Matching the rig to the hull

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I present below a clearer explanation of my statement in a forum post that started a long debate:
There is no advantage in a high lift-drag ratio rig on a low lift-drag ratio hull of a multihull with stub keels.

My justification for the statement it is divided into 3 parts: some background notes, rig efficiency and sail efficiency.

Notes:
1. This is no longer about all the pros and cons of fat-head mains, it is about their windward performance.
2. This is not a definitive explanation, there are generalisations which mean that the argument does not always apply; but it does work for most boats and sailing conditions.
3. I have not considered the impact of sail-carrying power on the argument. It will doubtless influence it, but I don't think it negates it.
4. The book I refer to as "Garrett" is Symmetry of Sailing by Ross Garrett, published 1987 by Adlard Coles; and "Marchaj" is Sailing Theory and Practice by Tony Marchaj, published by Dodd Mead & Co 1982 i.e. the revised edition, not the original 1964 one. I have also looked at other sources but I have not referenced them here in the interests of brevity (already failing!)

Hull efficiency:
By "hull" I mean canoe body, keels and rudders. I will not examine hull efficiency in detail, rather I will make use of the on-water observation that high efficiency hulls point higher and have less leeway than low efficiency hulls. This appears to be supported by VPPs, as evidenced by the design approach taken by many/most designers. All I need assume is that a multihull with stub keels will sail at around 40 deg to Apparent Wind Angle (AWA) and 5-10 deg leeway, making for a total sailing angle (path relative to apparent wind) of 45-50 deg. (open to refinement, but doesn't make much difference to the overall argument). This compares with a high efficiency hull which sails at, say, 30 deg AWA and 3-5 deg leeway (total sailing angle 33-35deg).

Rig efficiency:
Consider the lift v. drag (L/D) curve of a typical mainsail. L/D max occurs at the point tangent to the origin, but a boat will almost always sail at a point further along the curve (i.e. away from the origin), at a higher lift value. This is because it will operate at the point of maximum thrust, which is the point tangent to a line perpendicular to the sailing path, which is further along the curve than the L/D max point. Therefore increasing L/D max does not *of itself* increase thrust (hence boat speed, hence VMG for a given sailing angle). What matters is how a change in the rig alters the shape of the L/D curve beyond the point of L/D max.
Consider then a change in rig efficiency. The nearest data I have for flat-top v triangular mainsail is the Lionheart 1980 elliptic rig tests shown in Marchaj p83 fig 52. However, I suspect this data is probably flawed (it shows the elliptic rig reducing profile drag but not induced drag; opposite of theory). So I will have to generalize from flat-top v triangular, to high aspect ratio (AR) v. low AR…..
Look at the L/D curves in Garrett p110 fig 4.21 (replicated in Marchaj p150 fig 100), showing the L/D curves for 3 different AR. Ignore the curve for the highest AR (it is an aberration for the purposes of this argument – a mast interference effect – but if you choose not to ignore it, it strengthens my argument).
The data shows that the high AR rig will generate more thrust than the low AR rig at low

sailing angles (no surprises there), but less thrust at high sailing angles (the "gaff rig phenomenon"). The crossover point between the two rigs is at a sailing angle of about 45 deg. I made the observation earlier that the sailing angle of the low hull efficiency stub-keel cat is about 45-50 deg. It should now become clear that the high AR rig does not improve the performance if put on the low efficiency hull. Depending on the exact numbers for a particular boat, the low AR rig might even generate the greater thrust, and certainly not less thrust. Conversely, if you put the high AR rig on a high efficiency hull, you will indeed reap the benefits of the higher rig efficiency, because you are operating lower down the curve. There is an assumption here that increased thrust equates to increased VMG. This is only true for unchanged sailing angle so there is a second order correction to be made. There is also the heeling force to consider, but as I said near the beginning, I don't think that will negate the conclusion.
So this argument supports my original statement, that there is no advantage in putting a high efficiency rig on a low efficiency hull. It is not a rigid proof – there are far too many generalizations and approximations – but I hope it explains the point rather better than my previous attempt.

At sailing angles greater than about 90 deg, a low aspect ratio (e.g. gaff) sail generates more thrust than a high aspect ratio (e.g. bermudan) sail. Marchaj's book contains more info, based wind tunnel tests conducted in the 1980s at Southampton in conjunction with full scale trials conducted by Colin Palmer, on a simple Indian fishing boat fitted with a range of different rigs. The project was summarised by Colin in Wooden Boat magazine, issue no. 92 Jan/Feb 1990, p76-89.
In hindsight I should have provided that reference right at the beginning, it contains the following sentence:
Perhaps the most significant result of these projects has been to provide experimental support to the intuitive view that no amount of perfection in a sailing rig can compensate for an inferior hull shape.