Visual Analytics

VAST Challenge

Project Report

Master Degree in Data Science and Business Informatics

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Contents

1 Data Understanding and Description

The dataset used for this project is provided by the VAST Challenge 2024 (Mini-Challenge 2). It represents a knowledge graph named *CatchNet*, which aggregates data from various sources regarding the fishing industry in the fictional nation of Oceanus. The primary goal of the dataset is to enable the identification of illegal, unreported, and unregulated (IUU) fishing activities.

1.1 Dataset Overview

The core dataset is provided in a JSON format ('mc2.json') structured as a directed multi-graph allowing multiple edges between nodes. The original graph statistics are as follows:

- **Nodes:** 5,637 entities representing vessels, locations, organizations, and documents.
- **Edges:** 271,752 links representing events and relationships.
- **Components:** The graph forms a single (weakly) connected component.

1.2 Schema and Entity Types

The graph schema distinguishes between *Entities* (Nodes) and *Events* (Edges).

1.2.1 Nodes (Entities)

The primary entities in the graph include:

- `Entity.Vessel`: Represents maritime vessels. Attributes include `id`, `name`, `type` (e.g., Fishing, Cargo, Tourism), `flag_country`, and `tonnage`.
- `Entity.Location`: Represents geographic points of interest. Sub-types include *Cities*, *Fishing Zones*, and *Ecological Preserves*. Attributes include `fish_species_present` and allowed `activities`.
- `Entity.Commodity.Fish`: Represents the types of fish traded (e.g., *Thunnini*, *Gadus*).
- `Entity.Document.DeliveryReport`: Represents the administrative record of a transaction, containing details like `qty_tons` (weight) and `date`.

1.2.2 Edges (Events)

Relationships between entities are modeled through the following edge types:

- `Event.TransponderPing`: Links a `Vessel` to a `Location`, including `time` and `dwell` (duration) attributes.
- `Event.HarborReport`: Links a `Vessel` to a `Location` based on visual confirmation by harbor masters.
- `Event.Transaction`: Connects `DeliveryReports` to `Locations` and `Commodities`.

2 Data Preprocessing and Transformation

The preprocessing phase began with a data cleaning operation to remove irrelevant attributes and system metadata. Specifically, fields containing non-analytical text (e.g., `'aphorism'`, `'holiday_greeting'`, `'wisdom'`, `'saying of the sea'`) and administrative logs (e.g., `'_date_added'`, `'_last_edited_date'`, `'_last_edited_by'`, `'data_author'`, `'_raw_source'`, `'key'`) were dropped to reduce dimensionality.

Subsequently, a data quality assessment was performed to verify the integrity of key numerical metrics—`tonnage`, `length_overall`, and `qty_tons`—across different entity types. This step aimed to identify missing values or inconsistent attribute assignments. Statistical profiling of these entities confirmed domain expectations, showing that `Cargo Vessels` possess significantly higher capacity and length compared to `Fishing Vessels`. However, an inspection of `Delivery Reports` revealed the presence of negative values in the `qty_tons` field, an anomaly flagged for downstream analysis (see Section 3.2).

Finally, an analysis of the data distribution highlighted distinct patterns: the `tonnage` variable exhibits a bimodal distribution, with the majority of vessels clustering between 0 and 5,000 GT, and a secondary cluster near 75,000 GT. In contrast, the cargo quantity distribution (`qty_tons`) follows a standard normal distribution.

2.1 Data Preparation for Dashboard

2.1.1 First Dataset

To enable the visual analysis and specifically address the challenge's research questions—namely the attribution of cargo to vessels (**RQ1**) a dedicated data fusion pipeline was implemented in Python. This workflow reconstructs the missing links between the high-frequency *Vessel Movements* and the *Harbor Import Records*.
The initial phase focused on dataset reduction. The graph was filtered to retain only nodes classified as `Entity.Vessel.FishingVessel`, discarding extraneous traffic (e.g., cargo, passenger ferries). This minimizing ambiguity in the provenance inference. Simultaneously, a "Ground Truth" dictionary (`REGION_ECOLOGY`) was established to map Oceanus' geographic regions to their regulatory status (*Fishing Ground* vs. *Ecological Preserve*) and to the specific fish species endemic to those areas.
The primary obstacle to answering RQ1 is the lack of vessel identifiers in delivery records. To resolve this, a spatiotemporal join was executed based on the `location_id`. Recognizing that delivery reports represent port-exit events, the algorithm assumes that the delivering vessel must have docked shortly beforehand. A heuristic window was applied: a vessel is flagged as a candidate for a report only if its arrival timestamp ($T_{arrival}$) occurred within a range of $[0, 2]$ days prior to the report date (T_{report}):

$$0 \leq (T_{report} - T_{arrival}) \leq 2 \text{ days}$$

To detect illicit activities and assign the most probable product delivered, we must know its origin. To infer this missing variable, the pipeline utilizes an as-of merge algorithm (`merge_asof`) with a backward search direction. For every valid docking event, the system traces the vessel's trajectory backwards (up to 60 days) to identify the last recorded *dwell* event within a mapped ecological zone. This process generates a derived attribute, `provenance`, indicating the most probable fishing location prior to docking.
In the final stage, a rule-based classification logic assigns a status to each candidate match by cross-referencing the vessel type and its inferred provenance:

- **Legitimate Operations:** If a vessel arrives from a permitted *Fishing Ground*, the carried commodity is inferred to be the species native to that region.
- **Suspect Anomalies:** If a *Fishing Vessel* is traced back to an *Ecological Preserve* (e.g., *Nemo Reef*), the activity is flagged as "Suspect". The system overrides the standard commodity label with a warning tag (e.g., "Suspect Activity"), allowing the downstream visual interface to immediately highlight these violations.

The output of this pipeline is consolidated into a hierarchical JSON file (`candidates_enriched.json`), which serves as the primary data source for the analytic dashboard.

2.1.2 Second Datasets

To support the complex visual analysis required for RQ2, RQ3, and RQ4, a dedicated Python processing pipeline was developed to transform raw transponder pings into semantically enriched vessel trajectories. The primary objective was to distinguish between legitimate transit, where a vessel crosses an area simply to reach a destination, and illicit activities, such as loitering near navigation buoys for potential transshipment or illegal fishing in preserved zones.
Prior to defining the anomaly detection rules, a **statistical profiling** of the entire fishing fleet's behavior was conducted to understand the baseline of "normal" navigation. Figure 1 illustrates the distribution of dwell times across different locations.

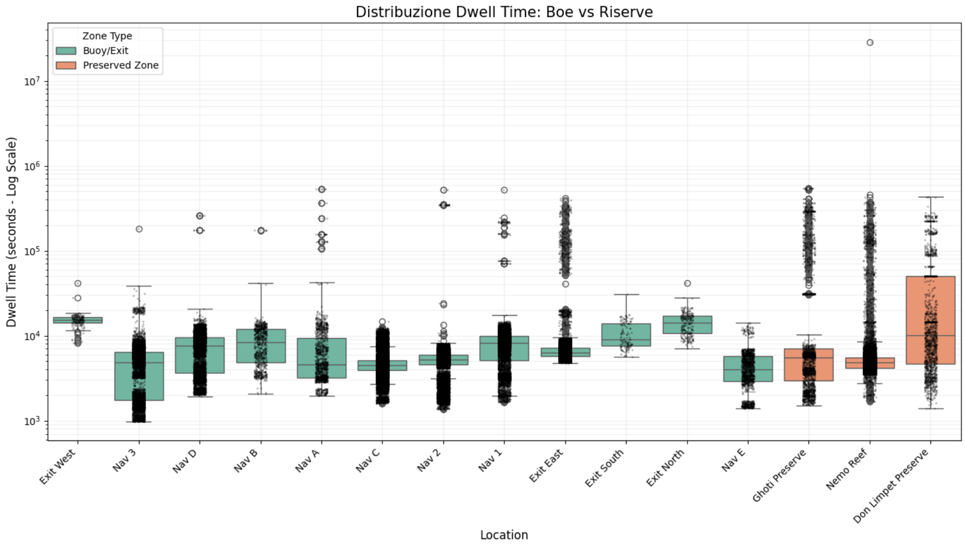

Figure 1: Distribution of Dwell Times (Log Scale).

As evidenced by the boxplots, the data follows a heavy-tailed (right-skewed) distribution. In strategic locations such as navigation buoys (e.g., Nav C, Exit East), the tight interquartile range indicates that the vast majority of vessels transit quickly. However, distinct outliers extend orders of magnitude beyond the median. This exploratory analysis highlighted that static time thresholds would be ineffective. Consequently, a **dynamic thresholding approach** was adopted based on statistical percentiles: the pipeline was configured to flag dwell times exceeding the 90^{th} percentile as "Extreme" (Violations) to capture the outliers, and those between the 75^{th} and 90^{th} percentiles as "Warning" (Suspicious).
The output is finally exported into two optimized JSON datasets: `south_seafood_pings.json` for specific target analysis, and `other_candidates.json` for comparative fleet analysis.

3 Dashboard Design and Uses

3.1 State of the Art and Design

Maritime Situational Awareness (MSA) is a mature field where detecting Illegal, Unreported, and Unregulated (IUU) fishing remains a primary challenge. Standard visualization techniques, such as **Density Maps** or Heatmaps, are effective for identifying aggregate shipping lanes but often suffer from overplotting, making it difficult to isolate individual outlier vessels. Similarly, **Space-Time Cubes** (STC) introduce 3D occlusion issues that hinder rapid decision-making. To overcome these limitations, our design eschews raw point clouds in favor of a **semantic abstraction** approach: vessel movements are visualized as discrete "events" (e.g., loitering at buoys, entering preserves) on a 2D map, prioritizing behavioral meaning over geometric precision. Furthermore, to analyze behavioral shifts following the fishing ban (Task 4), we moved beyond traditional superposed **Line Charts**, which tend to become illegible when comparing multiple entities simultaneously. Instead, we implemented a **Diverging Stacked Bar Chart**. Unlike standard trend lines, this visualization explicitly encodes the *delta* of activity—extending right for displacement and left for cessation—providing a pre-attentive mechanism to instantly assess the net impact of the new regulations.

3.2 Dashboards

For this challenge, four dashboards were developed.

3.2.1 Cargo Traffic Monitor

This visualization component is specifically designed to address **RQ1** (Cargo Attribution).

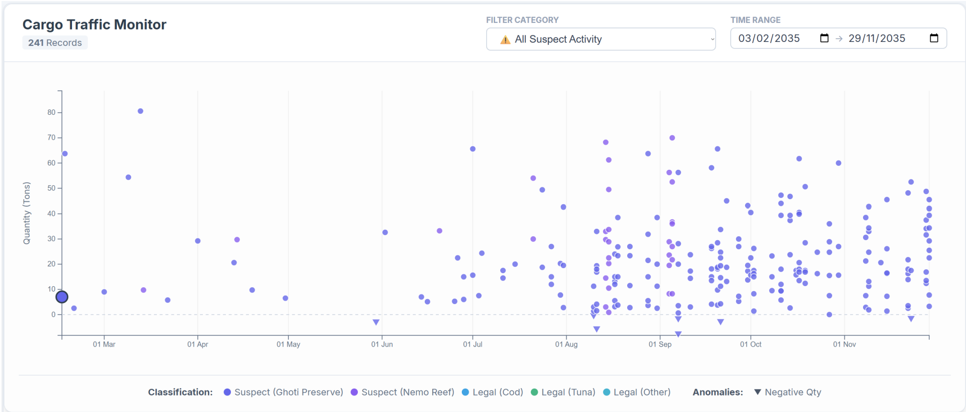

Figure 2: Cargo Traffic Scatterplot: Visualization of suspect activities over time.

Figure 2 presents a temporal scatterplot where each data point represents a specific *Delivery Report*. The x-axis maps the timeline, while the y-axis represents the quantity of cargo recorded in tons.

The visual encoding utilizes both color and shape to convey semantic information extracted during the preprocessing phase:

- **Color (Provenance):** Points are colored based on the inferred ecological origin of the candidate vessel. In the filtered view shown in the figure, the focus is on "Suspect Activities": **Indigo** points indicate vessels originating from the *Ghoti Preserve*, while **Light Purple** points denote origin from *Nemo Reef*.
- **Shape (Anomalies):** To immediately highlight data quality issues, records with negative quantity values are encoded as **triangles**, distinguishing them from the standard circular marks.

The interface supports exploratory analysis through interactive filtering mechanisms. The user can filter the dataset by specific commodity types (e.g., focusing only on Tuna) and adjust the temporal window to investigate specific periods of interest.

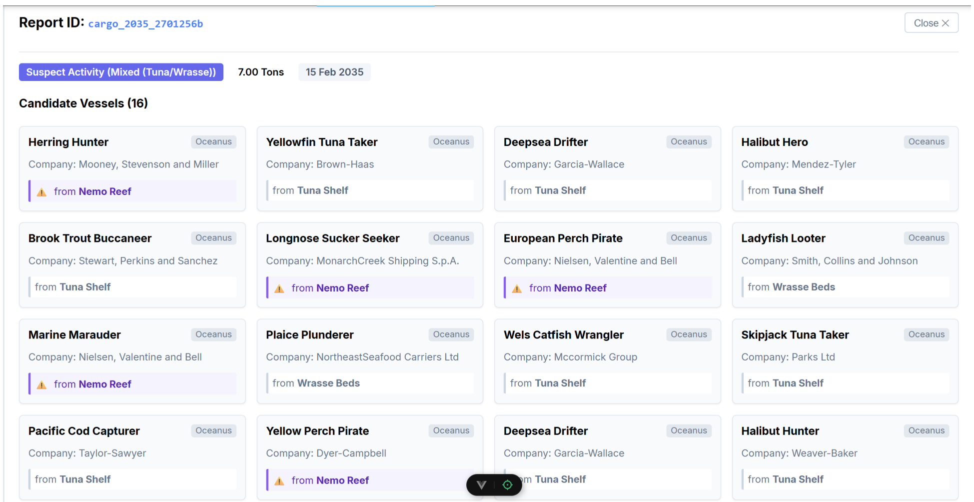

Figure 3: Details-on-Demand: Candidate vessels attribution panel.

Following the *Overview-first, Details-on-demand* mantra, selecting a specific report on the scatterplot reveals a detailed inspection panel (Figure 3). This section displays the precise cargo metrics and lists the potential vessels identified by the spatiotemporal matching algorithm (0-2 days window). For each candidate, the system provides crucial metadata—including the vessel's name and company along with the computed provenance, allowing the analyst to verify the legitimacy of the transaction.

3.2.2 Target Vessel Analysis

To enable a granular investigation of specific trajectories and confirm suspected illegal activities, particularly regarding the high-risk SouthSeafood for RQ2, a dedicated analysis dashboard was developed.

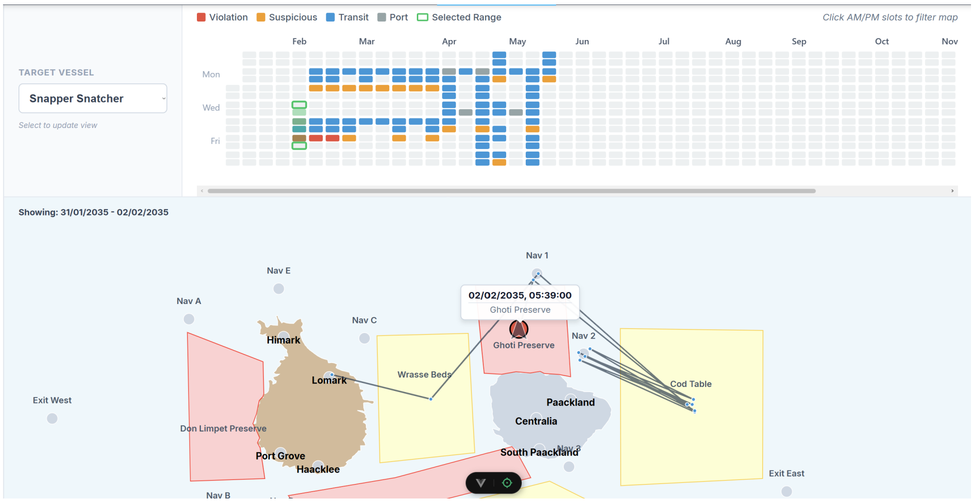

Figure 4: View of the *Snapper Snatcher*: Calendar Heatmap (Top) and Trajectory Map (Bottom).

As shown in Figure 4, the interface is composed of two coordinated views:

- **Temporal View (Calendar Heatmap):** The upper section visualizes the vessel's activity pattern over the year. To increase temporal precision, each day is split into two time slots: Morning (AM) and Afternoon (PM). This allows for the immediate identification of regular schedules versus erratic behavior.
- **Spatial View (Trajectory Map):** The lower section projects the vessel's path onto the Oceanus geography. The visualization abstracts the movement by connecting the centroids of the visited locations, providing a clear sequential path.

The dashboard supports interactive filtering by vessel ID and time range. The map includes pan-and-zoom capabilities for detailed inspection. Hovering over any node in the trajectory reveals some details, including the exact timestamp and location name. In the example shown in Figure 4, the view is filtered for the vessel *Snapper Snatcher* during the specific window of January 31, 2035, to February 2, 2035.
A consistent semantic color scheme is applied across both views to classify events and regions: **Vessel Activities:** in blue legitimate transit, in grey port calls or docking events, orange suspicious activity (e.g., loitering near buoys or extended dwell times as defined by the statistical thresholds) and in red violation (extended presence detected inside an Ecological Preserve). **Map Regions:** in yellow legal fishing zones, in red Restricted Ecological Preserves, in grey Ports and Navigation Buoys.

3.2.3 Comparative Behavioral Analysis

To comprehensively address **RQ2** and **RQ3**, the investigation must extend beyond the initial suspects to identifying the broader network of illicit actors. To this end, a "Similarity Search" dashboard was developed. This component facilitates the direct comparison of spatio-temporal patterns between known offenders (SouthSeafood fleet) and the rest of the Oceanus fleet.

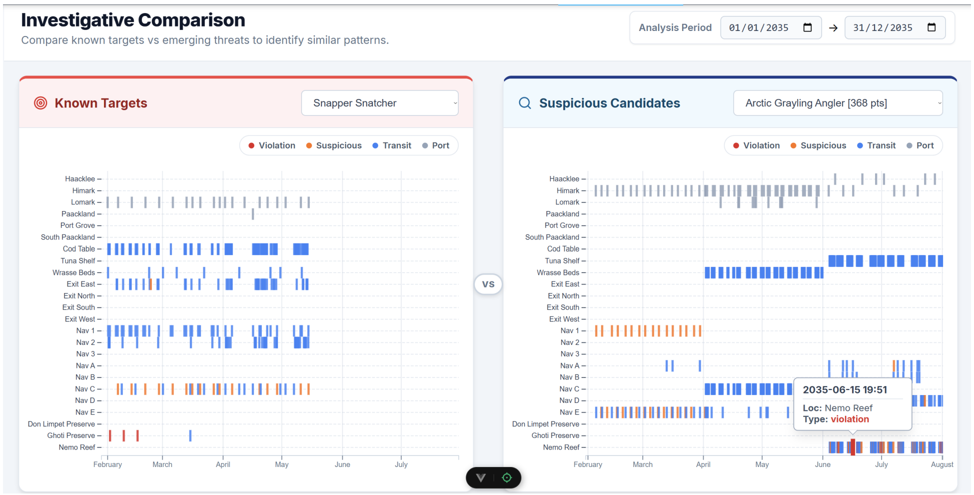

Figure 5: Comparative Dashboard: Ground Truth Target (Left) vs. High-Risk Candidates (Right).

As illustrated in Figure 5, the interface adopts a split-screen comparative layout:

- **Left Panel (Ground Truth Anchor):** Displays the activity timeline of a confirmed suspect vessel (e.g., *Snapper Snatcher* or *Roach Robber*). This serves as the visual baseline for illegal behavior.
- **Right Panel (Candidate Exploration):** Displays the timeline of other vessels in the fleet. Crucially, this list is not sorted alphabetically but is **ranked by the Suspicion Score** calculated during the preprocessing phase. This "relevance sorting" ensures that the most anomalous vessels appear at the top, immediately drawing the analyst's attention.

The visualization represents vessel trajectories as linear timelines of discrete events. The time axis is synchronized and supports semantic zooming, allowing the user to drill down from a yearly overview to specific days or hours.

- **Pattern Matching:** By visually aligning the locations, the user can detect shared behaviors. For instance, if the target vessel exhibits a pattern of "Orange" events (suspicious loitering) or violation in a certain location, the analyst can scan the right panel for candidates showing identical sequences.
- **Visual Encoding:** The color scheme remains consistent with previous views to reduce cognitive load: **Red** indicates confirmed presence in restricted zones, while **Orange** highlights statistical anomalies.
- **Details-on-Demand:** Hovering over any specific event marker (vertical line) reveals a tooltip with precise timestamp and location data, enabling the validation of synchronized activities or transshipments.

3.2.4 Post-Ban Impact Assessment

This dashboard component provides a macro-level insight into the systemic behavioral shifts of the fleet following the interdiction of the SouthSeafood vessels (May 14th, 2035), directly addressing the requirement to analyze the consequences of the ban.

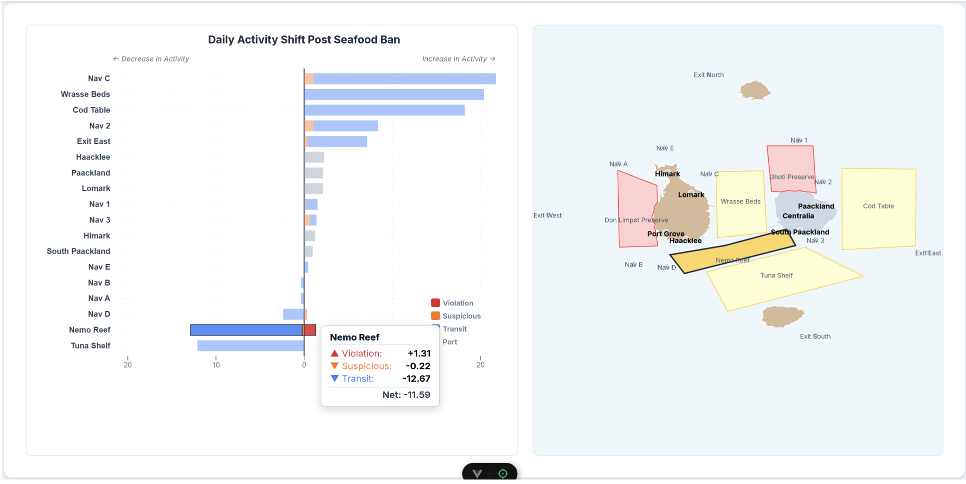

Figure 6: Activity Shift Analyzer: Diverging bars illustrate the "Delta" in daily activity pre- and post-ban.

As presented in Figure 6, the interface utilizes a split-view layout combining statistical metrics with geospatial context.

The Activity Shift Analyzer (Left Panel) The core visualization is a **Diverging Stacked Bar Chart**, designed to show the net change in average daily vessel activity for each location (locations that did not exceed the delta threshold of 0.15 are omitted from the plot for a better readibility).

- **Directionality:** Bars extending to the **left** indicate a decrease in activity (abandonment of a location), while bars extending to the **right** indicate an increase (displacement or new hotspots).
- **Segmentation:** The bars are stacked by activity type (Violation, Suspicious, Transit, Port), allowing the analyst to discern not just *where* traffic moved, but *what kind* of traffic it was.
- **Details-on-Demand:** Hovering over a bar reveals a tooltip with precise statistics, quantifying the daily average shift for each specific category.

To ground the abstract statistics in geography, the chart is tightly coupled with the map on the right. When the user hovers over a location bar in the chart, the corresponding geographic feature is immediately **highlighted** on the map. This *linked view* mechanism is crucial for understanding the strategic implications of the shift, for example, verifying if a surge in activity (Right Bar) corresponds to a buoy located just outside a restricted preserve.
With the help of the previous dashboard this helps to answer to the RQ4.

3.3 Design Choices and Visual Identity

The overall aesthetic of the platform adheres to a modern, maritime-inspired "Clean Dashboard" philosophy, designed to minimize cognitive load while maximizing data legibility. The interface is grounded by a Dark Slate header (#0f172a) that houses the navigation controls, creating a high-contrast container where the active view is highlighted in Bright Sky Blue, while inactive elements recede in a muted Grey (#94a3b8). This chrome sits atop a neutral Off-White background (#f4f7f6) to ensure the analytical charts remain the focal point. Navigation is further reinforced by semantic SVG iconography: a box/cube for the Cargo Network, an anchor for Target Analysis, a target scope for Similarity Search, and a trend arrow for Post-Ban Impact. A deliberate chromatic distinction was applied between the initial cargo analysis and the subsequent geospatial tasks to prevent semantic interference. In the Cargo Traffic Monitor, "Suspect" activities are encoded using cool Indigo and Violet hues rather than alarmist reds—which are reserved for confirmed spatial violations in later tasks—while legitimate commodities are mapped to a natural spectrum of Emerald, Sky Blue, and Cyan; additionally, data anomalies such as negative quantities are highlighted via shape encoding (triangles) rather than color. Conversely, the geospatial dashboards (Tasks 2, 3, and 4) adopt a rigorous "traffic light" logic where Bright Red and Orange immediately signal violations and suspicious loitering, respectively. These high-saturation markers are overlaid on a desaturated, pastel-toned map (Ice Blue water, Pale Red preserves) to ensure that the semi-transparent Dark Blue vessel trajectories and the directional GPS arrow marker remain clearly visible without visual clutter.

Context	**Semantic Meaning**	**Swatch**	**Hex Code**
Task 1: Cargo Traffic Monitor			
Suspect	Suspect (Nemo Reef)		#8b5cf6
	Suspect (Ghoti Preserve)		#6366f1
Legal	Legal Tuna		#10b981
	Legal Cod		#0ea5e9
	Legal Others		#06b6d4
Anomalies	Negative Qty (Triangle)		#475569
Tasks 2, 3 & 4: Geospatial & Trajectory			
Activity	**Violation** (In Preserve)		#e74c3c
	Suspicious (Loitering)		#f39c12
	Normal Transit		#3498db
	Port Call		#97A4A6
Nav	Vessel Path (Trail)		#2c3e50
	Current Position (Arrow)		#2c3e50
Map	Water / Ocean		#eef7fc
	Ecological Preserves		#ffcccc
	Fishing Grounds		#ffffcc
	Neutral Zones		#cbd5e1

Table 1: Color Encoding Scheme by Dashboard Context. The table illustrates the specific hex codes and visual swatches used to semantically encode activities and geographic features across the different views.

4 Research Question

Question 1: FishEye analysts have long wanted to better understand the flow of commercially caught fish through Oceanus's many ports. But as they were loading data into CatchNet, they discovered they had purchased the wrong port records. They wanted to get the ship off-load records, but they instead got the port-exit records (essentially trucks/trains leaving the port area). Port exit records do not include which vessel that delivered the products. Given this limitation, develop a visualization system to associate vessels with their probable cargos. Which vessels deliver which products and when? What are the seasonal trends and anomalies in the port exit records?

Answer: To address the limitation of missing vessel identifiers in the port-exit records, the developed Cargo Traffic Monitor, shown in Figure 2 and Figure 3, employs a spatiotemporal matching algorithm to attribute probable ownership to delivered goods. The system successfully links anonymous cargo records to specific vessels based on docking windows, as demonstrated by the specific case of transaction cargo_2035_2701256b. On February 15, 2035, this report recorded 7.00 tons of product delivered; the matching algorithm identifies the Herring Hunter, operated by Mooney, Stevenson and Miller, as the primary candidate. The visualization highlights a critical anomaly regarding the vessel's provenance, as it arrived directly from Nemo Reef, a designated Ecological Preserve. Although the product was administratively registered as a legal commodity, likely Tuna or Wrasse, the trajectory implies that the catch was harvested illicitly within a protected zone and subsequently laundered through the official port exit system.
Several reports indicate negative quantities, which are visualized as triangular glyphs in the scatterplot to mark them as anomalies. More importantly, a macroscopic view of suspect activities originating from

Nemo Reef indicates that illegal extraction is not continuous but highly episodic. The data shows a dense concentration of these suspect activities during two specific windows, namely August 14-15 and September 4-5. This temporal clustering suggests a coordinated extraction strategy rather than opportunistic fishing. The mid-August and september spike likely corresponds to a specific holiday period where port inspections and ranger patrols may be reduced, allowing the illegal fleet to exploit a window of lower enforcement.

Question 2: Develop visualizations that illustrate the inappropriate behavior of SouthSeafood Express Corp vessels. How do their movement and catch contents compare to other fishing vessels? When and where did SouthSeafood Express Corp vessels perform their illegal fishing? How many different types of suspicious behaviors are observed? Use visual evidence to justify your conclusions.

Answer: To answer this question, the second and third dashboards were used. Regarding the *Snapper Snatcher*, its movement and behavior can be observed in the following images:

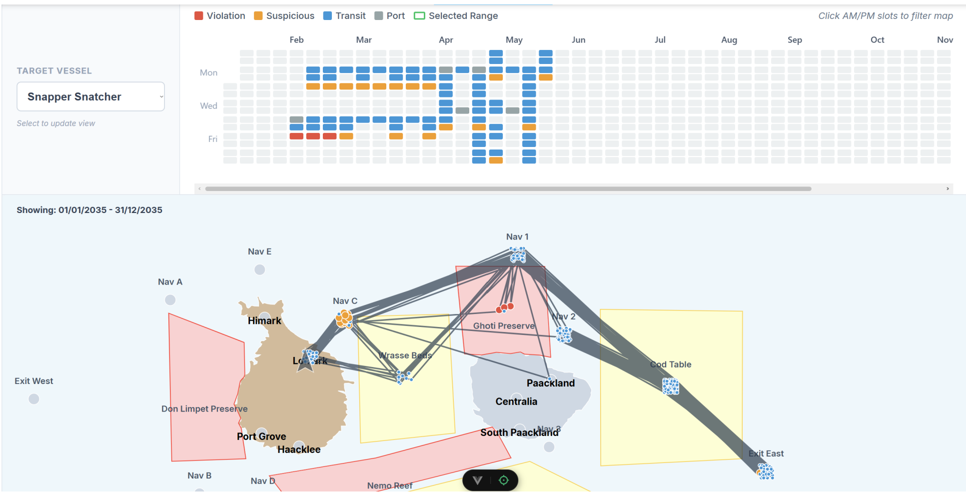

Figure 7: Calendar Heatmap (Top) and Trajectory Map (Bottom).

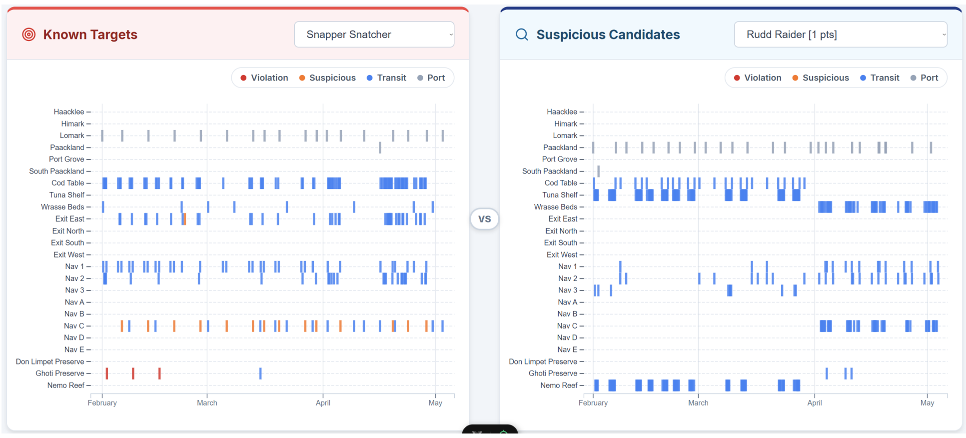

Figure 8: Comparison view: contrasting the activity patterns of suspicious vs. regular vessels.

Figure 7 displays the ship's movements and the types of activities in each area. In particular, there are suspicious activities at Buoy "Nav C", where the ship stays significantly longer than others, as well as illegal activities in the Ghoti Preserve. This suggests that the vessel likely engages in transshipment near Nav C before returning to port, while also conducting illegal fishing in a Preserved Area.
The daily heatmap shows that from February to April, the *Snapper Snatcher* exhibits a regular pattern: on Mondays, it conducts legal activities, but on Tuesday mornings (around 5 AM, checking the tooltip), it lingers at Nav C for an extended period. Another irregular behavior occurs on early Friday mornings, where the vessel stays in the Ghoti Preserve for an excessive amount of time.

In contrast, the *Roach Robber* shows suspicious activities primarily near Nav C (suggesting transshipment) and Nav 1, which is located near the Ghoti Preserve. It is suspected that the vessel loiters there to wait for an opportunity to enter the preserve undetected.
Figure 8 presents a comparison between the *Snapper Snatcher* and the *Rudd Raider*, a vessel with no suspicious record. In this case, it can be observed that the *Rudd Raider* spends most of its time in the Tuna Shelf area and Wrasse Beds, fishing in legal zones. It also passes near some buoys and enters the Nemo Reef area, but only for a reasonable duration.
In conclusion, SouthSeafood Express Corp vessels spend excessive time illegally transiting through Preserved Zones and engage in suspicious activities near buoys, likely either for transshipment or to wait before entering illegal fishing grounds.

Question 3: To support further Fisheye investigations, develop visual analytics workflows that allow you to discover other vessels engaging in behaviors similar to SouthSeafood Express Corp's illegal activities? Provide visual evidence of the similarities.

Answer: Visual evidence of these similarities is presented in Figure 9.

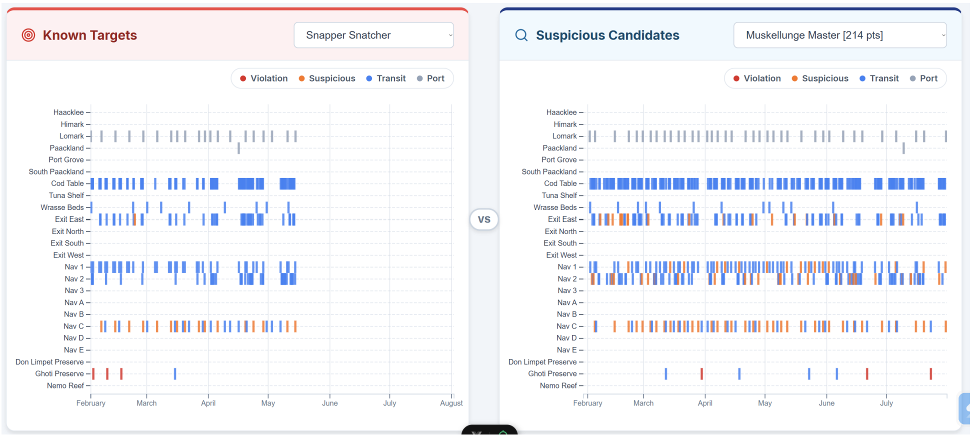

Figure 9: Comparison view: contrasting the activity patterns of suspicious vs. regular vessels.

This comparison features the *Snapper Snatcher* alongside one of the identified suspicious vessels, the *Muskellunge Master*. Although the latter does not have the highest anomaly score among the candidates discussed previously, it exhibits behavior patterns remarkably similar to the *Snapper Snatcher*. For instance, both vessels operate on the same routes, conduct suspicious activities near the "Nav C" buoy, likely for transshipment purposes, and spend excessive time within the Ghoti Preserve.
However, a slight difference is observed: the *Muskellunge Master* spends suspicious amounts of time near Exit East. This is likely an attempt to offload illegal catch to international carrier vessels just outside the monitored jurisdiction, thereby avoiding inspections at local ports.
In general, other suspicious candidates appear to engage in illegal activities even more frequently than the SouthSeafood vessels. A common pattern emerges across the dataset: most suspicious vessels loiter near buoys situated in close proximity to preserved zones, likely waiting for the opportune moment to enter undetected, or they blatantly remain within illegal fishing grounds for extended periods.

Question 4: How did fishing activity change after SouthSeafood Express Corp was caught? What new behaviors in the Oceanus commercial fishing community are most suspicious and why?

Answer: While the third dashboard (Figures 9 and 8) highlights the behavioral changes of specific vessels following the ban of SouthSeafood Express Corp, an overview of the fleet is provided by the fourth dashboard in Figure 6.
The *Daily Activity Shift* plot (left panel) reveals a counter-intuitive trend. Despite the removal of SouthSeafood vessels, which primarily operated in "Nav C", "Wrasse Beds", "Cod Table", and "Exit East", suspicious activities in these areas have not decreased; in many cases, they have intensified.
Specifically, "Nav C" shows an increase in transit activity (+20.70) and a marked increase in suspicious behavior (+1.03). Similar upward trends in suspicious activities are observed at "Nav 2" (+1.02), "Nav

1" (+0.90), Nav 3 (+0.33) and "Exit East" (+0.37). Even "Nav D", while showing a decrease in general transit, exhibit an uptick in suspicious events (+0.64).
A critical anomaly is observed in "Nemo Reef": while general traffic has significantly decreased, recorded violations have spiked by +1.31. Conversely, the "Ghoti Preserve" is absent from the plot, indicating that the net change in activity levels did not exceed the significance threshold (< 0.15).

These shifts can be translated into three key phenomena resulting from the ban:

1. **The Replacement Effect:** The increase in suspicious activities at "Nav C", "Nav 1", and "Nav 2" (buoys located near preserved zones) suggests that other vessels have filled the void left by SouthSeafood. New actors appear to be adopting the same *modus operandi*: loitering at these strategic buoys to wait for the opportune moment to enter the preserves undetected or to perform transshipments.

2. **Aggressive Poaching in Nemo Reef:** The data for "Nemo Reef" describes a scenario where legitimate traffic has diminished, but illegal poaching has become more brazen and frequent (+1.31 violations), suggesting a shift in target for illegal fishermen.

3. **Seasonal vs. Criminal Factors:** The general decrease in activity at the "Tuna Shelf" is likely attributable to seasonal factors or fish migration patterns rather than the ban itself.

In conclusion, the ban successfully removed SouthSeafood vessels, but the infrastructure of illegal fishing (using specific buoys as staging grounds) persists and has been co-opted by other suspicious entities.

5 Conclusions

The visual analytics system developed for the VAST Challenge 2024 (Mini-Challenge 2) successfully addressed the complex task of identifying Illegal, Unreported, and Unregulated fishing within the CatchNet network. By shifting the analytical focus from raw geospatial points to semantically enriched trajectories, the system overcame the limitations of traditional density maps, allowing for the precise reconstruction of illicit behaviors and the logic behind them.
From a methodological perspective, the adoption of **Dynamic Thresholding** proved essential. The statistical profiling of dwell times, specifically utilizing the 90^{th} percentile to flag outliers, successfully filtered out legitimate transit noise, isolating true loitering events without relying on arbitrary constants. Furthermore, the implementation of the **Diverging Stacked Bar Chart** for the post-ban analysis provided an attentive mechanism for detecting displacement trends compared to traditional time-series line charts.
The investigation yielded three critical insights regarding the Oceanus fishing industry. First, the project demonstrated the feasibility of **Cargo Attribution** despite missing identifiers in port-exit records. Spatiotemporal matching algorithms revealed that legitimate trade channels are frequently used to launder fish harvested from protected areas, specifically tracing the flow of illegal catch from *Nemo Reef* directly to commercial ports. Second, the analysis of *SouthSeafood Express Corp* confirmed that their vessels utilized specific navigation buoys (e.g., Nav C) as staging grounds for transshipment. However, the comparative analysis revealed that this *modus operandi* is systemic: numerous other "shadow" vessels in the fleet exhibit identical behavioral signatures, confirming that illegal fishing is not limited to a single rogue operator.
Finally, the most significant finding concerns the impact of the ban imposed on SouthSeafood. While the targeted company was removed, the infrastructure of illegal activity persisted. The "Activity Shift" analysis quantified a distinctive **Replacement Effect**, where new actors immediately filled the void in strategic loitering zones like Nav C and Nav 1. Moreover, the data highlighted a worrying intensification of aggressive poaching in *Nemo Reef* post-ban. This suggests that the regulatory intervention treated the symptom rather than the disease, as the lack of effective surveillance at buoys and preserves continues to be exploited.