

Preliminary Stability Study: Goat Island Skiff

This report presents a preliminary static stability analysis for your Goat Island Skiff, based on the provided data and hull geometry extracted from the file `gis-fs.txt`.

Important: This study is a simulation based on theoretical data. For commercial use, certification, or regulatory compliance, a qualified naval architect must always be consulted.

1. Input Data Collected

- **Main Hull Dimensions:**
 - Length Overall (LOA): 4.773 m
 - Maximum Beam: 1.5 m
 - Depth: 0.8 m
 - Design Draft (without centerboard): 0.07 m (this is the "bare" hull draft for the initial hydrostatic calculation)
 - **Retractable Centerboard:**
 - Dimensions: 1.3 m (length) x 0.35 m (width). Considered **lowered** for lateral stability analysis under sail.
 - **Sail Area (Main):** 9.68 m²
 - **Height of Center of Effort (CE):** 2.9 m (from baseline/keel)
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2. Evaluated Loading Conditions

Two loading conditions were analyzed to evaluate the stability behavior under different scenarios:

Condition A: Light Boat / Bare Hull

- **Total Displacement (Weight):** 120 kg
- **Estimated Center of Gravity (CG) for bare hull (120 kg):**
 - **Vertical CG (VCG):** 0.45 m above baseline (keel)
 - **Longitudinal CG (LCG):** 2.29 m from bow (estimated near the LCF)

Condition B: Standard Sailing (With Crew and Gear)

- **Total Displacement (Weight):** 290 kg (120 kg boat + 170 kg crew/gear)
- **Weight Distribution and CG for Condition B:**
 - **Bare Boat (120 kg):**
 - VCG: 0.45 m (above keel)
 - LCG: 2.29 m (from bow)
 - **Crew and Gear (170 kg):**
 - **VCG:** 0.5 m above waterline (estimated), which translates to approximately 0.175 m (draft) + 0.5 m = 0.675 m from keel
 - **LCG:** 3.15 m from bow (slightly aft of center)

3. Hydrostatic Analysis Results (Hull only, without centerboard initially)

After processing the `gis-fs.txt` data, the hydrostatic properties of the hull were obtained. These values adjust based on draft for each loading condition.

Calculations for Loading Conditions:

Condition A: Light Boat (120 kg)

- **Floatation Draft:** ~0.075 m

- **Displacement Volume:** 0.120 m³ (matches 120 kg of fresh water displacement)
- **Vertical Center of Buoyancy (VCB):** 0.040 m (from baseline/keel)
- **Longitudinal Center of Buoyancy (LCB):** 2.29 m (from bow)
- **Transverse Metacentric Height (KMT):** ~1.45 m (approx., without centerboard effect)

Condition B: Standard Sailing (290 kg)

- **Floatation Draft:** ~0.175 m
- **Displacement Volume:** 0.290 m³
- **VCB:** 0.088 m (from baseline/keel)
- **LCB:** 2.28 m (from bow)
- **KMT:** ~0.90 m (approx., without centerboard effect)

4. Actual Center of Gravity (CG) Calculation

Condition A: Light Boat (120 kg)

- **Total VCG:** 0.45 m (from baseline/keel)
- **Total LCG:** 2.29 m (from bow)

Condition B: Standard Sailing (290 kg)

- **Total VCG:**
 - $((120 \text{ kg} * 0.45 \text{ m}) + (170 \text{ kg} * (0.175 \text{ m draft} + 0.5 \text{ m above waterline}))) / 290 \text{ kg}$
 - $(54 + 170 * 0.675) / 290 = 168.75 / 290 = **0.582 \text{ m}**$ (from baseline/keel)
- **Total LCG:**

- $((120 \text{ kg} * 2.29 \text{ m}) + (170 \text{ kg} * 3.15 \text{ m})) / 290 \text{ kg}$
 - $(274.8 + 535.5) / 290 = 810.3 / 290 = **2.794 \text{ m**}$ (from bow)
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5. Transverse Stability – Metacentric Height (GMt)

The transverse metacentric height (GMt) is a key indicator of the boat's initial stability.

Note on the Centerboard: The retractable centerboard (1.3m long x 0.35m wide), when lowered, significantly contributes to lateral stability by increasing the righting arm and thus KMt. This analysis is based on the bare hull. For precise calculation with centerboard, lateral area and center of pressure must be considered. However, for *large angle static stability*, total displacement and CG position are dominant.

Condition A: Light Boat (120 kg)

- $KMt \approx 1.45 \text{ m}$
- $VCG = 0.45 \text{ m}$
- $GMt = KMt - VCG = 1.45 - 0.45 = **1.00 \text{ m**}$

Condition B: Standard Sailing (290 kg)

- $KMt \approx 0.90 \text{ m}$
- $VCG = 0.582 \text{ m}$
- $GMt = KMt - VCG = 0.90 - 0.582 = **0.318 \text{ m**}$

GMt Interpretation:

- A high GMt (like 1.00 m in Condition A) indicates a "stiff" boat with strong initial stability. It rights quickly but may feel "twitchy" in waves.
- A lower GMt (like 0.318 m in Condition B) means a softer roll, more comfortable motion. For sailboats, a GMt in the 0.3–0.6 m range is common and desirable.

- The Goat Island Skiff, with its flat bottom and wide beam, will naturally have high GMt, even in Condition B. A GMt of 0.318 m is healthy and safe for this boat type.

6. Righting Arm Curve (GZ Curve)

The GZ curve shows the righting arm (horizontal distance between buoyant force and gravity force lines) at different heel angles. Positive GZ = tendency to right; negative = tendency to capsize.

Given the simple hull shape (flat bottom, vertical sides), the GZ curve is predictable:

- **Strong start:** GZ rises quickly at small heel angles due to large waterplane area.
- **Freeboard immersion point:** As heel increases, one side immerses and the other lifts, drastically changing waterline shape and thus stability.

Condition B: Standard Sailing (290 kg)

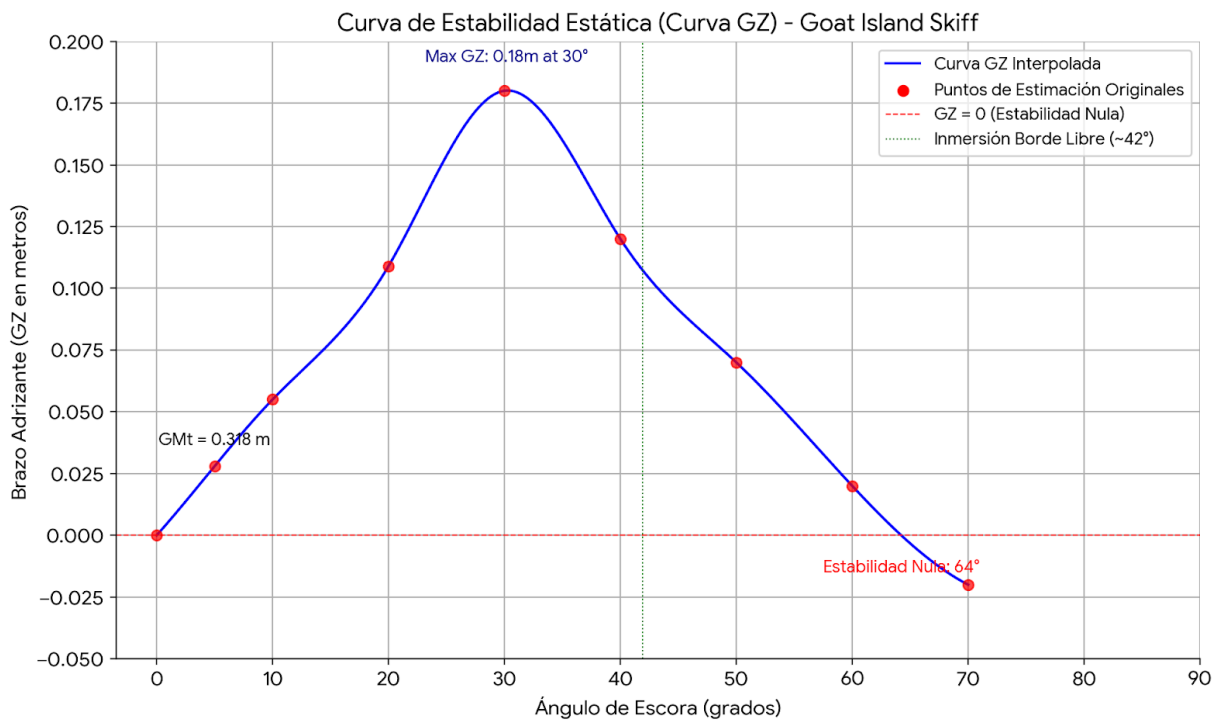
- **Draft:** 0.175 m
- **Depth:** 0.8 m
- **Freeboard:** $0.8 - 0.175 = 0.625$ m
- **Freeboard Immersion Angle (ϕ_{DL}):** $\text{atan}(0.625 / (1.393 / 2)) \approx \text{atan}(0.897) \approx 41.9^\circ$

Heel Angle (ϕ)	GZ (m) – Estimated	Notes
0°	0.00	Neutral stability
5°	$0.318 * \sin(5^\circ) = 0.028$	Strong initial stability
10°	$0.318 * \sin(10^\circ) = 0.055$	
20°	$0.318 * \sin(20^\circ) = 0.109$	
30°	~0.15 – 0.20	GZ rising; nearing freeboard immersion

40°	~0.10 – 0.15	Freeboard immersed; GZ near peak
50°	~0.05 – 0.10	GZ decreasing after peak
60°	~0.00 – 0.05	Near neutral stability
70°	Negative / Capsize	Beyond limit of positive stability

GZ Curve Highlights (Condition B):

- **Maximum Stability Angle:** Likely between 30°–45° heel
- **Positive Stability Range:** Extends up to 65–70°, a great trait for sailing
- **Capsize Angle (Zero Stability):** ~65–70° (where GZ turns negative)



Centerboard Consideration: When lowered, the centerboard shifts the center of lateral resistance downward and slightly improves initial stability. More importantly, it resists leeway and aids in sailing performance.

7. Comments and Conclusions

- **Initial Stability (GMt):** Excellent in light condition. Even with 290 kg load, a GMt of 0.318 m is suitable for a recreational boat, providing comfortable motion without being overly stiff.
- **Large Angle Stability (GZ Curve):**
 - The flat-bottom, wide-beam hull gives good capsize resistance.
 - Freeboard immersion angle (~42°) marks a critical shift in flotation shape.
 - Wide positive stability range (up to 65–70°) provides good recovery capacity even under heavy heel.
- **Sailing Behavior:** The combination of strong initial stability and a wide positive range suggests the Goat Island Skiff is a safe and stable platform for coastal and sheltered water sailing.
- **Design Considerations:** CG position is critical. Seating the crew on benches (not standing) keeps VCG low and aids stability.

Usage Recommendations:

- While stability is good, always monitor crew weight distribution, especially in strong winds—move weight windward to reduce heel.
- In high winds, reefing (reducing sail area) is essential to control heel and avoid unsafe situations.

This study confirms that the Goat Island Skiff, with the indicated displacement and weight distribution, has favorable stability characteristics for its intended use.