welfare ($\rho = 0.530$; $p < 0.01$). Substantively, this means that higher modernization levels are associated with better household welfare. This pattern aligns with Hamzah et al. (2019), who found that modernization reshapes work patterns, social structures, and income, as well as Yulistiani et al. (2024), who emphasized the direct link between fishing technology and

economic opportunities. However, the effects are uneven across groups and strongly shaped by local contexts such as limited capital, the ecological characteristics of the south coast of Java, and institutional conditions.

Capital shapes trip duration, provisioning (fuel, ice, logistics), ownership security, and maintenance capacity, all of which influence net margins and asset accumulation. Higher engine power expands range and weather tolerance, enabling access to more distant grounds and longer operations, though increases in fuel and maintenance costs must be managed to preserve gains. Larger gross tonnage allows multi-day trips, clearer labor specialization, and higher storage capacity, which stabilize catches but require adequate landing infrastructure. Upgrading gear quality and diversifying gear improve selectivity and product value, providing seasonal flexibility that stabilizes income. Together, these channels range, weather resilience, cost structure, and product quality, offering a coherent explanation for the positive association.

Despite aggregate gains, benefits are unevenly distributed. Owners internalize upfront costs but capture a larger share of net margins and asset accumulation, while crew members face tighter monthly liquidity and greater vulnerability to bad seasons. In our sample, 50% do not own vessels, 33% own, and 17% rent or borrow; welfare is mostly moderate (61.7%) with 23.3% high and 15% low, reflecting this stratification. Operational costs (fuel/ice/logistics) and maintenance rise with HP/GT, so efficiency depends on cost management. Infrastructure constraints limited landing facilities and quality issues in some government aid also dampen diffusion of larger units, even as gear upgrading (≥IDR 80 million in 53.3% of cases) proceeds faster than engine/GT upgrading. These features explain why some crews remain in the low-welfare tail while owners of ≥5 GT units more readily convert modernization into welfare gains.

Benefits accrue unevenly across actors. Owners typically capture higher net gains than crew due to capital control, risk-bearing, and profit-sharing rules, while crew welfare remains vulnerable to seasonality and price shocks. Operating costs (fuel, repairs, ice) can dilute the welfare effect of engine and GT upgrades if efficiency gains and cost management are insufficient. Landing-site infrastructure berthing capacity, handling facilities, and storage mediate the payoff from larger vessels; constraints at these nodes' slow diffusion of higher GT and compress potential improvements for smaller operators. Qualitative findings illustrate how modern units provide access to more distant fishing grounds, greater resilience in bad weather, and tactical flexibility (multi-gear). Yet, these benefits require high upfront and operating costs. Many fishers prefer daily trips of 6–12 hours to remain close to their families, while infrastructure constraints at fish landing sites and suboptimal quality of government assistance limit the ability of all groups to fully benefit. Recent literature similarly shows that modernization benefits tend to concentrate among those with stronger access to capital, skills, and market networks (Yulisti et al., 2024; Putri et al., 2024).

The correlation between capital and welfare ($\rho = 0.456$; $p < 0.01$) highlights its central role. Capital determines the ability to finance the trip duration (fuel, ice, logistics), acquire vessels and engines, and secure ownership. Field data show that boat owners (juragan) bear significant

operating costs before sharing profits, shaping expenditure and asset accumulation differently from crew members (ABK), who often face mismatches between income and household needs (Wahidhani, 2024; Sujarwo, 2022). These patterns resonate with Riantini et al. (2024), who identified profit-sharing as a source of vulnerability for small-scale fishers, and Yulisti et al. (2024), who stressed adaptive financing and cost efficiency as keys to healthier margins.

Patterns documented here align with Indonesian and regional studies that link technology adoption to shifts in organization of work, incomes, and opportunity structures, while highlighting uneven diffusion driven by access to capital, skills, and market networks. Positive associations between modernization and welfare are consistent with prior reports of efficiency gains, yet distributional frictions and institutional conditions frequently determine the extent to which households translate capacity into sustained welfare.

Engine power ($\rho = 0.374$; $p < 0.01$) is also significant. Engines over 55 HP on vessels ≥5 GT enable longer trips, greater weather resilience, and wider reach. Yet higher power increases fuel and maintenance costs, so net gains depend on effective management. Fishers' perception that "large engines are safer but costly" reflects a cost–risk trade-off. This supports Putri et al. (2024), who argued that a sense of safety is an essential dimension of welfare, implying that upgrading engines must be paired with safety training and cost management. Potential reverse causality is acknowledged: higher incomes may facilitate modernization rather than modernization raising incomes. Cross-sectional Spearman correlations establish robust associations but do not identify causal direction. Future designs longitudinal tracking, quasi-experimental approaches, or models with controls for seasonality, skipper characteristics, crew size, and instruments for capital or program exposure would strengthen causal inference.

Narratives of the local transition from oar or *jukung* sail and basic gear to fiberglass vessels, higher-HP engines, multi-gear strategies, and navigation devices indicate practical gains in range, perceived safety, and catch capacity. Contemporary welfare metrics (income–expenditure balance, education and health access, catches, housing quality) suggest that many households now meet basic needs more reliably, yet stratification persists. Owners are more likely to convert technological capacity into asset accumulation, whereas crew members face narrower margins and remain highly sensitive to operating costs and seasonal variability.

Pre-modernization narratives in Pangandaran describe small *jukung* with oars or sails (1970s), 5 HP *gantar* engines (1980s), and 1–2 GT fiberglass with 9–15 HP (1990s), implying short range, higher weather risk, and lower product quality control. By the 2000s–2010s, the shift to 3–10 GT, 15–85 HP, GPS/radio, and multi-gear systems enabled longer trips and higher catches (>100 kg per trip for many ≥5 GT units). Against current metrics, 61.7% moderate and 23.3% high welfare, these narratives illuminate practical gains (range, safety, product quality) and show that owners capture a larger share of benefits unless crew protections and financing schemes are strengthened. Gross tonnage ($\rho = 0.444$; $p < 0.01$) shows a similar pattern. Larger vessels allow longer operations and greater catch volumes, often exceeding 100 kg per trip, while smaller boats are usually limited to

less than 20 kg. Yet, the diffusion of larger GT vessels is constrained by inadequate landing site infrastructure and high post-assistance costs, leaving many fishers reliant on small boats. These findings affirm that catch performance depends not only on vessel size but also on strategies of timing, location, and weather mitigation (Briton et al., 2020).

Fishing gear ($\rho = 0.358$; $p < 0.01$) also correlates positively with welfare. Gear diversity gives seasonal flexibility, enabling fishers to target high-value species while minimizing the risk of lean seasons. Many choose to upgrade gear first, as it is more affordable than investing in larger vessels or engines. Technological innovations such as the millennium gill net have proven more productive and relatively eco-friendly compared to conventional nets, though they still require careful management of selectivity and bycatch (Adhawati et al., 2023; Nurfarida et al., 2023).

While the correlations are strong, possible two-way causality must be acknowledged: higher incomes may enable modernization rather than the other way around. Thus, the results should be read alongside qualitative evidence and, ideally, tested further with controls for seasonality, crew size, or skipper characteristics. Policy implications point to the need for supportive ecosystems: staged financing schemes for engine/vessel upgrades, training in operations and safety, cost management support, and stronger primary services around landing sites. This approach aligns with the vision of inclusive and sustainable modernization for small-scale fisheries highlighted in recent literature (Putri et al., 2024; Yulisti et al., 2024).

In sum, modernization is positively associated with welfare through well-identified operational channels, but its benefits are conditional on fair cost/risk sharing and supportive infrastructure. Policy should prioritize staged financing for engine/GT upgrades, safety and cost-management training, improvements at landing sites, and stronger protections for crew (profit-sharing standards, JKN uptake, financial literacy), so that modernization does not widen within-fleet inequality.

CONCLUSION AND SUGGESTION

Conclusion

Modernization in capture fisheries is associated with higher household welfare through practical channels extended trip range, better weather tolerance, lower unit costs, and improved product quality, yet its benefits are uneven and conditional. Boat owners more readily convert technology into durable gains than crew, and outcomes hinge on access to affordable finance, fair and transparent profit-sharing, and reliable landing-site and cold-chain infrastructure. Compared with pre-modernization practices marked by short ranges, greater risk, and weaker product control, current operations deliver tangible improvements while increasing exposure to operating costs and seasonal volatility. As the evidence is cross-sectional, the findings indicate association rather than causation; policy should therefore pair technology upgrading with inclusive financing, standardized crew protections, and targeted facility investments so welfare gains are broad-based.

Suggestion

Policy implications go beyond simply providing boats or engines; more comprehensive strategies are needed. These include phased financing schemes to enable small-scale fishers to upgrade, training in safety and cost management to prevent technological gains from being eroded by expenses, and improvements to landing infrastructure to support larger vessels. Protection for crew members through standardized profit-sharing, access to the National Health Insurance (JKN), and financial literacy initiatives is also crucial to ensure welfare gains are not concentrated only among boat owners.

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