Hydrodynamic Optimization of Turtle Excluder Device (TED) for Enhanced Trawl Performance and Sustainability

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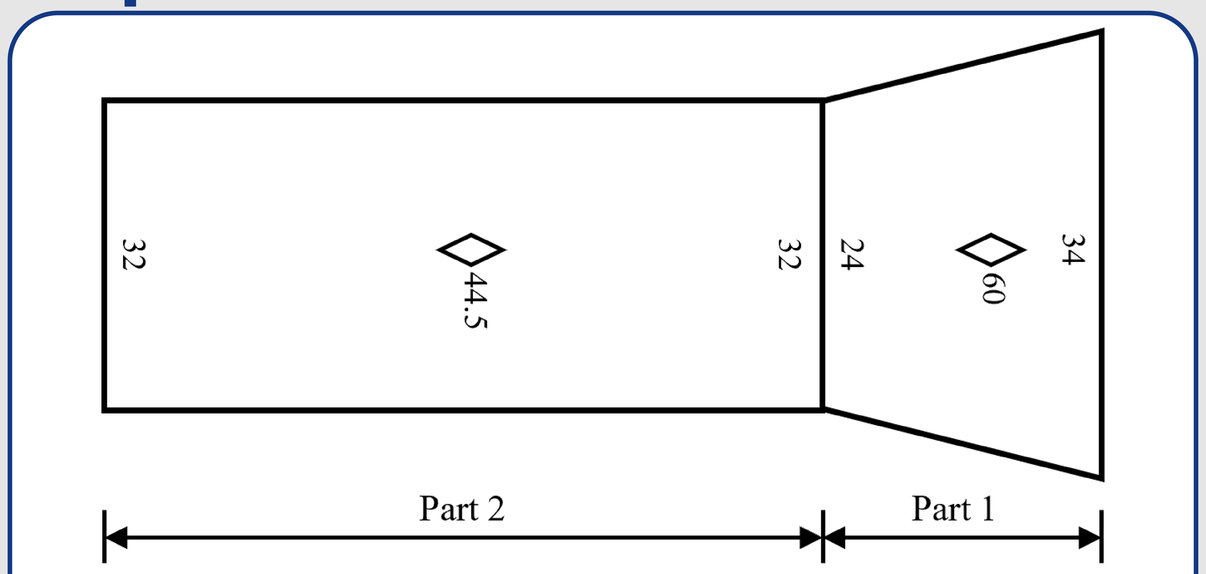
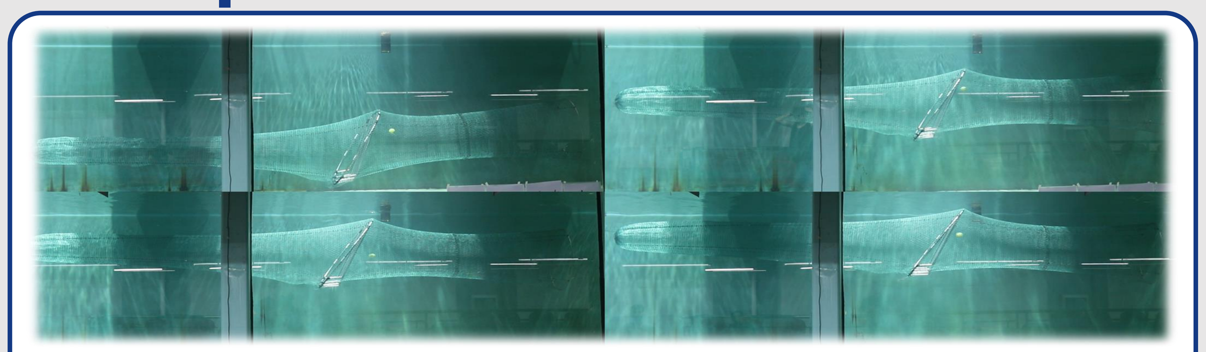
Experiment model

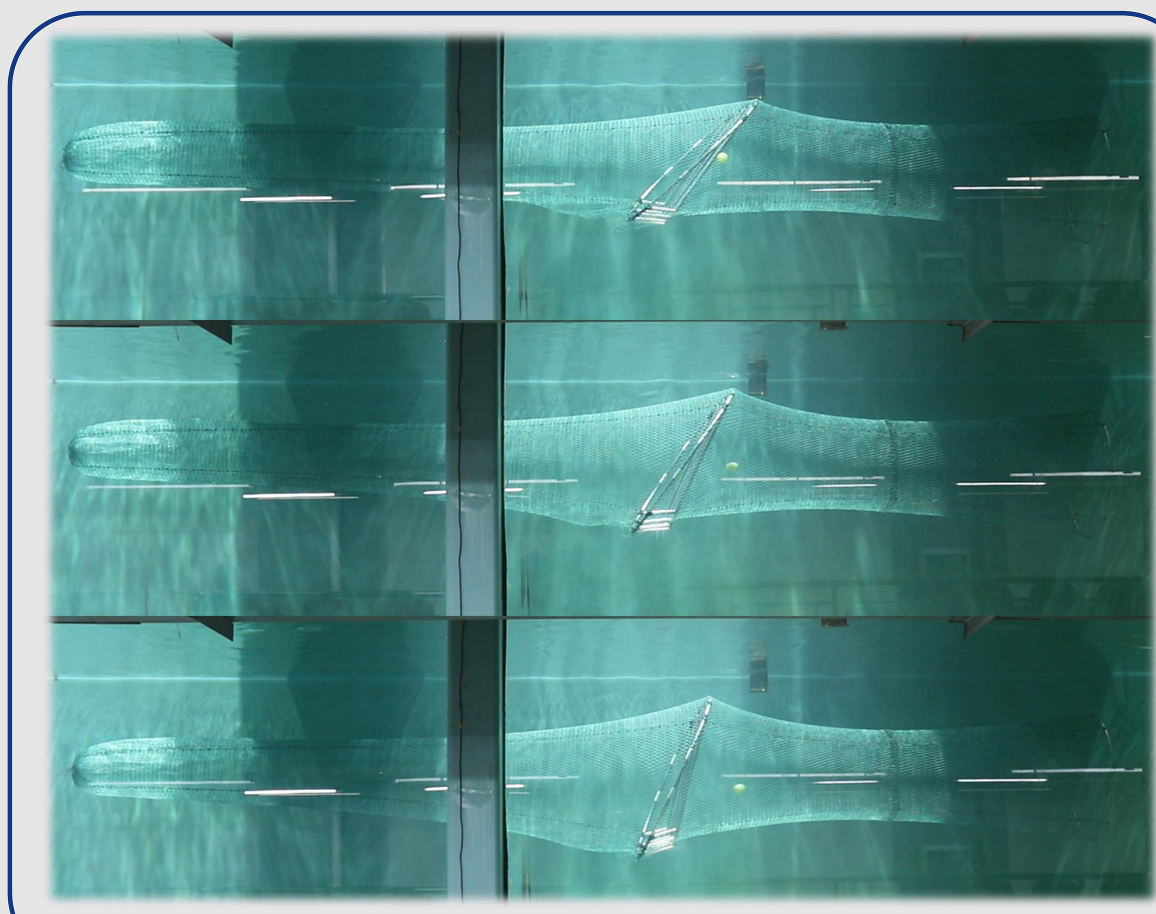


Model codend

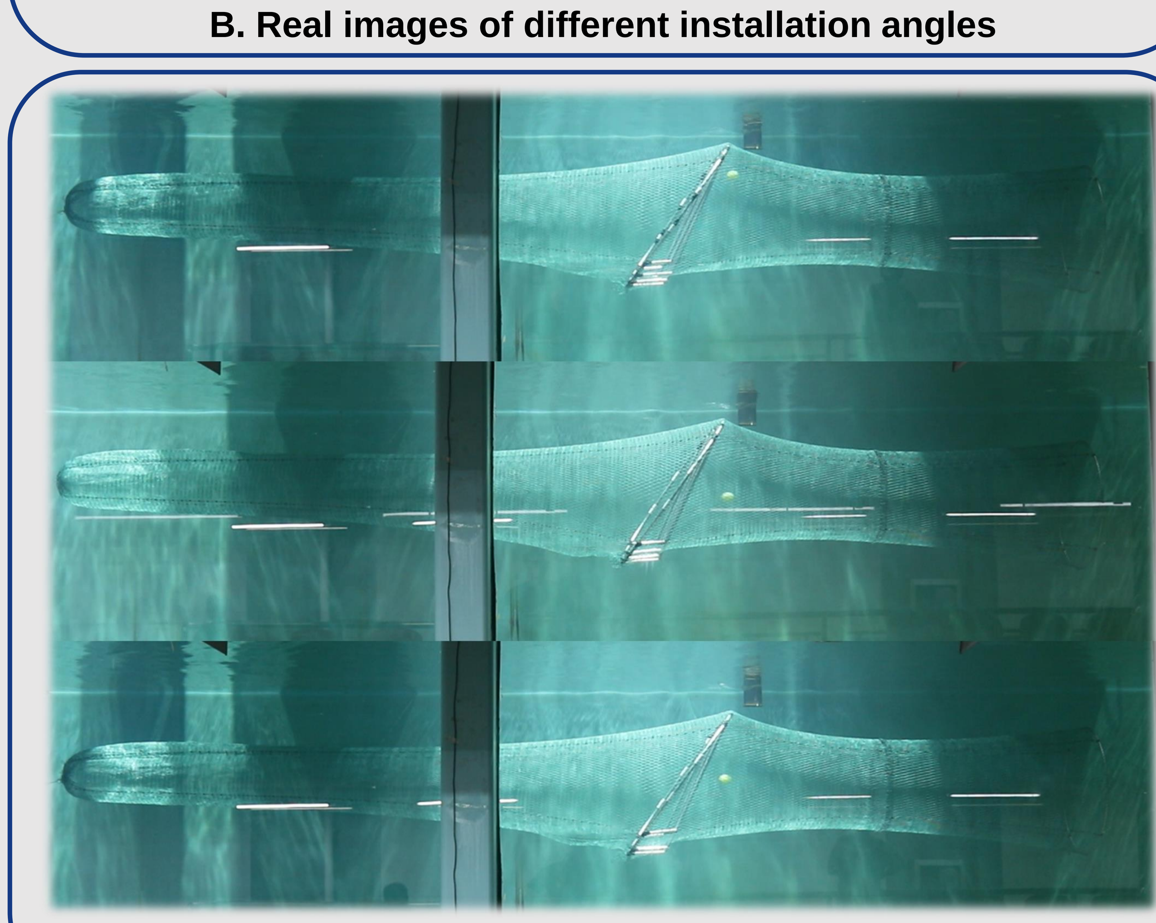
Real photos of the test



A. Real images of different flow velocity



B. Real images of different installation angles



C. Real images of different grid spacings

Background

The Turtle Excluder Device (TED) is one of the most effective and widely used selective devices in global trawl fisheries. It plays a vital role in reducing bycatch, enhancing the escape success of non-target species, and improving trawl selectivity, thereby contributing to sustainable fishery management. However, the hydrodynamic performance and structural stability of the TED–codend system are strongly influenced by its bar spacing, installation angle, and flow velocity. These parameters directly affect drag force, flow pattern, and the morphological behavior of the codend during operation. To address these issues, this study experimentally investigated the hydrodynamic characteristics of the codend equipped with sorting grids under varying conditions and developed a genetic algorithm framework to identify the optimal configuration that achieves both hydrodynamic efficiency and gear stability.

Materials and Methods

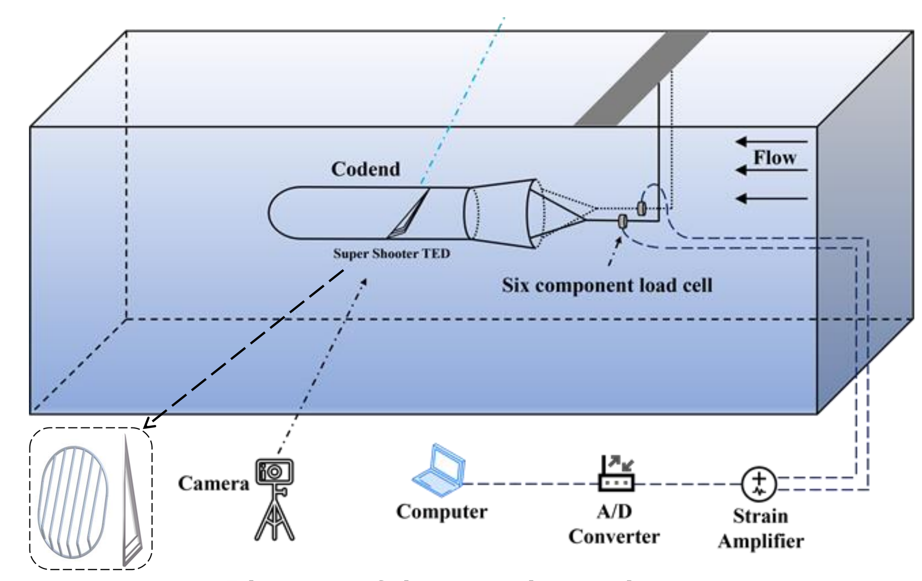
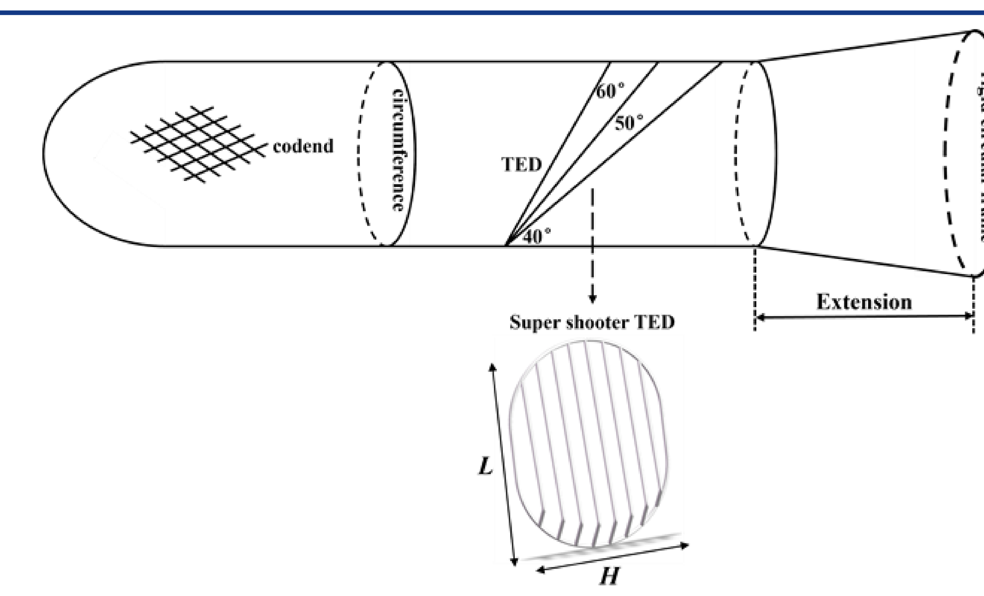


Diagram of the experimental setup



Schematic diagram of the codend model equipped with TED assembly

Measurement system

- The model codend was centered in the flume and allowed to move freely.
- High-definition video (59 Hz, 1920 × 1080) recorded the shape variations of the codend.
- Drag force was measured using a submerged steel ring (Ø 0.7 m) connected to two bridles and equipped with micro tensiometers.
- Signals from the sensors and flow meters were amplified and digitized at 100 Hz for analysis.

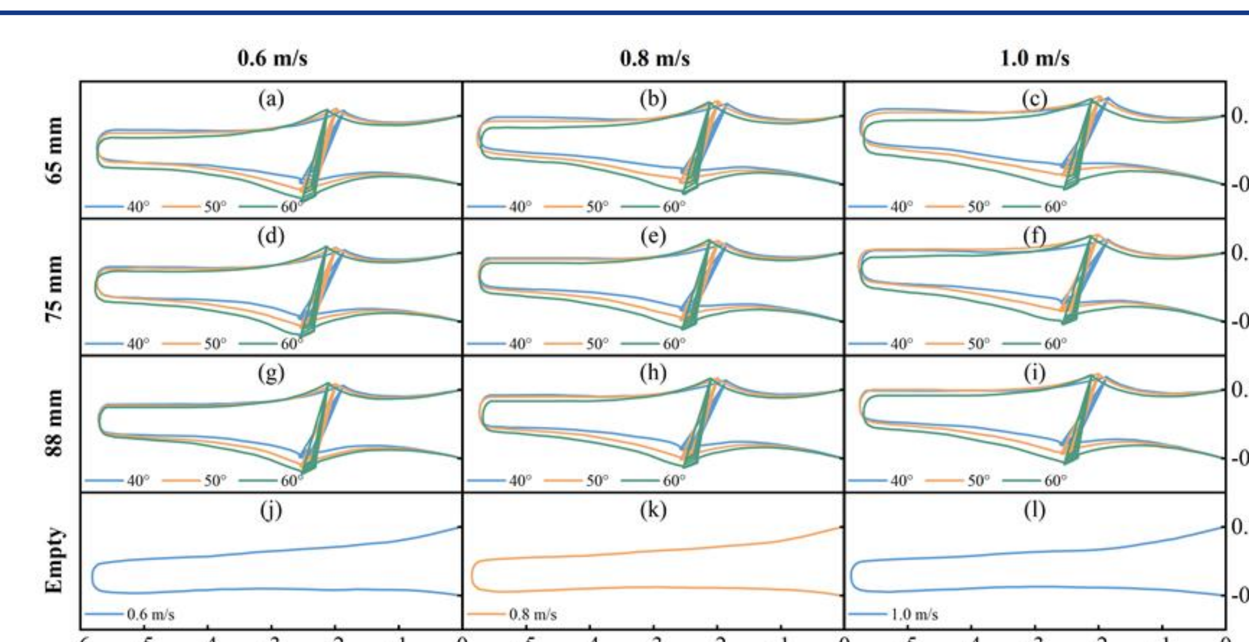
Test procedure

- Baseline drag of the circular frame was measured at three velocities.
- The empty codend was tested under identical conditions.
- The TED-equipped codend was then installed and measured for all combinations of bar spacing and installation angle.
- A 30-second video was recorded after flow stabilization to capture the final codend shape.

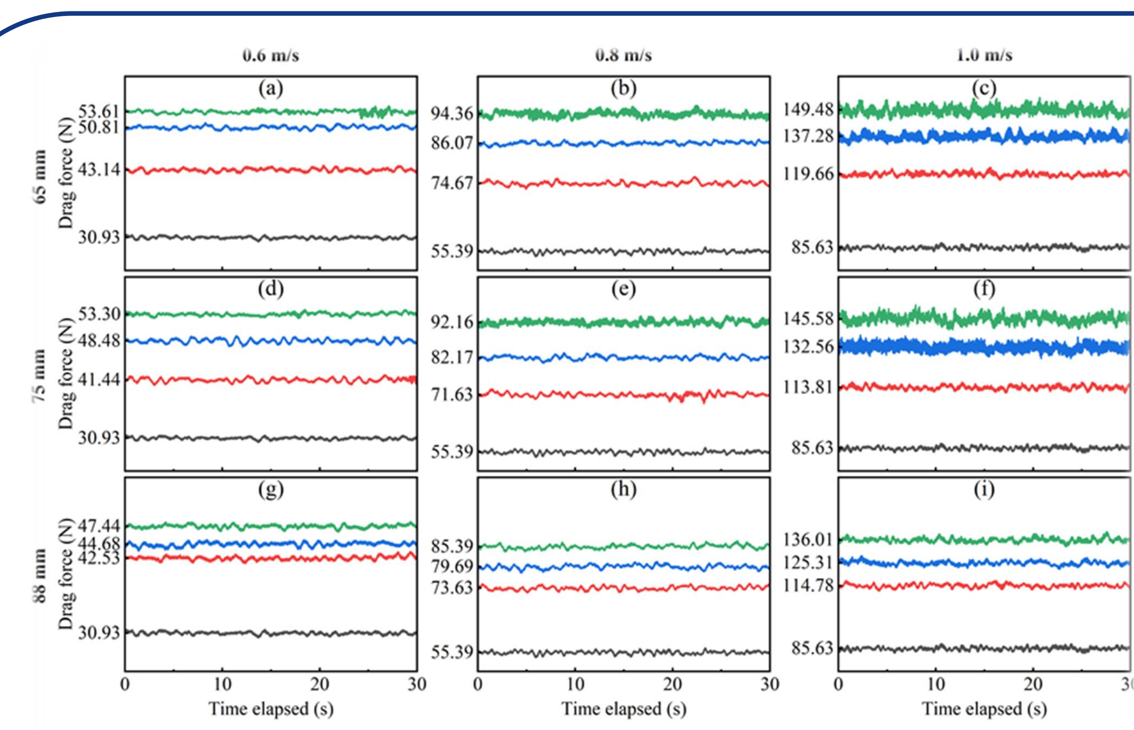
Results

(1) **Codend morphology under different conditions**

- **Empty codend:** Maintained a uniform cross-sectional shape across all flow velocities, though a slight contraction occurred with increasing flow speed.
- **TED-equipped codend:** The installation of the TED significantly altered the codend shape, producing a localized contraction and a lifted centerline as flow velocity increased.
- Installation angle was the dominant factor affecting codend stability.
- Bar spacing had a minor effect on morphology.



Codend morphological changes in response to different grid bar spacings, TED installation angles, and flow velocities from recorded video cameras

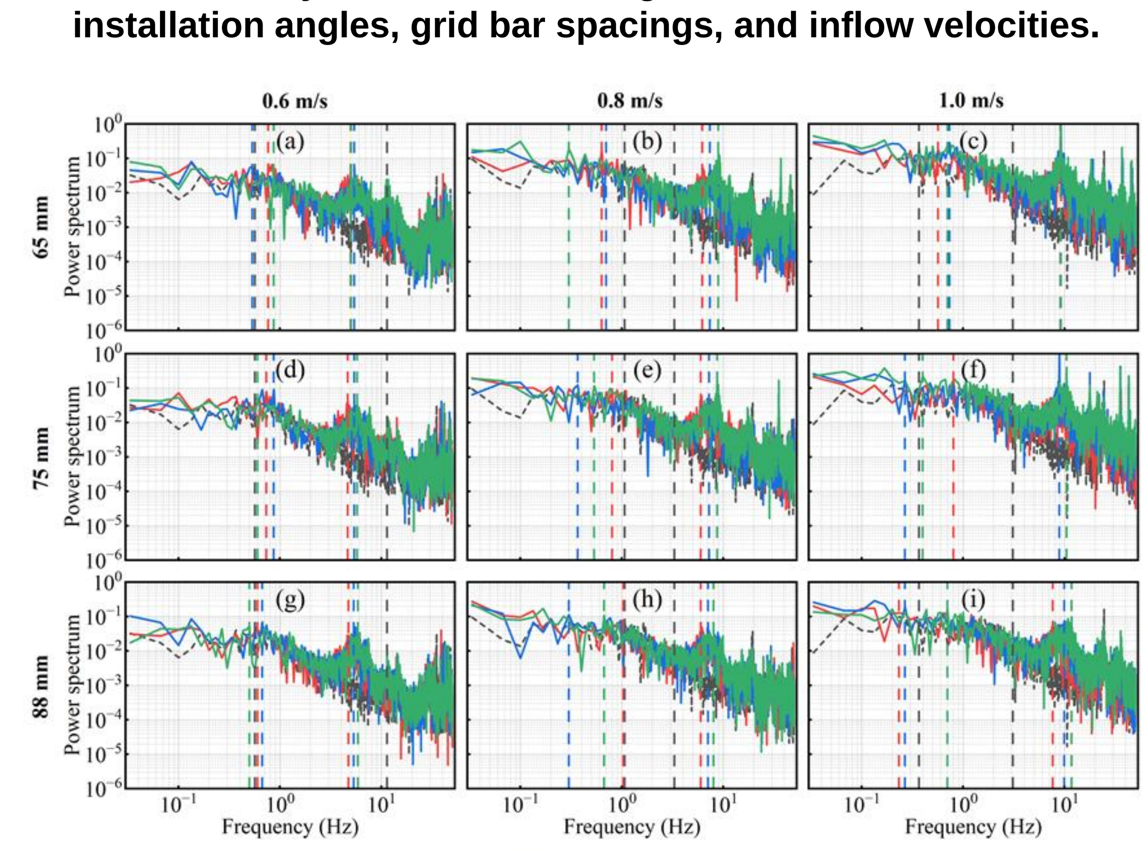


Time history of the codend drag force at under different installation angles, grid bar spacings, and inflow velocities.

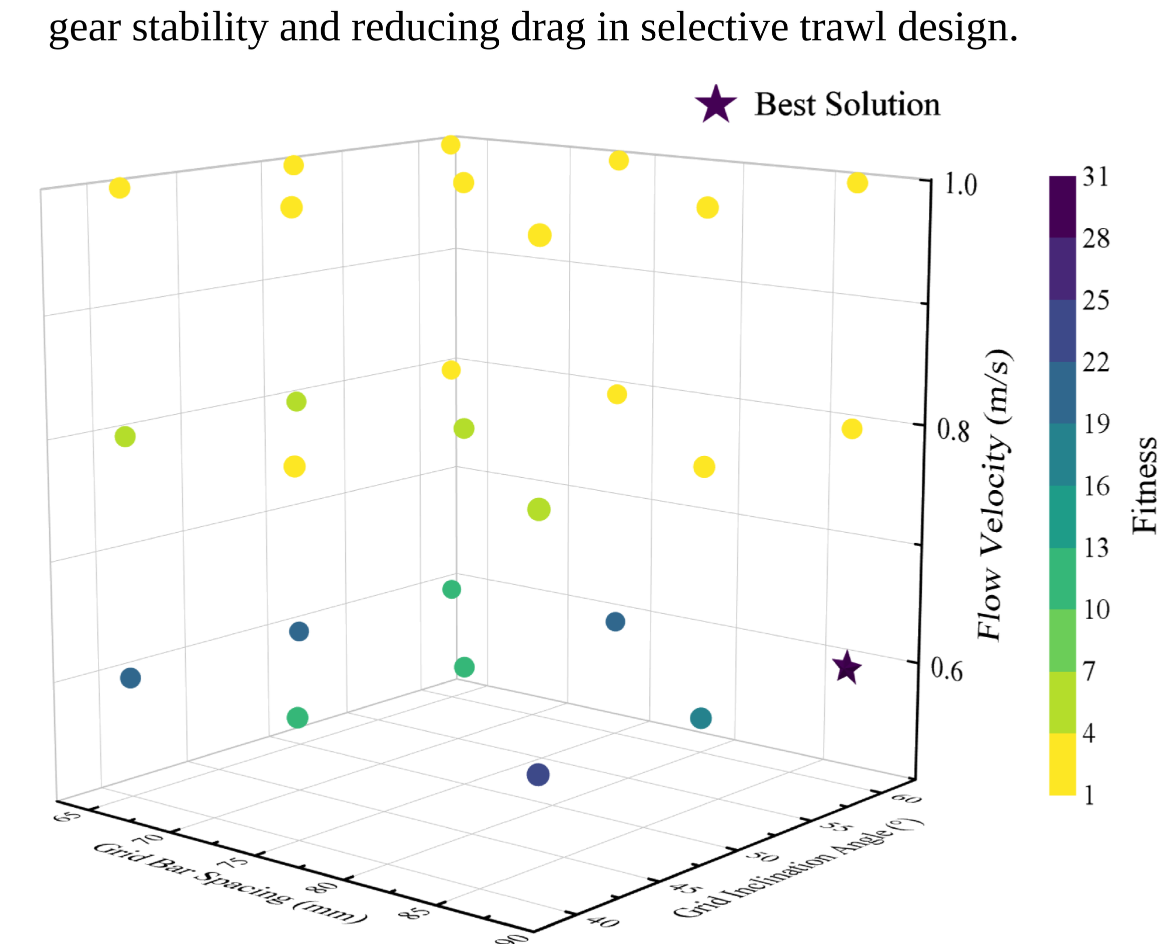
(2) The presence of TED substantially increases codend drag and oscillation amplitude, with installation angle being the primary driver, followed by bar spacing and flow velocity.

(3) The TED grid induces low-frequency dominant oscillations and significantly increases hydrodynamic fluctuation energy, particularly at higher flow speeds and larger installation angles.

(4) The GA effectively identified the optimal TED setup (88 mm, 60°, 0.6 m/s), providing a quantitative guideline for enhancing gear stability and reducing drag in selective trawl design.



Normalized frequency spectrum of the codend drag force under different grid bar spacings installation angles, and flow velocity



Parameter space fitness distribution.

Conclusions

- TED significantly alters the hydrodynamic behavior and morphology of the trawl codend.
- Installing a TED increased mean drag by 29–75% compared to an empty codend, with drag rising as bar spacing decreased, and as installation angle and flow velocity increased.
- 60° improved codend stability, maintaining a greater cross-sectional area and reducing shape deformation under flow.
- Fourier analysis revealed that drag fluctuations were dominated by low-frequency components and the power spectral energy of TED codends was 68–96% higher than that of the empty codend due to grid-induced flow disturbances.
- The genetic algorithm efficiently converged within six generations, identifying the optimal.