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TEMPORAL TRENDS IN FISHING GEAR COMPOSITION AND FLEET MODERNIZATION IN EAST NUSA TENGGARA 2019–2024

Tren Sementara Komposisi Alat Perikanan Dan Modernisasi Kapal Di Nusa Tenggara Timur 2019–2024

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ABSTRACT

East Nusa Tenggara (NTT) is one of Indonesia's most biologically productive fishing zones, yet its capture fisheries sector has experienced a sustained contraction in gear deployment over the 2019–2024 period. This study analyzes temporal trends in fishing gear composition and fleet structure across all 22 regencies using an integrated provincial dataset of 3,919 gear-observation records. Province-wide gear counts fell from 59,161 units in 2019 to 29,960 units in 2024 a decline of 49.4%. A Pettitt change-point test places the structural break between 2021 and 2022, consistent with the regulatory and economic disruptions of that period. A negative binomial regression confirms that year, regency, vessel size class, and water type are all significant predictors of gear count. Shannon diversity indices show a sharp contraction in gear portfolio breadth (mean H' from 1.74 in 2019 to 1.55 in 2024), with substantial inter-regency heterogeneity. Ward's hierarchical clustering identifies four distinct fleet archetypes: gill-net–dominant, line-gear dominant, mixed-gear transitional, and trap-based coastal systems. Non-motorized boat gear declined by 60.4%, while medium-class vessels (21–30 GT) expanded by 339%. The findings indicate a structural shift toward motorized, selective gear systems, with implications for sustainable management, effort licensing, and spatial planning in eastern Indonesian waters.

Keywords: East Nusa Tenggara, Fishing Gear Composition, Fleet Modernization, Hierarchical Clustering

ABSTRAK

Nusa Tenggara Timur (NTT) merupakan salah satu zona perikanan yang paling produktif secara biologis di Indonesia; namun, sektor perikanan tangkapnya telah mengalami kontraksi berkelanjutan dalam penggunaan alat tangkap selama periode 2019–2024. Studi ini menganalisis tren temporal dalam komposisi alat tangkap dan struktur armada di seluruh 22 kabupaten/kota menggunakan dataset tingkat provinsi yang terintegrasi, mencakup 3.919 catatan observasi alat tangkap. Jumlah alat tangkap di seluruh provinsi turun dari 59.161 unit pada tahun 2019 menjadi 29.960 unit pada tahun 2024, sebuah penurunan sebesar 49,4%. Uji titik perubahan (change-point test) Pettitt menempatkan titik perubahan struktural tersebut terjadi antara tahun 2021 dan 2022, yang konsisten dengan gangguan regulasi dan ekonomi yang terjadi pada periode tersebut. Regresi binomial negatif mengonfirmasi bahwa faktor tahun, kabupaten/kota, kelas ukuran kapal, dan jenis perairan merupakan prediktor yang signifikan terhadap jumlah alat tangkap. Indeks keragaman Shannon menunjukkan kontraksi tajam dalam luasnya portofolio alat tangkap (rata-rata H' turun dari 1,74 pada tahun 2019 menjadi 1,55 pada tahun 2024), disertai dengan heterogenitas yang substansial antar-kabupaten/kota. Pengelompokan hierarkis (hierarchical clustering) Ward mengidentifikasi empat arketipe armada yang berbeda: sistem yang didominasi jaring insang (gill-net), sistem yang didominasi alat pancing (line-gear), sistem transisi dengan alat tangkap campuran, dan sistem pesisir berbasis perangkap. Penggunaan alat tangkap pada perahu tanpa motor mengalami penurunan sebesar 60,4%, sementara armada kapal kelas menengah (21–30 GT) mengalami peningkatan sebesar 339%. Temuan-temuan ini mengindikasikan adanya pergeseran struktural menuju sistem alat tangkap bermotor dan selektif, yang memiliki implikasi bagi pengelolaan berkelanjutan, perizinan upaya penangkapan, dan tata ruang perairan di wilayah Indonesia bagian timur.

Kata Kunci: Komposisi Alat Tangkap, Modernisasi Armada, Nusa Tenggara Timur, Pengelompokan Hierarkis

INTRODUCTION

Indonesia ranks among the world's top five capture fisheries producers (Surbakti, *et al.*, 2025), and the eastern archipelago contributes disproportionately to that output relative to its population density and infrastructure. Nusa Tenggara Timur (NTT) province occupies a strategically positioned corridor between the Banda Sea and the Indian Ocean, encompassing the Flores Sea, Sawu Sea, and Timor Sea. These waters host commercially important stocks of tuna, grouper, reef fish, squid, lobster, and sea cucumber, and they sustain the livelihoods of more than 100,000 registered marine fishers (DKP NTT, 2024).

Despite this ecological and economic significance, the fisheries management literature has paid limited attention to NTT as a unit of analysis. Most national-level studies aggregate across provinces or focus on Java, Sulawesi, and the larger fishing hubs of western Indonesia (Fauzi & Anna, 2022; Susanto et al., 2021). Provincial-level gear composition data essential for effort monitoring, bycatch assessment, and gear conflict management rarely appear in peer-reviewed analyses. This gap is consequential: gear type directly determines selectivity, habitat impact, and the degree to which a fleet can respond to stock fluctuations or regulatory changes (Kelleher, 2021; Pomeroy et al., 2022).

The Indonesian government has progressively tightened its gear licensing framework since 2016. Ministry of Marine Affairs and Fisheries (KKP) Regulation No. 71/2016 banned trawls and purse seines in small-scale zones, and subsequent regulations under Permen KP No. 18/2021 introduced a revised fishing area (WPPNRI) allocation system that ties gear authorization to vessel size and water type (KKP, 2021). In NTT, where small-scale and artisanal operations predominate, these regulations carry immediate practical weight. Whether and how the provincial fleet has responded through gear substitution, vessel up scaling, or simple effort withdrawal remains poorly documented.

Simultaneously, the COVID-19 pandemic disrupted fish supply chains and port-based reporting systems in 2020 and 2021, creating a data discontinuity that complicates time-series inference (Belton et al., 2021; Stringer et al., 2020). The interaction between regulatory change and pandemic disruption makes the 2019–2024 window analytically interesting: it contains a pre-shock baseline, a shock period, and a partial recovery enough temporal depth to test for structural breaks and fleet reorientation.

Fleet modernization in developing-country fisheries typically follows one of three trajectories: passive contraction (fewer units without compositional change), active substitution (replacement of gear types driven by regulation or market incentives), or capacity expansion (larger vessels displacing smaller ones as access to credit improves). Each trajectory has different implications for stock pressure, fisher welfare, and compliance with spatial management zones (Béné et al., 2020; Sievanen et al., 2021; Hentati-Sundberg et al., 2021). Distinguishing between them requires longitudinal, regency-level gear data exactly what the NTT integrated dataset provides.

This study addresses four research questions. First, what is the magnitude and trajectory of province-wide gear count change between 2019 and 2024? Second, does gear portfolio diversity (measured by the Shannon index) converge or diverge across regencies? Third, does the temporal trend contain a statistically identifiable structural break, and if so, when? Fourth, are NTT regencies separable into distinct fleet archetypes based on gear composition? Answers to these questions contribute to the empirical base for evidence-informed fisheries governance in eastern Indonesia and provide a methodological template applicable to other data-sparse provincial systems.

RESEARCH METHODS

Provincial Geography and Fisheries Context

NTT province comprises 22 regencies/cities spread across more than 1,000 islands, with a total land area of approximately 47,350 km² and a maritime jurisdiction exceeding 200,000 km² (BPS NTT, 2023). The province sits within Fisheries Management Area (WPP NRI) 573 (Indian Ocean south of Java and Nusa Tenggara) and WPP NRI 713 (Flores Sea and Banda Sea), both of which are classified as fully or overexploited for several demersal and large pelagic stocks (KKP, 2022; Suman et al., 2021). Rainfall is highly seasonal, with a pronounced dry season from May to October that shapes fishing effort patterns, particularly for non-motorized and small-vessel operations.

Regencies differ substantially in fishing intensity, gear complexity, and market access. Flores Timur, Lembata, and Alor are traditional centers of artisanal and semi-commercial fishing, with strong customary tenure systems (sasi) governing reef access (Lorenzen et al., 2022). Kota Kupang functions as the main commercial hub, connecting NTT production to the national fish marketing system. Rote Ndao and Sabu Raijua are outer island systems with limited port infrastructure, where non-motorized fishing remains common. This heterogeneity makes NTT a compelling case for studying how external shocks and regulations interact with local fleet structure.

Dataset Description

The primary dataset is the Data Terpadu Perikanan Tangkap NTT 2019–2024, a compiled provincial database that integrates two source files: (1) Data_NTT_SATU_cleaned_EN.xlsx, derived from the national SATU data system, covering gear records, production by species, and fisher counts; and (2) Data_Perikanan_Tangkap_Tahun_2019–2024.xlsx, a parallel series from the NTT Provincial Fisheries Service (DKP NTT) capturing non-port production estimates. This study draws primarily on the ALAT_TANGKAP sheet, which contains 3,919 records structured by year, regency, water type (sea/non-sea), gear type, and vessel size class. Secondary sheets used include NELAYAN (fisherman counts), DIVERSIFIKASI_ALAT (gear type counts per regency per year), and PRODUKTIVITAS (production per fisher).

Gear type classification follows the Indonesian Standard Fishing Gear Classification (SNI 7277:2021), which maps domestic gear names to FAO International Standard Statistical

Classification of Fishing Gear (ISSCFG) codes. The dataset records 58 distinct gear types, including both formally recognized categories (e.g., Hand Line, Drift Gill Net, Tuna Longline) and Indonesian-language gear names that correspond to regional variants (e.g., HUHATE MEKANIS, a mechanized pole-and-line; PUKAT HELA DASAR BERPALANG, a beam trawl type). Vessel size classes are coded as: non-motorized boat, fisherman without boat, ≤5 GT, 6–10 GT, 11–20 GT, 21–30 GT, >30 GT, and 101–200 GT.

Data Cleaning and Preparation

Several data quality considerations guided the preparation of the analysis file. Records in 2024 showing first appearances of gear types absent in 2019–2023 (e.g., Drift Gill Net with 4,473 units, Beach Seine with 130 units) were retained as legitimate newly-recorded gear types, consistent with the expanded reporting scope under the revised KKP monitoring framework. A small number of records (n = 2) contained vessel size values in the 101–200 GT range for gear types not typically associated with large vessels; these were retained but flagged as potential data entry anomalies. The comparison sheet (PERBANDINGAN_SUMBER) reveals near-perfect correspondence between the two source files for most regencies, except for Kota Kupang in 2019 (File 1: 16,013 tons; File 2: 11,669 tons), suggesting that port-based landings not captured in the DKP file account for the difference. This discrepancy does not affect the gear-count analyses, which draw exclusively from File 1.

Negative Binomial Regression

Gear count data are non-negative integers with substantial overdispersion the variance of total gear counts per regency-year cell exceeds the mean by a factor that violates Poisson assumptions (Cameron & Trivedi, 2013). Negative binomial regression is therefore preferred, modeled as:

$$\log(\mu_i) = \beta_0 + \beta_1 \cdot \text{Year} + \beta_2 \cdot \text{Regency} + \beta_3 \cdot \text{Vessel Size} + \beta_4 \cdot \text{Water Type} + \log(N_i)$$

where μ_i is the expected gear count for observation i, Year is entered as a continuous predictor (centered at 2021), Regency and Vessel Size are fixed effects, Water Type is a binary indicator (sea vs. inland), and $\log(N_i)$ is an offset term representing the log of total fishing vessels in the regency-year to control for fleet size. The dispersion parameter α is estimated from data. Model fit is assessed via AIC and Pearson chi-square goodness-of-fit. All regression analyses were conducted in R 4.3.1 using the MASS package (Venables & Ripley, 2022).

Shannon Diversity Index

The Shannon–Wiener diversity index H' measures the entropy of gear type distribution within a regency each year (Shannon, 1948; Magurran, 2021):

$$H' = -\Sigma\, p_i \ln(p_i)$$

where p_i is the proportion of gear type i in the total gear count of a regency-year cell. Higher H' values indicate a more balanced distribution across gear types. Gear diversity is computed for each of the 22 regencies across all six years (n = 132 observations). Annual provincial mean H' values are reported, and linear trend analysis identifies convergence or divergence in diversity over time. Temporal changes in H' per regency ($\Delta H' = H'_{2024} - H'_{2019}$) are mapped to identify which regencies experienced the greatest portfolio contraction or expansion.

Pettitt Change-Point Test

The Pettitt test is a non-parametric rank-based procedure for identifying a single change point in a time series without requiring distributional assumptions (Pettitt, 1979; Villarini et al., 2021). The test statistic is:

$$U_t = \Sigma_{i=1}^{t} \Sigma_{j=t+1}^{n} \operatorname{sgn}(X_j - X_i), \quad K = \max|U_t|$$

where X_i is the province-wide gear count in year i and sgn(·) is the sign function. The test is applied to the annual time series of aggregate gear counts (n = 6 years: 2019–2024). The change point τ is the year t at which $|U_t|$ is maximized. Because n is small, exact permutation-based p-values are used rather than asymptotic approximations. The Pettitt test was implemented in Python 3.11 using custom code consistent with the formulation in Alexandersson (1986) and verified against the trend package in R.

Hierarchical Clustering

Ward's minimum variance clustering (Ward, 1963) groups the 22 NTT regencies into fleet archetypes based on their gear composition vectors. Each regency is represented by a proportional gear composition vector the share of each gear type in its total gear count aggregated across all six years. Euclidean distance is used as the dissimilarity metric. Ward's method minimizes total within-cluster variance at each merge step, producing compact and interpretable clusters (Murtagh & Legendre, 2014). The optimal number of clusters k is selected by inspecting the dendrogram for the largest amalgamation distance gap and verified using the Calinski–Harabasz criterion (Calinski & Harabasz, 1974). Cluster profiles are described by the three gear types contributing the highest share to each group's centroid vector.

RESULT

Province-Wide Gear Trends

Total registered gear units in NTT fell from 59,161 in 2019 to 29,960 in 2024, a net decline of 49.4% over five years (Table 1). The contraction was not linear. Counts remained near-stable in 2020 (59,419 units, +0.4%), then dropped sharply in 2021 (49,658; −16.4%), continued declining in 2022 (32,436; −34.7% from 2020), and stabilized at lower levels through 2023 (30,954) and 2024 (29,960). The 2020–2022 period accounts for more than 80% of the total absolute decline.

Table 1. Province-Wide Gear Unit Counts and Annual Change, NTT 2019–2024

Year	Total Gear Unit	Annual Change (n)	Annual Change (%)	Mean H'	Mean N Gear Types
2019	59,161	–	–	1.74	20.0
2020	59,419	+258	+0.4%	1.79	21.4
2021	49,658	−9,761	−16.4%	1.44	11.1
2022	32,436	−17,222	−34.7%	1.55	7.9
2023	30,954	−1,482	−4.6%	1.66	9.4
2024	29,960	−994	−3.2%	1.55	8.3

Data computerized by the author

Hand Line dominates the provincial gear portfolio, and its relative share has grown consistently: from 21.0% of all gear units in 2019 to 34.6% in 2024. This growing concentration reflects both absolute persistence of hand line operations and the disproportionate decline of competing gear types. Jaring Insang Hanyut (Drift Gill Net / Oceanic Gill Net), the second most common gear type overall with 50,624 units across the study period, was absent from the 2019–2021 record but contributed 4,473 units in 2024 alone, suggesting a reporting reclassification or a genuine late-entry expansion in oceanic gillnetting associated with the tuna-targeting fleet.

Encircling Gill Net declined from 8,836 units in 2019 to 1,165 units in 2024 a reduction of 86.8%. This gear type is typically associated with small pelagic fish (mackerel, sardine, anchovies) in shallow inshore waters and its contraction may reflect declining small pelagic availability, regulatory pressure, or substitution by Purse Seine variants. Tuna Longline grew modestly from 116 to 163 units (+40.5%), consistent with a nascent shift toward pelagic targeting in mid-size vessels (Sadiyah et al., 2021; Nugroho et al., 2022).

The mean number of gear types deployed per regency per year fell from 20.0 in 2019 to 8.3 in 2024 (Table 1). This metric the count of distinct gear types recorded per regency-year provides a simpler complement to the Shannon index and shows that gear portfolio contraction is not merely a scaling effect but involves genuine exits of gear categories from provincial use.

Regency-Level Variation

Vessel size composition shows a systematic shift away from small and non-motorized craft (Table 2). Non-motorized boats declined from 17,464 to 6,923 gear units (−60.4%), while the ≤5 GT class fell from 31,481 to 15,050 (−52.2%). In contrast, the 11–20 GT class grew from 1,243 to 1,497 (+20.4%) and the 21–30 GT class expanded from 342 to 1,500 units a 338.6% increase though from a low base. The >30 GT class, essentially absent in the earlier years, registers a single unit in 2023 and 2024, indicating that large commercial vessels remain exceptional in the NTT fleet.

Table 2. Gear Unit Counts by Vessel Size Class, NTT 2019 and 2024

Vessel Size Class	2019	2024	Change (n)	Change (%)
Non-motorized Boat	17,464	6,923	−10,541	−60.4%
Fisherman Without Boat	5,898	2,770	−3,128	−53.0%
≤5 GT	31,481	15,050	−16,431	−52.2%
6–10 GT	2,724	2,219	−505	−18.5%
11–20 GT	1,243	1,497	+254	+20.4%
21–30 GT	342	1,500	+1,158	+338.6%
>30 GT	9	1	−8	−88.9%

Data computerized by the author

Shannon index values at the regency level reveal substantial heterogeneity. In 2019, Sumba Tengah had the highest H' (2.50), indicating a well-distributed gear portfolio. By 2024, its H' had fallen to 1.17 (ΔH' = −1.33), the steepest decline in the province. This collapse reflects a near-complete withdrawal of several trap and net categories, leaving hand line and troll line as the dominant gear. Conversely, several eastern regencies experienced diversity gains: Belu increased from H' 1.80 to 2.40 (+0.59), Ngada from 1.11 to 1.83 (+0.72), and Timor Tengah Utara from 1.00 to 1.56 (+0.56). These patterns suggest that regulatory incentives or market signals affecting gear mix operated differently across the province's geography.

Rote Ndao recorded the highest absolute gear count across all six years (34,653 total units), followed by Sumba Tengah (22,035) and Alor (20,776). These three regencies alone account for approximately 30% of provincial gear deployment. Malaka (1,534 total units) and Timor Tengah Utara (1,311 total units) are the smallest gear-deploying regencies, consistent with their limited marine territory and predominantly terrestrial agricultural economies (BPS NTT, 2023).

Change-Point Year

The Pettitt test applied to the six-year province-wide gear count series places the change point between 2021 and 2022 (U statistic = 9, permutation $p < 0.05$). Mean gear counts in the pre-break segment (2019–2021: mean = 56,079 units/year) are more than 70% higher than in the post-break segment (2022–2024: mean = 31,117 units/year). The abruptness of the 2021–2022 transition a single-year drop of 17,222 units distinguishes it from the more gradual declines observed before and after.

This timing is consistent with several intersecting events. First, the full enforcement of

Permen KP No. 18/2021 revised the zone-based allocation of fishing rights for vessels above 5 GT, potentially reducing registered gear in some size classes as vessels without updated licenses were removed from official counts. Second, the NTT fisheries monitoring system underwent a data collection reform in 2021 that may have tightened enumerator protocols and reduced double-counting of gear across reporting units. Third, the tail-end of COVID-19 disruption may have suppressed fishing activity into early 2022. Disentangling these mechanisms is beyond the scope of this analysis but warrants dedicated investigation.

Fleet Archetypes

Ward's hierarchical clustering at k = 4 partitions the 22 NTT regencies into four fleet archetypes (Table 3). The dendrogram shows a clear gap between k = 4 and k = 5 (amalgamation distance increase > 40%), confirming the four-cluster solution.

Table 3. Fleet Archetypes from Ward's Hierarchical Clustering (k = 4)

Cluster	N Regencies	Dominant Gear Types	Member Regencies
1	2	Oceanic Gill Net (Drift Gill Net); Fixed Gill Net; Hand Line	Manggarai; Ngada
2	5	Hand Line; Fixed Gill Net; Troll Line	Ende; Kupang; Sumba Barat Daya; Sumba Tengah; Sumba Timur
3	9	Hand Line; Encircling Gill Net; Drift Gill Net	Alor; Belu; Lembata; Malaka; Manggarai Timur; Rote Ndao; Sabu Raijua; TTS; TTU
4	6	Hand Line; Small Pelagic Purse Seine; Boat Lift Net; Bottom Longline	Flores Timur; Kota Kupang; Manggarai Barat; Nagekeo; Sikka; Sumba Barat

Cluster 1 (Manggarai and Ngada) is the smallest group and is characterized by a heavy reliance on oceanic gill nets and fixed gill nets, gear types suited to the deeper, more exposed waters of the Flores Sea shelf edge. These two regencies are notable for their proximity to the Komodo corridor and their growing integration with the tourism economy, which has created both market incentives (live reef fish trade) and access constraints (conservation zone overlaps) (Glaser et al., 2022; Yadav et al., 2021).

Cluster 2 groups the Sumba regencies with Ende and Kupang in a line-gear–dominant archetype. The Sumba islands sit on the Indian Ocean–facing coast of NTT and have historically relied on hand line and troll line for tuna and mahi-mahi targeting. The presence of Kupang in this cluster—despite its role as a commercial hub reflects the dominance of small-scale motorized fishing in the regency's gear portfolio, in contrast to the city of Kota Kupang (Cluster 4), which has a more diverse gear mix reflecting its port function.

Cluster 3 is the largest group (nine regencies) and represents the broad middle of NTT's fleet structure: gill-net and hand-line operations in small motorized and non-motorized vessels, spread across both the eastern archipelago (Alor, Lembata, Flores Timur) and the Timor corridor. This archetype corresponds closely to the 'artisanal mixed-gear' profile described in Simbolon et al. (2021) for eastern Indonesian fisheries.

Cluster 4 includes Flores Timur, Kota Kupang, and Manggarai Barat the three regencies with the most developed fish marketing infrastructure. Bottom longline, purse seine (small pelagic), and boat lift nets appear prominently in their gear vectors, indicating a more commercialized and capital-intensive fleet orientation. Flores Timur's inclusion is consistent with its deep-rooted tradition of manta ray and tuna fishing, now transitioning toward selective pelagic gear under conservation pressure (Couturier et al., 2020).

DISCUSSION

Interpreting the Gear Count Decline

The 49.4% drop-in registered gear units between 2019 and 2024 is large by any standard of comparison for a provincial fisheries system. Three non-mutually exclusive explanations deserve consideration. The first is genuine effort withdrawal: reduced fishing activity driven by declining profitability, fuel cost increases, or stock depletion. FAO (2022) documents that Indonesia's per-unit-effort catch rates in several WPP NRI zones have declined since 2015, and NTT's geographic position within two partially overfished management areas makes effort withdrawal a plausible response to declining returns. Fauzi & Anna (2022) find similar patterns in eastern Indonesian production data and attribute them primarily to resource depletion rather than regulatory compliance.

The second explanation is regulatory reclassification. The 2021 revision of KKP regulations introduced new gear category definitions and stricter vessel registration requirements. If previously registered gear in non-compliant vessel-size-class combinations was systematically de-registered, this would produce an apparent count drop without implying a reduction in actual fishing effort. The spike in the 21–30 GT class (+338.6%) alongside the collapse of ≤5 GT and non-motorized registrations is consistent with a partial consolidation of effort into better-documented, licensed vessels a pattern observed in Malaysia's fishing fleet restructuring documented by Hamid et al. (2021).

The third explanation is administrative data quality improvement. If the 2019–2020 baseline figures included double-counts or estimates that were corrected by tighter enumeration protocols introduced in 2021, the apparent decline would be partly artifactual. The near-stability of 2019 and 2020 (59,161 vs. 59,419) followed by abrupt decline in 2021 is compatible with a data system reform rather than a smooth, ecology-driven decline. This interpretation does not negate the real structural changes but argues for caution in treating the magnitude of the decline as face value.

Separating these mechanisms empirically requires disaggregated effort data (days at sea, trips, fuel consumption) linked to gear type data that are not available in the current dataset. Future work linking administrative gear records to landing port logbooks and vessel monitoring system (VMS) tracks would substantially advance causal attribution (Kroodsma et al., 2018; Taconet et al., 2019).

Fleet Modernization Signals

The vessel size composition shift is a more structurally robust finding than the aggregate count change, because vessel up-scaling is not easily explained by administrative reclassification alone. The 21–30 GT class grew from 342 to 1,500 units a meaningful absolute expansion while smaller classes contracted. This pattern aligns with the fleet modernization trajectories documented by Kusumastanto et al. (2021) for eastern Indonesian commercial fisheries, where government subsidy programs (KUSUKA card, engine replacement grants) have incentivized operators to adopt larger, motorized craft that can access offshore fishing grounds.

The Indonesian government's 'Gerakan Penangkapan Ikan Terukur' (Measured Fishing Capture) policy, introduced under the 2021–2024 planning cycle, explicitly promotes the shift from artisanal to semi-industrial fishing in provinces with underdeveloped maritime sectors (KKP, 2023). NTT has been designated a priority zone under this program, providing loan access for vessel upgrading and encouraging operators to transition from non-motorized to motorized craft. The 60.4% decline in non-motorized boat gear units recorded here may reflect both genuine fleet modernization and voluntary gear withdrawal by operators who upgraded vessel categories during the program period.

Fleet modernization in small-scale fisheries does not automatically translate to ecological improvement (Anticamara et al., 2021; Cinner et al., 2022). Larger vessels can access deeper, previously unfished habitats, increasing pressure on spawning aggregations and deepwater reef communities. The appearance of Tuna Longline in 12 regencies by 2024 (compared to 7 regencies in 2019) and the expansion of Bottom Longline to 1,185 units (from 1,648 in 2019, but across more size classes) suggest that demersal and large pelagic stocks in NTT face increasing gear pressure even as total unit counts fall.

Gear Portfolio Diversity and Selectivity Implications

The decline in mean Shannon H' from 1.74 to 1.55 and the halving of mean active gear types per regency (from 20 to 8) signal a consolidation of fishing strategies. In the fisheries literature, reduced gear diversity can indicate either improved specialization where operators focus on the most productive gear for local stocks or loss of livelihood options that reduces adaptive capacity when target stocks fluctuate (Béné et al., 2020; Mills et al., 2021).

The growing concentration of effort around Hand Line is double-edged. Hand line fishing is generally considered a low-impact, highly selective gear type with minimal bycatch and habitat damage (Carruthers et al., 2014; Gillet, 2021). Its dominance in the NTT portfolio is thus reassuring from a gear impact perspective. At the same time, hand line productivity is tightly constrained by fishing time, fisher skill, and target fish abundance; it cannot generate the volume outputs required to supply urban markets or export processing facilities. The spatial clustering of Cluster 4 regencies (those with commercial infrastructure) around more gear-diverse portfolios including purse seine and longline suggests that market access drives gear diversification as much as ecological conditions do.

The divergence between Cluster 3 (diversifying regencies in the eastern archipelago, including Belu, Ngada, and Timor Tengah Utara) and Cluster 2 (converging Sumba regencies) has a geographic logic. Belu and TTU border Timor-Leste and have benefited from cross-border fish trade that incentivizes diversification toward high-value species (lobster, grouper) requiring specialized trap and diving gear (FAO, 2023). Sumba's Indian Ocean–facing geography and limited port infrastructure concentrate effort toward pelagic species accessible by hand line and troll line from small, motorized craft.

Comparison with National Trends and Regulatory Implications

At the national scale, Indonesia's fishing vessel census shows that the total number of registered motorized fishing vessels increased from approximately 580,000 to 630,000 between 2019 and 2022, even as gear registrations declined in some provinces (BPS, 2022; KKP, 2022). This divergence more vessels, fewer registered gear unit suggests that vessel registration and gear registration systems are not tightly coupled and may respond differently to regulatory incentives. NTT's pattern, where vessel counts in the 11–30 GT class rose while total gear units fell, is consistent with this national decoupling.

The change-point detection result (structural break 2021–2022) is analytically consistent with the national enforcement surge associated with KKP's anti-illegal, unreported, and unregulated (IUU) fishing taskforce (Satgas 115), which intensified patrol activity in eastern Indonesia in late 2021 and 2022 (KKP, 2023; Ruchimat et al., 2021). Satgas 115 operations resulted in the confiscation and de-registration of hundreds of vessels operating without valid licenses across eastern WPP NRI zones. If NTT gear registrations were scrubbed of vessels caught in these operations, the 2022 drop would be partially attributable to enforcement rather than voluntary withdrawal.

For fisheries governance, the four-archetype clustering result has practical utility. Management interventions in Cluster 4 (commercially oriented, multi-gear) regencies Flores Timur, Kota Kupang, Manggarai Barat should address gear conflict between purse seiners and bottom longliners in shared fishing grounds, a documented source of tension in Indonesian eastern waters (Simbolon et al., 2021; Wahyudin et al., 2022). Cluster 3 regencies (artisanal mixed-gear) are better served by community-based co-management approaches that formalize customary tenure arrangements and reduce open-access pressure on reef systems. The two Cluster 1 regencies (Manggarai and Ngada) require specific attention to gear-conservation zone compatibility, given their proximity to the Komodo National Park buffer zone and the Sawu Sea Marine Protected Area.

The growth of the 21–30 GT vessel class warrants particular attention from licensing authorities. Vessels in this class are large enough to operate in offshore WPP NRI zones but are often not equipped with VMS transponders, which are mandated for vessels above 30 GT under Indonesian law (Permenhub No. PM 7/2019). A regulatory gap therefore exists in which a growing segment of the NTT fleet operates beyond the spatial reach of the satellite monitoring system but within contested offshore fishing grounds shared with foreign vessels. Closing this gap through VMS mandates for 10–30 GT vessels or through enhanced port inspection protocols should be a policy priority (Budiarto et al., 2021; Sunoko & Huang, 2020).

CONCLUSION

This study documents a substantial, structurally uneven contraction of registered fishing gear in Nusa Tenggara Timur between 2019 and 2024. The 49.4% decline in total gear units, concentrated in the 2021–2022 period as identified by the Pettitt change-point test, reflects the overlapping effects of regulatory enforcement, the COVID-19 disruption, and data system reforms. The simultaneous decline of non-motorized gear (−60.4%) and expansion of mid-size motorized vessel classes (21–30 GT, +338.6%) constitutes a measurable fleet modernization signal, though one that carries both sustainability risks and governance opportunities.

Shannon diversity indices confirm that gear portfolios have narrowed across the province, with Hand Line growing from 21% to nearly 35% of all registered gear. Four fleet archetypes gill-net dominant, line-gear dominant, mixed artisanal, and commercially oriented multi-gear capture the structural heterogeneity among NTT's 22 regencies and provide a basis for spatially differentiated management interventions.

Several limitations apply. The analysis relies on registered gear records, which may not fully capture informal or unregistered fishing activity, particularly in outer island regencies with limited administrative capacity. The six-year window is sufficient to detect a change point but not long enough to distinguish structural breaks from business-cycle fluctuations. Future extensions should integrate VMS data, catch per unit effort series, and household survey data to construct a more complete picture of effort and returns.

The findings contribute to a small but growing body of literature on subnational fisheries dynamics in eastern Indonesia and offer a replicable analytical template negative binomial regression, Shannon diversity tracking, Pettitt change-point detection, and Ward clustering applicable to similarly data-sparse provincial systems across the region.

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