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Direct marking method for the gillnet fishing gear deposit system using a multi-criteria value function

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01

Introduction

01. Introduction

1.1 Research background

➢ Research background

- ALDFG causes **ghost fishing, plastic pollution, bycatch**, and **habitat damage**
- Passive gears such as **gillnets and traps** are difficult to recover and may continue fishing even after they are lost
- Korea loses ~38,000 t of fishing gear/year; **gillnets account** for about **38.0%**
- Gear marking can support ownership, accountability, and gear recovery under the **FAO guidelines**
- Korea expanded the fishing gear deposit system from **traps** (2024) **to gillnets, buoys, and eel traps** in Jan. 2026

➢ Research necessity

- Effective marking requires durability, identification, fisher acceptance, and appropriate management units
- Previous studies mainly relied on expert **AHP analysis**, with limited fisher preference and sea-trial evidence
- An integrated decision framework is needed to link marking methods with refund, recovery verification, and traceability

1.2 Research objective

Research objective

Develop a multi-criteria framework for traceable gillnet marking by integrating expert AHP weights, fisher preferences, and sea-trial evidence to evaluate marking methods and management units

01 Develop an **MCVF*** for gillnet marking using existing **AHP weights**
* MCVF: Multi-Criteria Value Function

02 Select a **marking method** based on **fisher preferences and sea-trial retention**

03 Determine the **management unit** using **mixed weights** and assess its applicability to **ALDFG management**

02

Materials and Method

02. Materials and Method

2.1 Data collection

Decision components

① Marking type

Physical form of the mark attached to gillnet webbing

② Marking unit

Reference unit used to manage and identify the markings

Data sources

① Expert AHP weights

Reused from prior study

- Experts from government, research institutes, universities and gear companies
- Nine-point pairwise comparison survey (Figure 1 hierarchy)
- Only consistency-qualified weights used, without modification

② Stakeholder survey

Jul–Oct 2024

- 143 gillnet fishers (7 provinces) + 10 gear companies, pooled (n = 153)
- **Preferences for marking types and units** → preference proportions
- Marking type: effective n = 96 (62.7%); stated, not technical, performance

③ At-sea trials

Nov 2024

- A total of 1,856 markings on 3 types of gillnet (9 net panels)
- 6 repeated cycles per gear → 18 deployment–retrieval cycles
- Actual commercial operation; output = detachment rate

02. Materials and Method

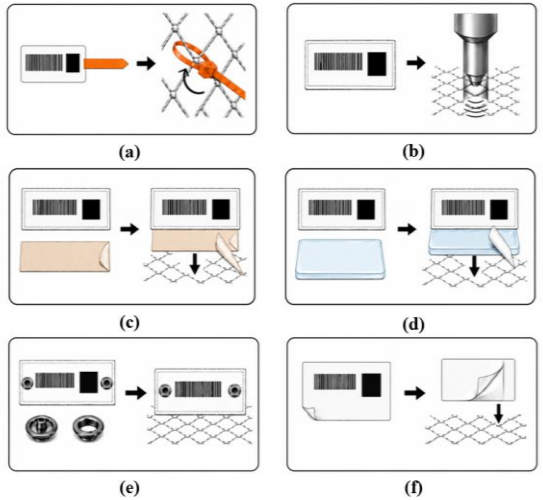
2.1 Data collection

Gillnet gear

<Table 1. Specifications of gillnet gear used in the at-sea trials>

Target species	Twine thickness (mm)	Mesh size (mm)	Horizontal mesh (mesh)	Vertical mesh (mesh)
Snow Crab ***(Chionoecetes opilio)***	0.435	240	1,265	18
Swimming Crab ***(Portunus trituberculatus)***	0.284	150	1,000	13
Yellow Croaker ***(Larimichthys polyactis)***	0.284	51	1,050	330

Six marking types

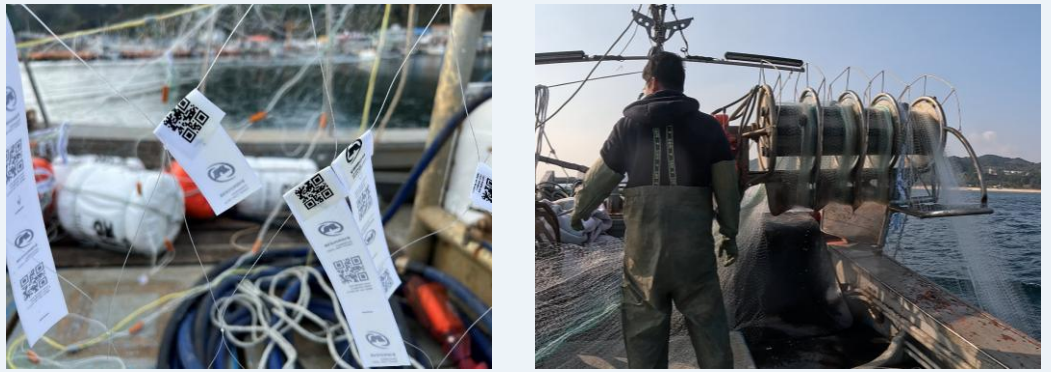


(a) Cable tie type 8 × 100 mm
Fiber label 16/30 × 80/160/240 mm
(b) Ultrasonic-welded
(c) Textile double-sided tape
(d) Gel-type double-sided tape
(e) Rivet-fastened
(f) Sticker type 26 × 630 mm

<Fig. 2. Schematic illustrations of the gillnet marking types used in at-sea trials>

Trial procedure

- 3 net panels per gear, tracked cumulatively over 6 fishing cycles (setting·hauling·onboard handling)
- Markings split equally between twine sections and knot points (fixed alternating pattern)
- Detachment was inspected after the 2nd, 4th and 6th trials
- Final evaluation = last available observation for each marking type



<Fig. 3. Label-type markings on fishing gear during hauling.>

2.2 Multi-criteria value function model

Model structure

AHP criteria weights
Expert judgment from our prior study

Field durability
Detachment rate · cost-type criterion

Stakeholder preference
Survey · benefit-type criterion

Approximate value function

- Inputs min–max normalized to a common suitability scale
- Increasing $V_i(u)$ for benefit · decreasing $V_d(u)$ for cost; curvature C
- Reference values = mean ± 1.96 × SE (95% CI of the mean)

Overall value

Weighted aggregation of single-attribute values → ranking of the six marking types

Sensitivity analysis

- Monte Carlo (N = 10,000) on AHP weights (mean, SD); negatives → 0, re-normalized to sum to 1
- Expanded run: detachment rates and preference proportions also resampled (binomial SE, n = 153)
- Linear weighted-sum model (c = 0) compared via Kendall's τ and Spearman's ρ

Agreement assessment

- Compared AHP-only vs integrated model against field-performance scores
- Discrepancy: RMSE and MAE·rank agreement: Kendall's τ, Spearman's ρ
- Not an independent validation: detachment data are already included in the model

2.3. Marking unit

Candidate units | Net-panel | Length | Weight | Price

AHP weights

Expert judgment, reused from prior study

Stakeholder preference

Effective n = 139 of 153 (90.8%), re-normalized to sum to 1

Mixed weight

$$W_i(\alpha) = \alpha \cdot W_{stakeholder,i} + (1 - \alpha) \cdot W_{AHP,i}$$

$\alpha \in [0, 1]$ · higher $\alpha \rightarrow$ greater influence of stakeholder preferences

α=0.5 adopted as the equal-weighting baseline

Analysis procedure

- Integrates expert judgment with the practical units used in gear purchase, handling and recovery
- α = 0.5 adopted as a baseline of equal expert–stakeholder weighting, not as an empirically optimized value
- Unit with the highest mixed weight selected; AHP, preference and mixed rankings compared descriptively
- α swept 0.00–1.00 (0.01 step) to identify the point where the top-ranked management unit changed

03

Results

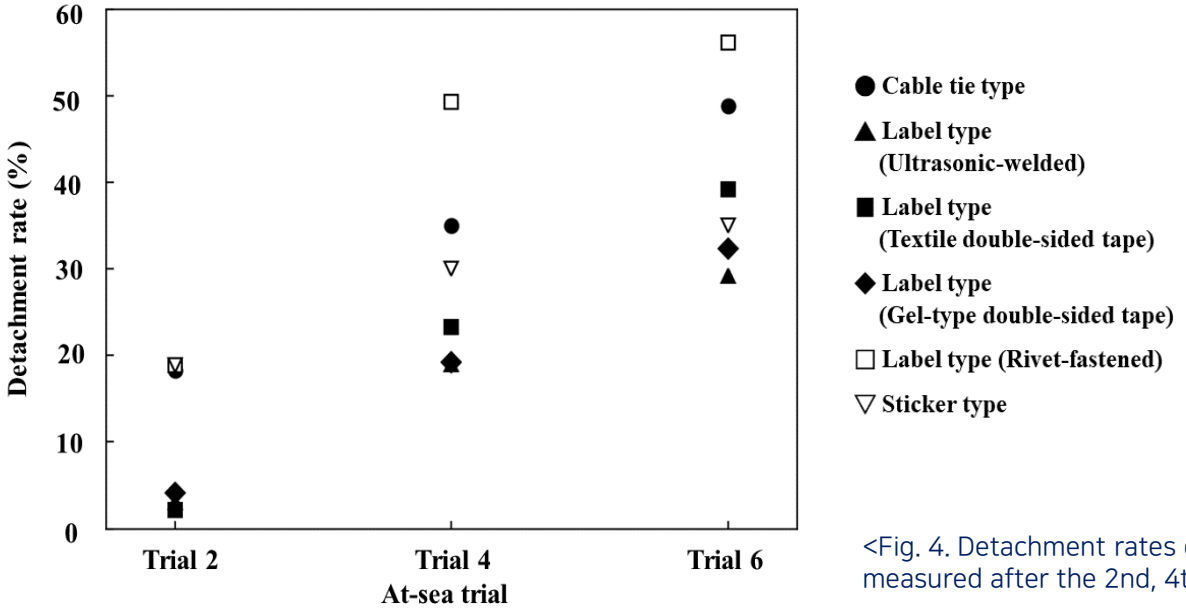
3.1 Marking type — Evaluation results

AHP criteria weights

<Table 4. Evaluation criteria weights derived from AHP analysis: $W_{AHP(x)}$, $W_{AHP(y)}$, $W_{AHP(z)}$ >

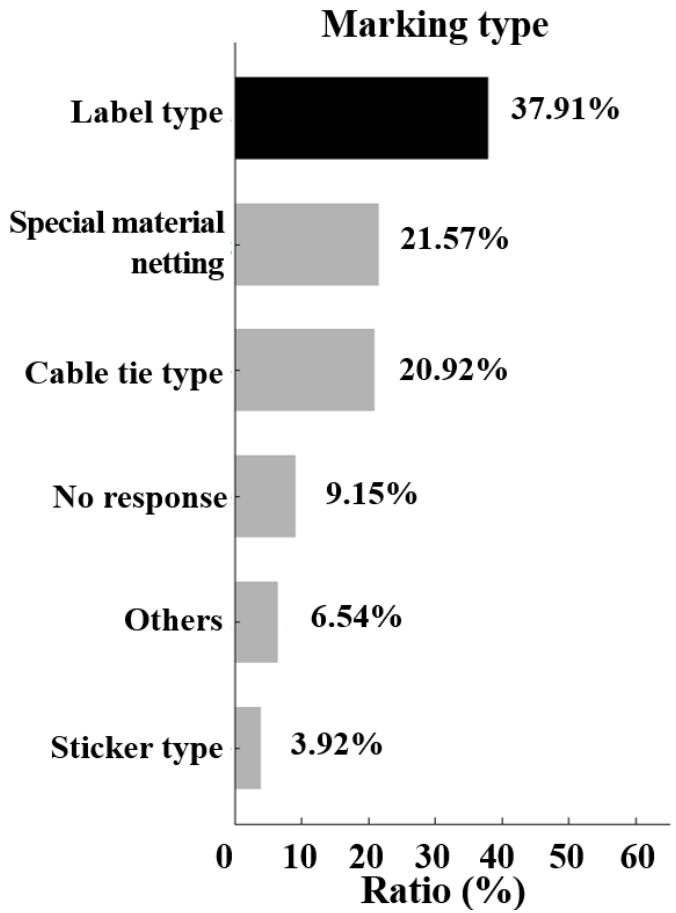
Evaluation criteria		Weights		
		Weighted average	Standard deviation	Rank
Hierarchy 1	Gear-specific usability ($W_{AHP(x)}$)	0.48	0.27	1
	Ease of deposit calculation ($W_{AHP(y)}$)	0.2	0.08	3
	Support from fishers and producers ($W_{AHP(z)}$)	0.32	0.27	2

Field performance



<Fig. 4. Detachment rates of gillnet marking types measured after the 2nd, 4th, and 6th at-sea trials>

Stakeholder preference



<Fig. 5. Stakeholder preferences for (a) gillnet marking types, based on the full pooled sample (n = 153) prior to exclusion of non-comparable categories>

03. Results & Discussion

3.1 Marking type — Evaluation results

Value function

$$V_{(x,y,z)} = W_{AHP(x)}\left(\frac{1-e^{c_1(x-x^0)}}{1-e^{c_1(x^*-x^0)}}\right) + W_{AHP(y)} + W_{AHP(z)}\left(\frac{1-e^{c_2(z-z^0)}}{1-e^{c_2(z^*-z^0)}}\right)$$

$$V_{(x,y,z)} = 0.48\left(\frac{1-e^{0.326(x-0.697)}}{1-e^{0.326(0.11-0.697)}}\right) + 0.198 + 0.322\left(\frac{1-e^{-0.045(z-0.074)}}{1-e^{-0.045(0.676-0.074)}}\right)$$

$W_{AHP(x)}, W_{AHP(y)}, W_{AHP(z)}$ AHP-derived criterion weights

c_1, c_2 curvature coefficient

x min–max normalized detachment-rate component

x^0, x^* 95% CI bounds of mean normalized detachment rates

z min–max normalized stakeholder preference score for a given alternative

z^0, z^* 95% CI bounds of mean normalized stakeholder preference scores

Final evaluation results

<Table 5. Final evaluation results for marking types using the AHP-based multi-criteria value function >

Alternative	Attachment type	Stakeholder preference (%)	Detachment rate in at-sea trial			Final value	Rank
			Mean (%)	SD (%)	SE (%)		
Cable tie type	Direct attachment	20.92	32.50	45.89	26.50	0.59	5
Label type	Ultrasonic-welded	37.91	20.59	28.84	16.65	0.77	1
	Textile double-sided tape	37.91	27.29	36.61	21.14	0.72	3
	Gel-type double-sided tape	37.91	21.97	30.66	17.71	0.76	2
	Rivet-fastened	37.91	40.53	39.19	22.63	0.61	4
Sticker type	Direct attachment	3.92	28.89	18.36	10.60	0.52	6

- 1. Ultrasonic-welded label ranked 1st (Final value = 0.77)
- 2. Gel-type double-sided tape (0.76): Second highest overall value
- 3. Sticker type (0.52): Ranked last due to lowest stakeholder preference

* Rankings reflect relative performance, not absolute readiness

03. Results & Discussion

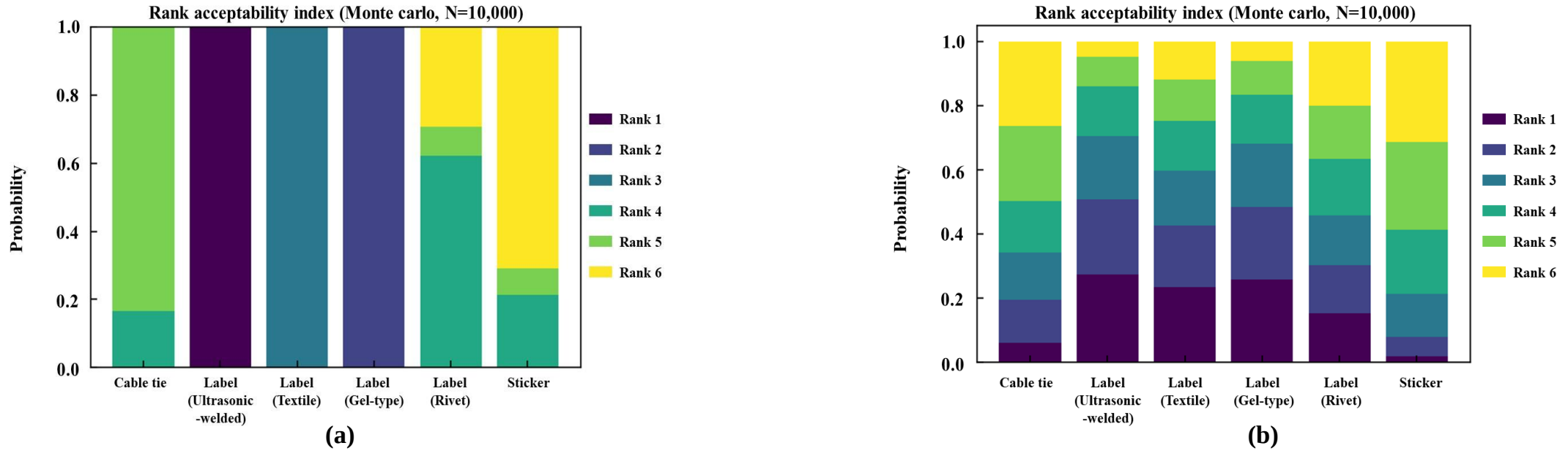
3.1 Marking type — Sensitivity and Agreement

Sensitivity analysis

- **Weight uncertainty only:** Top 3 ranks retained in 100% of simulations
- **Combined uncertainty :** Top 3 alternatives became statistically indistinguishable (retained 1st rank in 23.5%–27.4% of simulations)
- **Key indication:** Ranking is robust to expert weights but sensitive to field/preference uncertainty

Agreement assessment

- **Linear weighted-sum model:** Confirmed identical ranking ($\tau = 1$)
- **Multi-criteria model:** Lower RMSE (0.29) vs. conventional AHP (0.60)
- **Integration effect:** Direct inclusion of at-sea trial data improves alignment, although this does not represent independent predictive validation



<Fig. 5. Rank acceptability index of gillnet marking types from Monte carlo simulation of (a) criteria weight uncertainty only, and (b) combined weight, at-sea trial detachment-rate, and stakeholder preference uncertainty (N = 10,000 each).>

3.2 Marking unit — Mixed-weighting evaluation

Mixed weights at $\alpha = 0.5$

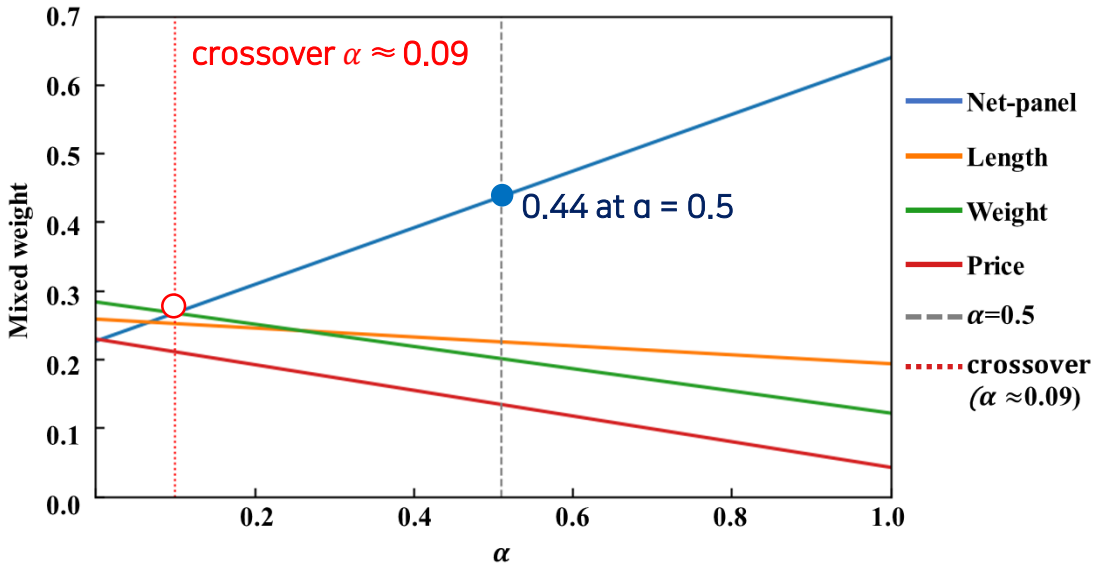
<Table 7. Comparison of AHP weights, stakeholder preference weights, and mixed weights (α) at the equal-weighting baseline (α = 0.5) for marking unit alternatives>

Unit	AHP	Stakeholder preference	Mixed weight	Rank
Net-panel	0.23	0.64	0.44	1
Length	0.26	0.19	0.23	2
Weight	0.28	0.12	0.20	3
Price	0.23	0.04	0.14	4

➢ Why the units rank this way

- Net-panel : matches how gear is bought, used and handled
- Length : standardized and easy to understand
- Weight : simple bulk measure, but biased by mud, moisture, float lines & ropes
- Price : varies by market, region and fishery

Sensitivity to balancing parameter (α)



<Fig. 6. Sensitivity of marking-unit mixed weights to the balancing parameter α, showing the equal-weighting baseline (α = 0.5) and the crossover point ($\alpha \approx 0.09$) at which the net-panel-based unit overtakes the weight-based unit as the top-ranked alternative. >

- Experts alone (α = 0) favor **weight**; stakeholders favor **net-panel**
- Net-panel stays **#1 for every α ≥ 0.09** → robust at the **α = 0.5** baseline

04

Discussion

04. Discussion

4.1 Marking type: ultrasonic-welded label

- A point estimate within a closely competitive top tier (ultrasonic·gel·textile)
- Detachment varied by gear: **4.4%** snow crab·**3.5%** yellow croaker vs **53.9%** swimming crab — confounded with mesh, twine and handling
- Not universal → combine **with indirect marking, records, loss reporting, recovery infrastructure**

4.2 Marking unit: net-panel

- Reflects Korean practice: gear is bought, used and handled by net panel
- Needs gear surveys**, standard classification and conversion rules** to deposits and recovery checks
- α = 0.5 is a **baseline, not an optimum**; experts alone (α = 0) would choose weight

4.3 Policy relevane & transferability

- Marking links ownership, recovery records and refund eligibility – basis for the 2026 deposit expansion
- Policy outcomes (cost, recovery rate) were not measured
- Transferable by recalibrating options and local data, not copying Korean results

4.4 Limitations

- ① Short-term trials, limited gear subset
- ② Repeated measures, not independent replicates
- ③ Between-gear variability > between-type differences
- ④ Only 10 companies; stated, not revealed, preference
- ⑤ Preference at category level, not per method
- ⑥ Internal consistency, not independent validation

05

Conclusion

Conclusions

Expert judgement·stakeholder acceptance·field-performance evidence combined to evaluate gillnet marking type and unit for preventive ALDFG management

01 **Marking type : Ultrasonic-welded fiber label** scored highest (0.77)
Ranking uncertain under field & preference variability → long-term tests on durability, abrasion, biofouling, readability

02 **Marking unit : Net-panel-based unit** most suitable under mixed weights (0.44)
Reflects net-panel-based gear practice; distinct from expert judgment alone, which favored weight

03 **Framework :** Links marking with **ownership, recovery records, administration** (FAO guidelines)
Transferable with local recalibration · deposit-system effectiveness still to be verified in the field

Thank you

Q&A

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