

## Calculation sequence for determining the construction parameters of a gillnet: a case study

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### Abstract

Gillnet performance is largely determined by construction and rigging parameters that control gear shape, stability, buoyancy, ballast, and ultimately fishing efficiency. However, the technical calculations needed to define these parameters are frequently dispersed in specialized literature, limiting their standardized application in artisanal fisheries. This study presents a stepwise calculation sequence for estimating the principal design parameters of gillnets, including twine requirements, hanging twine length, netting weight in air and water, buoyancy force, ballast needs, and the number of floats and sinkers. The proposed framework integrates established technical criteria for rope diameter, twine thickness, and hanging coefficients, offering a practical basis for gear design, adjustment, and evaluation. Its applicability was examined using an artisanal fixed surface gillnet operated in San Juan de Urabá, Colombian Caribbean, by contrasting calculated values with the gear configuration used in practice. Results indicated partial agreement with technical recommendations: while the upper selvage rope and main netting twine were within acceptable ranges, the lower selvage rope, hanging twine diameter, and hanging coefficient showed departures from expected values. In addition, the gear displayed a tendency toward excessive buoyancy and insufficient ballast, which may reduce operational stability, affect selectivity patterns, and limit overall fishing effectiveness.

### 1. Introduction

Fishing gears have been used for centuries as fundamental tools for harvesting aquatic resources, playing a crucial role in food security and the economy of many coastal communities (Friedman, 1986). However, their design and operation generate environmental and productive impacts that depend on their efficiency and selectivity. Among these gears, gillnets are widely used because of their versatility and effectiveness, yet their performance and sustainability are directly associated with

construction parameters such as the buoyancy coefficient and the sinking coefficient (Boopendranath, 2002). Inadequate design may lead to negative effects, including the incidental capture of non-target species and the generation of ghost nets, thereby contributing to the overexploitation of marine ecosystems (Wayte et al., 2007).

In small-scale fisheries in particular, the optimization of construction parameters is even more relevant, since these determine the stability, selectivity, and efficiency of the nets used by local fishing communities. Despite the importance of these factors, the technical information required for their calculation is scattered throughout the literature, which hinders both access and application (Baranov, 1948; Okonski & Martini, 1987). This creates a knowledge gap that limits the development of standardized methodologies for the design and adjustment of gillnets according to specific operating conditions.

The lack of detailed and systematic studies providing accessible and applicable calculation methodologies for gillnet design represents a major limitation for the optimization of small-scale fisheries. Although general references on fishing-gear design principles are available (Boopendranath, 2002; Baranov, 1948), the absence of consolidated information prevents rigorous comparisons between theoretical values and those used in practice. In this sense, it is essential to develop studies addressing this problem and providing tools for the analysis and adjustment of construction coefficients in gillnets.

In this context, the aim of this document is to establish a detailed calculation sequence for determining the construction parameters of a gillnet, and to conclude with a case study of an artisanal surface gillnet operating in San Juan de Urabá, Colombia. Based on the results obtained, a comparative analysis is proposed between theoretical values and those used in the field, thus allowing evaluation of the relationship between the buoyancy coefficient and the sinking coefficient. In this way, the document seeks to contribute to the optimization of artisanal fishing gears by improving their efficiency and sustainability.

## 2. Technical recommendations

### Recommended material thicknesses for net construction

#### Selvage rope diameters

##### Upper selvage rope diameter (drs)

For surface nets:  $drs = (8-10)$  mm

For bottom nets:  $drs = (4-6)$  mm

##### Lower selvage rope diameter (dri)

$dri \geq 15$  to 20% greater than the upper selvage rope diameter.

##### Lateral selvage rope diameter (drl)

$drl = (0.6-0.8) \cdot drs$

#### Hanging twine diameter (den).

$Den = (2 \text{ to } 4) \cdot dpp$  where:  $dpp$  = twine diameter of the main netting panel

#### Twine diameter for the main netting panel (dpp)

For the selection of twine diameter, the diameter should be proportional to the dimension of one side of the mesh or bar ( $a$ ) (Fig. 1):  $Kh = dpp/a$ ; the ratio must be expressed in the same unit.

$Kh$  should range from 0.005 for nets used in calm waters with limited catch, to 0.02 for high-seas drift nets or nets set on the bottom. The average ratio is 0.01 (FAO, 1988).

Other  $Kh$  relationships for different configurations are presented below:

For synthetic netting twine,  $Kh = (0.007-0.008)$

For drift nets with high catches,  $Kh = (0.015-0.020)$

For large-mesh netting panels (trammel nets),  $Kh = (0.003-0.005)$

For the main panel of a trammel net,  $Kh = (0.004)$

For gilling nets with low catches and good fishing conditions,  $Kh = (0.004)$

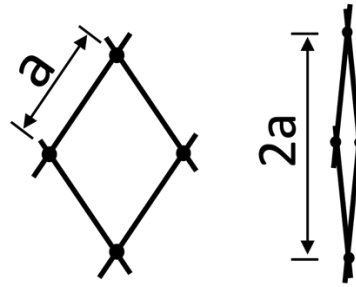


Figure 1. Mesh geometry.

**Recommended hanging or mounting percentage (U1 or E)**

When referring to the mesh, it is expressed as U1, and when referring to the net, as E

- For gillnets:  $E = (0.5-0.67)$
- For bunt netting in purse seines:  $E = (0.80)$
- For the main panel of a trammel net:  $E = (0.6-0.75)$
- For the outer panel of a trammel net:  $E = (0.5-0.55)$

The horizontal or vertical mesh opening may be expressed as a ratio between the stretched mesh length “2a” (Fig. 2) and either diagonal “X” or “Y”.

$U_1$ : Horizontal opening coefficient =  $X / 2a$

$U_2$ : Vertical opening coefficient =  $Y / 2a$

These coefficients may be expressed either as percentages of mesh opening or as fractions of mesh size.

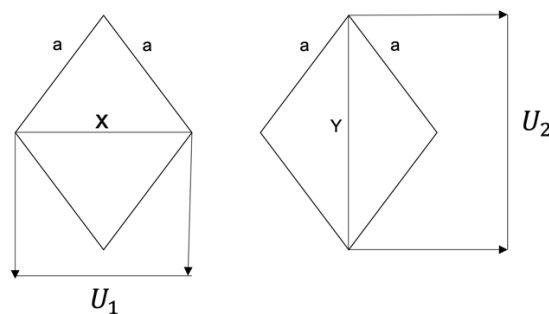


Figure 2. Mesh geometry.

**3. Calculation sequence**

First, it is necessary to know the weight of the fishing gear in air and in water in order to determine its buoyancy and ballast. However, before doing so,

the quantity and weight of all elements composing the fishing gear must be calculated.

### 3.1. Amount of twine for the net (Lmt)

$$Lmt = Lm + Lnt \quad (1)$$

Where:

Lm: Length of twine required for the bars, for two rows.

$$\text{Thus, } Lm = 2 \cdot Np \cdot Le \quad (2)$$

Where:

Np: Number of meshes in depth

Le: Stretched mesh length

On the other hand,

Lnt: Amount of twine required for the knots.

$$\text{Thus, } Lnt = Ln \cdot Nn \quad (3)$$

Where:

Ln: Length of twine required for one knot

$$Ln = C \cdot d$$

where C is a constant that depends on the knot type and twine diameter (Table 1)

Continuing with Eq. 3, the number of knots (Nn) is equal to:

$$Nn = Np \cdot \frac{Le}{a}$$

where a is the length of one mesh bar (Fig. 1).

Substituting into (3),

$$Lnt = C \cdot d \cdot Np \cdot \frac{Le}{a}$$

Substituting into (1),

$$Lmt = (2 \cdot Np \cdot Le) + (C \cdot d \cdot Np \cdot \frac{Le}{a})$$

Simplifying yields,

$$Lmt = 2 \cdot Le \cdot Np \left(1 + C \cdot \frac{d}{2a}\right) \quad (4)$$

Table 1. Values of C for Scottish-type knots.

d (mm)	C
0.25	12.12–12.90
0.25–0.30	12.90–13.80
0.30–0.40	13.80–14.80
0.40–0.60	14.80–16.67
0.60–0.80	16.67–18.18
0.80–1.00	18.18–19.05
1.00–1.20	19.61

### 3.2. Amount of twine for hanging (Len)

$$Len = Cf \cdot Ct \cdot Cl \cdot Lt \quad (5)$$

Where:

Cf: coefficient whose magnitude depends on the bending force of the hanging loop or sagitta ( $f$ ) and the diameter of the selvage rope (Table 2).

Ct: coefficient that depends on the type of hanging method and the type of knot to be used (Table 3).

Cl: coefficient that depends on the length of the hanging loop (Table 4).

Lt: Length of the selvage rope on which the netting panel is hung.

Table 2. Cf coefficient as a function of selvage rope diameter and hanging-loop sagitta.

Sagitta	SELVAGE ROPE DIAMETER (mm)		
	Up to 16	From 17 to 38	More than 38
30	1.68	1.69–2.25	2.40
40	1.87	1.88–2.47	2.53
50	1.92	1.93–2.57	2.65
60	2.05	2.06–2.70	2.80
70	2.18	2.19–2.80	2.95
80	2.39	2.40–3.05	3.15

\*The flexion sagitta (f) corresponds to the distance between the selvage rope and the maximum amplitude of the curve generated by the hanging loop (Fig. 3).

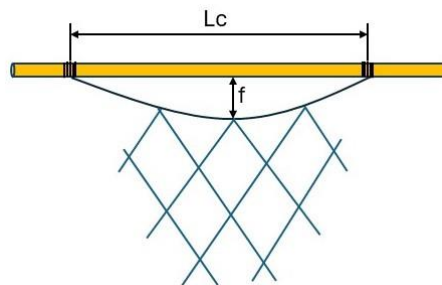


Figure 3. Dimensions associated with the hanging loop, where  $L_c$  is the cord length and  $f$  is the sagitta.

Table 3. Values of coefficient CT according to hanging type.

HANGING TYPE	CT SINGLE KNOT	CT DOUBLE KNOT
Classic running hanging	1.0	1.5
Running hanging with loose mesh	1.0	1.5
Running hanging with fixed mesh	1.0	1.5
With fixed meshes in the hanging loops	1.5	2.0
Running on a line parallel to the selvage rope	1.5	2.0

Table 4. Relationship between coefficient CI and hanging-loop length

Hanging-loop length (mm)	CI
Up to 150	1.00
From 150–200	0.98
More than 200	0.95

### 3.3. Weight of the netting panel in air (Gap)

$$\text{Gap} = \text{Lmt} \cdot \text{Gu}$$

Substituting Lmt from Eq. 4.

$$\text{Gap} = 2 \cdot \text{Le} \cdot \text{Np} \left(1 + \text{C} \cdot \frac{d}{2a}\right) \text{Gu}$$

Where: Gu: Unit weight of the twine material (Table 5).

Table 5. Breaking strength and unit weight (Gu) of monofilament polyamide (taken from Araty).

Diameter mm	Breaking strength (kgf)	Unit weight (Gu)
0.20	2.7	0.0382
0.25	4.2	0.0575
0.30	5.7	0.0808
0.35	7.6	0.1080
0.40	9.4	0.1391
0.45	11.6	0.1742
0.50	15.2	0.2132
0.60	20.0	0.3030
0.70	27.1	0.4082
0.80	31.9	0.5291
0.90	38.6	0.6803
1.00	48.7	0.8333

### 3.4. Weight of the hanging twine in air (Gaen)

$$Gaen = Len \cdot Gu$$

Substituting Len from Eq. 5.

$$Gaen = Lt \cdot Cf \cdot CT \cdot Cl \cdot Gu$$

Where: Gu: Unit weight of the hanging material.

Table 6. Main characteristics of some twisted polyamide twines (according to Klust).

Twine number			D (mm)	Weight of 100 m (g)	Breaking strength (kgf)
Nm	Tt	Td			
43.5/2	23/2	207/2	0.2	5.0	3.1
43.5/3	23/3	207/3	0.3	7.5	4.6
43.5/4	23/4	207/4	0.3	10.0	6.2
43.5/6	23/6	207/6	0.4	15.5	9.0
43.5/9	23/9	207/9	0.5	23.0	14.0
43.5/13	23/12	207/12	0.6	30.9	18.0
43.5/15	23/15	207/15	0.7	39.1	22.0
43.5/18	23/18	207/18	0.7	46.9	26.0
43.5/21	23/21	207/21	0.8	34.1	30.0
43.5/24	23/24	207/24	0.9	61.7	34.0
43.5/27	23/27	207/27	0.9	69.9	39.0
43.5/30	23/30	207/30	1.1	78.1	43.0
43.5/33	23/33	207/33	1.1	86.2	47.0
43.5/36	23/36	207/36	1.2	95.2	51.0
43.5/39	23/39	207/39	1.2	103.1	55.0
43.5/45	23/45	207/45	1.3	120.5	64.0
43.5/48	23/48	207/48	1.4	128.2	67.0
43.5/54	23/54	207/54	1.4	142.9	75.0
43.5/60	23/60	207/60	1.4	156.3	82.0
43.5/72	23/72	207/72	1.5	169.5	91.0

### 3.5. Weight of the selvage rope in air (Gar)

$$G_{ar} = L_r \cdot G_u$$

Donde:

L<sub>r</sub>: Length of the selvage rope

G<sub>u</sub>: Unit weight of the selvage rope material (Table 7)

Table 7. Breaking strength and unit weight (G<sub>u</sub>) of some twisted cordage products made of different synthetic fibers (average values; according to Grant and Klust).

Diameter (mm)	Polyamide		Polypropylene		Polyethylene		Polyester	
	Rr	Gu	Rr	Gu	Rr	Gu	Rr	Gu
6	680	22.2	520	17.9	425	20.0	505	27.2
8	1200	42.1	930	30.0	720	33.0	890	46.4
10	1780	63.0	1430	50.8	1100	49.0	1390	76.4
12	2500	91.3	2040	72.4	1500	71.0	2000	110.0
14	3300	121.5	2750	95.2	2100	102.0	2700	143.5
16	4280	157.3	3640	124.0	2750	136.0	3530	186.0
18	5400	200.0	4540	159.5	3400	166.0	4450	238.5
20	6580	245.5	5550	199.0	4200	209.0	5390	298.0

### 3.6. Weight of the net in water (G<sub>wr</sub>)

$$G_{wr} = (G_{ap} + G_{aen}) \cdot \left( \frac{\rho_m - \rho_w}{\rho_m} \right)$$

$\frac{\rho_m - \rho_w}{\rho_m}$ : specific sinking factor.

$\rho_m$ : density of the material

The density of polyamide may vary depending on the specific type of polyamide (for example, PA 6, PA 66, etc.) and its grade or additives, but in general the density of polyamide falls within the range of:

- 1130 to 1150 kg/m<sup>3</sup> for polyamide 6 (PA 6).
- 1140 to 1160 kg/m<sup>3</sup> for polyamide 66 (PA 66).

$\rho_w$ : seawater density

The density of seawater varies depending on several factors, such as temperature, salinity, and pressure. However, under standard conditions (20 °C and an average salinity of 36 g/L), seawater density is generally around:

- 1025 a 1035 kg/m<sup>3</sup>.

When the selvage ropes are made of PE or PP, it must be considered that these cordage materials are less dense than water; therefore, they float and are not included in this calculation.

### 3.7. Rigging calculation

The buoyancy and ballast forces of gillnets must be balanced.

#### a) Buoyancy force (Fft)

$$F_{ft} = K_f \cdot G_{wr} \quad (6)$$

Where:

K<sub>f</sub>: Buoyancy coefficient.

-Fixed nets:

: Bottom            K<sub>f</sub> = (3.0–6.0)

: Midwater        K<sub>f</sub> = (5.0–8.0)

: Surface          K<sub>f</sub> = (6.0–9.0)

-Drift nets with upper or lower floatline, or without a floatline:            K<sub>f</sub> = 1.0

-River nets:

Bottom            K<sub>f</sub> = (2.0–3.0)

Midwater        K<sub>f</sub> = 2.0

Surface          K<sub>f</sub> = 3.0

-Surrounding nets            K<sub>f</sub> = (6.0–9.0)

G<sub>wr</sub>: Weight of the net in water. If the different components are made of different materials, their specific sinking forces for each material must be summed.

**b) Weight of ballast in water (Gwl)**

$$Gwl = K1 \cdot Fft \quad (7)$$

K1: Ballast coefficient.

-Fixed nets:

Bottom	K1 = (1.25-1.5)
Midwater I	K1 = (0.65-0.75)
Midwater II	K1 = (1.10-1.20)
Surface	K1 = (0.30-0.40)

-Drift nets:

With lower floatline	K1 = 0.0
With upper floatline	K1 = 0.1
Without floatline	K1 = 0.1

-River nets:

Bottom	K1 = (0.6-0.75)
Midwater	K1 = (0.90-1.00)
Surface	K1 = (0.20-0.40)
-Surrounding net	K1 = (1.00-1.20)

**c) Weight of ballast in air (Gal)**

$$Gal = Gwl / \left( \frac{\rho_{Pb} - \rho_w}{\rho_{Pb}} \right) \quad (8)$$

Substituting Gwl from Eq. 7.

$\rho_{Pb}$ : lead density

The density of lead is approximately:

- 11,340 kg/m<sup>3</sup>.

**3.8. Number of floats (Nf)**

$Nf = Fft / \text{buoyancy of one float}$

Substituting Fft from Eq. 6.

**3.9. Number of sinkers (Npb)**

$Npb = Gal / \text{weight of one sinker}$

Substituting Npb from Eq. 8.

4. Case study

Determine the construction parameters of an artisanal fixed surface gillnet operating in San Juan de Urabá, Colombia, whose technical plan is presented below (Fig. 4). The calculation sequence aims to analyze the construction parameters and establish the relationship between the buoyancy and sinking coefficients by comparing theoretical calculations with those used in the net under study.

RED DE ENMALLE  
 De superficie  
 Carite (*Scomberomorus brasiliensis*), Cojinoa (*Caranx crysos*), Bagre (*Bagre filamentosus*)  
 SAN JUAN DE URABA – Colombia

Lancha F/V  
 Et : 12 m  
 Propulsión : 40 hp

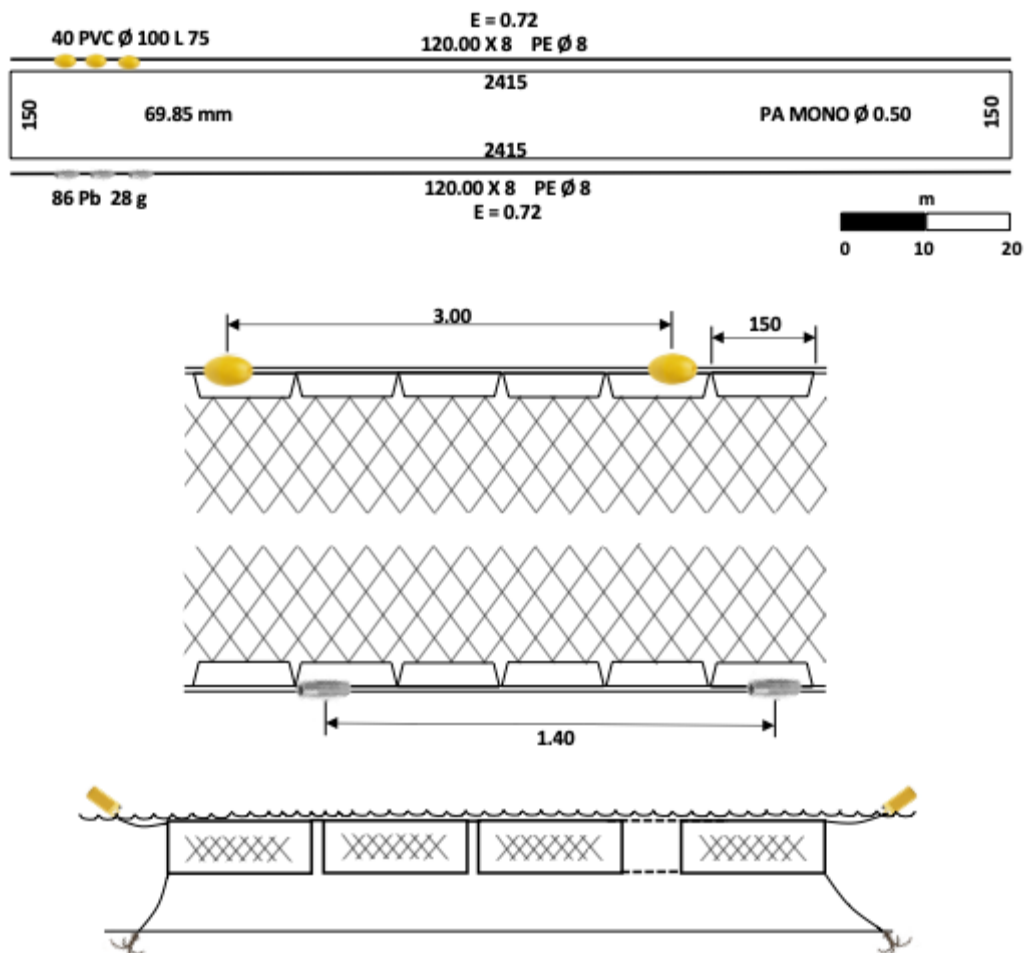


Figure 4. Technical plan of the artisanal fixed surface gillnet from San Juan de Urabá, Colombia

#### 4.1 Verification of compliance with technical recommendations

##### Selvage rope diameters

###### Upper selvage rope diameter (drs)

For surface nets:  $drs = (8-10)$  mm

The upper selvage rope diameter is 8 mm (within the recommended range).

###### Lower selvage rope diameter (dri)

$dri \geq 15$  to 20% greater than the upper selvage rope diameter.

$$dri = 8 \cdot 1.15$$

$$dri = 9.2$$

The lower selvage rope diameter is 8 mm (outside the recommended range).

###### Hanging twine diameter (den).

$den = (2 \text{ to } 4) dpp$  where:  $dpp =$  twine diameter of the main netting panel

$$den = 2 \cdot 0.5 = 1$$

$$den = 4 \cdot 0.5 = 2$$

The hanging twine diameter is 0.85 mm (outside the recommended range).

###### Twine diameter for the main netting panel (dpp)

$$dpp = Kh \cdot a$$

$Kh = 0.02$  for high-seas drift nets or nets set on the bottom. The average ratio is 0.01.

$$dpp = 0.02 \cdot 34.93 \text{ mm} = 0.70$$

$$dpp = 0.01 \cdot 34.93 \text{ mm} = 0.35$$

The twine diameter of the main netting panel is 0.50 mm (within the recommended range).

###### Recommended hanging or mounting percentage ( $U_1$ or E)

For gillnets:  $E = (0.5-0.67)$

The hanging or mounting coefficient is 0.72 (outside the recommended range).

## 4.2 Calculation sequence

### Amount of twine for the net

$$L_{mt} = 2 \cdot (2415 \cdot 0.06985) \cdot 150(1 + 15.74 \cdot 0.5 / 69.85) = 56308 \text{ m}$$

### Amount of twine for hanging

$$L_{en} = 2.39 \cdot 1.5 \cdot 1 \cdot 120 = 430 \text{ m}$$

### Weight of the netting panel in air (Gap)

$$G_{ap} = 56308 \cdot 0.213 = 11993 \text{ g}$$

### Weight of the hanging twine in air (Gaen)

$$G_{aen} = 430 \cdot 0.952 = 410 \text{ g}$$

### Weight of the net in water

$$G_{wr} = (G_{ap} + G_{aen}) \cdot ((\rho_{PA} - \rho_w) / \rho_{PA})$$

$$G_{wr} = (G_{ap} + G_{aen}) \cdot ((1140 - 1028) / 1140) = 1216 \text{ g}$$

### Buoyancy force

$$F_{ft} = 9.0 \cdot G_{wr} = 10.94 \text{ kg}$$

### Weight of ballast in water (Gwl)

$$G_{wl} = 0.3 \cdot F_{ft} = 3.28 \text{ kg}$$

### Weight of ballast in air (Gal)

$$G_{al} = G_{wl} / ((\rho_{pb} - \rho_w) / \rho_{pb})$$

$$G_{al} = G_{wl} / 0.909 = 3.61 \text{ kg}$$

**Number of floats (Nf)**

$$Nf = Fft / 0.3 = 36$$

The net is slightly oversized, as it uses 40 floats, that is, four more than estimated.

**Number of sinkers (Npb)**

$$Npb = Gal / 0.028 = 129$$

According to the calculations, the net has insufficient ballast (86 sinkers), which may affect its proper deployment in the water column.

**4.3 Conclusion**

The analysis of the fixed surface gillnet used in San Juan de Urabá shows partial compliance with the technical recommendations for the design of efficient and sustainable fishing gears. On the one hand, the diameter of the upper selvage rope (8 mm) and the twine diameter of the main netting panel (0.50 mm) are adequate, both falling within the ranges suggested by the specialized technical literature.

However, major deviations were identified in other construction parameters. The diameter of the lower selvage rope (8 mm) and of the twine used for hanging (0.85 mm) are below the recommended values, which could compromise the structural strength and durability of the fishing gear. Likewise, the hanging coefficient ( $E = 0.72$ ) exceeds the suggested range (0.50–0.67), which could negatively affect selectivity and gilling efficiency by favoring the retention of non-target species or undesirable size classes.

Regarding the force balance, the net was found to have slightly oversized buoyancy (40 floats instead of 36) and insufficient ballast (86 sinkers versus the 129 required). This imbalance may directly affect the operating position of the net in the water column, hindering its proper deployment and reducing its effectiveness during capture. In addition, deficient ballast could increase the risk of drift, thereby raising the probability of net loss and aggravating the ghost-net problem, with its corresponding ecological and economic implications.

Taken together, these results highlight the importance of applying a systematic and standardized methodology for the design and adjustment of gillnets, based on precise calculations and validated parameters. The comparison between theoretical values and those used in the field makes it possible to identify concrete opportunities for improvement in order to optimize gear performance, extend service life, minimize impacts on non-target species, and contribute to more sustainable artisanal fisheries.

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