Adastra

The Search for a Seakindly Fuel Efficient Vessel

By John Shuttleworth

Part 1 – Fuel Efficiency

In recent years there have been a few attempts to find a new solution to achieving low fuel consumption in large ocean going yachts. In this article we will look at the design considerations and compare performances of some of the types of vessel in commission today. We will review aspects of the design of various vessels, not with a view to criticising them, but to show how our thinking has been guided by what has gone before, and then to give our ideas and design concepts on how we have taken up the challenge to reduce fuel consumption and still retain sea kindliness. Finally we will endeavour to demonstrate how successful our solution has been and to explain why the concept has worked so well.

Length to Beam Ratio

Most vessels in the superyacht category cross oceans at about 13 knots. At these relatively low speeds it has long been known that a thinner hull will be more efficient. This is because frictional drag dominates the resistance of the hull at low speed. In fact research conducted by the US navy many years ago indicated that efficiency would continue to improve past length to beam ratios of 13.5.

Currently it appears that the limiting length to beam ratio of a monohull in the 40 m range is about 7. Increasing the L/B ratio above 7 starts to become problematic for two reasons. Firstly the boat will have an increasing tendency to roll uncomfortably at sea and at anchor, and secondly in order to meet current safety standards the Vertical Centre of Gravity (VCG) will have to be kept low in order to increase the stationary stability to required levels. Keeping the VCG low increases the tendency to roll and limits the accommodation space. Most monohulls have to have some form of added stabiliser, usually using hydraulic fins, or gyroscopes, or both. Palmer Johnson have recently introduced a new type of stabilisation for a monohull with a length to beam ratio of 7. They have added small outer hulls aft to increase the righting moment of the hull and further reduce rolling. The first vessel is due to launch in a year or so.

Catamarans in this size and accommodation range, on the other hand, have length to beam ratios of around 10 which is an improvement on 7 as seen on monohulls, however having two hulls in the water increases wetted surface for the same weight carrying ability. Thus a catamaran and a monohull of similar length with length to beam ratios of 10 and 7 respectively have similar fuel efficiency. The catamaran gains by having much more accommodation and is inherently very stable.

In the case of a trimaran the centre hull has no inherent stability of its own and all the stability is created by the outriggers. These vessels can achieve length to beam ratios in excess of 17 which has been shown to significantly increase fuel efficiency and has been proven by boats like Earthrace and Cable & Wireless which were stripped out record breaking machines, and now by the sea trial results of Adastra, which is a fully fitted out superyacht, with space for

6 crew and 9 guests. The comparisons in the table 1 and Fig. 1 show the differences in the length to beam ratios of a number of vessels in the 40m range.

Vessel Type	Stabilising method	Length/beam ratio
Planing	Hull form	5
Semi displacement	Hull and Fins	5.2
Long thin monohull	Hull and Hydraulic Fins or gyroscope	7
Long thin monohull	Hull and Gyroscope stabilisers	7
Long thin monohull	Hull and outriggers	7
Catamaran	2 equal hulls	10
Trimaran	Outriggers	17

Table 1. Length to beam ratio for various 40 m vessels.

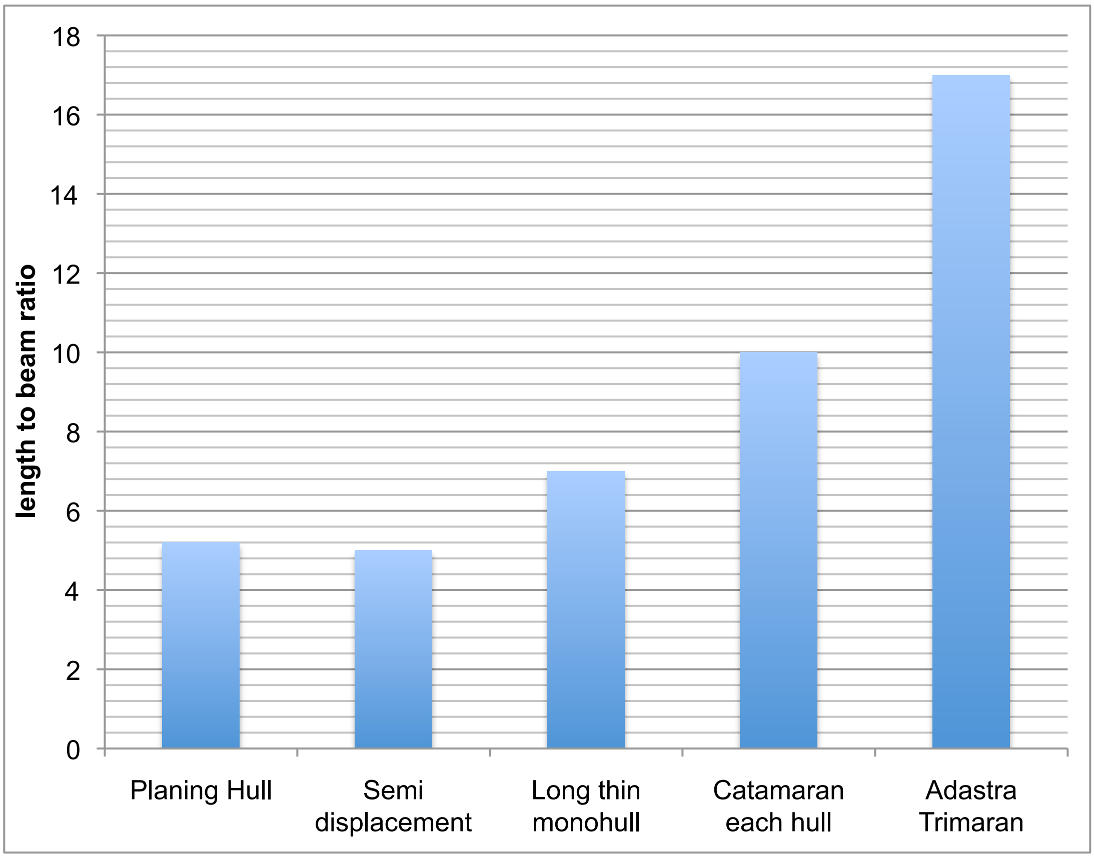

Fig. 1. Length to beam ratio for five 40 m vessels

Weight

The other key factor in achieving fuel efficiency is weight. The lighter the boat, the easier it will be to propel through the water. Composite materials and modern analysis methods allow us to design much lighter structures. The easily driven hull of the trimaran which needs much smaller engine/s can be significantly lighter than other types of vessel. This is shown in Fig. 2.

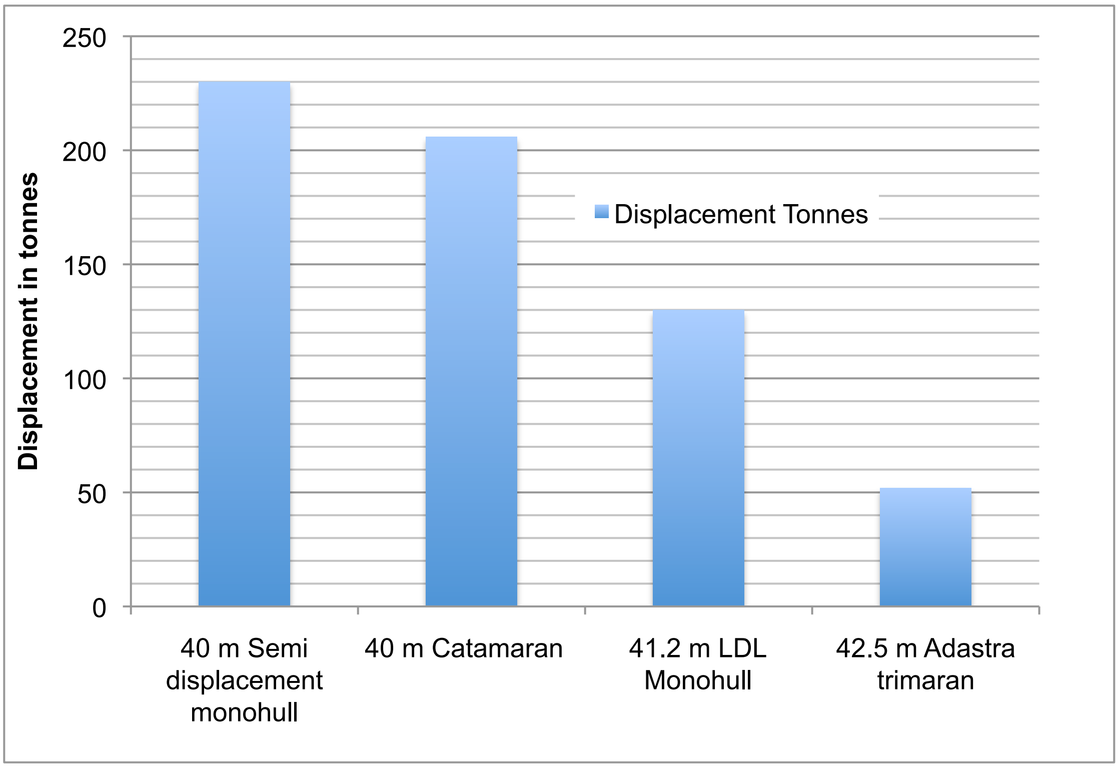

Fig 2. Displacement in tonnes of four 40m vessels.

Displacement to Length Ratio

Naval architects use a formula (see appendix) to calculate the displacement to length ratio of a vessel. The lower the displacement to length ratio, the more efficient the vessel.

Vessel name	Vessel type	Displacement to length ratio
40 m. Monohull LOA Displacement 230 tonnes	Displacement monohull	115
41.8 m. LDL Monohull Displacement 130 tonnes	Gyroscope stabilised long thin monohull	61.6
40 m. Catamaran Displacement 206 tonnes	Catamaran	Each hull 44.8
Adastra. LOA 42.5 m. Displacement 52 tonnes	Trimaran	18.9

Table 2. Displacement to length ratio for four 40m vessels.

In a catamaran the displacement to length ratio of each hull will be less than a monohull, but the fact that there are two hulls in the water means that the catamaran performs like a monohull with displacement to length ratios of approximately 50 % higher than the displacement to length ratio of each hull. Hence the 40 m Catamaran will have similar performance to the Outrigger stabilised LDL 42m monohull and the 41,2 m LDL monohull. All of these vessels will use about half the fuel of the 40 m semi-displacement monohull.

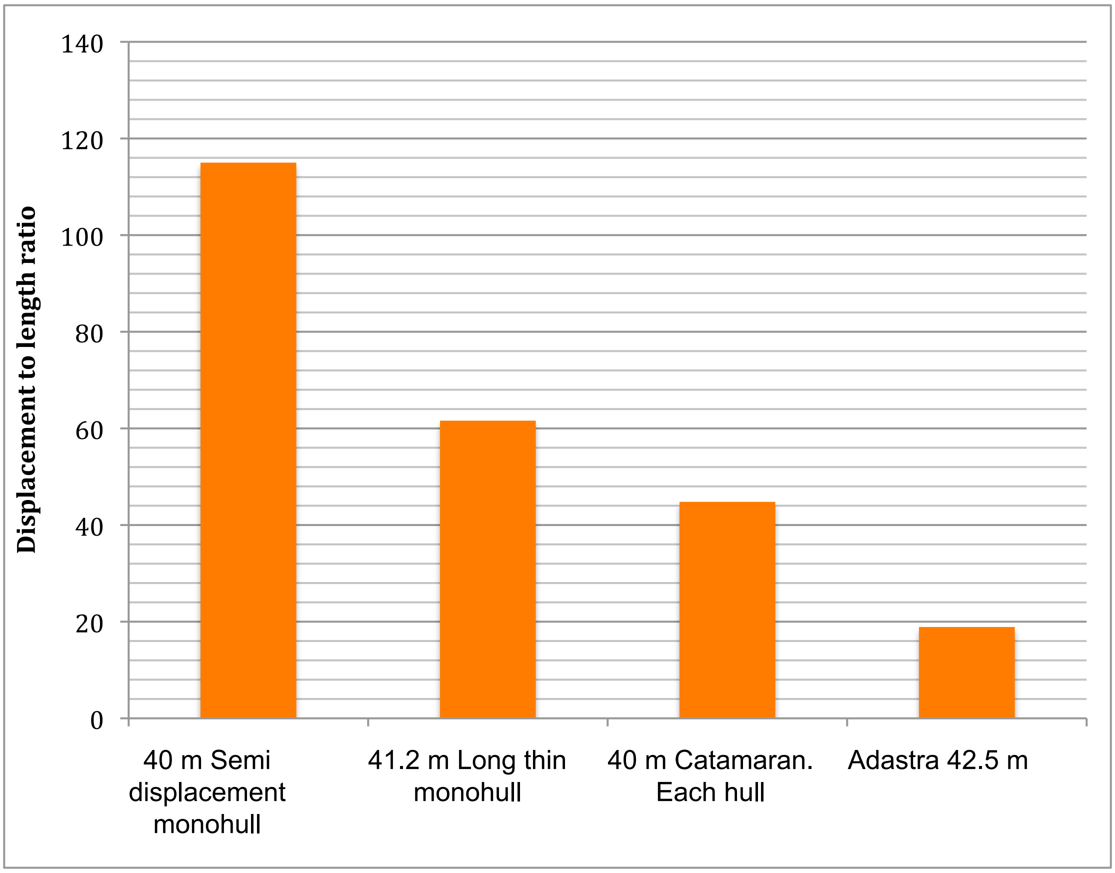

Fig 3. Displacement to length ratio of four 40 m vessels.

Earthrace trimming bow up at speed.

The picture of Earthrace shows how some vessels trim bow up at speed. As the length to beam and the displacement to length ratios are critical in creating low drag, it is essential that the vessel remains trimmed flat throughout the speed range. The above image shows that the waterline of Earthrace has reduced to about 80% of the stationary waterline. By tank testing we have been able to develop a hull shape for Adastra that has near zero change in trim up to 30 knots, thereby using the full waterline length for maximum efficiency through the whole speed range.

Speed and Powering

Adastra could have a top speed of over 32 knots, but on balance we calculated that by keeping the top speed at a maximum of 23.2 knots, we could keep the engine weight on Adastra to a very reasonable 1.2 tonnes compared to the two engines on the Outrigger stabilised LDL monohull weighing 15.6 tonnes. This approach increases the efficiency considerably throughout the speed range because the boat is not carrying the extra weight of large engines.   23 knots is still a very respectable speed for a 40 m superyacht as shown in Table 3 and Fig. 3.

It is clear that the trimaran Adastra will be orders of magnitude more efficient than other solutions, on the basis of the light weight, the displacement to length ratio and the length to beam ratio.

Vessel	top speed knots	HP
43.4 m Outrigger stabilised LDL monohull	32	7018
43 m Planing Monohull	29	6000
42.5 m Adastra Trimaran	23.2	1150
40 m Semi displacement monohull	22	7018
40 m Catamaran	20	3840
41.2 m LDL Monohull	16	985

Table 3. Six current versions of Power Yachts in the 40m range, showing published figures for top speed and HP. Arranged in order of top speed.

Shuttleworth Designs “Adastra” 42.5 m – top speed 23.2 knots – 1150 HP

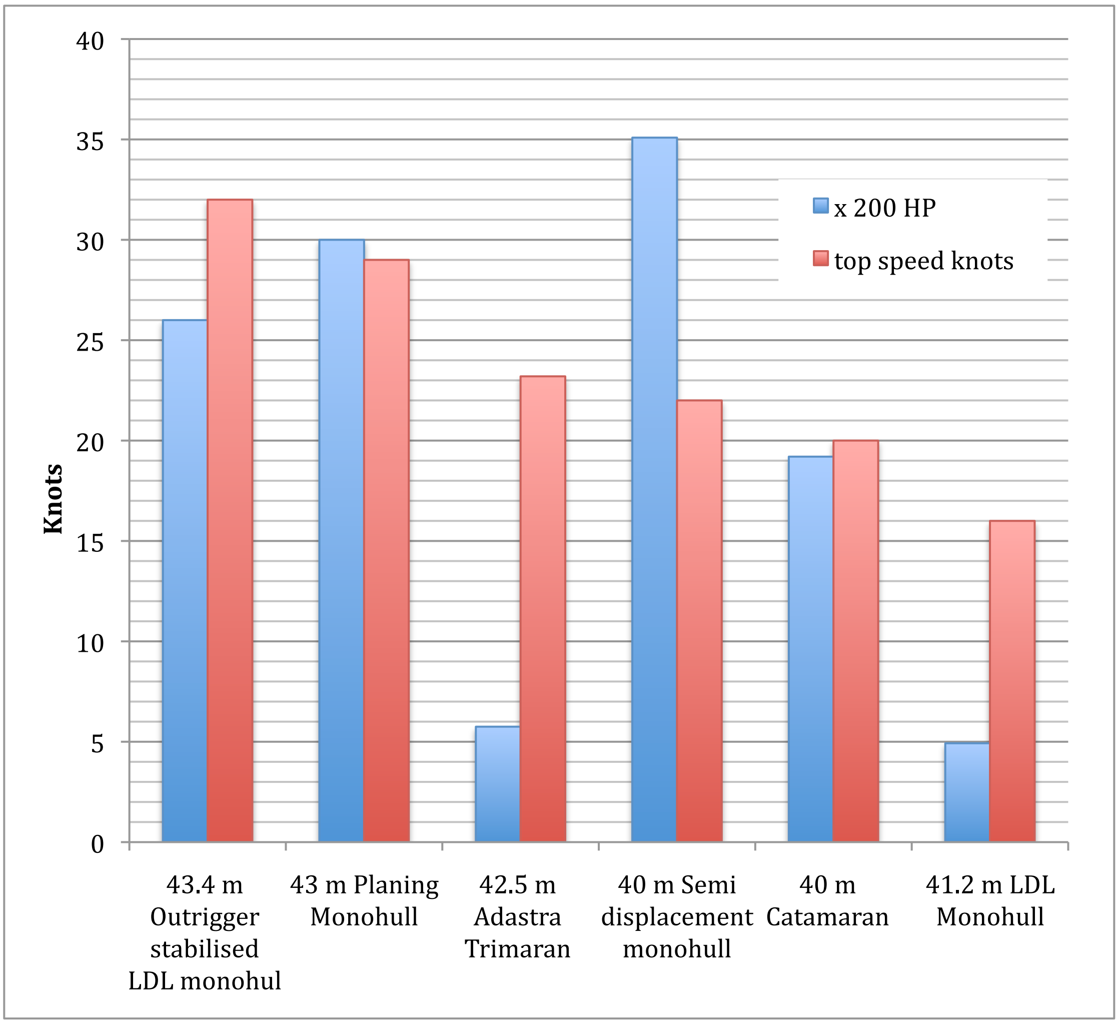

Fig. 4. Top speed (red) in knots vs maximum HP/200 (blue) for six vessels. shows how efficient Adastra is compared to other 40 m vessels.

Comparing Fuel Consumption for the Same Weight

Accurate figures for fuel consumption for most yachts are very difficult to obtain, however using our own data we find that Adastra uses **one third** of the fuel of a semi displacement monohull **of the same weight** over most of the speed range. Table 4 shows how Adastra compares speed and fuel consumption for an equal weight semi-displacement monohull.

Speed Knots	Adastra 42.5 m trimaran at 69 tonnes (full fuel) litres/hr	25 m Semi displacement monohull at 69 tonnes litres/hr
10.5	29	85
13.5	62	220
17	130	365
23	235	512

Table 4. Litres per hour for Adastra vs. same weight monohull

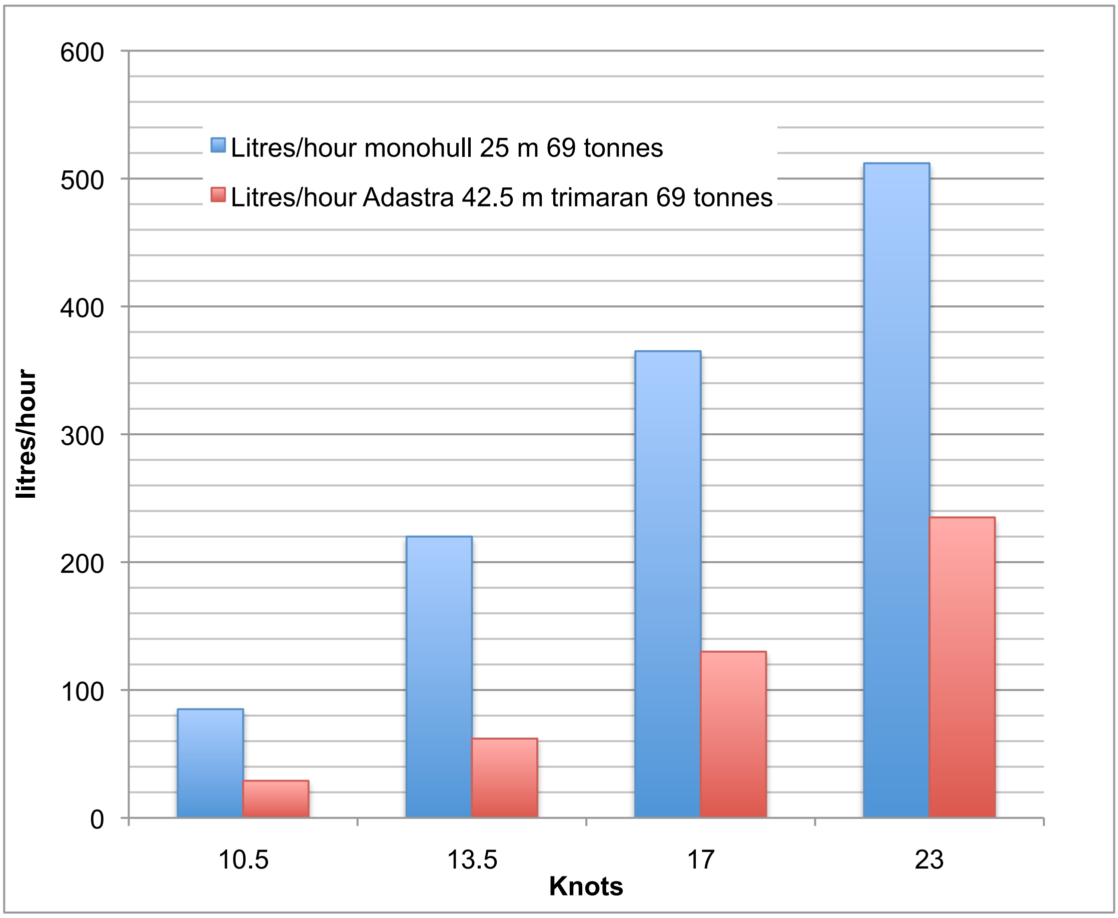

Fig. 5. Speed in knots vs Litres per hour for trimaran Adastra and a semi displacement monohull of the same weight.

Comparing Fuel Consumption for the Same Length

A semi displacement 40m monohull power yacht will use approximately 250 to 300 litres per hour at 12 to 14 knots. Published figures do not state whether they are for full fuel or empty lightship.

A 40m LDL monohull or as predicted the outrigger stabilised monohull, and a catamaran, will use half that at 120 to 150 litres per hour. The outrigger stabilised monohull is predicted to use 112 litres per hour at 13.5 knots. We assume that this is at light load.

At 12 knots Adastra uses a measured 38 litres per hour with 19 tonnes of fuel, and 29 litres per hour at light load (10% fuel)

At 13.5 knots Adastra uses a measured 65 litres per hour with 19 tonnes of fuel and 43 litres per hour at light load (10% fuel)

Comparing fuel consumption on a length for length basis, Adastra uses **less than a seventh** of the fuel at 12 knots of a similar length semi displacement monohull, and **a third** of an LDL monohull.

For maximum range Adastra has extremely low fuel burn at 10.5 knots. 23 litres per hour with 19 tonnes fuel and 17 litres per hour at 10% fuel load. So if time is not an issue the range could be 10,000 miles starting with 30,000 litres of fuel.

It is clear from these figures and the actual measured fuel consumption of Adastra, that if all the factors that improve fuel consumption are achieved in one vessel the gains that can be made are huge.

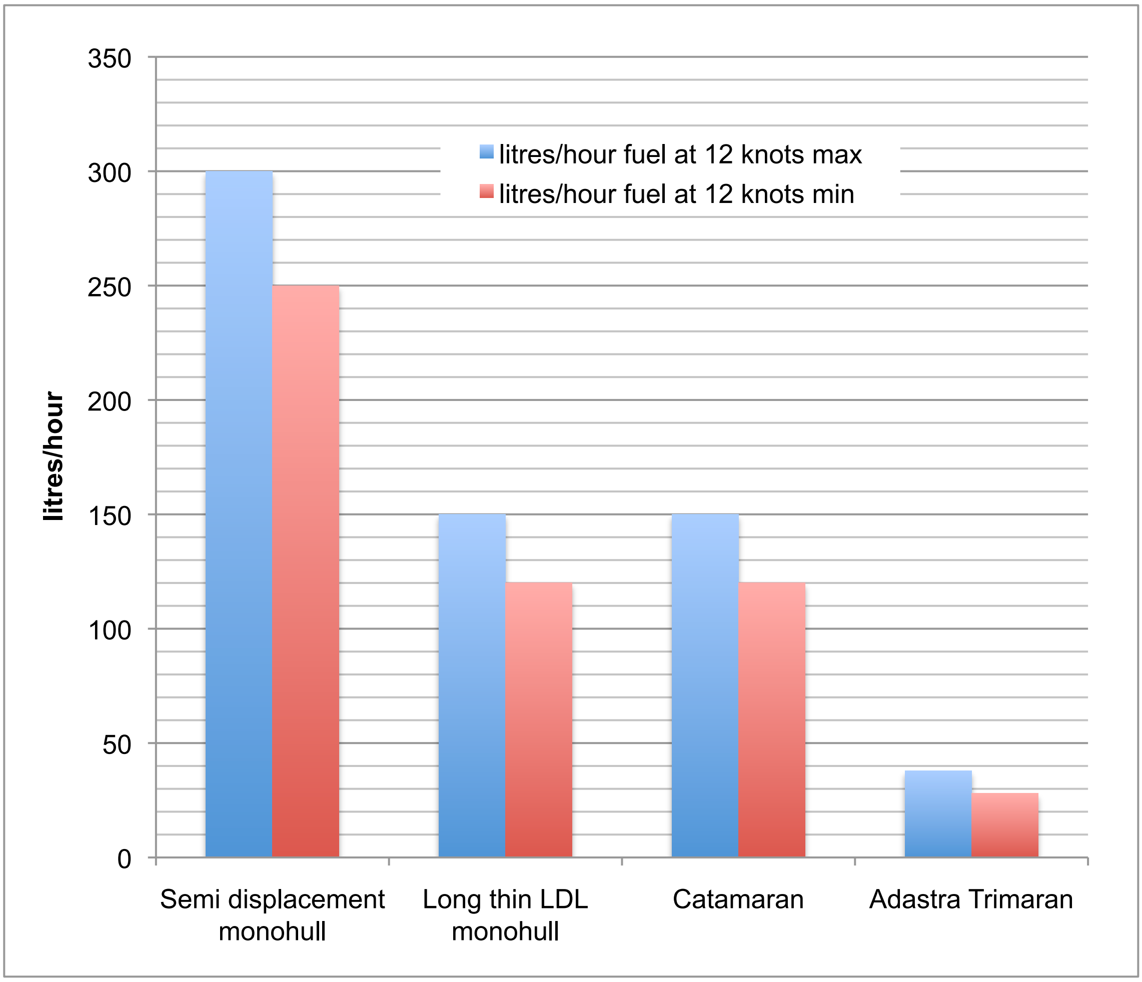

Fig 6. Fuel consumption at 12 knots with minimum and maximum fuel for four 40m vessels.

Accommodation

At 40m LOA it is clear that the trimaran does not have as much accommodation as a 40m Semi displacement or planing monohull, however compared to the Hang Tuah or other similar LDL vessels the accommodation space is similar to Adastra. The outrigger stabilised monohull is an improvement because they have been able to widen the vessel at deck level, but they still do not achieve the same accommodation as the heavier wider designs.

If fuel economy is the aim, we suggest that LOA has to be much higher for the same interior volume. Due to the fact length and weight reduction are the key factors in achieving displacement to length ratios in the region of 20 and below, and length to beam ratios of 17 and above. In a superyacht like Adastra increasing the length of the main hull does not significantly increase the cost of the vessel, compared to the other costs of systems and accommodation, as long as the added length is in the bow, which is very low volume and low surface area compared to a conventional yacht.

In developing the Adastra concept we have found that when the LOA increases to 65 m and above, the same concept as Adastra can be retained, but with full standing headroom inside the wings enabling us to significantly increase the accommodation space in relation to the LOA.

Further Increasing the LOA to 75 metres and keeping a length to beam ratio of 17 it is possible to fit two double cabins side by side with a corridor between on the lower deck, and very large cabins on the mid deck extending into the wings. The additional length also enables us to maintain the displacement to length ratio required for maximum fuel efficiency.

Appendix

Formulae referred to in the text.

The **Displacement/Length ratio** is determined by the following formula:

Displacement to Length ratio = **Displ.** / (0.01 x **WL**)^3

Where:
Displ. is the displacement in long tons (2240 lbs)
WL is the waterline length in feet.

The **Length/beam ratio** is determined by the following formula:

L/B ratio = WL / B

Where:
WL is the waterline length.
B is maximum beam at the waterline.