



At-sea comparative testing of the effects of different towed objects on the aerial performance of tori lines in tuna longline fisheries



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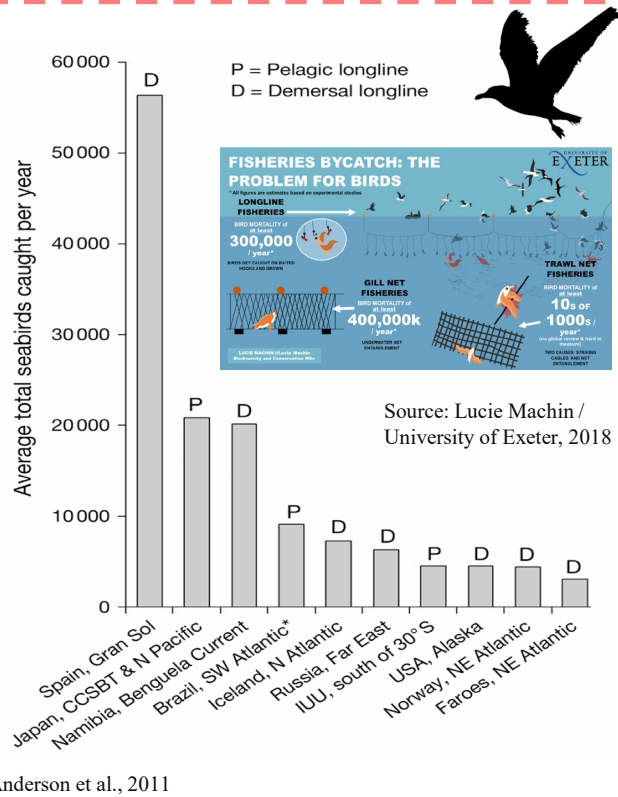
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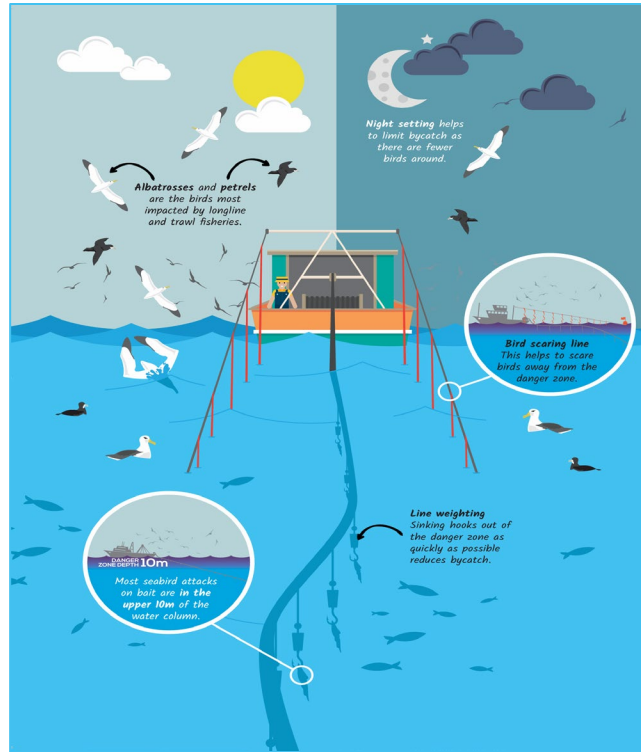
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Seabird Bycatch in Longline Fisheries and the Need for Mitigation

Seabird bycatch in fisheries



Mitigation measures



Source: ACAP

Mitigation measures

- Effective mitigation aims to reduce seabird access to baited hooks.
- In practice, mitigation measures are often used in combination.
- Tori lines are widely used
 - Highly adaptable
 - Low cost
 - Simple to deploy

Current status

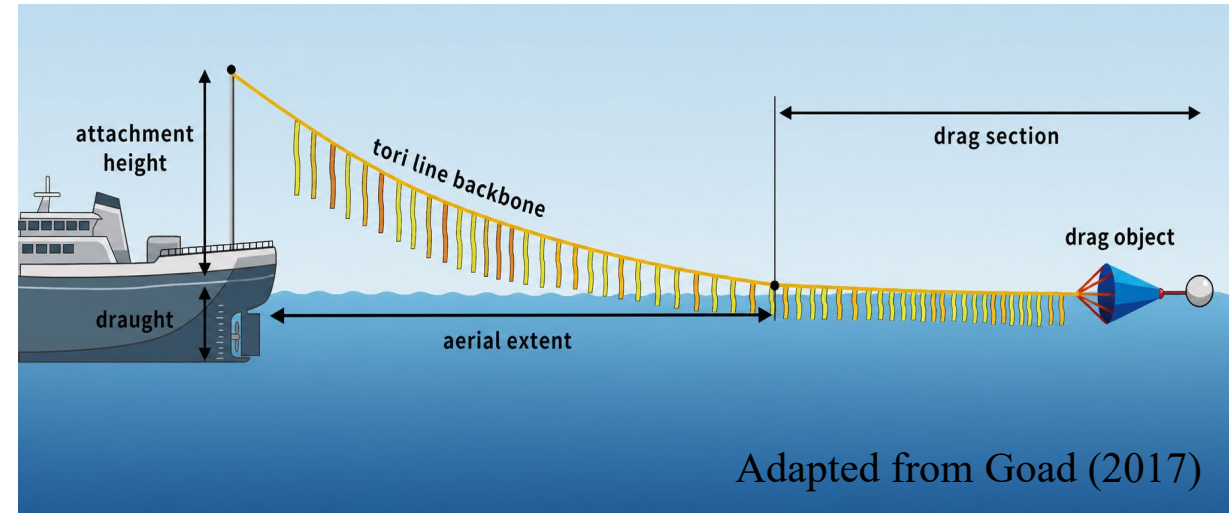
- Fishing operations cause substantial seabird mortality worldwide each year.
- Longline fisheries are one source of seabird bycatch.

Tori Line Aerial Performance and Aerial Extent

Aerial Extent: Definition and Importance

The protective performance of a tori line depends largely on whether it can form a sufficiently long and relatively stable aerial coverage over the key area astern of the vessel. The core quantitative indicator used to evaluate this coverage is **aerial extent**, which refers to the horizontal above-water distance from the tori line attachment point to the point where the line first contacts the sea surface (ACAP, 2019; Melvin et al., 2014).

How can sufficient aerial extent be maintained?



Increasing the overall length of the tori line

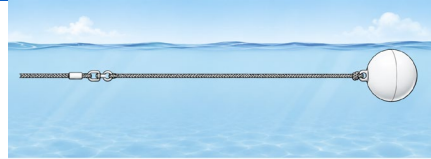
- Provides the basis for forming an aerial coverage zone, but does not necessarily ensure stable deployment.
- Deployment height, streamer length, streamer spacing, and other parameters are also important.

Tail-end towed objects provide drag

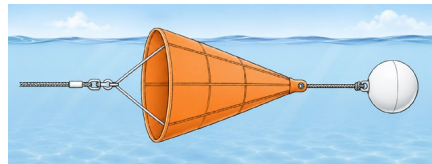
- Different towed objects may vary in drag magnitude, stability, and motion at the water surface, resulting in marked differences in aerial extent.

Principle and Progress of Tori-line Towed Objects

Principle



- Towed objects generate hydrodynamic drag in the water.
- This helps maintain tension in the tori line backbone and the deployment state of the aerial section.
- It can increase and stabilize the aerial coverage area astern of the vessel.



Research progress

- Goad (2017) divided the tori line into an **aerial section** and a **drag section**, and tested different drag-section designs.
- Melvin et al. (2014) and ACAP indicate that **drag is an important condition** for achieving sufficient aerial extent.
- Existing studies have focused more on the overall effectiveness and deployment specifications of tori lines.

Do different types of towed objects provide sufficient and stable drag to maintain tori-line aerial extent?

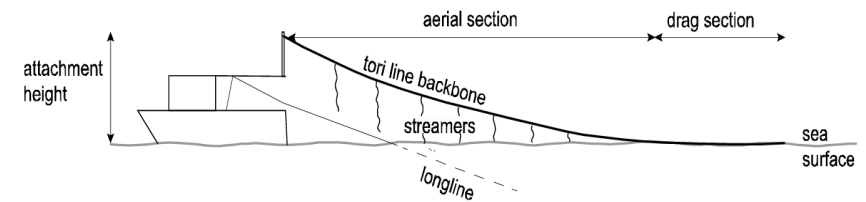


Figure 1: Tori line components.

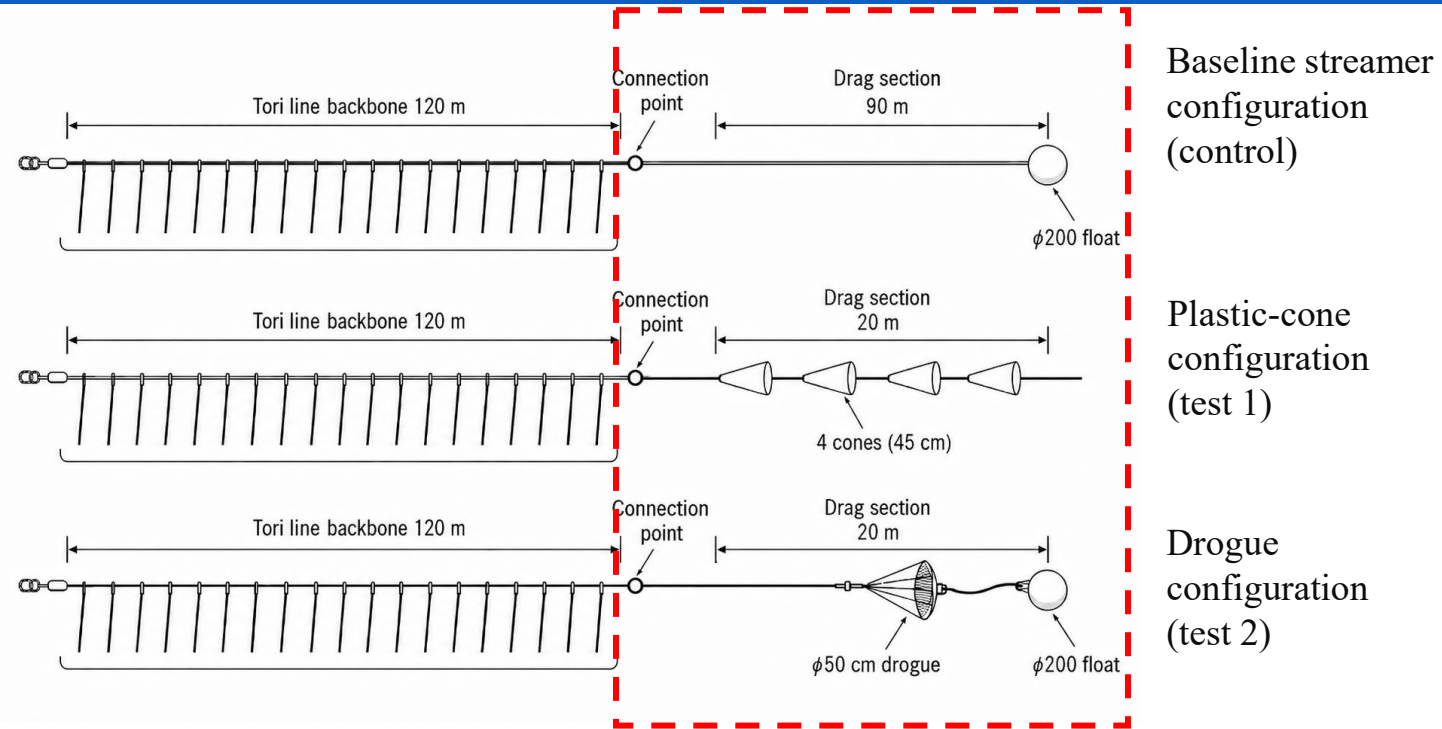


Figure 4: Drag section components for demersal longliners.

(Goad, 2017)

Design rationale

- Keep the main-section structure fixed
- Modify the towed objects in the drag section
- Compare aerial extent under representative vessel speeds






Objective: To evaluate how different tail-end towed objects affect the aerial extent of tori lines.

Evaluation metrics

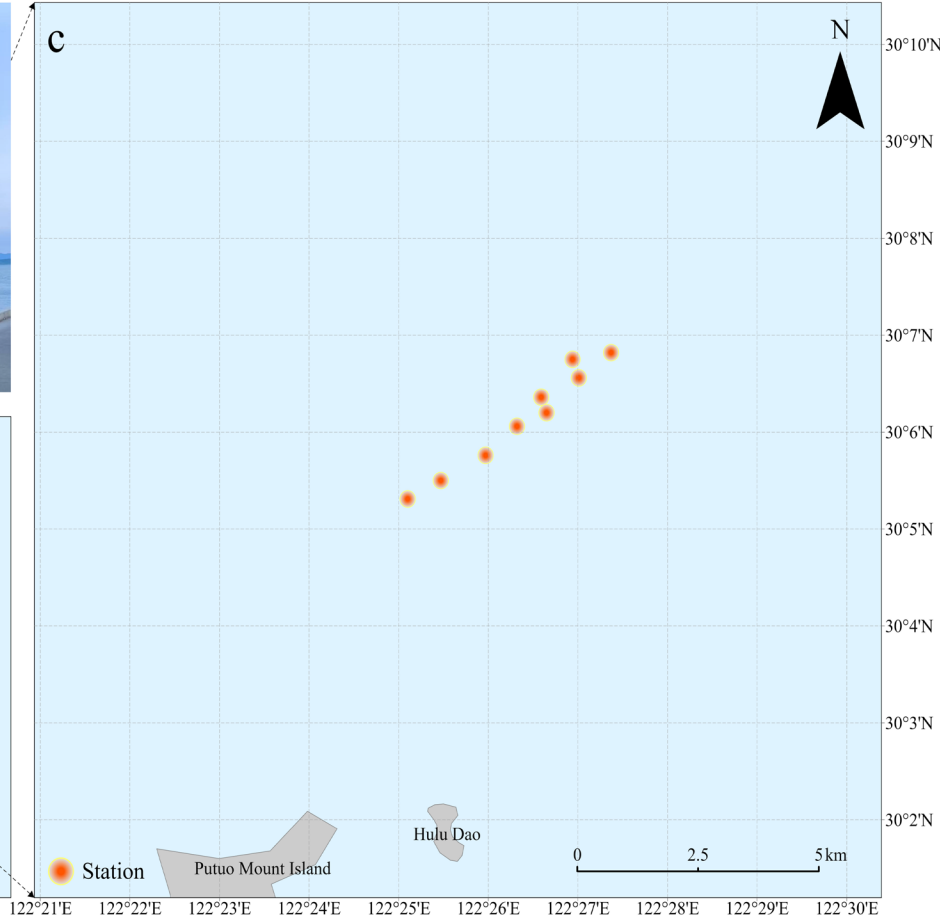
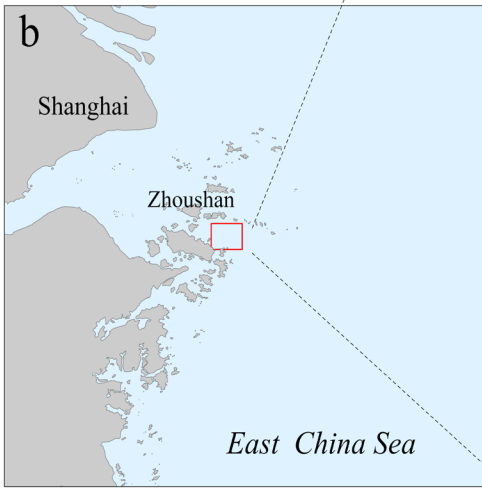
- Aerial extent
- 100 m reference benchmark
- Relative change compared with the baseline streamer configuration

Three Tori Line Configurations

Main structural parameters of the three tori line configurations

Type	Photograph	Overall length	Design rationale	Backbone
Baseline streamer configuration (control)		210 m	Used as the baseline control configuration to represent the conventional aerial deployment state without additional towed objects.	The backbone was 120 m long and made of 4.8 mm-diameter ultra-high-molecular-weight polyethylene rope.
Plastic-cone configuration (test)		140 m	Lightweight plastic cones were arranged in series along the drag section to modify the drag distribution and test whether small distributed objects could increase tail-end disturbance and drag, thereby improving aerial extent.	120 m, consistent with the backbone structure of the baseline streamer configuration.
Drogue configuration (test)		140 m	A drogue with a relatively large submerged projected area was attached to the drag section, together with a float to control its operating posture and depth. This was designed to generate more stable and concentrated hydrodynamic drag, thereby increasing backbone tension and improving aerial stability.	120 m, consistent with the backbone structure of the baseline streamer configuration.

Test Vessel and Study Area



Date: 2025/11/03

Location: waters near Zhoushan,
Zhejiang Province, China

Area: 30°05'N-30°07'N

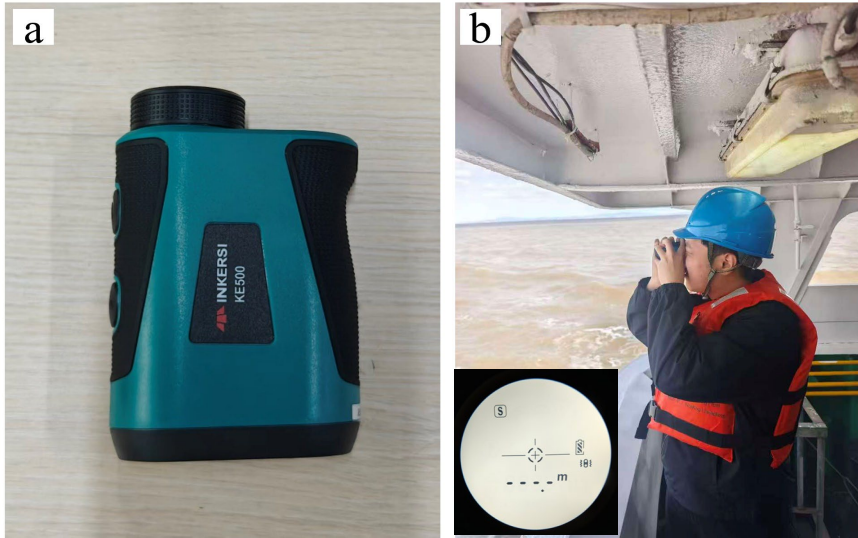
122°25'E-122°28'E

Vessel: *Rongheng 513* (tuna longline)

- Length: 44.19 m
- Beam: 7.60 m
- Gross tonnage: 471 t
- Engine power: 960 kW

Schematic map of the test vessel, study area, and test stations

Aerial Extent Measurement and Data Recording

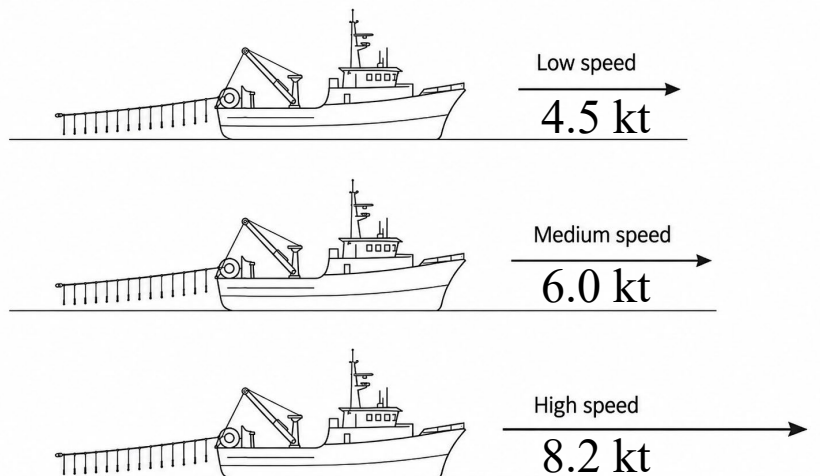


Equipment and field measurement of tori-line aerial extent

Main measurement instruments

- Visual laser rangefinder (INKERSI KE500)
 - Measurement accuracy: $\pm(1 + D \times 0.3\%) \text{ m}$
 - Horizontal distance measurement mode
- Handheld anemometer and onboard instruments

Procedure



After 5 min of stable towing



- Core metric
 - Aerial extent
- Other parameters
 - Wind speed
 - Current speed
 - Current direction

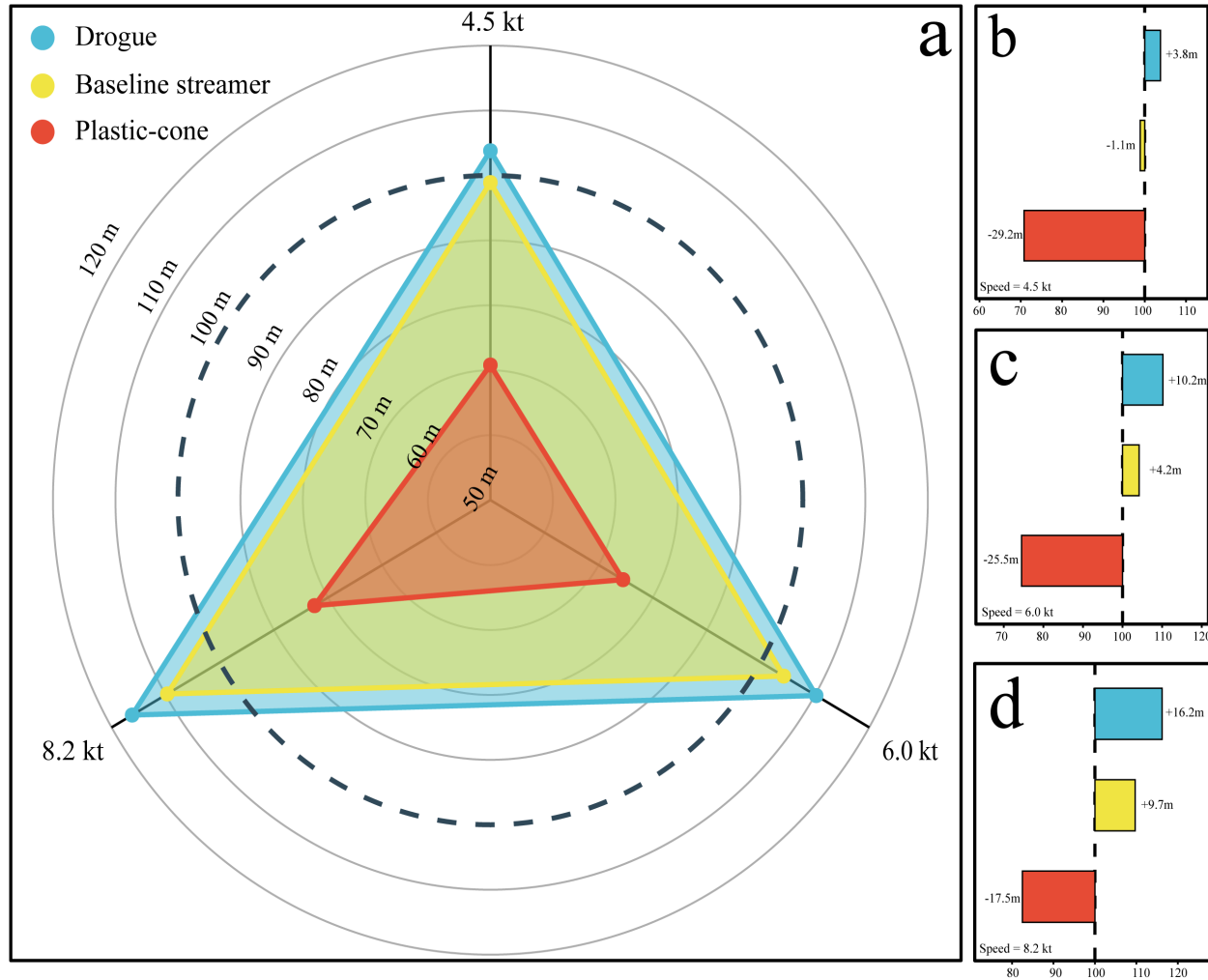
At-sea Test Conditions

Meteorological and current conditions were relatively stable during the overall testing window

- Current speed remained stable at 1.4–1.6 km/h
- Wind speed ranged from approximately 12.7 to 28.6 km/h
 - Wind speed was relatively lower during tests of the baseline streamer configuration
 - Wind speed was relatively higher during tests of the plastic-cone and drogue configurations

No.	Type	Vessel speed (kt) / heading	Wind speed (km/h)	Current speed (km/h) / direction
1	Plastic-cone	4.5/59°	28.6	1.6/65°
2	Plastic-cone	6.0/59°	27.9	1.6/65°
3	Plastic-cone	8.2/59°	26.3	1.6/65°
4	Drogue	4.5/38°	26.2	1.5/65°
5	Drogue	6.0/38°	24.8	1.5/65°
6	Drogue	8.2/38°	22.7	1.5/65°
7	Baseline streamer	4.5/225°	15.8	1.4/65°
8	Baseline streamer	6.0/225°	13.9	1.4/65°
9	Baseline streamer	8.2/225°	12.7	1.4/65°

Aerial Extent Performance of Different Configurations



Comprehensive comparison of aerial extent among different tori line configurations at different vessel speeds. Panel a shows the overall performance of the three configurations, while panels b–d show the margins relative to the 100 m reference benchmark at vessel speeds of 4.5, 6.0, and 8.2 kt, respectively.

Type \ Speed (kt)	4.5	6.0	8.2
Baseline streamer	98.9	104.2	109.7
Plastic-cone	70.8	74.5	82.5
Drogue	103.8	110.2	116.2

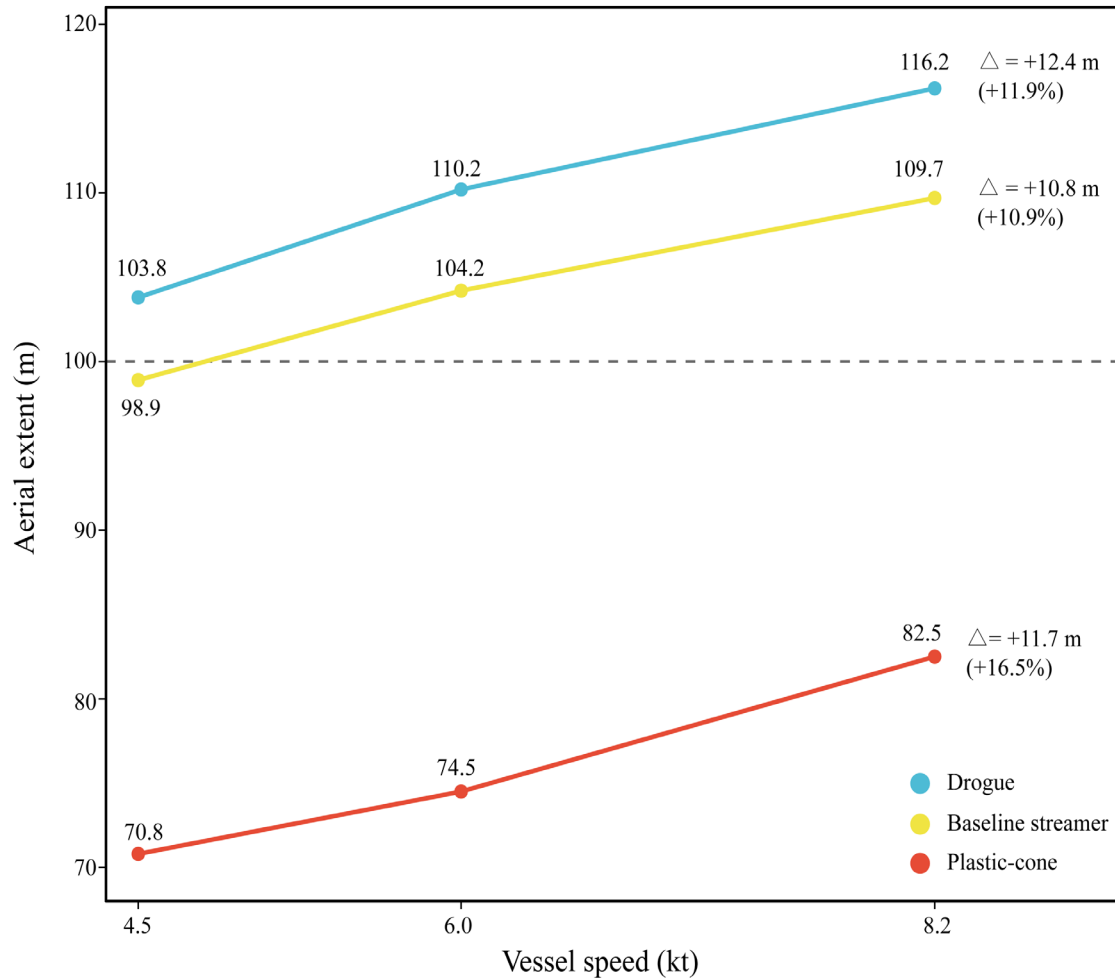
Aerial extent

- At all three vessel speeds, the **drogue configuration performed best**, followed by the baseline streamer configuration, while the plastic-cone configuration performed worst.

100 m reference benchmark

- Drogue remained above 100 m with sufficient margins.
- Baseline streamer was slightly below 100 m at low speed.
- Plastic-cone remained below 100 m at all speeds.

Response of Aerial Extent to Vessel Speed



Baseline streamer configuration

- Aerial extent increased with vessel speed
- Aerial extent gain per unit vessel speed was 2.92 m/kt

Plastic-cone configuration

- Aerial extent gain per unit vessel speed was 3.16 m/kt
- Aerial extent was 28.4%, 28.5%, and 24.8% lower than that of baseline streamer configuration at the three vessel speeds

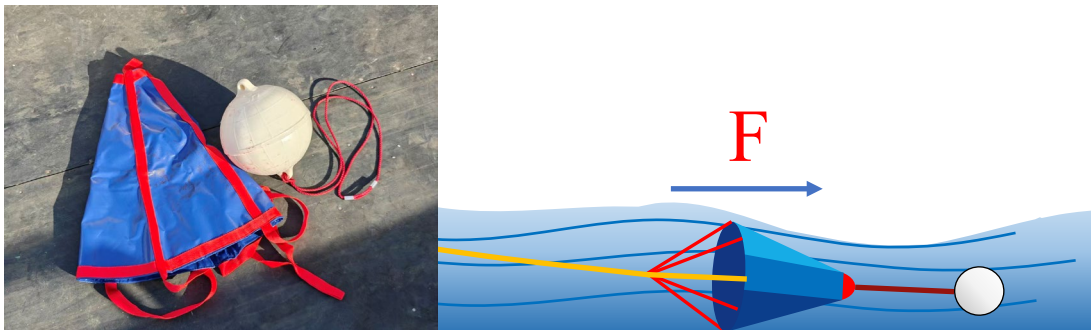
Drogue configuration

- Aerial extent gain per unit vessel speed was 3.35 m/kt
- Aerial extent was 5.0%, 5.8%, and 5.9% higher than that of baseline streamer configuration at the three vessel speeds

Possible Explanations for Differences in Aerial Performance

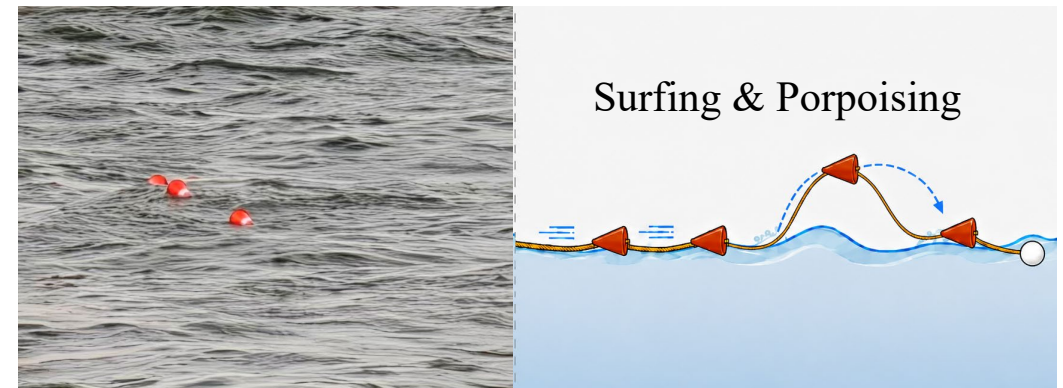
Drogue configuration

- Larger submerged projected area
- Float helps maintain working depth and posture
- Working posture provides stable hydrodynamic drag
- Increases backbone tension and extends aerial extent

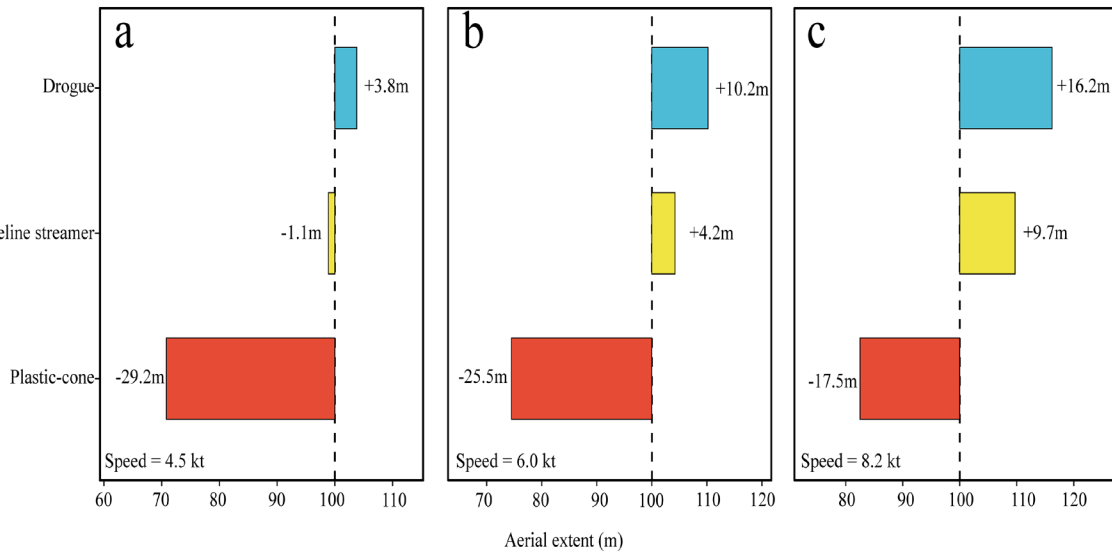


Plastic-cone configuration

- Relatively lightweight, with insufficient drag
- Prone to surfing or porpoising at the water surface
- Causes fluctuating or temporary loss of drag
- Reduces backbone tension and shortens aerial extent



Conclusions and Management Implications



Compared with the baseline streamer:

- Adding a drogue to the drag section **increased aerial extent**
- Adding plastic cones to the drag section **reduced aerial extent**
- The stability of tail-end drag affected aerial performance

Key implications

- Objects added to the drag section are not automatically beneficial.
- Poorly selected or dynamically unstable objects may reduce tori-line tension and deployment stability.
- CPCs are encouraged to evaluate different objects used in the drag section under fleet-specific operating conditions, with “sufficient and stable drag” as a design consideration.

Acknowledgements

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Comments and Questions?



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