Evaluating the impact of a fishing-gear data management system on fishery productivity

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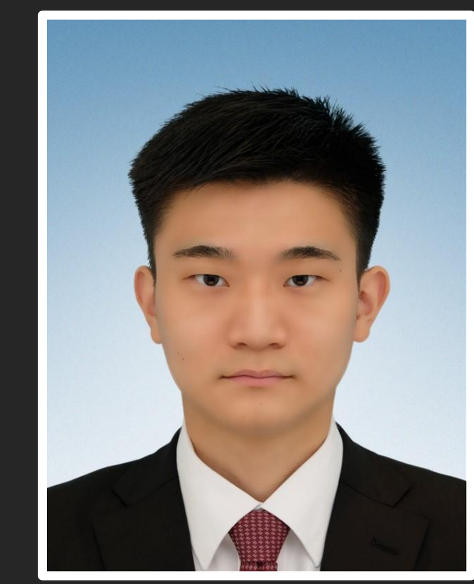


Abstract

The rapid adoption of smart technologies has become imperative in the fisheries sector. In Japan, shrinking manpower and the need to enhance sustainability have underscored the importance of developing and deploying smart-fishery solutions that can drive industry growth. Worldwide as well, leading fishing nations and major corporations are actively investing in IoT applications for fisheries. Against this backdrop, Lighthouse Inc. has developed and introduced ISANA, a fishing-gear data-management system that aggregates gear data—traditionally managed on a vessel-by-vessel basis—and shares it across an entire fleet. By facilitating information sharing, ISANA is expected to improve operational efficiency. This study statistically verifies the effect of ISANA on fishery productivity by analyzing catch volumes, fuel consumption, and vessel-behavior logs from fleets that have adopted the system. Its contributions are twofold: (i) it examines an IoT application designed to directly enhance productivity—as opposed to the more common resource-monitoring IoT tools—and (ii) it provides a statistical assessment of that application's impact, filling a gap in the existing literature. Using catch and fuel-consumption records together with GPS coordinate logs from ISANA-equipped fleets, we conducted two analyses: A difference-in-differences (DiD) estimation of catch volume, fuel consumption, and catch-per-unit-fuel. A behavioral analysis tracing changes in vessel speed and heading to measure search-time dynamics. The DiD results indicate that ISANA increases catch per unit of fuel but does not significantly affect total fuel consumption. The behavioral analysis further suggests a reduction in search time during fishing operations. In conclusion, statistical evidence from catch, fuel, and positional data implies that the implementation of ISANA enhances overall fishery productivity.

Background

Background: As part of a global trend, governments and major corporations around the world are accelerating the introduction of smart technologies into the fisheries sector. For instance, Norway, one of the world's leading fishing nations, launched a large-scale Global Ocean Monitoring Program in 2023. Although the program primarily aims to prevent fisheries-related crimes, its core infrastructure is a digital platform managed by the United Nations Development Programme (UNDP).Furthermore, a variety of research initiatives have demonstrated that there remains considerable potential for the digital transformation of the fisheries industry—from aquaculture and capture to market operations. These studies highlight the broad applicability and promise of smart technologies across the entire fisheries value chain.Among such technological advancements, the fishing equipment data management system "ISANA" developed by Lighthouse Inc. represents one of the most innovative examples. This system is expected to enhance the productivity of fishing operations by facilitating the efficient collection, management, and sharing of operational data within fishing fleets.

Purpose and Novelty

Purpose of this study: This study aims to analyze the operational data of fishing fleets that have adopted the ISANA system in order to examine its effects on catch volume, fuel consumption, and behavioral patterns. Through this analysis, the study seeks to verify the potential of ISANA to improve productivity in the fisheries industry.

Novelty: Although digital transformation in the fisheries industry is increasingly needed, few studies have statistically examined how smart technologies affect fishing productivity. In many advanced fishing nations, smart initiatives have mainly focused on resource management, monitoring, and reporting rather than on efficiency improvement. While some technologies analyze fishing grounds or oceanographic conditions to enhance productivity, their effectiveness has rarely been validated statistically. Statistical analysis offers potential for deeper insights; thus, this study provides an innovative and necessary contribution by examining whether the adoption of ISANA leads to measurable economic outcomes and improved productivity in fisheries.

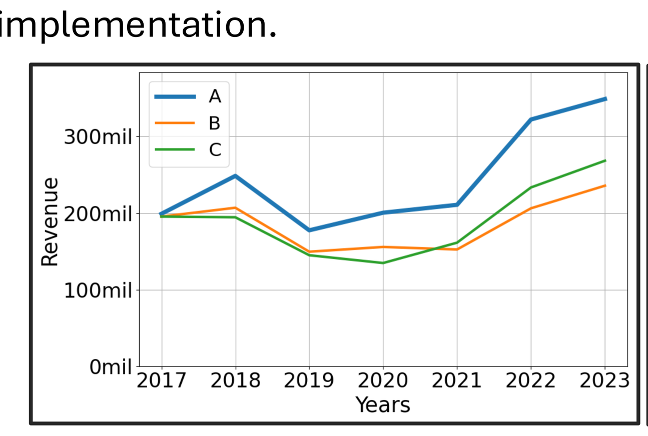
Data and Method

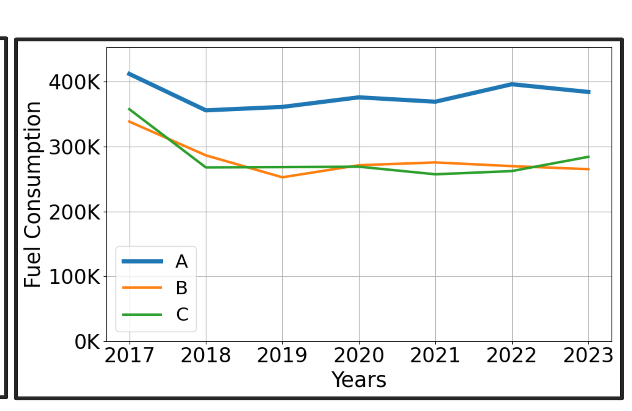
Data: Operational data were obtained from Company A, which has adopted the ISANA system, including information on catch volume and fuel consumption. The dataset covers the period from April to December for each year between 2017 and 2023. Data for January through March are absent because fishing operations are suspended during that period.In addition, two other companies, B and C, operate from the same port under similar conditions in terms of fleet size, fishing methods, and fishing areas. The trends in catch volume and fuel consumption for these three companies are illustrated in the accompanying graphs. Furthermore, coordinate data recorded through ISANA were used to calculate vessel speed and movement direction, which were also incorporated into the analysis.

Methodology: To estimate the effect of ISANA introduction on catch volume, fuel consumption, and Catch per Fuel (CPF), a difference-in-differences (DID) model was applied. The assumption of parallel trends was confirmed for all three outcome variables. The estimation model is specified as follows:

$$y_{it}=\alpha+\beta_1(treat_i \times Post_t)+\gamma_i+\delta_t+\varepsilon_{it}$$

where y_{it} represents catch volume, fuel consumption, or CPF; α is the intercept; $treat_i$ is a treatment dummy (1 for Company A, 0 for others); $Post_t$ is a post-treatment dummy (1 for the period after April 2020, 0 otherwise); γ_i and δ_t denote firm and time fixed effects, respectively; and ε_{it} is the error term.In addition, vessel speed and movement direction were calculated from coordinate data and visualized in scatter plots to examine behavioral changes in Company A's fishing operations following ISANA implementation.





Results

DiD Analysis: In this study, three DID models were estimated, each differing in the dependent variable while fixing the independent variable as the presence or absence of ISANA implementation:Model ①: Dependent variable — Catch volume, Model ②: Dependent variable — Fuel consumption, Model ③: Dependent variable — Catch per unit of fuel consumption (CPF)Figure 1 presents the estimation results of Model ①. The introduction of ISANA increased the catch volume by ¥5,423,848 per month, and the result was statistically significant at the 5% level, indicating a reliable positive impact.Figure 2 shows the results of Model ②. The p-value of 0.92391 suggests that fuel consumption (the dependent variable) is statistically unrelated to ISANA adoption.Figure 3 reports the estimation results of Model ③. The introduction of ISANA increased CPF by ¥210.444 per liter per month. However, the p-value of 0.11916 exceeds the 10% significance threshold, indicating that the result is not statistically significant.

Scatter Plot Analysis: To further investigate behavioral changes in vessel operations, three types of scatter plots were created using vessel speed (x-axis) and directional change (y-axis):A single scatter plot including all data pointsYearly scatter plots with data classified by yearFigure 4 displays the scatter plot including all data. Darker points indicate older data, while lighter points represent more recent data; the data were plotted chronologically from oldest to newest. Areas that appear dark indicate regions where recent data points are absent.Notably, the region defined by speed 3–10 knots/hour and directional change ±50–150 degrees (hereafter referred to as the "medium-speed × medium-direction-change region") appears dark, suggesting that this behavioral pattern occurred primarily in earlier years.Figure 5 shows the scatter plots classified by year. The medium-speed × medium-direction-change region identified in Figure 4 has gradually decreased from 2022 to 2024, indicating a potential shift in vessel movement behavior following ISANA implementation.

Fig. 1

```
OLS estimation, Dep. Var.: catch
Observations: 186
Fixed-effects: company: 3,  year_month: 62
Standard-errors: Clustered (company)
           Estimate Std. Error t value Pr(>|t|)
treat_post  5423848    1052012 5.15569 0.035623 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 4,212,632.7      Adj. R2: 0.845014
                     Within R2: 0.082315
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Fig. 2

```
OLS estimation, Dep. Var.: fuel
Observations: 186
Fixed-effects: company: 3,  year_month: 62
Standard-errors: Clustered (company)
           Estimate Std. Error  t value Pr(>|t|)
treat_post  203.178    1882.56 0.107926  0.92391
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 3,614.1      Adj. R2: 0.900262
                 Within R2: 1.71e-4
```

Fig. 3

```
OLS estimation, Dep. Var.: catch_per_fuel
Observations: 186
Fixed-effects: company: 3,  year_month: 62
Standard-errors: Clustered (company)
           Estimate Std. Error t value Pr(>|t|)
treat_post  210.444    79.9771  2.6313  0.11916
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 218.3      Adj. R2: 0.501364
               Within R2: 0.047861
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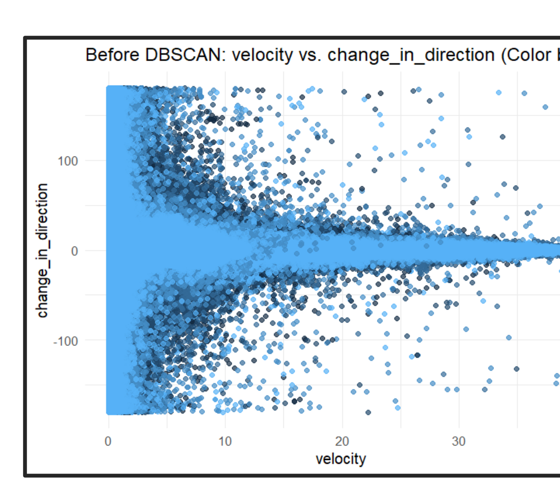

Fig. 4

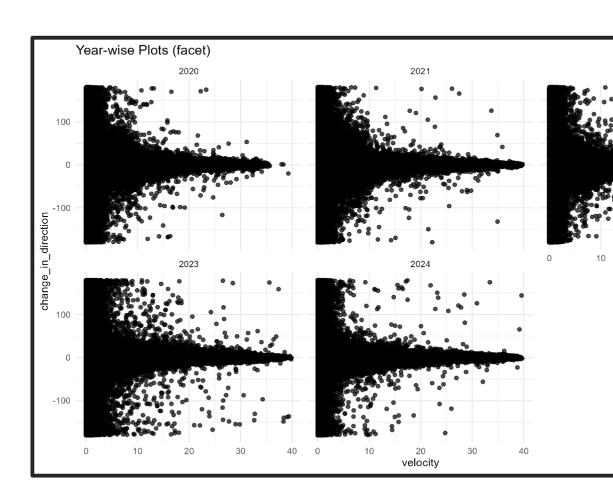

Fig. 5

Discussion

DiD Analysis: The estimation results of Model ① indicate that the introduction of ISANA generated an average monthly revenue increase of approximately ¥5.4 million. Considering that the average monthly catch value is around ¥30 million, this corresponds to a 15–20% increase in revenue. In contrast, the results of Model ② suggest that ISANA had no significant effect on fuel consumption.Given these outcomes, one would expect that ISANA improved fuel efficiency—measured as catch per unit of fuel (CPF)—since catch increased while fuel use remained unchanged. The results from Model ③ support this interpretation: the regression coefficient was positive, and the t-value sufficiently high. Although the p-value of 0.11916 slightly exceeds the conventional 10% threshold, two factors justify confidence in this result: (1) it is very close to the significance level, and (2) the small sample size likely inflated the p-value. Therefore, the observed increase in CPF can reasonably be interpreted as an improvement in fishing productivity.Nevertheless, if additional data become available—particularly from more clusters or fleets—the application of alternative methods such as the synthetic control approach could be considered to enhance robustness.

Scatter Plot Analysis: To further investigate fleet behavior, operational patterns were categorized into three activity types: transit, searching, and fishing. According to interviews with fishermen, operations typically follow the cycle of "transit to fishing grounds → search → set nets (harvest)." Based on these interviews, transit was characterized by direct movement toward fishing grounds, while searching involved meandering movements to detect fish schools and assess currents. Accordingly, "transit" was defined as high speed × low directional change, and "searching" as medium speed × medium directional change.In addition, according to Chui, Yagi, and Sakai (2024), purse seine vessels exhibit low speed, substantial directional changes, and close proximity between netting and carrier boats during fishing operations. Thus, "fishing" was defined as low speed × medium-to-large directional change.Analysis of the scatter plots revealed that the medium-speed × medium-direction-change region gradually decreased between 2022 and 2024, as shown in Figures 4 and 5. This area corresponds to the "searching" behavior pattern, suggesting that ISANA contributed to a reduction in searching time. Given that 2022 marks the period when crews had become accustomed to using ISANA, this behavioral shift likely reflects enhanced operational efficiency resulting from improved access to spatial and environmental information.

Overall Interpretation: Combining the DID and behavioral analyses, this study suggests that the introduction of ISANA improved fishing productivity primarily by reducing searching time. The saved time likely allowed vessels to allocate more effort to travel and harvesting, thereby increasing catch volume without increasing fuel consumption. Consequently, the findings indicate that ISANA has the potential to enhance operational efficiency and economic performance in the fisheries sector.