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Design Viability of Purse Seiners Operating in Bone

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Design Viability of Purse Seiners Operating in Bone Regency, South Sulawesi, Indonesia

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Abstract. The success of fishing operations is influenced by various factors that interact with each other, one of which is the fishing vessel. Purse seine fisheries make a substantial contribution to capture fisheries in much of eastern Indonesia, including the seas around Sulawesi. Purse seiners must conform to standard criteria to ensure the success of the catch. Therefore, this study aimed to explore the design viability of purse seiners operating from Bone Regency in South Sulawesi. This study evaluated four purse seiner vessels, measuring the main dimensions and curvature of the vessels to obtain vessel offset data. The data obtained were analysed using the Maxsurf V8.20i program to produce line drawings and calculate the three-dimensional (3D) hydrostatic and stability properties of the vessels. These were used to evaluate the design viability based on compatibility with standard criteria. The purse seiners operating in Bone Regency had a casco hull type design, with V-bottom bow sections and U-bottom stern sections. The vessels had a large cross-sectional area which allowed considerable space for the placement of the purse seine net and fishing catch. The ratio of the main dimensions and hydrostatic parameters of the sample vessels did not match the standard criteria for purse seine vessels. However, the results obtained for the static stability of the sampled vessels did meet standards that are in accordance with the criteria of the International Maritime Organization.

1. Introduction

The success of fishing gear operation is determined by the condition of the fishing vessels used, in particular with relation to the design, construction, stability, and general seaworthiness of the vessels so that the safety and comfort of work at sea can be guaranteed before, during and after fishing operations. Fishing vessels must therefore fulfil several safety and efficiency criteria [1].

The purse seine is a type of fishing gear designed to catch pelagic fishes. The purse seiners in Bone Regency, South Sulawesi, Indonesia are still built based on the traditional knowledge and beliefs of local craftsmen, being constructed without any formal design or construction planning processes. This has implications for the potential mismatch between the characteristics of these vessels and the widely accepted criteria and standards now in vigour. Fishing activities at sea have very high work risks [2]. Accidents at sea are very high for fishing vessels compared to other types of ships [3]. From the results of interviews conducted with several fishermen, anecdotal information was obtained that several purse seiners in Bone Regency had experienced accidents; however, these accidents had not been reported to the local Marine and Fisheries Service.

Design is important in the construction of fishing vessels, in particular the design needs to take into account the technical requirements for the fishing gear used and mode of operation, as well as

the sea conditions prevalent in the proposed fishing grounds. In response to these various needs, many different fishing vessel designs and construction types have evolved, with hull shapes, internal structure and superstructures suited to their various functions and working environments [4].

The stability of a vessel is one of the most important considerations. Static and dynamic stability are both of vital importance to safety of the vessel and crew. Static stability (inherent stability) is the stability of the vessel measured in calm water conditions and when not moving, and should be evaluated at a range of angles of heel as well as at different loading conditions in terms of tons of displacement and distribution of the weight in the vessel. The key parameter measured to evaluate stability is the righting lever GZ, which is strongly affected by the position of the metacentre as well as the hull shape. GZ is typically evaluated theoretically over angles of heel from upright to the point of capsize, producing a GZ curve. The dynamic stability of a ship is the area enclosed within its static stability curve and quantifies the external heeling energy that the ship can absorb before capsizing [5].

In order to evaluate whether a particular vessel fulfils the requirements for safe and successful fishing operations, important factors to consider are good design and vessel stability. Based on this consideration, and the reported problems, this study aimed to analyse the design and static stability of purse seiner vessels operated in Bone Regency.

2. Methods

2.1. Time and Place

The research was conducted from January to March 2019. The research site was in Bone Regency, South Sulawesi, Indonesia (Figure 1)

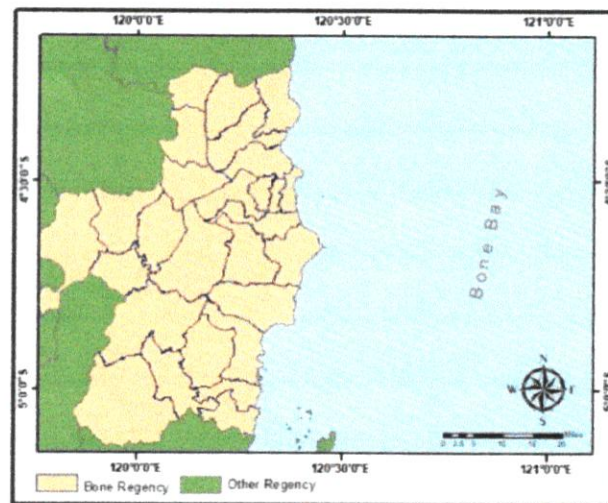


Figure 1. Research Location

2.2. Research equipment and methods

This research is a case study of four purse seine vessels in Bone Regency. The four vessels were selected as being representative of traditionally built purse seiners operating in the region. Measurements of vessel dimensions were made while the vessels were docked, using builders roll-up tape measures. The curvature of the vessels was measured using a rope and pendulum, spirit level, rulers, and stationery to record the measurement results. The measurements recorded were

used to determine vessel geometry and to make a general arrangement plan and line drawings for each vessel.

2.3. Data Analysis

The Maxsurf V8.20i simulation program was used for the analysis. This program can simulate vessel response to a given set of sea conditions in three-dimensions (3D). The measurements taken from the four vessels were entered into the MaxsurfV8.20i program. The first stage of data analysis was reverse-construction of the vessel design plans, in order to obtain hull drawings and hydrostatic parameter values. The outputs from this stage were then used to analyse the stability of the vessels. The results of the analyses for all four vessels were output in numerical and graphic forms.

3. Results and Discussion

3.1. Purse Seiner Size

The key dimensions of the vessels, were: Length overall (LOA) and Breadth (B) measured at the design waterline; hull Depth (D); and Draft at the design waterline (d) (Table 1). The key ratios calculated were L/B, L/D, and B/D (Table 2). These ratios were compared to the Indonesian standard criteria, adopted from International Maritime Organisation (IMO) standards [6].

Table 1. Key dimensions of four purse seiners in Bone Regency

Purse Seiner (PS) parameters (m)	PS 1	PS 2	PS 3	PS 4
Length overall (LOA)	25.45	26.46	26.00	21.57
Breadth overall (BOA)	5.19	5.40	5.25	5.25
Depth	2.28	2.40	2.32	2.10
Draft	1.59	1.68	1.61	1.63

Table 2. Key ratios of four purse seiners in Bone Regency (L is LOA)

Purse Seiner	L/B (Length/Breadth)	L/D (Length/Depth)	B/D (Breadth/Depth)
PS 1	4.90	11.14	2.27
PS 2	4.90	11.00	2.25
PS 3	4.95	11.17	2.26
PS 4	4.11	10.25	2.50
Standard criteria [6]	4.30 – 4.50	10.00 – 11.00	2.10 – 2.15

3.2. Purse seiner tonnage

The tonnage of a vessel is a quantity that indicates the capacity or volume of space that is enclosed within the vessel, and (in general) is considered watertight. The capacity of a vessel can be evaluated from the gross tonnage (GT) value. The length (L) and GT values of the four purse seiners in Bone Regency in relation to the standard criteria [6] can be seen in Table 3.

Table 3. Tonnage (capacity) of four purse seiners in Bone Regency (GT)

Purse Seiner	LOA (m)	GT	Standard criteria [6]	
			LOA (m)	GT
PS 1	25.45	45.86	>20	50 – 90
PS 2	26.46	51.23	>20	50 – 90
PS 3	26	47.76	>20	50 – 90
PS 4	21.57	46.73	>20	50 – 90

Vessels with a length overall (LOA) of more than 20 metres ($L > 20$ metres) have GT values ranging from 50 - 90 GT. Table 3 shows gross tonnage (GT) values for all four purse seiners close to the GT values according to criteria [6].

3.3. General arrangement of the four purse seiners

The general arrangement plan is a series of scale drawings depicting the division and arrangement of the vessel. There are three views that show the general layout and the compartments within the vessel as seen from above (plan view) and from the side (lateral view) of the vessel. The general arrangement plans produced for the four vessels (PS 1, PS 2, PS 3 and PS 4) are shown in Figure 2 and all show a similar layout. From the stern to the bow, the order of main above-deck compartments were: the galley (roofed but semi-open), crew accommodation, and wheelhouse, with the deck area forward of the wheelhouse left open for fishing operations and hatches to access the hold. The below-deck area was divided into the engine room at the rear and the hold area to the fore. The hold area was used to store equipment as well as the boxes containing ice and used for storing the catch.

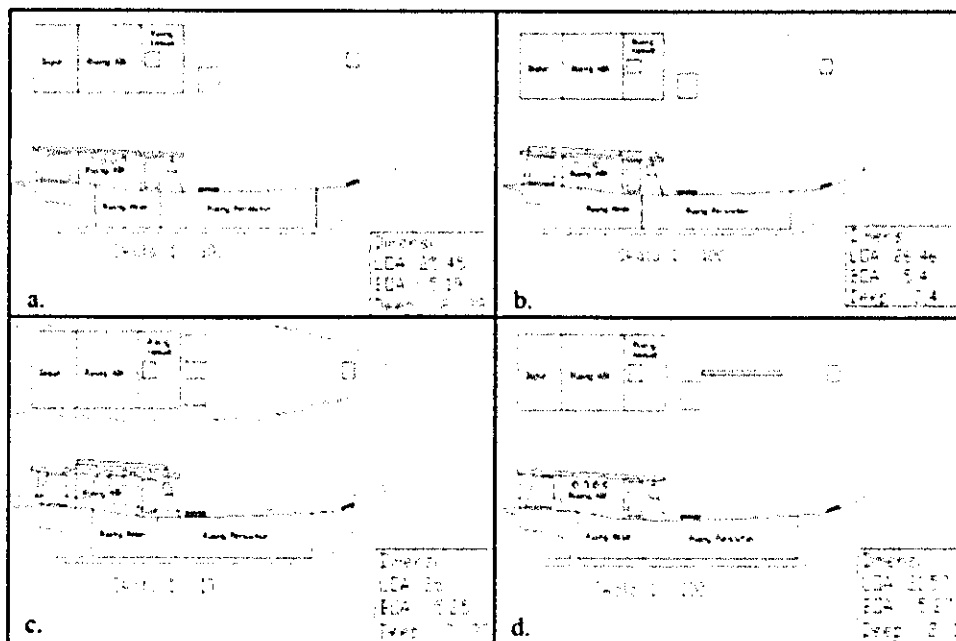


Figure 2. General Arrangement of four purse seiners in Bone Regency (Scale 1:100): a. Purse Seiner PS 1, b. Purse Seiner PS 2, c. Purse Seiner PS 3, d. Purse Seiner PS 4. Legend: dapur = galley; ruang ABK = crew accommodation/living-space; ruang kemudi = wheelhouse; ruang mesin = engine room; ruang peralatan = hold.

3.4. Purse seiner line drawings

The line drawings are a series of drawings projecting the shape of a number of cross-sections of the vessel onto three pairs of the three axes (X = fore-aft, Y = port-starboard; Z = vertical). The line drawings comprise the transverse body plan (YZ), as seen from the front; the plan view or half breadth plan (XY, for one side of the hull); and the lateral plan or profile view (XZ) which shows longitudinal slices through the vessel. Line drawings (Figure 3) were produced from the

measurements made in the field using the Maxsurf V8.20i program. The transverse cross-sections were one metre apart, while the plan view shows the shape of the hull intersecting five horizontal planes at heights between the keel and the waterline (draft). Figure 3 also shows the contour of each longitudinal section (called buttock lines), which are sections or planes through the hull parallel to the centre line.

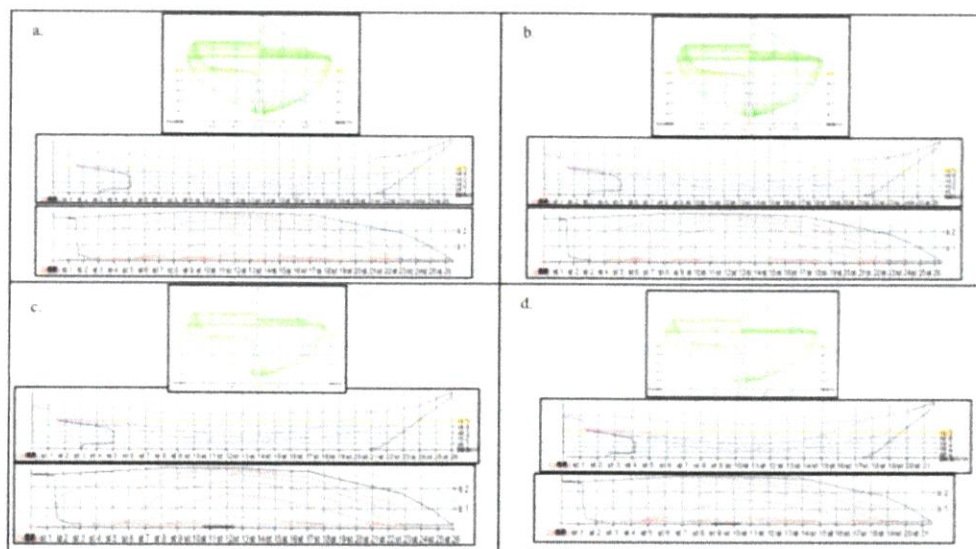


Figure 3. Line plans of four purse seiners in Bone Regency: a. Purse Seiner PS 1, b. Purse Seiner PS 2, c. Purse Seiner PS 3, d. Purse Seiner PS 4

In general, the purse seiners had V-shaped bow sections. This is a shape which can make it easier for a vessel to divide the mass of water in front of the vessel as it advances, creating relatively low resistance to the movement of the vessel through the water, so that the vessel can travel efficiently at relatively high speeds; a fine bow can also facilitate maneuvering [7]. The bow stem was raked, giving a considerably longer length overall (LOA) compared to the waterline length (LWL) and providing extra working deck space in the fore section of the vessel. The mid-sections and stern sections of the vessels were U-shaped, providing more space below decks and greater stability. This combination of cross-sectional shapes should enable the vessels to have relatively low drag, a good ability to cut through and ride the waves, while maximising useful space both in the hold and on deck.

3.5. Hydrostatic parameters of the purse seiners

The hydrostatic parameters are measures or values that describe the static stability of a vessel and the viability of a vessel design. The value of the coefficient of fineness can determine the viability of a vessel design. The hydrostatic parameters for the four purse-seiners studied are given in Table 4 to Table 7.

Table 4. Hydrostatic Parameters of Purse Seiner PS1 in Bone Regency

No.	Parameter ^a	WL 1	WL 2	WL 3	WL 4
1	Displacement volume (m ³)	2053068.46	9785789.76	25237534.16	48389615.09
2	Displacement (ton)	2103	10006	25872	49599
3	Waterline area (Aw) (m ²)	220292.48	474971.87	717094.31	969596.49
4	Midship area (Ao) (m ²)	90668.61	291708.10	483335.00	675842.27
5	Tons per centimetre (TPC)	0.093	0.299	0.495	0.693
6	Block coefficient (Cb)	0.280	0.235	0.286	0.323
7	Prismatic coefficient (Cp)	0.812	0.565	0.573	0.574
9	Waterplane coefficient (Cw)	0.494	0.562	0.656	0.722
10	Midship coefficient (Co)	0.345	0.417	0.498	0.568
11	LCB (cm)	1237.67	1302.45	1317.17	1307.68
12	KB (cm)	21.99	54.66	83.41	110.95
13	BM (cm)	21.58	139.33	183.99	184.33
14	KM (cm)	43.57	193.99	267.40	295.28
15	BML (cm)	6009.50	3775.39	3075.31	3122.65
16	KML (cm)	6031.49	3830.06	3158.72	3233.59

^aLCB = longitudinal centre of buoyancy ; KB = height of the centre of buoyancy above the keel; BM = metacentric radius; KM = distance from the keel to the metacentre; BML = longitudinal metacentric radius; KML = height of longitudinal metacentre above keel line

Table 5. Hydrostatic Parameters of Purse Seiner PS 2 in Bone Regency

No.	Parameter ^a	WL 1	WL 2	WL 3	WL 4
1	Displaced volume (m ³)	2345363.14	11188120.61	28857750.28	55317298.08
2	Displacement (ton)	2402	11442	29579	56700
3	Waterline area (Aw) (m ²)	240418.08	517370.65	780809.44	1055778.63
4	Midship area (Ao) (m ²)	98456.59	316287.36	523919.79	732490.46
5	Tons per centimetre (TPC)	0.101	0.324	0.537	0.751
6	Block coefficient (Cb)	0.279	0.235	0.286	0.323
7	Prismatic coefficient (Cp)	0.810	0.565	0.573	0.573
9	Waterplane coefficient (Cw)	0.494	0.562	0.656	0.722
10	Midship coefficient (Co)	0.344	0.417	0.499	0.568
11	LCB (cm)	1286.99	1354.25	1369.45	1359.42
12	KB (cm)	23.21	57.65	87.96	116.99
13	BM (cm)	22.44	143.60	189.27	189.49
14	KM (cm)	45.65	201.25	277.23	306.48
15	BML (cm)	6164.50	3871.42	3156.94	3207.00
16	KML (cm)	6187.71	3929.07	3244.89	3323.99

^aLCB = longitudinal centre of buoyancy ; KB = height of the centre of buoyancy above the keel; BM = metacentric radius; KM = distance from the keel to the metacentre; BML = longitudinal metacentric radius; KML = height of longitudinal metacentre above keel line

Table 6. Hydrostatic Parameters of Purse Seiner PS 3 in Bone Regency

No.	Parameter	WL 1	WL 2	WL 3	WL 4
1	Displaced volume (m ³)	2166795.05	10340698.36	26667071.88	51127453.20
2	Displacement (ton)	2220	10576	27339	52406
3	Waterline area (A _w) (m ²)	229020.45	493188.96	744428.44	1006635.16
4	Midship area (A _o) (m ²)	94056.11	302152.97	500507.17	699790.30
5	Tons per centimetre (TPC)	0.096	0.310	0.513	0.717
6	Block coefficient (C _b)	0.279	0.235	0.286	0.323
7	Prismatic coefficient (C _p)	0.810	0.565	0.573	0.573
9	Waterplane coefficient (C _w)	0.494	0.562	0.656	0.722
10	Midship coefficient (C _o)	0.344	0.417	0.499	0.568
11	LCB (cm)	1264.61	1330.71	1345.64	1335.78
12	KB (cm)	22.45	55.78	85.10	113.19
13	BM (cm)	21.92	140.29	184.91	185.12
14	KM (cm)	44.37	196.07	270.01	298.31
15	BML (cm)	6152.00	3863.57	3150.52	3201.08
16	KML (cm)	6174.45	3919.35	3235.62	3314.26

* LCB = longitudinal centre of buoyancy ; KB = height of the centre of buoyancy above the keel; BM = metacentric radius; KM = distance from the keel to the metacentre; BML = longitudinal metacentric radius; KML = height of longitudinal metacentre above keel line

Table 7. Hydrostatic Parameters of Purse Seiner PS 4 in Bone Regency

No.	Parameter	WL 1	WL 2	WL 3	WL 4
1	Displaced volume (m ³)	1921760.05	24456166.58	46703946.08	76880932.07
2	Displacement (ton)	1.965	9.776	25.056	47.798
3	Waterline area (A _w) (m ²)	201559.05	429133.38	649434.44	890479.25
4	Midship area (A _o) (m ²)	95909.11	280672.89	459531.86	648080.87
5	Tons per centimetre (TPC)	0.098	0.288	0.471	0.664
6	Block coefficient (C _b)	0.243	0.240	0.303	0.326
7	Prismatic coefficient (C _p)	0.734	0.560	0.580	0.561
9	Waterplane coefficient (C _w)	0.489	0.569	0.687	0.730
10	Midship coefficient (C _o)	0.331	0.429	0.523	0.591
11	Midship coefficient (c _o)	1058.29	1108.25	1116.20	1099.49
12	LCB (cm)	23.11	55.48	83.98	111.59
13	KB (cm)	42.35	170.86	206.16	200.29
14	BM (cm)	65.46	226.33	290.14	311.87
15	KM (cm)	4436.44	2740.15	2370.82	2594.91
16	BML (cm)	4459.55	2795.62	2454.81	2706.50

* LCB = longitudinal centre of buoyancy ; KB = height of the centre of buoyancy above the keel; BM = metacentric radius; KM = distance from the keel to the metacentre; BML = longitudinal metacentric radius; KML = height of the longitudinal metacentre above the keel

Displaced volume (V) (displacement) indicates the volume of the vessel's hull and is equal to the volume of seawater which is displaced by the vessel at a given waterline position. This value serves to estimate the volume of cargo that can be accommodated by the vessel, and is also important in calculations related to propulsion.

Displacement in tons (Δ) is a value that shows the vessel's load or mass at a particular waterline position. This value estimates the weight of the vessel, and is directly proportional to the displacement volume so that the displacement volume curve always intersects with the ton displacement curve.

The waterline area (A_w) is the area of a horizontal section through the vessel at a given waterline (draft). A relatively high waterline area value indicates that the vessel has a good ability to distribute loads horizontally. The midship area (A_m) is the area of the midships cross-section of the vessel at a given waterline.

The Tons per centimetre (TPC) parameter shows the amount of load/mass needed to change the draft of the vessel by 1 cm. The TPC varies for each draft or waterline. For the waterline from 1 to 4, the TPC ranged from 0.093 - 0.693 for PS 1, from 0.101 - 0.751 for PS 2, from 0.096 to 0.717 for PS 3 and from 0.098 - 0.664 for PS 4. These values serve to estimate the maximum load that can be tolerated by the vessel under different conditions.

One important set of parameters used to assess the design viability of a vessel are the parameters of form. Table 8 shows four parameters of form (the block, prismatic, waterplane and midship coefficients) for each of the four purse seiners studied.

Table 8. Comparison of parameters of form for four purse seiners in Bone Regency with the standard quality criteria

Coefficients of fineness	Purse Seiner				Standard Criteria [6]
	PS1	PS2	PS3	PS4	
C_b	0.323	0.323	0.323	0.326	0.57 – 0.68
C_p	0.574	0.573	0.573	0.561	0.67 – 0.75
C_w	0.722	0.722	0.722	0.730	0.91 – 0.95
C_m	0.568	0.568	0.568	0.591	0.76 – 0.94

The block coefficient (C_b) is the ratio of the volume of displacement at a particular draft to the volume of a rectangular block having the same overall length (L), breadth (B), and draught (D) as the vessel. The value of C_b is always between 0 and 1 and describes the overall shape of a vessel or fullness of form. A vessel with a low C_b is said to be finer, while values of C_b approaching 1 indicate a full form. In general, for a given set of external dimensions (L , B , D), a higher C_b means more payload, while a vessel with lower C_b will generally have a lower resistance. Lower values of C_b are generally associated with vessels designed to operate at relatively high speeds. The value of the block coefficient at waterline 5 for all four purse seiners in Bone Regency ranged from 0.323 - 0.326. The value of the block coefficient is lower than the standard value, indicating that these vessels are more elongated (slimmer) than is recommended for purse seine fishing vessels.

The prismatic coefficient (C_p) of a vessel at any given draft is the ratio of the volume of displacement at that draft to the volume of a prism having the same length as the ship and the same cross-sectional area as the ship's midships area. For the four purse seiners in Bone Regency, the prismatic coefficient at waterline 5 ranged from 0.561 to 0.573. The prismatic coefficients were also below the standard criterion range, although the gap was less than for the block coefficient.

The waterplane coefficient (C_w) is the ratio of the longitudinal cross-sectional area of the vessel to the rectangles enclosing the area. The value of the waterplane coefficient at waterline 5 for all four purse seiners in Bone Regency ranged from 0.722 - 0.730, lower than the standard. This was primarily due to the tapered bow shape.

The midship coefficient (C_m) is the ratio of the area of the underwater midship section of a vessel at a particular draft to the area of a rectangle (the circumscribing rectangle) of the same breadth (B) and draught (D) as the ship. The midship coefficient value at waterline 5 ranged from 0.568 - 0.591. The midship coefficients were all below the standard criteria in [6].

The LCB (longitudinal centre of buoyancy) is a virtual distance indicating where the longitudinal centre of buoyancy is located. The metacentric radius of a vessel (BM) is the vertical distance between its centre of buoyancy and metacentre. Whereas KM is the virtual distance of the metacentre above the keel, and KML is the virtual height of the longitudinal metacentre above the keel. The hydrostatic parameters LCB, KB, BM, BML, and KML are related to the position of B

(the centre of buoyancy of the vessel) and the position of M (the metacentre). The absolute and relative positions of B and M greatly affect the stability of a vessel. The hydrostatic curves produced by the analysis in Maxsurf V8.20i program represent the hydrostatic parameters of the four purse seiners in Bone Regency in a graphical form (Figure 4).

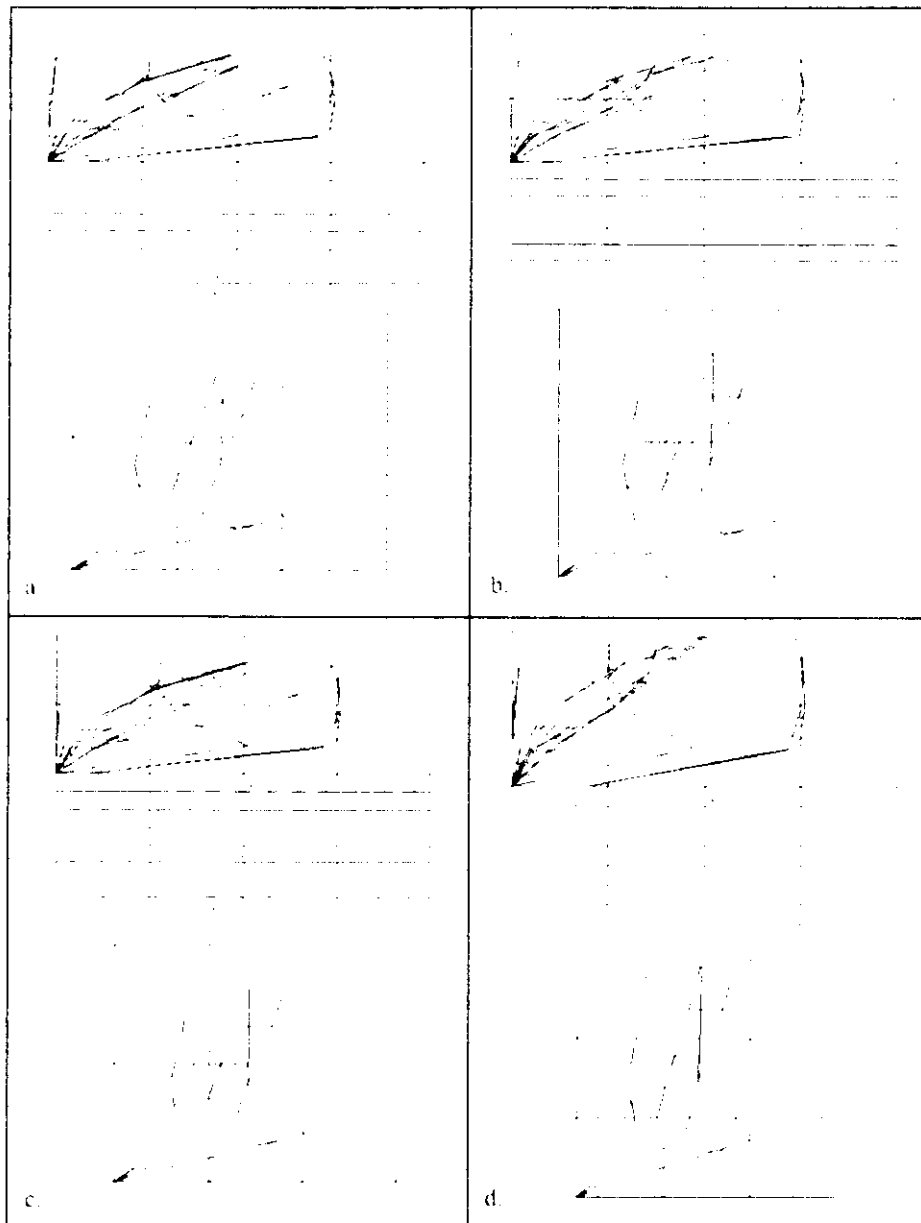


Figure 4. Hydrostatic curves of four purse seiners in Bone Regency: a. Purse Seiner PS 1, b. Purse Seiner PS 2, c. Purse Seiner PS 3, d. Purse Seiner PS 4

3.6. Purse Seiner Stability

Calculation of the righting moment arm GZ is a very important part of stability analysis. The value of GZ is related to the likelihood of preventing the entry of water into the vessel and eventual capsize. The GZ curve shows the relationship of GZ with angle of heel [8]. The stability of the four vessels was analysed using the MaxsurfV8.20i program and produced GZ curves for each vessel (Figure 5).

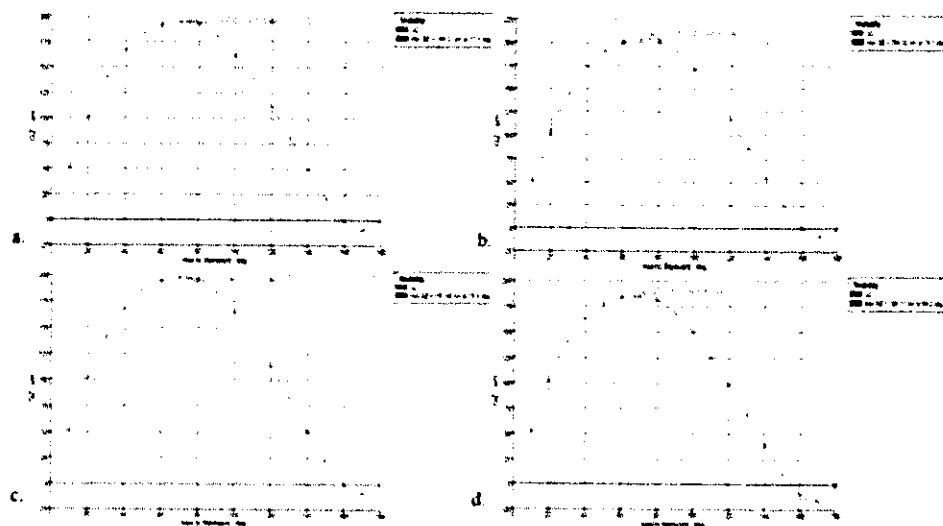


Figure 5. GZ curve of purse seiner in Bone Regency. Purse Seiner PS 1, b. Purse Seiner PS 2, c. Purse Seiner PS 3, d. Purse Seiner PS 4

The four curves in Figure 5 show that the GZ righting moment arm remained positive, which means that the vessels should be able to return to the upright position after experiencing quite considerable angles of heel. For safety, the GZ should be positive and able to return the vessel to an upright position even when fully loaded [9]. Based on the GZ curve for PS 1, the maximum GZ value of 194.23 cm was obtained at an angle of heel of 73.6°. For PS 2, the maximum GZ value was 204.02 cm at 74.5°; for PS 3 the maximum GZ was 197.48 cm at 73.6°, and for PS 4 the maximum GZ was 185.11 cm at 68.2°. The stability criteria of purse seiners in Bone Regency analysed using the Maxsurf V8.20i program are compared to criteria in the International Maritime Organisation (IMO) standards [9] in Table 9. The stability curves in Figure 5 and the values in Table 9 show that the GZ values of the sampled vessels tend to increase with angles of heel from 0° - 40°.

Table 9. Stability parameters of four purse seiners in Bone Regency compared with IMO standards

Criteria of stability	IMO standard [9]		Purse Seiners in Bone Regency			
	Value	Units	PS 1	PS 2	PS3	PS4
Area 0 to 30	315.130	cm.deg	2231.831	2319.875	2256.331	2277.956
Area 0 to 40	515.660	cm.deg	3767.037	3921.386	3811.650	3798.233
Area 30 to 40	171.890	cm.deg	1535.207	1601.512	1555.319	1520.276
Max GZ at 30 or greater	20.00	Cm	194.20	204.00	197.50	185.10
Angle of maximum GZ	25.0	Deg	73.6	74.5	73.6	68.2
Initial GMt	15.00	Cm	295.30	306.40	298.20	306.80

4. Conclusion

The bows of the four purse seiners studied were V-shaped while the stern part of the vessels was U-shaped. The ratios L/B, L/D, and B/D did not match the standard ratios according to standard criteria. The purse seiners sampled had an elongated (slim) hull form, so that the parameters of form (block, prismatic, waterplane and midship coefficients) had values lower than the range of values in the standard criteria for purse seine vessels. The stability parameters of the four vessels did meet the standard criteria set by the IMO (International Maritime Organization).

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