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INCREASING STABILITY AND OPERATIONAL PERFORMANCE OF MULTI DAY FISHING BOATS IN SRI LANKA

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ABSTRACT

The deep sea fleet of Sri Lanka has been expanding rapidly. The vessels are manufactured in 48 boat yards which make fibreglass boats according to plans approved by the Ministry of Fisheries and Aquatic Resources Development. The design of the boats shows little variation, except in length. Common length is 12-15 m. A template was made to analyse existing deep sea fishing boats in Sri Lanka. It addresses basic issues regarding vessel design, construction and operation. A general hydrostatic software (GHS) was used to calculate hydrostatic data and to analyse vessel stability under various operating conditions. A power prediction software (HydroComp NavCad 2013) was used to analyse both hull resistance and propulsion parameters which help to establish an efficient trim and corresponding optimum speed for better fuel economy and performance. The template an analytical tool for vessel modifications and design. In this way, a boat can be modelled and analysed for stability, resistance and propulsion by governmental institutions, boat yards and designers. It will help to ensure safety at sea, establish better operation and service life of single vessels, and improve the general condition of the national fleet.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Sri Lanka is an island in the Indian Ocean with an EEZ of 517,000 km^2, a coastline of 1585 km and access to international waters (Figure 1). There has been a rapid increase in the number of vessels operating in the offshore waters, called multi-day boats in Sri Lanka. In 2013 there were about 4400 such boats in operation, an increase of about 50% since 2009 (Table 1).

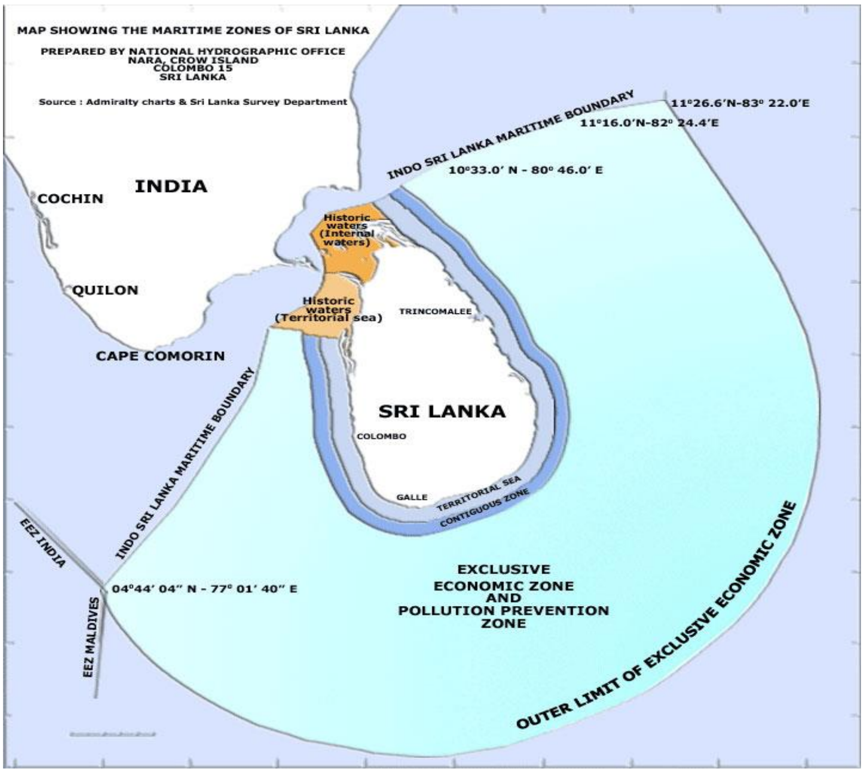

Figure 1. Sri Lanka and the EEZ (MFARD 2013)

Table 1. Number of fishing vessels with inboard engines in Sri Lanka. Vessels are classified according to how long they can stay at sea (MFARD 2013).

Vessel type	*2009*	*2011*	*2012*	*2013 (estimated)*
Multi-day boats (offshore vessels)	*2,934*	*3,872*	*4,080*	*4,430*
Single day boats	*958*	*1,120*	*890*	*570*

There are twenty fisheries harbors located around the island. Those have the capacity to berth fishing boats which have maximum draught of up to 6 m (Table 2). In 2013 there were 48 boat yards in Sri Lanka (MFARD). The boats are made of fibre reinforced plastic and the method of hand layup is used for construction. Engines are imported from Japan, Korea and China. The boats are of relatively uniform design. There is a trend towards larger vessels with time, but the same moulds are used and the boats are becoming longer and higher. Therefore there are increasing concerns about the stability of these vessels and operational performance.

Table 2. Berthing capacity of fisheries harbours in Sri Lanka (Ceylon fisheries Harbours Cooperation).

Dredging Depth (m)	Active harbours	Berthing capacity (No. of vessels)
2.5	1	250
2.5 – 3.0	4	375
2.5-5.0	3	530
3.0	7	1892
3.5	2	275
4.0 -6.0	3	1050
Total	**20**	**4372**

Local boat yards are regulated and supervised to comply with local boat building standards. In addition, boat designs are to be registered and approved under the competent authority, the Department of Fisheries and Aquatic Resources. There is an established procedure for approving the mould. Specifications and set of drawings that describe a design should be submitted in order to get approval for construction. Lines plan, general arrangement plan, construction details with sectional views, and auxiliary system drawings such as electrical, bilge system are included. Based on the drawings, the department considers hydrostatic particulars for hull geometry. Once the boat has been completed, an inclining experiment is carried out in order to evaluate light ship details such as its weight, centre of gravity as well as metacentre to ensure that the boat has a sufficient intact stability at a small angle. A rolling test is also carried out when evaluation of stability is needed. Running trials are carried out for new and existing vessels to check manoeuvrability as well as seaworthiness of boats before they are registered or their registration renewed.

In this project the stability and operational performance of a standard boat are analysed using General Hydrostatic Software (General Hydrostatic, 2014) and HydroComp NavCad softwares (HydroComp, 2014) respectively. Operational performance is also calculated based on different scenarios, catch, storage and weight of nets and water, amount of fuel on board and so on. A template is created for these calculations which should help the department in fulfilling its functions. It can also be used to give advice on how to improve the safety and operational performance of individual vessels. This should reduce costs and improve safety.

2 APPLIED THEORY AND FORMULAS

2.1 Resistance and power

In general estimates of resistance and propulsion are based on calculations in four different stages. These four basic components of resistance and propulsion, are effective power/hull resistance, the propeller, hull/propeller interaction, and ship/model correlation (Tupper and Rawson, 2001). When applying related theories, and in model tests and other calculations the technique of dimensional analysis is commonly used. To present test data and to compare performances, following non dimensional coefficients are commonly used (Tupper and Rawson, 2001).

$R/\rho V^2 L^2$ is called the resistant coefficient
$T/\rho n^2 D^4$ is called the thrust coefficient is represented by K_T
$Q/\rho n^2 D^5$ is termed the torque coefficient and represented by K_Q
$VL\rho/\mu$ or $VD\rho/\mu$ are referred to as the Reynolds' number
$V/\sqrt{gL}$ or $V/\sqrt{gD}$ are referred as Froude number
$P/\rho V^2$ is termed the cavitation number
V/nD is the advance coefficient and is represented by the letter J

The ratio μ/ρ is termed the kinematic viscosity and is represented by v
Where R is resistance, ρ is density of water. V is velocity, L is waterline length, T is thrust, n is revolution per minute. D is diameter, Q is torque, μ is coefficient of kinematic viscosity, g is acceleration due to gravity and. P is pressure (Tupper and Rawson, 2001).

The followings are definitions used when resistance estimates are calculated:

Bare hull resistance: The resistance of a ship at a given speed is the force required to tow the ship at that speed in smooth water, assuming no interference from the towing ship. Without appendages, it is called the bare-hull resistance.

Total resistance: Total resistance is made up of three main components. Frictional resistance is due to the motion of the hull through a viscous fluid, the wave making resistance due to the energy that must be supplied by the ship to the wave system created on the surface of the water and eddy resistance, due to the energy carried away by eddies shed from the hull or appendages. These are explained in more detail below.

Frictional resistance: When boat moves in water, it generates a boundary layer. This layer moves with the boat. Energy is absorbed by the layer to create its momentum. The resistance due to this effect is called frictional resistance. It can be calculated by using non-dimensional coefficientC_F, and is calculated on $C_F = 0.075/(\log_{10} L_n - 2)^2$ (Ragnarsson, 2003).

Wave making resistance: When a boat moves in water it generates wave patterns. A pressure field around the hull and water surface creates the wave patterns. There are two different wave patterns generated, at the bow and at the stern. The boat must provide the energy to create these waves and to break waves. This effect will create resistance for the boat and it is called wave making resistance (Fyson, 1985).

Eddy making resistance: There are structural components which are connected to the hull below the waterline. These are termed appendages which create eddies and separation resistance to the streamlined flow. The resistance thus created is called Eddy making resistance (Fyson, 1985). Here it is referred to as an appendage drag considering above resistance components and roughness allowance, total resistance can be estimated (Fyson, 1985).

Propeller and Hull propeller interaction: The following definitions used in power estimations (Ragnarsson, 2003). Effective power is the power needed to tow a boat without self-propulsion. Indicated power is the power generated inside the cylinders of an engine. Brake horse power is the power taken out from the flywheel of the engine Power supplied to the propeller at the aft end of the propeller shaft is called delivered horse power. The propeller creates a thrust and it creates movement of the boat. This power is called thrust horse power.

The propeller is the primary device which produces the thrust to move the boat. Suitably matched propeller gives maximum possible thrust without overloading the engine and must have the correct diameter and pitch (Gerr, 2001). Propeller characteristics are studied in a testing tank without a hull. This is called an open water test (Ragnarsson, 2003). Results of open water tests are presented by non-dimensional coefficient forms (Figure 2).

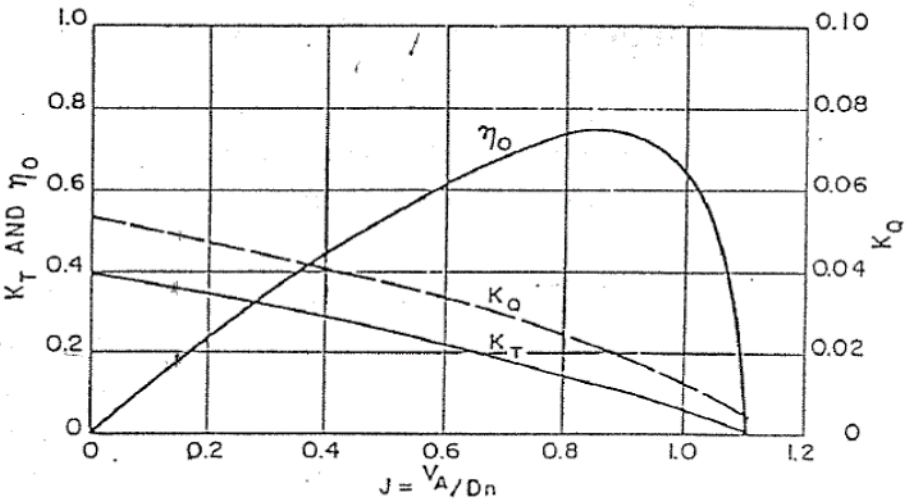

Figure 2. Propeller diagram from open water test showing the changes in: Torque coefficient ($K_Q=Q/(\rho n^2 D^5)$), Thrust coefficient ($K_T=T/(\rho n^2 D^4)$) and Propeller efficiency ($\eta_0=(JK_T)/(2\pi K_Q)$) with changes in the advance coefficient J (Ragnarsson, 2003).

When hull and propeller act together a new physical system comes into play. The propeller increases resistance but also generates thrust. The point where the thrust generated exceeds the added resistance is called the augment of resistance (Figure 3) (Tupper and Rawson, 2001).

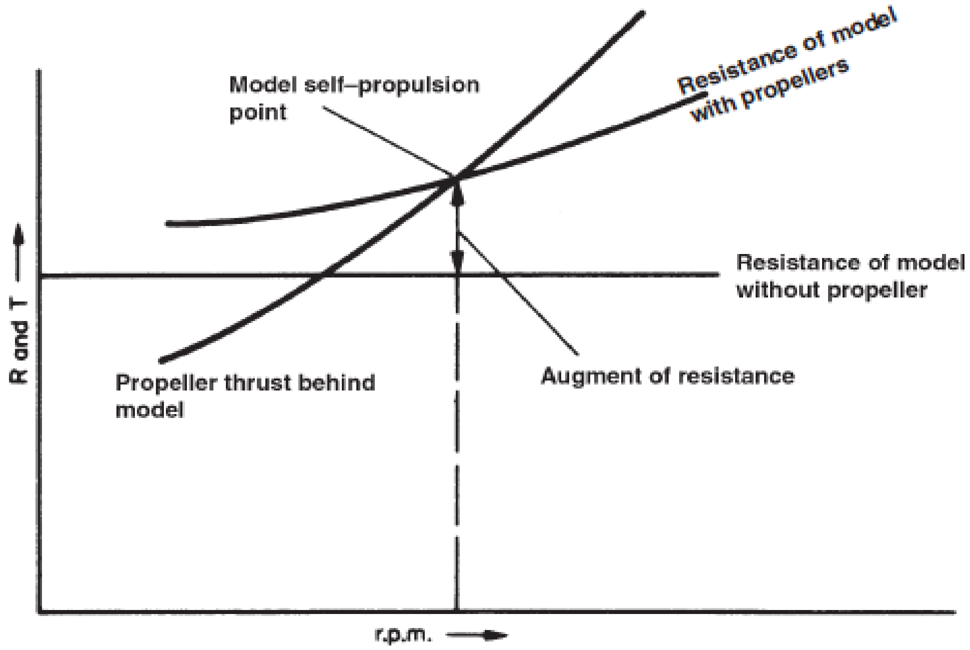

Figure 3. Hull propeller interrelation (Tupper and Rawson, 2001).

Thrust deduction factor (t), wake fraction (w), relative rotative efficiency (η_R) are three parameters that solve the real physical system of hull- propeller combination. The effective thrust on hull is a bit smaller than the generated thrust by propeller due to self propulsion arrangement (augment resistance). The thrust deduction factor is calculated to include this difference for the analysis. When a ship moves at a certain speed, its propeller does not move with the same speed relative to the water.The wake fraction is calculated to consider this physical effect that is due to the boundary layer generated by the hull. There are variations in water velocities over the propeller disc due to flow pattern infuenced by the hull. These variations are considerable compaired to open water conditions in which the propeller efficiency was determined. Hence, the relative rotative efficiency, (η_R) is calculated and used to give more accuracy in the propulsion analysis (Ragnarsson, 2003).

2.2 Model tests, analysis and trials

There is a procedure to calculate total resistance of a boat through a model experiment. Total resistance is measured in a towing tank for a model that is scaled to a boat. Residual resistance of the model is calculated by subtracting its calculated frictional resistance. The residual resistance for boat is scaled according to the Froude number. Total resistance of the boat is then estimated by adding frictional resistance calculated to the derived residual resistance of the boat. Speed can then be predicted for given engine power. It is recommended that the propeller be "under-pitched" so there is a margin to increased load of a vessel. In modern approach, the RPM is set at the full rated value and based on that, propeller is sized for reduced (95%) rated power (MPTE, 2006).

When a boat has been built, a trial is carried out to ensure that boat meets its design parameters by determining speed, shaft power, propeller RPM, pitch and drafts relevant to load conditioned. It helps to establish the relationship of these parameters and to obtain performance data for use in future design (Ragnarsson, 2003).

2.3 Stability

Stability is the most important factor regarding overall safety of the boat. It describes the ability of a boat to return to its upright position after being heeled (Gudmundsson, 2009). Commonly, transverse stability is evaluated to ensure the safety of a boat. A boat's stability is evaluated for small angles of inclination based on metacentric height (GM). When GM is positive, zero or negative it is called stable, neutral and unstable equilibrium respectively. The metacentric height GM can be determined by an inclining experiment (Ragnarsson, 2003).

A righting arm diagram (GZ curve) is used to evaluate the stability at large angles of inclination. Weight stability and form stability are investigated by interpreting this curve. Maximum value of GZ, angle at which the maximum value is reached, initial gradient of the curve, area under the curve at different ranges of angle and range of stability are some of characteristics that are examined to evaluate dynamic stability. The shape of the curve depends on freeboard and ratio of length to breadth. The centre of gravity of the boat also determines the shape of this curve (Gudmundsson, 2009).

An inclining experiment is carried out to determine the centre of gravity and displacement of the completed vessel in lightship condition with some accuracy. The draught readings for forward, amidships and aft are to be taken during the test. While weights are being moved transversely on the deck in a standard manner, the corresponding angles of heel are calculated through pendulum readings. The pendulum is suspended on board at any suitable location (Fyson, 1985). Using the following equation, metacentric height, GM can be calculated:

$GM = qd / (\Delta \tan\emptyset)$,
where q=moving weight,
d=moving distance,

Δ = displacement, and
$\emptyset$=angle of pendulum.

If draught has been seen in the displacement sheet, the displacement and metacentric height above keel can be determined. Finally vertical centre of gravity can be determined (Ragnarsson, 2003).

3 BOAT SAFETY REGULATIONS

Under the *fishing boat safety regulation 2009 of Sri Lanka*, it is compulsory that new fishing boat designs should comply with criteria for basic stability as well as stability under defined operating conditions. The Department of Fisheries and Aquatic Resources is the competent authority that must analyse new designs and make sure they conform with the regulations.

The followings are the criteria and the operating conditions stated in the regulations in Sri Lanka.

"The following minimum stability criteria shall be satisfied by all deck boats, unless the Competent Authority is satisfied that operating experience justifies a departure there from:

(a) The area under the righting lever curve (GZ curve) shall not be less than 0.55m-rad up 30 to angle of heel and not less than 0.090m-rad up to 40 or the angle of flooding θ_F,, if the angle is less than 40. Additionally, the area under the righting lever curve (GZ Curve) between the angles of heel of 30 and 40 or between 30 and θ_F, if the angle is less than 40, shall not be less than 0.030 m-rad. 0f is the angle of heel at which openings in the hull, superstructures or deckhouses which cannot rapidly be closed watertight commence to immerse. In applying this criterion small openings through which progressive flooding cannot take place, need not be considered as open.

(b) The righting lever GZ shall be at least 200 mm at an angle of heel equal to or greater than 30, however the righting lever GZ may be reduced to the satisfaction of the competent authority, but in no case by more than 2(24-LOA) %, where length overall (LOA), in meters, is as defined in paragraph (1) of regulation 179.

(c) The maximum righting lever GZ max shall occur at an angle of heel, preferably exceeding 30 but not less than 25.

(d) The initial metacentric height GM0 shall not be less than 350 mm.

The number and type of operating conditions to be considered shall be to the satisfaction of the competent authority and where appropriate, shall include the following:-
(a) Departure for the fishing grounds with full fuel, stores, ice, fishing gear etc.
(b) Departure from the fishing grounds with full catch, 30% stores, fuel etc.
(c) Arrival at home port with full catch and 10% stores, fuel etc.
(d) Arrival at home port with 10% stores, fuel etc. and minimum catch, which shall normally be 20% of full catch but may be up 40%, provided the competent authority is satisfied that operating patterns justify such a value" (MFARD, 2009).

4 METHODOLOGY

4.1 Collection of technical and operational data

The most common hull shape of existing boats of the national off shore fishing fleet of Sri Lanka (multiday boats) was selected as reference boat for evaluation purposes. Complete data set for such a boat was obtained from lines plan, general arrangement plan, specification booklet and a result sheet from an inclining experiment for the selected boat or a sister boat. General hydrostatic software (GHS) was also used to prepare initial data and carry out final propulsion analysis.

Lines plan (Annex 1) is the basic technical drawing that gives the dimensions of a boat at each and every stations along the longitudinal axis of the vessel. Profile with buttock lines, waterlines, body plan and offset tables provide many details of a boat's geometry. Fairness (smoothness) of outer surface of the hull and flow patterns of water around under water portion of the hull can be visualized and considered in to a design throught a lines plan.The lines plan is prepaired by dimensions that can be easilly measured by the radial method called *offsets*, and can be taken from an exsisting boat, mould or plug (Traung *et al.*, 1955).

Utilization of space onboard is mainly described in a general arrangement plan (Annex 2). It gives details on such aspects as load distribution, efficient access of every space, and capacity to hold fuel, water, ice etc. It also gives details by which cost estimation will be possible. It explains how accommodation is arranged, navigational lights are set, propulsion machinery is installed and fishing gear and equipment are arranged in an efficient manner. Specification sheets for a vessel provides general technical information such as designed speed, construction and stability standards identifying criteria under which the boat should be built.

Accurate lightship data (i.e. vertical center of gravity, longitudinal center of gravity and light ship weight) are needed and should be obtained from inclining experiments done after completion of the construction of the boat, or obtained from previous experiments done for a sister ship. Engine performance data can be obtained from manufactures' leaflets. Engine manufactures should give engine test data according to international standards such as ISO 8665 (Gulbrandsen, 2012).

The three basic documents; the lines plan, the general arrangement plan and the specification sheets, light ship data and engine performance data play the vital role in analyzing a boat. If used in combination with modern design software tools, one can have a simple method or template to analyze load distribution on general arrangement plan, buoyancy distribution in lines plan, establish better strength, stability and performance, and evaluate trim and draught for optimum speed. Standard criteria given by specification booklets ensures the quality of such a template.

4.2 Design tools

Two modern software tools were used to estimate resistance, propulsion and stability of the vessel. General hydro static software (GHS) can be used to calculate hydrodynamic properties of the vessel such as hydrostatic particulars of hull form, righting arm, form coefficients, compliance of stability criteria, strength and damage stabilities. The documents of lines plan, GA plan, specifications and inclining test data are needed for calculations using this software.

The HydroCompNavCad software was used to estimate resistance of boat including an appendages drag. Then propulsion parameters were estimated with the selected propulsion machinery. Some results that had been obtained from GHS software were also used for final calculations. In this study, Holtrop and Mennen power prediction method is applied. This software can be used with new technical features of sizing and performance assessment for marine propellers, engines and transmissions.

4.3 Pre- estimating some parameters

GHS software can be used to quickly analyze many design parameters of the vessel. It was used to estimate the following parameters which are needed to carry out estimates of final resistance and propulsion analysis of the boat. Length, breadth, height and volumes are estimated for all geometrical components of the boat, the hull, water tanks, fuel tanks, chilled bath, fish hold sub divisions, stores, wheel houses, rudders, and kegs. It can be used to analyze the internal volume of a vessel make general arrangement plan in efficient manner.

Using coefficients that are commonly used in architectural calculations, volume of hull, block coefficient, ratio of displacement and length, water plane area coefficient, maximum sectional area coefficient, longitudinal and vertical prismatic area coefficients were calculated with draught intervals of 0.1 m at an angle for both trim and heel of zero. These results are needed for calculation of resistance of the boat at each draft condition, to established design water line and free board under the standard criteria. Hydrostatic properties (Annex 3) were calculated to use for final evaluation of resistance. These are displacement of boat, longitudinal center of buoyancy, vertical center of buoyancy, tons per one centimeter immersion, longitudinal center of flotation, moment for one degree of trim, and longitudinal and vertical metacentric height. These were estimated for draught intervals of 0.1 m with trim and heel angles r both set to zero.

4.4 Estimating and analyzing stability

GHS software was used to estimate the stability parameters of the boat for comparison with the stability criteria. The six loading conditions of the boat were defined according to the regulation and stability margins were calculated for each. Stability parameters for few modifications of the boat were also calculated for each loading condition.

The stability of the reference boat with modifications and flooding situation for fish hold were analyzed individually with the stability criteria. Comparisons of shape of GZ curves with the reference boat were also carried out. The modifications include increased deck level, chilled bath used for storing fishing nets and fish hold filled with water in case of emergency. These modifications are known to be commonly carried out by boat builders and boat owners.

4.5 Estimating resistance and propulsion

The HydroCompNavCad software was used to estimate parameters of both resistance and propulsion. Data from different sources such as curves of forms, volume of components, line plans, and general arrangement plans were used to evaluate resistance of the boat. When dealing with propulsion, parameters for the engine, gear box and propeller were obtained according to general arrangement plan and specification booklet provided with drawings.

4.6 The selected reference boat

Based on interviews and pre-studies in Sri Lanka a certain boat has been chosen as a reference boat for this project. This particular boat is representative for a large fleet and any findings for it can easily be extrapolated or used for a wider range of vessels (Figure 4).

Figure 4. Selected hull form for reference boat.

The lines plan (Annex 1) and general arrangement plan (Annex 2) for the reference boat were collected from Sindathri Boat yard in Negombo, a registered boat builder under the Department of Fisheries and Aquatic Resources (DFAR) in Sri Lanka. Figure 4 shows a boat which has the same hull dimensions. This hull shape has been commonly used in Sri Lanka for the last two decades (Annex 04). Engine performance curves were selected for the Doosan, L136T/TL marine engine which is widely used in Sri Lanka.

The vessel is built from fibreglass reinforced plastic (FRP) and is designed for operation in Sri Lankan waters. It was built as a combination vessel, and fitted to carry out gillnetting and long-lining. The propulsion machinery is a four cycle diesel engine, medium speed, connected to a reduction gear with a fixed pitch propeller. The engine room is in the aft of the vessel. The accommodation and wheel house is located above the engine room. The vessel has a one main deck, storage in the forepeak, fuel tanks and water tanks aft, fish hold and chilled bath between the engine room and stores. The main dimensions of the vessel are; overall length 14.63m, breadth 4.72m, depth 2.68m, design draft 1.1m and intended speed of 3.825 m/s (7.5 knots). It has a carrying capacity of; fish hold 8.3m^3, chilled bath of 3.5m^3, fresh water of 4m^3, and diesel oil of 8 m^3.

The fish hold is sub divided by means of wooden stanchions and pen boards. Sides, deck heads and bulkheads are insulated according to official standards. The rudder is of semi balance type with aerofoil cross section. The rudder is made from steel and covered by layers of FRP. The bottom pintle is stainless steel running in a water lubricated bearing. Propeller is to be fitted of fixed pitch type which has a diameter within the range of 0.711m-1.016m (28”-40”) and pitch within the range of 0.508m-0.762m (20”-30”).

The hull is constructed in accordance with the *fishing boat safety regulation 2009* of Sri Lanka and was inspected during construction by the Department of Fisheries and Aquatic Resources, and surveyed before registration for each year prior to renewal of the operational licence for fishing in Sri Lankan and international waters. The hull was built from fiberglass and wood with scantling given by regulations. Internal tank bulkheads and tanks are made of fibre reinforced plastic.

The operational pattern of the vessel can be described using service information. Engine performance data, gear ratio and propeller diameter are used for the reference boat (Table 3).

Table 3. Engine performance and propulsion data obtained from manufacturers leaflets.

RPM	Power/ps	Load/ps
1000	105	20
1200	130	32
1400	152	51
1600	172	80
1800	185	110
2000	192	150
2200	200	200
gear ratio		2,45
Propeller diameter		900 mm

4.7 Intermediate results

4.7.1 Hull form

GHS software was used to make a geometric model of the reference boat (Figure 5) and to carry out further calculations.

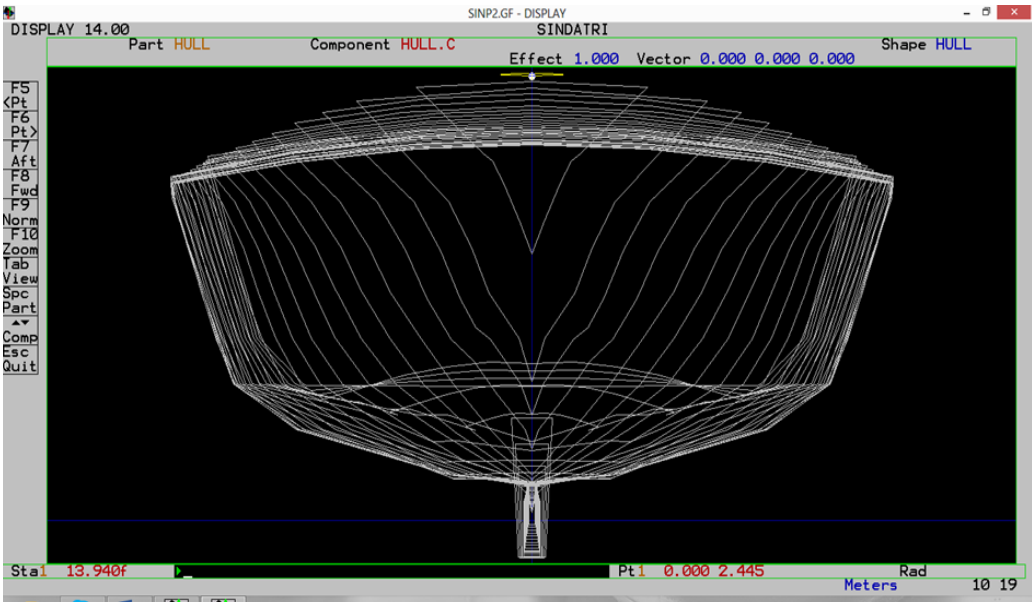

Figure 5. Geometrical boat model of the reference boat created by GHS software.

Hull particulars needed for resistance calculations were obtained from lines plan and other particulars were estimated from the geometric model made by using GHS software (Table 4).

Table 4. Calculated hull particulars of the reference boat.

Particulars	Value
Length on water line	12,923 m
Max beam on water line	3,461 m
Max moulded draught	1,1 m
Displacement	25 t
Weted surface area	46,8 m^2
Lcb fwd TR	5,905 m
Lcf fwd TR	5,615 m
Max sectional area	2,6m^2
Water plane area	35,3m^2
Transom beam	2,216 m
Half entrance angle	21 deg
Block coefficient	0,397
Water plane area coefficient	0,789
Maximum sectional area coefficient	0,69
Longitudinal prismatic coefficient	0,647
Vertical prismatic coefficient	0,504

4.7.2 Light ship data

Light weight, longitudinal centre of gravity and vertical centre of gravity for the boat is assumed to be 8 tons, 4.5 m from aft end and 1.0 m above the keel respectively. Therefore findings may only show trends but not necessarily the exact values for the behaviour of the reference boat.

4.7.3 Operating conditions and stability criteria

Operating/loading conditions and stability criteria are selected according to the safety regulations 2009 in Sri Lanka and IMO voluntary guidelines for fishing vessel less than 24m. Six operating/loading conditions were defined to be analysed. Of these conditions of 01, 03, 05, and 06 are according to the regulations and conditions 02 and 04 were included as they reflect common operational patterns in deep sea fishing in Sri Lanka today.

Condition 01 - departure for fishing grounds with full fuel, stores, ice, fishing gear etc.
Condition 02 - arrival at fishing grounds with 60% fuel, stores, fuel etc.
Condition 03 - departure from fishing grounds with full catch, 30% stores, fuel etc.
Condition 04 - departure from fishing ground without catch, 30% stores, fuel etc.
Condition 05 - arrival at home port with full catch, 10% stores, fuel etc.
Condition 06 - arrival at home port without catch, 10% stores, fuel etc.

Parameters for each operating condition were calculated using GHS software (Table 5)

Table 5. Calculated parameters for different operating conditions all weights are in tonnes.

Item		Cond01	Cond02	Cond03	Cond4	Cond05	Cond06
Light weight		8	8	8	8	8	8
Crew and store	Crew	0,7	0,7	0,7	0,7	0,7	0,7
	Store 01	1,5	1	0,5	0,5	0,15	0,15
	Store 02	0,2	0,13	0,06	0,06	0,01	0,01
Fishing gear		1,2	1,2	1,2	1,2	1,2	1,2
Total fixed		11,6	11,3	10,46	10,46	10,06	10,06
Fuel (three tanks)		1,49/2,54/3,02	1,03/1,77/2,10	0,52/0,88/1,05	0,52/0,88/1,05	0,16/0,27/0,32	0,16/0,27/0,32
Fresh water(two tanks)		1,4/1,64	0,97/1,14	0,49/0,57	0,49/0,57	0,15/0,17	0,15/0,17
Catch		0	0	11,59	0	11,59	0
Total tank weight		10,09	7,01	15,1	3,5	12,65	1,06
Total weight		21,69	18,04	25,56	13,96	22,71	11,02
Draft @ aft (0)		1,738	1,532	1,07	1,287	0,895	1,113
Draft @ Fwd(12,92) in meters		0,089	0,163	1,297	0,259	1,311	0,324
Trim in degree		7,27aft	6,05aft	0,64fwd	4,55aft	2,06 fwd	3,49aft

Stability criteria considered for evaluation are listed in Table 6. All indicators are obtained from righting arm diagrams relevant for each operating condition. GHS software was used to draw righting arm diagram and calculate parameters which are included in the criteria.

Table 6. Stability criteria for evaluating the 6 conditions.

Criteria 1		Area under GZ curve 0 to 30 should be greater than 0.55 m-rad
Criteria 2		Area under GZ curve 0 to 40 or flooding angle should be greater than 0.90 m-rad
Criteria 3		Area under GZ curve 30 to 40 or flooding angle should be greater than 0.30 m-rad
Criteria 4		Upright GM should be greater than 350mm
Criteria 5		Righting arm at 30 deg or max should be greater than 0.2m
Criteria 6		Absolute angle at maximum righting arm greater than 25 deg

Table 7. Modifications/emergency situations tested

Modification	Reason for selection
With an increased deck height	Popular practice
Chilled bath filled with water	Common practice
Chilled bath filled with net	Common practice
Fish hold flooded with water	Emergency situation
Fish hold with longitudinal compartments flooded with water	Emergency situation

5 RESULTS

5.1 Stability analysis

Six various loading conditions that cover operational patterns of the fishing boat were analysed and safety margins for six stability criteria were calculated. The reference boat was analysed for stability and fulfilled every stability criteria with positive margins for every loading conditions (1^{st} row in following Tables 8-13). When the boat was analysed for modifications, it failed stability criteria in some cases under all loading conditions (highlighted red boxes in tables 8-13).

Table 8. Results of stability analysis for vessel departing for the fishing grounds with full fuel, stores, ice, fishing gear etc. (operating condition 01).

operating condition 01		Stability criterion/margin						Draught Fwd	Draught Aft
Status	Description	1	2	3	4	5	6		
		%	%	%	%	%	deg	m	m
Basic boat	According to General Arrangement plan	158	153	186	88	148	13	0,089	1,738
Modification	with an incresed deck height	136	161	252	48	266	28	-0,218	2,03
	chilled barth filled with water	112	109	138	25	106	14	0,28	1,831
	chilled barth stored with nets	169	164	197	113	161	14	0,001	1,788
	Fish hold flooded with water	22	19	34	-56	16	12	1,655	1,436
	Fish hold flooded with water (with three longitudinal compartments)	24	24	46	-59	30	16	1,652	1,439

Table 9. Results of stability analysis for arrival of fishing ground with 60% remaining of fuel, stores, etc. (operating condition 02).

operating condition 02		Stability criterion/margin						Draught Fwd	Draught Aft
Status	Description	1	2	3	4	5	6		
		%	%	%	%	%	deg	m	m
Basic boat	According to General Arrangement plan	75	89	146	72	121	18	0,163	1,532
Modification	with an incresed deck height	37	75	173	14	244	36	-0,051	1,744
	chilled barth filled with water	51	63	114	11	92	18	0,348	1,636
	chilled barth stored with nets	92	106	166	94	142	20	0,073	1,572
	Fish hold flooded with water	-26	-19	7	-49	-5	16	1,725	1,228
	Fish hold flooded with water (with three longitudinal compartments)	-24	-13	22	-53	13	20	1,722	1,23

Table 10. Results of stability analysis for departure from fishing grounds with full catch, 30% remaining of stores, fuel etc. (operating condition 03).

operating condition 03		Stability criterion/margin						Draught Fwd	Draught Aft
Status	Description	1	2	3	4	5	6		
		%	%	%	%	%	deg	m	m
Basic boat	According to General Arrangement plan	89	96	141	107	114	16	1,297	1,107
Modification	with an incresed deck height	-50	-31	14	-62	123	43	1,329	1,156
	chilled barth filled with water	71	77	118	52	92	16	1,373	1,226
	chilled barth stored with nets	104	111	161	123	133	18	1,201	1,147
	Fish hold flooded with water	-25	-19	6	-36	-4	17	1,813	0,982
	Fish hold flooded with water (with three longitudinal compartments)	-21	-11	23	-42	15	20	1,81	0,985

Table 11. Results of stability analysis for departure from fishing ground without catch, 30% remaining of stores, fuel etc. (Operating condition 04).

operating condition 03		Stability criterion/margin						Draught Fwd	Draught Aft
Status	Description	1	2	3	4	5	6		
		%	%	%	%	%	deg	m	m
Basic boat	According to General Arrangement plan	89	96	141	107	114	16	1,297	1,107
Modification	with an incresed deck height	-50	-31	14	-62	123	43	1,329	1,156
	chilled barth filled with water	71	77	118	52	92	16	1,373	1,226
	chilled barth stored with nets	104	111	161	123	133	18	1,201	1,147
	Fish hold flooded with water	-25	-19	6	-36	-4	17	1,813	0,982
	Fish hold flooded with water (with three longitudinal compartments)	-21	-11	23	-42	15	20	1,81	0,985

Table 12. Results of stability analysis for arrival at home port with full catch, 10% remaining of stores, fuel etc. (Operating condition 05).

Operating condition 05		stability criterion/margin						Draught Fwd	Draught Aft
Status	Description	1	2	3	4	5	6		
		%	%	%	%	%	deg	m	m
Basic boat	According to General Arrangement plan	140	144	193	142	159	16	1,311	0,895
Modification	With an incresed deck height	-22	-10	29	-47	138	42	1,431	0,924
	Chilled barth filled with water	121	126	173	73	139	15	1,39	1,091
	Chilled barth stored with nets	161	166	219	161	184	17	1,259	0,976
	Fish hold flooded with water	5	10	37	-28	21	16	1,875	0,805
	Fish hold flooded with water (with three longitudinal compartments)	10	18	54	-34	40	18	1,873	0,807

Table 13. Results of stability analysis for arrival at home port without catch, 10% remaining of stores, fuel etc. (operating condition 06).

Operating condition 06		stability criterion/margin						Draught Fwd	Draught Aft
Status	Description	1	2	3	4	5	6		
		%	%	%	%	%	deg	m	m
Basic boat	According to General Arrangement plan	200	202	256	229	224	20	0,324	1,113
Modification	With an incresed deck height	155	159	210	166	311	37	3,98A	1,172
	Chilled barth filled with water	154	163	225	86	190	17	0,498	1,237
	Chilled barth stored with nets	236	240	306	260	271	21	0,233	1,165
	Fish hold flooded with water	5	10	37	-28	21	16	1,876	0,805
	Fish hold flooded with water (with three longitudinal compartments)	10	18	54	-34	40	18	1,873	0,807

5.2 Influence of modifications on stability

In each results table above, the figures of stability margins for the modifications (see Table 7) show stability failures for the every loading conditions. To find out the main cause of these changes, the righting arm curves for the operating condition 1 and each modification were drawn and compared with reference boat. Following graphs illustrate the influence of the five modifications on the stability for operating condition 1.

When the deck is increased, free board will be increased then range of stability (form stability) is better. But the initial metacentric height is lower because vertical centre of gravity is raised. The initial stability is slightly lower (Figure 6).

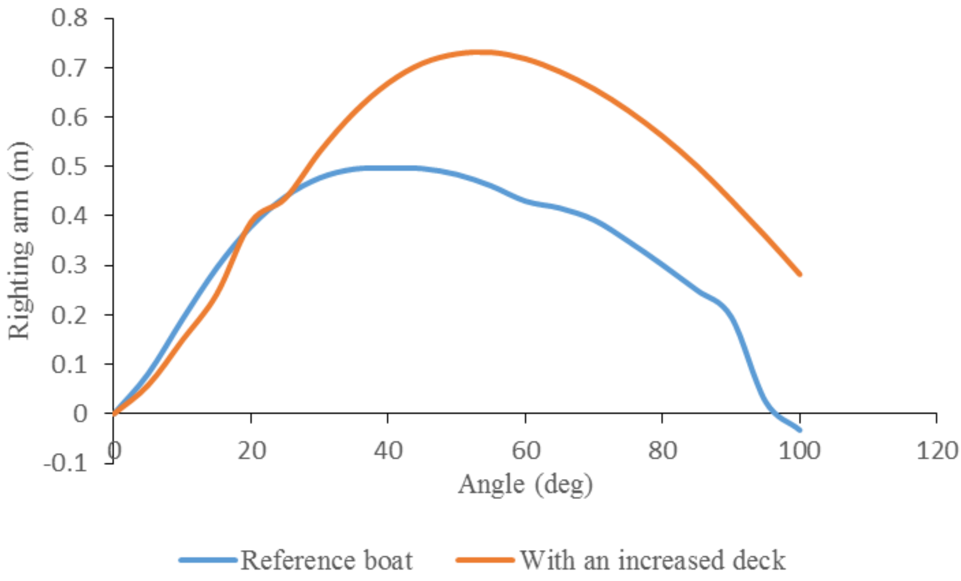

Figure 6. Stability criteria 1-6, modification increased deck height (operating condition 1).

When the chilled bath is filled with water metacentric height is decreased because of higher VCG and the effect of free surface (weight stability). Maximum value of GZ is decreased (form stability). When chilled bath is used for nets form stability as well as weight stability will be increased (Figure 7).

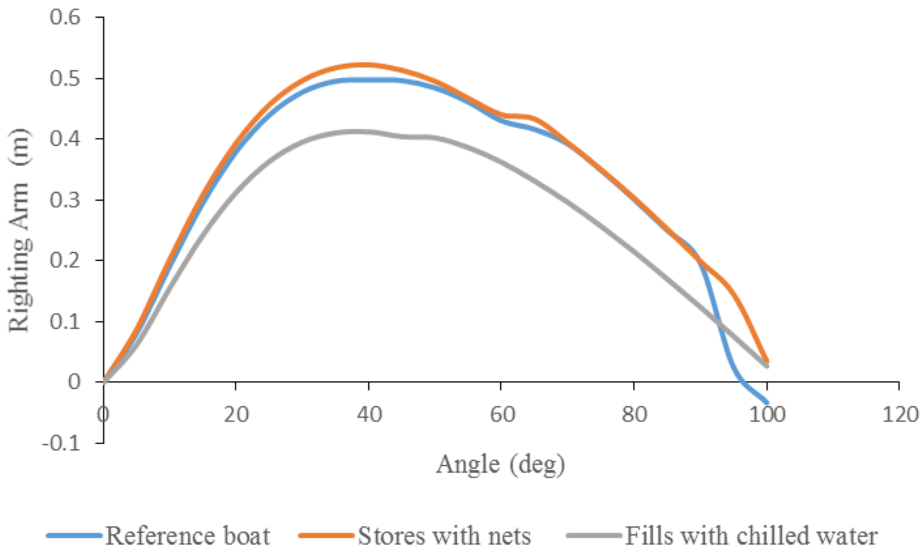

Figure 7. Stability criteria 1-6 modification use of chill bath (operating condition 1).

When fish hold is flooded with water by 70%, stability of the boat will be decreased because of the free surface effect. When the hold is fitted with partitions stability is bit better than without partitions. In both cases the graph shows that stability is significantly reduced (Figure 8).

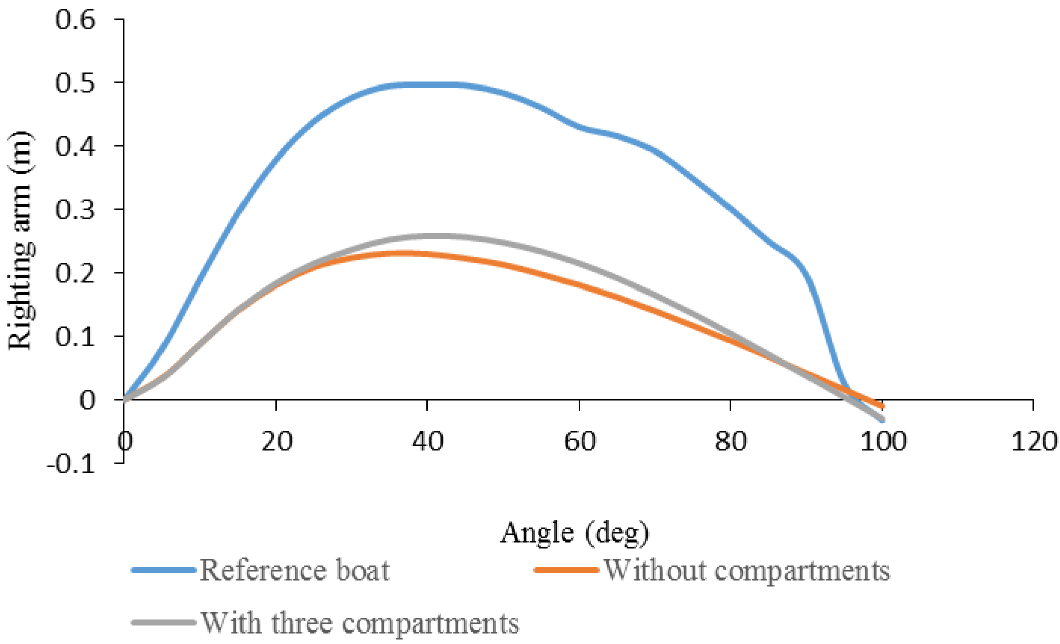

Figure 8. Stability criteria 1-6, modification fish hold flooded with water (operating condition 1).

5.3 Resistance and propulsion

5.3.1 Resistance and effective power

The HydroCompNavCad software was used to analyse resistance and propulsion of the reference boat designing conditions (maximum load). After the required dimensions, form coefficients, and speed limit are fed to the software, the program predicts the total effective power and resistance components through a regression analysis of random model experiments and full-scale data (Table 14).

Table 14. Main components of total resistance and effective power (reference boat).

Pediction method		Holtrop				
parameter		FN	Cp	LWL/BWL	BWL/T	Lambda
Value		0,37	0,72	3,73	3,15	0,93
Range		0,16-0,25	0,55-0,85	3,90-14,9	2,10-4,00	0,01-1,06
section	parameter	speed/knots				
		4	6	8	10	12
Speed Coefficient	Froude Number(LWL)	0,183	0,274	**0,366**	0,457	0,548
	Froude Number(VOL)	0,386	0,579	**0,772**	0,965	1,158
Resistance	RBARE(KN)	0,5	1,52	**4,77**	15,26	27,41
	RAPP(kN)	0,1	0,22	**0,37**	0,57	0,81
	RTOTAL(KN)	0,6	1,74	**5,14**	15,83	28,22
Power	PEBARE(KW)	1	4,7	**19,6**	78,5	169,2
	PETOTAL(KW)	1,2	5,4	**21,2**	81,4	174,2

5.3.2 Propeller efficiency

Input of maximum propeller diameter and basic propeller data, to the HydroComp NavCad software, provides parameters for monitoring a propellers open water efficiency (Table 15).

Table 15. Propeller parameters for the reference boat for five selected speeds.

Section	Parameter	Speed /Knots				
		4	6	8	10	12
Propulsor coifficient	Propulsor advance coefficient, J	0,5732	0,5364	0,4584	0,3596	0,3313
	Propulsor trust coefficient,KT	0,1413	0,156	0,1883	0,2268	0,2372
	Propulsor torque coefficient , KQ	0,02049	0,02215	0,02548	0,02935	0,03038
Cavitation	Cavitation number of propeller,SIGMAV	88,55	38,81	21,64	13,76	9,51
	Cavitation percentage	2%	2%	2%	15,20%	49,60%
	propellertip speed ,TIPSPEED (m/s)	8,12	13,1	20,53	32,82	42,85
	Minimum reccomended pitch to avoid face cavitation PITCHFC (mm)	630,6	613,8	580	540,1	529,3

5.3.3 Vessel propulsion parameters

The HydroComp NavCad software was used to evaluate the combination of hull, engine and propeller. The outcome gives sense of performance of the propulsion system as well as the boat, and performance variations with design parameters can be identified. Table 16 shows the propulsion parameters for the reference boat at five selected speeds.

Table 16. Propulsion parameters for the reference boat.

Section	Parameter	Speed / Knots				
		4	6	8	10	12
Hull -propulsor	Total vessel effective power (KW)	1,2	5,4	21,2	81,4	174,2
	Taylor wake fraction coifficient WFT	0,2803	0,2753	0,272	0,2697	0,268
	Trust Deduction Coefficient,THD	0,2306	0,2306	0,2306	0,2306	0,2306
	Relative rotative efficiency, EFFR	1,0202	1,0202	1,0202	1,0202	1,0202
Engine	Engine RPM,RPMENG (rpm)	422	681	1068	1706	2228
	Bracke power for propulsor (PS).(kw)	1,9	8,7	38,7	182	419,4
	Fuel rate per engine (l/h)	120,89	139,59	283,57	857,29	…
	Max available power (%)	1,4	6,5	28,8	135,6	312,5
power delivery	Propulsor rpm, RPMPROP (rpm)	172	278	436	696	909
	Propulsor open water torque (KNm)	0,1	0,29	0,81	2,4	4,23
	Delivered power for propulsor (PD). (KW)	1,8	8,2	36,4	171,3	394,6
	Shaft power per propulsor(PS). (kw)	1,9	8,7	38,7	182	419
	Transport factor.(%)	262,3	86,6	26,1	6,9	3,6
Effciency	Propulsor open water efficiency, EFFO	0,6245	0,6013	0,5391	0,4422	0,4117
	Overall propulson efficiency.	0,6607	0,6318	0,5639	0,4611	0,4283
Trust	Open water trust per propulsor (KN)	0,78	2,26	6,68	20,57	36,68
	Total vessel delivered thrust (KN)	0,6	1,74	5,14	15,83	28,22

5.4 Propeller failure and optimum power utilisation

Figure 9 shows that cavitation percentage increases at higher speed. High cavitation indicates poor propeller efficiency and in the case of the reference boat the propeller efficiency is drastically reduced above eight knots.

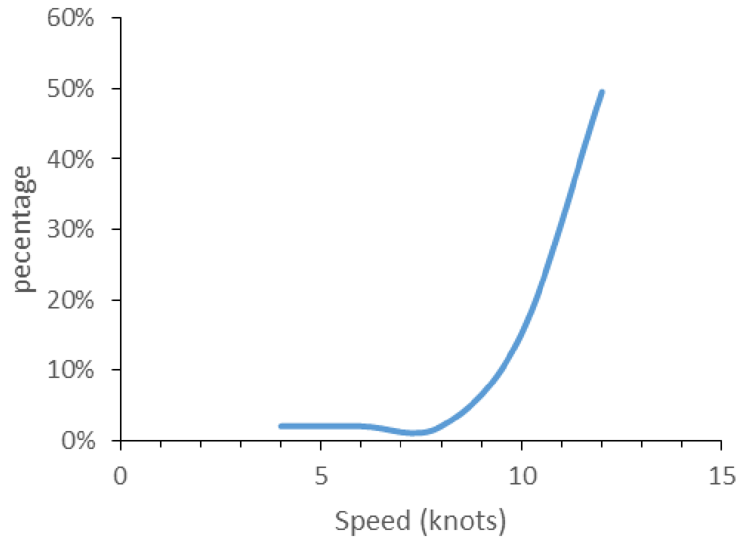

Figure 9. Reference boat propeller cavitation as predicted by the HydroComp NavCad software. (Plotted from Table 15).

In Figure 10 the maximum available power at each selected speed and the power transmission factor are plotted against speed, showing engine overload at approx. 9.5 knots and that the power transmission factor becomes drastically low.

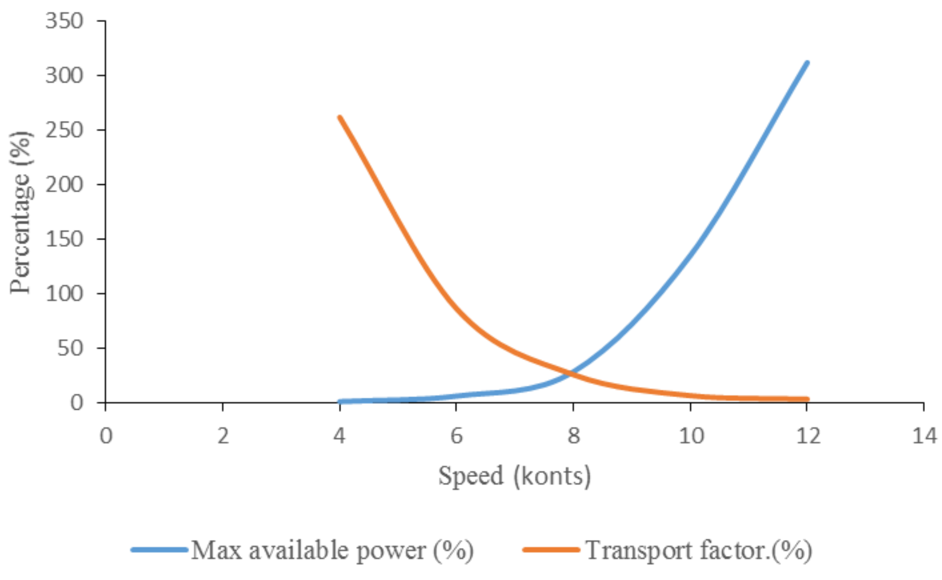

Figure 10. Reference boat, power utilisation (Plotted from Table 16).

6 DISCUSSION

6.1 Stability analysis with modification

Stability analysis under six operating conditions shows that the reference boat has a good stability. When the fish hold is flooded the stability fails. These failure is due to free surface effect of water in the fish hold. But if the fish hold with three longitudinal compartments, the results show these compartments can increase stability of the boat by reducing free surface effect. For many stability criteria, the marginal values increase when the fish hold has compartments, as can be seen by comparing last two rows in Tables 8-13.

The modifications related with chilled bath show some changes of their marginal values. By putting nets in the storage the stability will improve as the nets basically act like additional ballast by lowering centre of gravity. But by filling with chilled water the free surface effect will have negative influence on the stability in the same way as raising the centre of gravity.

When the deck is lifted, the freeboard and hull shape of the boat are changed. The stability was investigated for these changes and results are given in 1st row under modifications for every loading conditions. Some stability criteria margins increase due to higher freeboard and others decrease due to lift of the centre of gravity.

6.2 Total effective power, propeller efficiency and propulsion parameter

Total effective power can be determined (Table 14) without tank test for the reference boat. The main advantage of using HydroComp NavCad software that a tank test is not needed and big amount of money may be saved. The same goes for the estimation of propeller parameters (Table 15). Many propeller design parameters can be determined and investigated. Open water tests and cavitation tunnel tests are not required.

Hydrocomp NavCad programme has given enough details to match the suitable propeller for the reference boat. Then the propulsion system of the reference boat can be completed by assembling the required propeller having diameter of 900 mm and pitch of 580 mm to establish 8 knots of service speed (Table 3 and Table 15).

The engine delivers 28% of its total engine power used at 8 knots and the engine is overloaded at 10 knots (Table 16). It make sense that there might be better configuration of propulsion system than have been evaluated in this study.

In addition, the performance of a propulsion system can be monitored and evaluated according to the calculated results (Table 16). Performance variations with design parameters can be identified. This data is useful for new design to develop an efficient propulsion system and to evaluate running trail results.

Sea trial data are valuable and once analysed can be used to improve performance. The best answers can be found for such basic questions as:

- is the engine generating full power,
- what is the efficiency of the propulsion system,
- is there loss of thrust through excessive cavitation,
- does the vessel reach designed speed and if not how much more power is needed,
- how does this boat compare with other boats, and
- are the test numbers reliable (Macpherson, 2003).

6.3 The evaluating process

By using template it was found that the reference boat with a displacement of 25 tons can reach a speed of 8 knot using 28% of the available power of a 147kw engine and is unable to reach 10 knots because overloading the engine for the 4 bladed propeller having a diameter of 900 mm and pitch of 580 mm. The reference boat has a sound stability during the entire voyage and the intended operation.

Based on my experience of boat building and sea trails for existing fishing vessels in Sri Lanka over the last decade, it is my conclusion that results in this project give an accurate picture of the real world conditions. The theoretical models fit to the real operational parameters of existing boats using this hull form (Annex 4) as well as commonly available main engines and propulsion equipment in Sri Lanka.

There are some advantages using my template for these studies. No replacement of engine or other machinery component or hull modification are need for these evaluations. It will save time and labour.

7 CONCLUSION

Stability analysis (GHS)

Generally the reference boat has good stability, but stability margins for some operating conditions fluctuate and that needs to be considered in the design and operation of the vessels.

Resistance and propulsion prediction (HydroComp NavCad)

Two working templates have been prepared. One is for selecting the best propeller for an optimum design speed. The other is for evaluating sea trails for new vessels and how to use the results to fix problems and to improve vessel performance.

Using GHS and HydroComp NavCad together

General weight distribution that is suitable for design trim can be found by GHS. Optimum propulsion parameter can be analysed and selected by using HydroComp NavCad software in order to make a better fuel saving.

It has been beneficial to learn how to use the software and gain practical experience with a model that proved to be realistic and reliable for the selected vessel regarding its operational characteristics.

One can use these programs with confidence to recommend modifications to an existing boat regarding stability, propulsion performance and operation. The same applies for new designs except more detailed data is needed on intended fishing operation and existing parent boats.

In this way, a boat can be modelled and analysed for stability, resistance and propulsion by governmental institutions, boat yards and designers. It will help to ensure safety at sea, establish better operation and endurance of single vessels, and improve the general condition of the national fleet.

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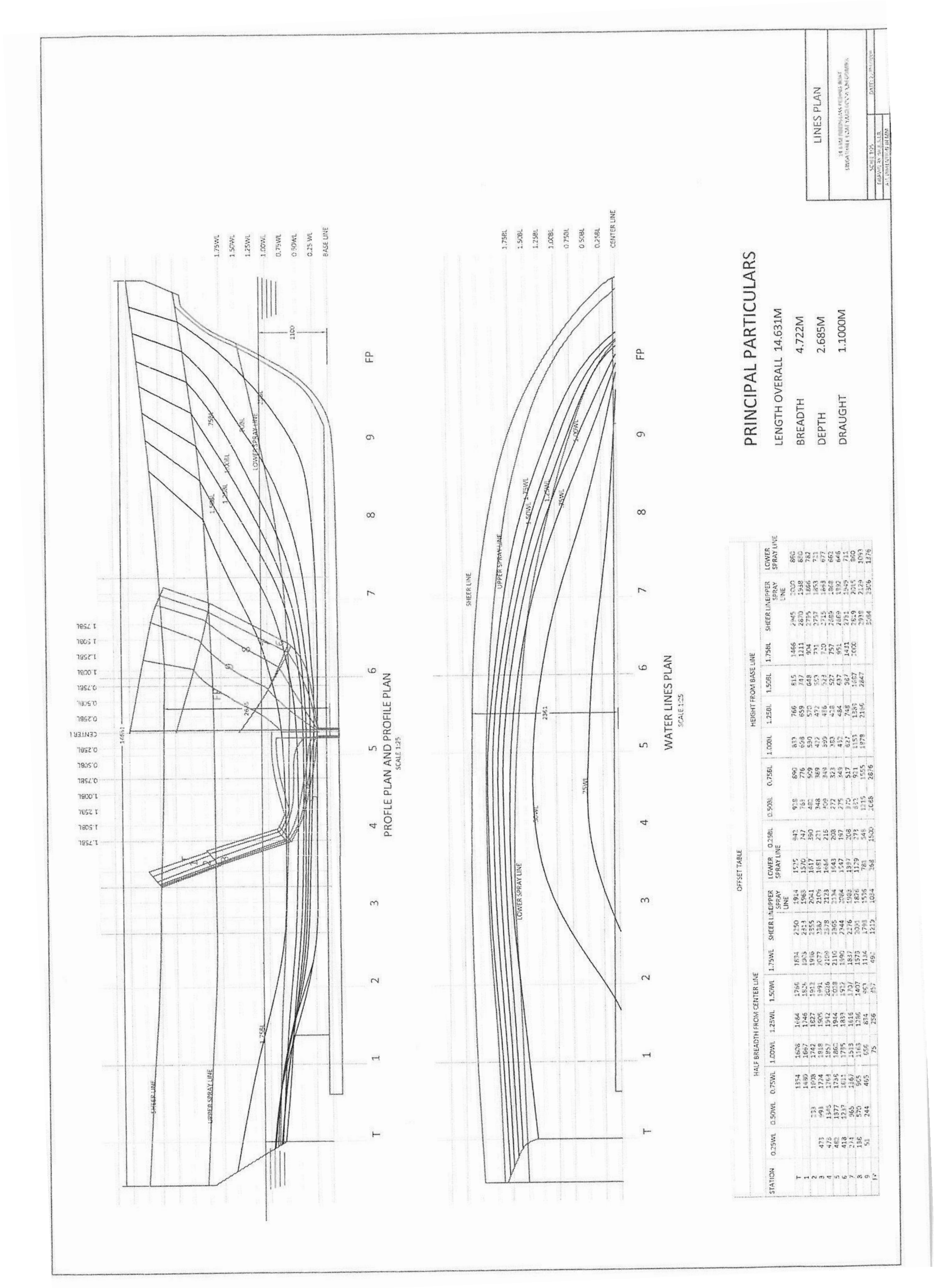
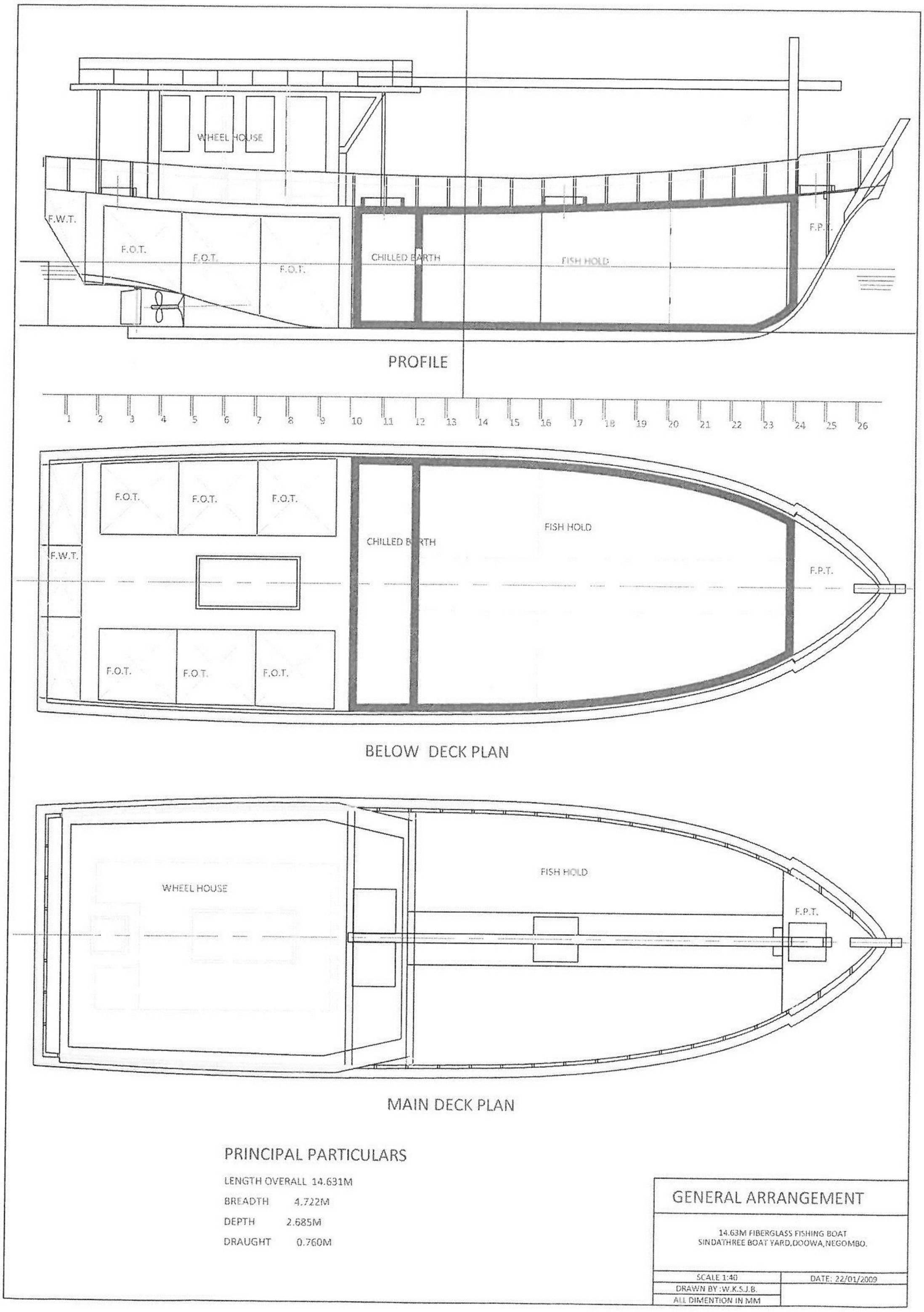
ANNEX 1: LINES PLAN



ANNEX 2: GENERAL ARRANGEMENT PLAN



ANNEX 3: HYDROSTATIC PARTICULARS

Hydrostatic properties (No Trim , No Heel, VCG = 0,00)

Draft (m)	Displacement weight(MT)	LCB (m)	VCB (m)	Weight (MT)/cm	LCF	moment(m.MT) trim(deg)	KML (m)	KMT (m)
0,1	0,23	4,988f	-0,032	0,01	5,478f	0,12	30,54	-0,028
0,2	0,3	5,032f	0,009	0,01	4,696f	0,07	13,62	0,013
0,3	0,77	5,874f	0,166	0,08	6,534f	0,62	46,29	1,269
0,4	1,85	6,301f	0,275	0,13	6,665f	1,11	34,34	1,988
0,5	3,44	6,451f	0,358	0,19	6,628f	1,68	27,89	2,642
0,6	5,5	6,493f	0,43	0,23	6,459f	2,46	25,63	2,657
0,7	8,05	6,435f	0,501	0,28	6,161f	3,65	26,01	3,015
0,8	11,25	6,264f	0,572	0,35	5,603f	5,89	30,02	3,171
0,9	14,88	6,086f	0,64	0,38	5,507f	6,84	26,33	2,824
1	18,71	5,972f	0,704	0,39	5,556f	7,4	22,66	2,619
1,1	22,68	5,905f	0,764	0,4	5,615f	7,87	19,87	2,453
1,2	26,77	5,865f	0,823	0,41	5,669f	8,33	17,82	2,35
1,3	30,97	5,842f	0,881	0,43	5,713f	8,77	16,22	2,286
1,4	35,28	5,829f	0,939	0,44	5,749f	9,19	14,93	2,248
1,5	39,69	5,822f	0,995	0,45	5,775f	9,57	13,82	2,229
1,6	44,21	5,820f	1,052	0,46	5,825f	10,08	13,06	2,229
1,7	48,84	5,823f	1,109	0,47	5,873f	10,59	12,42	2,241
1,8	53,6	5,830f	1,166	0,48	5,940f	11,21	11,98	2,268
1,9	58,48	5,844f	1,223	0,48	6,105f	11,73	11,5	2,167
2	62,88	5,876f	1,274	0,39	6,575f	10,94	9,96	1,744
2,1	65,88	5,938f	1,309	0,19	8,632f	5,97	5,19	1,434
2,2	67,03	6,012f	1,323	0,06	11,890f	1,64	1,4	1,353
2,3	67,46	6,052f	1,329	0,03	12,857f	1,58	1,34	1,337
2,4	67,6	6,067f	1,331	0	13,552f	1,57	1,33	1,332
Specific gravity = 1,025					Draft is from Base Line			

ANNEX 4: VESSEL DATA COLLECTED BY AUTHOR IN INTERVIEWS OF SRI LANKA SKIPPERS ON AUG 2013

Registration No	Length (foot)	Boat Yard	Period at sea (days)	No of hooks	Hauling method	Fuel Capacity (Litres)	Water Capacity (litres)	Ice capacity (*45 Kg)	Bait (kg)	Catch (Kg)
0217CHW	47	Lawrance	30	800	Winch	8000	3000	320	1500	2000
0356 CHW	46	Sindathri	30	750	Winch	6000	2000	210	1100	7000
0405 CHW	46	Ranil	15-20	1000	Winch	4000	2000	200	1000	2200
0461 NBO	45	Neil maine	20	1000	Winch	4500	2500	225	1200	1800
0493 CHW	45	Sindathri	20-25	1000	Winch	5000	2500	225	1000	2000
0507 CHW	45	Sindathri	20-25	1000	Winch	5000	2500	225	1000	2200
0543 CHW	45	Winarali	22-30	1000	Winch	7000	2500	280	1000	1900
0596 CHW	45	Winarali	30	750	Winch	6000	2000	240	1300	1800
1015 NBO	45	Neil marine	15-20	1000	Winch	4500	2000	235	1200	1900
0578 TLE	45	Blue star	15-20	1000	Winch	4500	2500	260	1200	1800
0289 CHW	45	Sindathri	15	750	Winch	6500	2500	350	1000	1500
0267 CHW	45	Sindathri	22	750	Winch	5000	3500	240	1000	1800
0178 CHW	45	Sealani		800	Winch	3000	2000	200	1000	1800
0119CHW	45	Sindathri		1000	Winch	3000	2000	200	1000	1800
0195 NBO	45	Sindathri		1000	Winch	4000	2000	250	1000	2000
0196 NBO	45	Ranil		1000	Winch	3000	2000	200	1000	1800
0510 CHW	45	Sindathri		1000	Winch	4000	2000	250	1000	2000
0609 CHW	45	Winarali		1200	Winch	4500	3000	270	1000	2200
0610 CHW	43	Winarali		1200	Winch	4500	3000	270	1000	2200
0633 CHW	43	Sindathri		1200	Winch	4500	3000	270	1000	2200
0341 CHW	42	VJ	21	450	Winch	6000	3000	250	FISH	2000
0224 CHW	42	VJ	21	750	Winch	6000	3000	250	1000	2000
0195 CHW	42	Sindathri	25	1000	Winch	5000	2000	180	1000	2000
0196 CHW	42	Sindathri	25	1000	Winch	5000	2500	200	1000	2000
0358 CHW	42	VJ	20-25	1000	Winch	6000	2800	250	1000	1500
0532 CHW	42	VJ	20-25	1000	Winch	6000	2800	250	1000	1500
0488 CHW	42	Winarali	25	700	Winch	5000	2000	300	1000	2000
0469 NBO	42	Sea horse	20-22	950	Winch	5000	3000	250	1000	2500
0405 CHW	42	Ranil marine	15	900	Winch	4000	2500	200	1000	2500
0513 CHW	40,6	KSLF	22	750	Winch	6000	3000	200	1200	2000

0627 CHW	40,5	Sindathri	21-25	1200	Winch	6000	3000	350	1200	2000
0646 CHW	40,5	Sindathri	21-25	1200	Winch	6000	3000	350	1200	2000
0599 CHW	40	Sindathri	21-25	1200	Winch	6000	3000	250	1200	2000
0522 CHW	40	Sindathri	22	1000	Winch	6000	2000	240	1000	1750
0110 CHW	40	Meril marine	20-25			4000	2500	250		2000
0292 CHW	40	Sealani	20	1000	Winch	5700	2600	240	1200	2500
0012 CHW	40	Blue star	20-22	1200	Winch	4000	2000	250	1200	2500
0556 CHW	40	Sindathri	20-22	1200	Winch	5000	2000	200	1200	2500
0090 CHW	40	Ranil	15-20	1000	Winch	4000	2000	220	900	2000
0236 CHW	40	Sindathri	20	900	Winch	4700	2000	220	1000	2000
0443 CHW	40	Sindathri	30	750	Winch	5000	2000	280	1000	2000
0391 CHW	40	Sindathri	25	1000	Winch	7000	3000	220	1200	2000
0134 CHW	40	Lawrance	22		Winch	7000	4000	275	1200	2200
0451 CHW	40	VJ	22	1000	Winch	5000	2000	230	1000	2500
0131 CHW	40	Sindathri	22	1200	Winch	5000	2000	240	1200	2400
0549 CHW	40	Sindathri	20-25	1000	Winch	6000	2000	240	1300	2500
0558 CHW	40	VJ	25	750	Winch	4000	2500	230	1000	2200
0621 CHW	40	Winarali	25		Winch	4000	2800	250	1000	2300
0512 CHW	40	Sindathri	30		Winch	8000	2000	400	1400	2300
0392 CHW	40	JMC	30		Winch	6000	2500	250	1000	1500
0652 CHW	40	Lawrance	30		Winch	7000	3000	300	1300	2000
0208 CHW	40	Sindathri	20-25	1000	Winch	5000	2000	250	1000	2500
0469 NBO	40	Sea horse	20	950	Winch	5000	3000	250	1000	2000
0562 CHW	40	Back horse	20	750	Winch	3000	2500	180	900	2200
0514 CHW	40	Kumari marine	20-25	1000	Winch	10000	4000	350	1100	2750
0420 CHW	40	VJ	20-25	1000	Winch	7000	3000	250	1000	2500
0447 CHW	40	VJ	20-25	1000	Winch	7000	3000	250	1000	2500
0173 CHW	40	Ranil	20-25	1000	Winch	4500	2000	200	1000	2200
0525 CHW	40	VJ	21	1000	Winch	6000	3000	250	1000	1500
0526 CHW	40	VJ	21	1000	Winch	6000	3000	250	1000	1250
0583 CHW	40	Winarali	20	800	Winch	5000	2000	220	1000	2000
0632 CHW	40	Sealani	25	800	Winch	5000	2000	240	1000	1500
0406 CHW	38	Ranil	15-25	850	Winch	5000	2000	250	1000	1500
0424 CHW	38	VJ	15-20	900	Winch	5000	3000	250	1000	1500
0010 CHW	38	Sindathri	20-25	900	Winch	6500	3000	250	1100	1500
0419 CHW	38	Blue star	20-25	1000	Winch	6000	3000	250	1000	1500

0346 CHW	38	Ranil	20	1000	Winch	5000	2000	250	1000	1800
0608 CHW	38	Winarali	20	1000	Winch	5000	2000	280	1100	2000
0625 CHW	38	North west	28	1200	Winch	7000	2000	400	1200	2200
0486 CHW	37,5	Winarali	20-25	1000	Winch	4500	3000	250	1000	1200
0401 CHW	34	Meril		500		2000	1000	120	300	1500
0655 CHW	34	Sithumini				700	400	40		300
0011 CHW	34	Kumari marine		500		2500	2000	150	500	1100
0049 CHW	34	Kumari marine		500		2500	2000	150	500	1100
0033 CHW	34	Neil marine		300		1000	600	60	100	850
0067 CHW	34	Meril marine		300		1500	700	75	200	1000
0365 CHW	34	Nandani		300		1500	700	75	200	1000
0643 CHW	32	Nandani	20	800	Winch	4000	2000	200	800	1600