Falmouth Area Yardstick, *or* Wolstenholme revisited

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1 Background

In 2015 PoFSA (the Port of Falmouth Sailing Association) adopted a new handicap or rating system, the Falmouth Area Yardstick (FAY), for Falmouth Week and the Village Regattas, replacing the previous handicaps for those cruising yachts without an IRC certificate.

Cruising yachts in the Port of Falmouth Sailing Association area have for some years used either the RYA's Portsmouth Number (PN)[1] [RYA, 2013] as a basis for handicaps, or RORC's IRC rule [IRC, 2015]. Diminishing returns to the RYA for cruising yachts, and a proliferation of yacht types eventually led to the demise of the PN system, and its replacement by a personal handicap, the National Handicap for Cruisers (NHC) [RYA, 2015], which owes much to the Irish ECHO handicap system [Irish Sailing Association, undated]. An advantage of PN and NHC is that they are free, while an IRC certificate incurs a cost (and is only valid for the year it was issued).

For at least one Falmouth Week (2013) the Byron handicap [Thompson, 2013] was also used, but perhaps because it also incurred a small cost in addition to the entry fee for the Regatta, the practise did not survive into a second year and was replaced by NHC. Byron is effectively a way of replicating a PY but from a suite of measurements taken from the yacht.

Apparent dissatisfaction with NHC led Mylor Yacht Club in particular to pursue another rating system which was developed by Wolstenholme [2010, 2012a,b, 2015a] who developed a series of equations to assist in the creation of a rating for cruising yachts. The rating uses fairly easily obtained measurements in a formula, and aims to provide a figure similar to the RYA's Portsmouth Number.

2 Portsmouth Number

Although not strictly relevant here it may be worthwhile briefly reviewing the Portsmouth Number, its assumptions and its implementation. Its initial assumptions are fairly demanding, (cf. [US Sailing, undated]) and include:

[1] Although the RYA consistently refers to this as the Portsmouth Number (PN), colloquially it tends to be called PY. PY is properly the Primary Yardstick, see Table 1.

PY	Primary Yardstick	well attested PNs published by the RYA
SY	Secondary Yardstick	less consistently attested PNs published by the RYA
RN	Recorded Number	PNs published by the RYA on the basis of limited information
CN	Club Number	PNs allocated or adjusted by clubs
TN	Trial Number	PNs allocated by a club until a CN is assessed

Table 1: The flavours of Portsmouth Numbers

- That each boat placing first in each class was sailed to its true potential by a perfect crew according to flawless strategy;
- That all boats sailed the same course, experienced the same wind/water conditions and degree of interference of clear air;
- That all one-design boats conform to class specifications and rules, and use sails specified by the class; and
- That boats with multiple sail inventories (genoas, spinnakers etc.) utilize the proper sails for the wind conditions and legs of the course.

A PN is not an exact and immutable value. The PNs which were produced each year (and still are for many dinghy classes) change subtly depending on the aggregated returns received by the RYA. There is a fairly sophisticated system, PYS, which allows clubs to upload results on a race by race basis and which feeds into the analysis. The PNs themselves come in the several flavours given in Table 1.

Since the PNs are not necessarily applicable to any one club, the RYA expects that a club should not hesitate to change a PN that appears to be inequitable, although any change would result in Trial or Club numbers. Fundamentally there is nothing sacrosanct about an individual PN. They are performance indicators, based on individual boat classes. If and when a particularly skilled cohort of sailors adopt a particular class, the handicap for that class could change markedly: similarly some older, perhaps less fashionable classes may find their handicap slip as age and agility take their toll (unless they are balanced by skill and experience).

There is no especial reason to be nostalgic about PN. In any case it did not map well to yacht racing where it is rare to find two identical boats. The data simply are not available to make aggregate comparisons possible. Having said this, both Byron and Wolstenholme are essentially slot-ins for PN, but with the important proviso that rather than aggregate data to establish a handicap (which itself may change year on year according to results), they assume the PN is set in aspic and use boat measurements to predict what that PN would be. But one feature should be that a Byron or Wolstenholme number should be very similar to a PN, where the PN is known. The reason we need Byron or Wolstenholme is that in many cases the PN is not available.

3 FAY

Basically we have several contenders to provide a rating system. All begin by taking a number of measurements and plugging them into an equation which generates a value – the rating. Some are more transparent than others. IRC is particularly opaque, deliberately so, "to prevent designers and builders building boats specifically to 'beat' the Rule or exploit any loopholes" [IRC, 2015]. The formulation and its application changes annually, therefore the same measurements provided to RORC may generate a different rating year on year. Byron has a pedigree which goes back to unpublished work from Terry Schell, (although Wolstenholme [2015a, Article 2.3] gives some clues to the form of the equation) but does not indicate quite what the formula is, although once calculated it stays the same. Appendix C attempts to fill in some details. Even NHC has a ready reckoner which can be applied to establish a base number (see Appendix D). For some reason the RYA makes the reckoner available but locks the equation away out of sight. At least Wolstenholme's formulæ are open and available to all.

Wolstenholme developed a series of suitable equations over several years. It may be fair to say that her formulæ are still evolving, but in the discussion which follows her Model 10A of 2012 is adopted, since it is this model on which Mylor Yacht Club has based their handicapping, adopted by PoFSA as the Falmouth Area Yardstick, FAY [Mylor Yacht Club, undated]. Although perhaps not the 'best' of her equations in statistical terms (her description) it is slightly simpler to use since it requires fewer and more easily obtained measurements. She also developed an equation for twin and triple keel boats, which will be included separately here. It is important to note the area of application of the equation: it is intended "for standard sloops of overall length less than 15 metres, and with draft of under 2.5 metres" [Wolstenholme, 2015a, Article 2.7].

The equation was initially developed from a reliable dataset which consisted of 34 fin-keeled boats[2] whose handicaps were either on the RYA PN list, or had PNs estimated by Byron [Thompson, 2013]. The PN values varied from 908 to 1149.

Goodness of fit was not the sole criterion for adoption: in addition the equation had to make a reasonable estimate for boats without a PN, but for which there was an "instinctive club view as to where the PN should lie". The formula also had to fit as closely as possible to some well-established PNs. The RYA list has/had 44 'trusted' PNs, and whichever of these appeared in the dataset would have to be reflected in the results. Another factor taken into account was 'user perception'. In other words, the formula had to 'look' right to the sailors whose handicaps would be evaluated by it. A formula which used 'unexpected' parameters would not be received with any confidence.

Although not critical at this point, it is worth noting that IRC and NHC ratings are 'time correction factors': take the elapsed time and multiply it by the rating to obtain the corrected time. The Byron, PN and the Wolstenholme approaches invert the process: divide the elapsed time by the rating (and multiply it by 1000) to obtain the corrected time. The apparently arbitrary 1000 is only there so that the ratings themselves scale conveniently (normally to some-

[2] Since then a larger dataset has been used: 66 classes of boat whose PNs range from 795 to 1058. This larger dataset does not include all the earlier dataset for data quality reasons. It would probably be unwise to rely on values which lie much beyond the limits of the datasets.

d	draft
l	waterline length
b	beam (only required for bilge keel yachts)
$\mathcal{S}$	total sail area
D	displacement

Table 2: Parameters used in calculating FAY ($\mathcal{F}$): dimensions in kilograms, metres or square metres as appropriate.

where between 600 and 1400). While the time correction factors are probably more intuitive, the use of the 'divisor' PN is well established.

There are some small differences between the present Wolstenholme Model 10A and the Mylor/PoFSA implementation, which will be noted later in Appendix B. The measurements to be used are given in Table 2. Sail area $\mathcal{S}$ is the sum of the area of the mainsail and the area of the largest foresail. It does not include any downwind sail (spinnaker or cruising chute), although the model assumes that a downwind sail of some kind is available.

3.1 Single fin keeled yachts

The hull and fin type are taken into account by a multiplier k:

$$k = 1 - 0.003t \tag{1}$$

where t is estimated as

$$t = \begin{cases} 0, & \text{flat single keel} \\ 1, & \text{slight flare/bulb} \\ 2, & ... \\ 3, & ... \\ 4, & ... \\ 5, & \text{winged keel} \end{cases} \tag{2}$$

Thus k varies between 1 and 0.985, but in the case of a long keel, $k = 0.98$.

The term c is derived through t, as $c = t/10$, and is presumably zero both in the case of a long keel and a flat single keel. This term does not appear in the current Wolstenholme equation (see Equation 9 in Appendix B). From Equation 3 below, the contribution of the term is rather small.

The Falmouth Area Yardstick, $\mathcal{F}$, is given by:

$$\mathcal{F} = \left[2091 - 407d + 86d^2 - 30.5l - 59.6\frac{\mathcal{S}}{l^2} - 810\frac{\sqrt[3]{\mathcal{S}}}{\sqrt[4]{D}} - 17c\right]k \tag{3}$$

Although she counsels against 'unpicking' the formula, the selection of terms is relevant: d the draft is related to boat size and to speed – since it appears as a squared term it is important to be as accurate as possible; $\mathcal{S}$ the sail area appears twice; clearly sail area is related to power, and when combined with the displacement D is a power to weight ratio; l the water line length is an indicator of speed potential; and as indicated earlier c and k are attempts to allow for the effect of different keel or hull types.

t	0	1	2	3	4	5	long keel
$\mathcal{F}$	1050	1045	1040	1035	1031	1026	1029

Table 3: Nominal effect of keel variable t on $\mathcal{F}$.

The terms are almost by definition highly correlated. Large displacement implies longer water line length implies larger sail area.

What is the effect of the keel? Taking a flat fin boat which has an $\mathcal{F}$ value of 1050, and varying the values of t between 0 and 5 gives about 5 points of difference for each step, to the minimum of 1026 for a winged keel (Table 3). The contribution of the term is therefore quite small, but these small differences amount to a few seconds in each hour. For a boat with a nominal $\mathcal{F}$ of 1050, each 1 point difference is equivalent to about 4 seconds in the hour. Of course, in a real boat, as t increases it is likely that the draft would have been reduced. The relationship is not quite as simple as suggested here.

3.2 2- and 3-keel yachts

A different equation is used for bilge keel yachts. It contains the same basic variables as before, but with the addition of b, the beam.

$$\mathcal{F} = \left[2211 - 1389d + 431d^2 - 137\frac{b}{l} - 54.9\sqrt{l} + 455\frac{\mathcal{S}}{D^{\frac{2}{3}}}\right] k \qquad (4)$$

The multiplier k is 1 for a twin keel, and 1.01 for triple keel. Data for bilge keels is less available, and Wolstenholme states that this equation was based on "a dataset that is a lot smaller than would be liked." Perhaps as a result of the paucity of data an anomaly appears. The (positive) sign of the term $\mathcal{S}/D^{\frac{2}{3}}$ (a power to weight ratio) implies that as the sail area increases, the handicap becomes larger – the boat becomes slower. This is counter intuitive, but no explanation is provided. *A priori* we expect this term to be negative.

4 Port list

To assist sailors in the port, the PoFSA handicapping committee has evaluated a $\mathcal{F}$ for as many of the local 'racing' boats as they can, using data provided by the owners, verified wherever possible. These data also refer to a 'configuration', which helps to distinguish between, for example, the range of GK24s, which are basically similar, but differ in small ways. It is hoped that by publishing the data variations will be more easily understood. The configurations are summarised in Table 4.

5 Some comparisons

A certain amount of data exists which may help to give a flavour of the degree of correspondence between some of the ratings. Up until 2013, Flushing SC sailed under PY. Figure 1 provides a plot of the handicaps for which a FAY and a PY exist. Sadly there are only 16. These sixteen are probably neither random nor

Rig-related:	
C	conventional spinnaker
A	Asymmetric spinnaker
0	No spinnaker
CH	Cruising chute
Keel-related:	
F	Fixed central keel
D	Drop or lifting keel, adjustable during racing
2K	Twin bilge keel
3K	Central and twin bilge keel
Engine-related:	
OB	Any arrangement that allows the propeller to be removed from the water, or no engine
IBF	Inboard, folding/feathering propeller
IB2	Inboard, fixed two-bladed propeller
IB3	Inboard, fixed three-bladed propeller

Table 4: Commonly used configuration abbreviations: expressed in the sequence rig-related, keel-related, engine-related: e.g. CFIBF(conventional spinnaker, fixed central keel, inboard folding propeller) or 0DOB (no spinnaker, lifting keel, no engine).

representative of any location other than Falmouth, and cannot form the basis of any wider conclusions.

What we really want is that the data points lie on a straight line at 45°; failing that, any other straight line; failing that we want as little scatter as possible. There is plausibly a linear relationship, but the scatter, especially at higher values is large. The next stage might be to identify the boats which give 'odd' results in an effort to understand the reasons and perhaps refine the equation. The two most anomalous data points in Fig. 1 (marked with solid dots) are for a Nordic Folkboat and an H-boat.

Since 2014 there has been encouragement at FSC to obtain an IRC rating and to 'dual score' IRC and NHC. This provides a convenient block of data, since $\mathcal{F}$ can also be calculated from the IRC data sheets. This time there are 27 discrete data points. Fig. 2 shows a degree of scatter, but none of the data points is obviously anomalous. Since IRC explicitly takes into account spinnaker area, it is not to be expected that there will be a very close relationship.

Looking at the relationship between observed $\mathcal{F}$ and NHC in Fig. 3, there is a reasonably tight linear relationship, except for two boats, a half-tonner and an Elan 320. Remove those two points and we have a fairly convincing graph. However, removing inconvenient data defeats the whole object of trying to fit a predictive equation. The correspondence between the two handicaps may suggest that the underlying models are similar. It would be surprising if the 'closed box' RYA calculator did not use functions of boat size and power to weight ratios, even allowing for the fact that they use overall boat length rather than waterline length. The two are by definition highly correlated, and using overall length rather than waterline length as a proxy for speed potential should

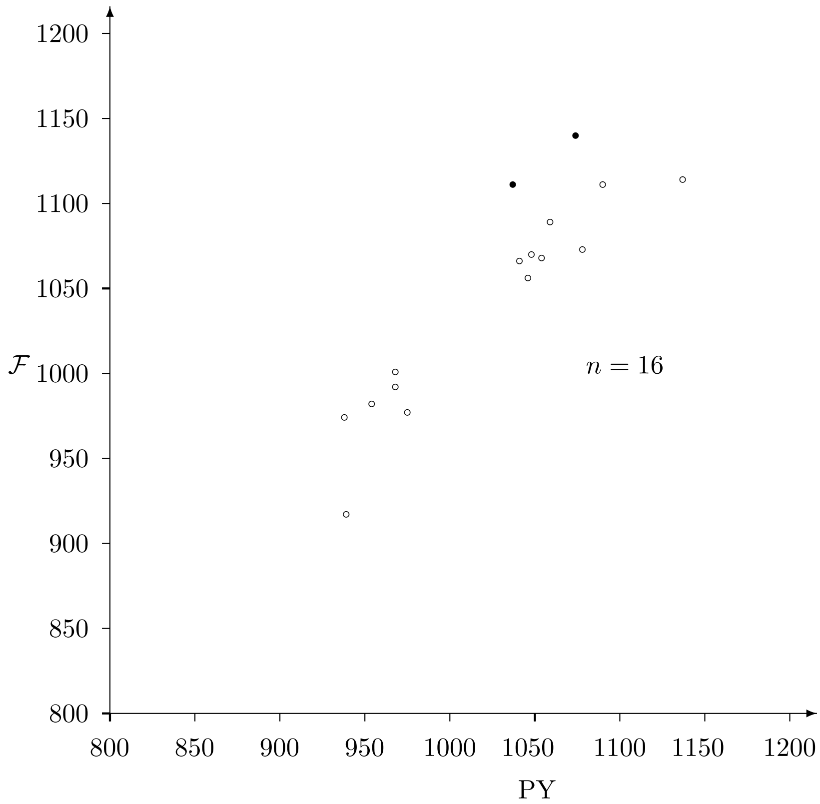

Figure 1: Based on yachts in E and U classes at FSC in 2013 for which there is adequate data. All values are 'normalised' to a CFIB2 configuration.. The two 'anomalous' data points are shown as solid dots.

still give reasonable results.

A Model 14A

Wolstenholme [2015a] provides Model 14A, which she states is statistically slightly superior to Model 10A, Equation B. Note that she uses a slightly different expression for the keel, adding a further intermediary, and adjusts the value for a long keel slightly.

$$k = 1 - 0.003t \tag{5}$$

where t is estimated as

$$t = \begin{cases} 0, & \text{flat single keel} \\ 1, & \text{slight flare/bulb} \\ 2, & \text{...} \\ 3, & \text{...} \\ 4, & \text{...} \\ 5, & \text{...} \\ 6, & \text{winged keel} \end{cases} \tag{6}$$

A long keel is given a value of $k = 0.99$.

$$\mathcal{F} = \left[1767 - 417d + 76.6d^2 - 82.2\sqrt{l} - 850\frac{\mathcal{S}_b}{D^{\frac{2}{3}}} + 1148\frac{d^2}{\mathcal{S}_a}\right] k \tag{7}$$

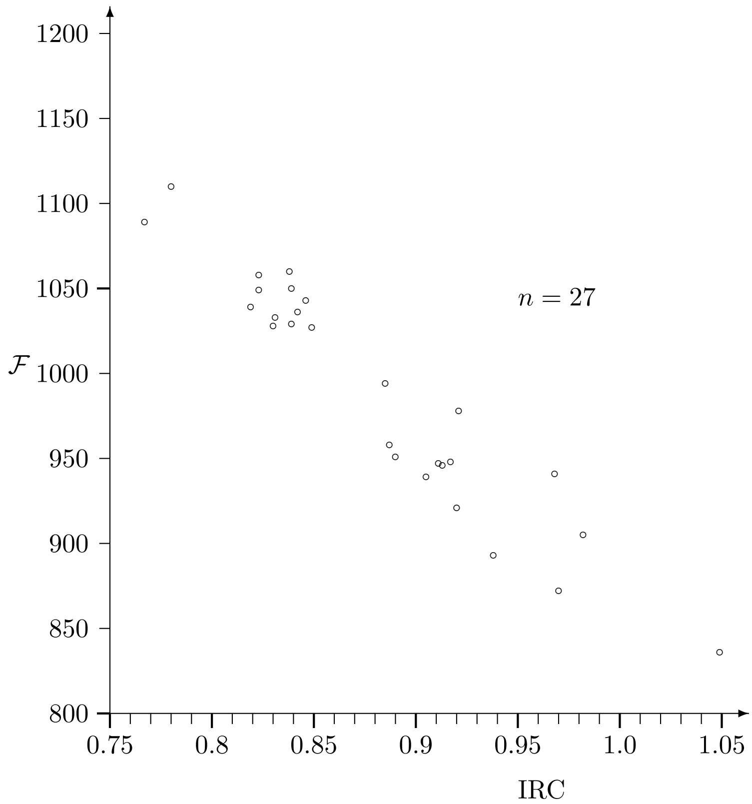

Figure 2: Based on the yachts with IRC certificates at Flushing Sailing Club in 2015.

The term $\mathcal{S}_a$ is the 'actual' sail area as determined earlier, ($\mathcal{S}$, the sum of the mainsail area and the largest jib or genoa), while $\mathcal{S}_b$ is a 'base' sail area determined from the mainsail area and the area of the largest jib or genoa. Wolstenholme calculates this as

$$\mathcal{S}_b = \frac{\text{mainsail area}}{1.18} + \frac{\text{area of largest jib or genoa}}{\text{genoa 'overlap'}} \tag{8}$$

where the 'genoa overlap' is probably around 1.3, i.e. a '130% genoa'. The extra 'complication' in providing the sail and overlap areas is one reason for preferring the relatively simpler Model 10A.

B Current Model 10A

This is the current favoured model, [Wolstenholme, 2015a]. Note that it does not contain the c term of Equation 3. The calculation of k is the same as in Equation 3.

$$\mathcal{F} = \left[2091 - 407d + 86d^2 - 30.5l - 59.6\frac{\mathcal{S}}{l^2} - 810\frac{\sqrt[3]{S}}{\sqrt[4]{D}} \right] k \tag{9}$$

Note however that at Mylor Yacht Club, the raw number is modified by an allowance reflecting the engine related and rig related configurations in Table 5

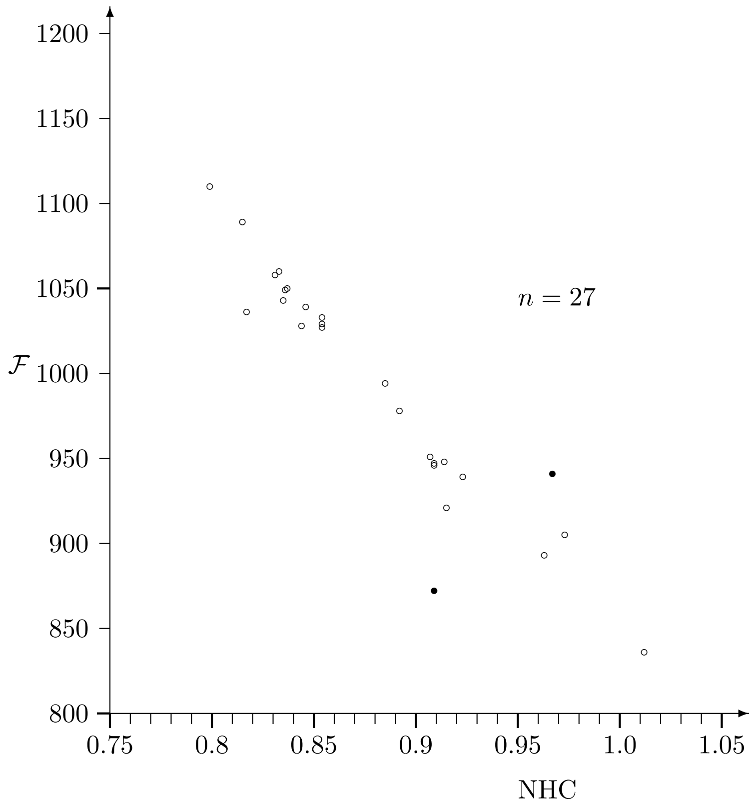

Figure 3: Based on the yachts with IRC certificates at FSC and using RYA 'base' NHC or their ready reckoner. The two values which might be considered anomalous are highlighted as solid dots.

in line with earlier RYA recommendations [RYA].[3] In addition, their policy states that there will also be adjustment to "reflect the age of a boat's sails and equipment, crew skill and weight factors and historic performance data." This is the practise at MYC, but not that of the PoFSA handicapping committee. The 'Falmouth Week Notice of Race' [PoFSA, 2015] made no mention of these adjustments or allowances.

The allowances are qualitative rather than quantitative. A folding or feathering propeller clearly confers some advantage by reducing drag, but the degree is not likely to be uniform across all types of yachts. The choice of (say) a 1% change to the yardstick is not rigorously supported by evidence.

Wolstenholme [2015a, Article 2.11] addresses these issues and again stresses that the variations for boat features lack scientific support but are "fairly workable". Her club applies a +3% adjustment for non-use of spinnaker, rather than the +4% suggested in Table 5.

C Terry Schell

Wolstenholme [2015a, Article 2.3] states that Terry Schell developed the following 'time on distance' equation in the 1990s. A convenient explanation of time

[3] Where there is more than one allowance to be applied they should be multiplied together, not added. The difference is unlikely to be noticed. At most it is about 0.25%, which would normally disappear in rounding.

Engine-related:	
Inboard with 2-bladed fixed propeller	0%
Inboard with 3-bladed fixed propeller	+2%
Inboard with feathering/folding propeller	−1%
Any arrangement that allows the propeller to be removed from the water, or no engine	−2%
Rig-related:	
No spinnaker	+4%
Conventional spinnaker	0%
Asymmetric spinnaker	−2%
Cruising chute but no spinnaker	+2%
Other:	
Twin mast ketch	+3%
High tech sails	−1%
In mast reefing	+2%

Table 5: Allowances: in the RYA formulation, the engine/propeller recommendations are *trial* allowances; the sail related allowances are maxima. The *Other* category is not explicit in the RYA list.

P	length of maximum hoist point of mainsail on mast
E	length of maximum outhaul point of the mainsail on the boom
I	distance from the front of the base of the mast to the top of the foresail
J	distance between the front of the base of the mast and the bottom of the forestay

Table 6: Rig dimensions used in Schell's equation

on distance is given in [Portland Yacht Club, undated].

$$r' = 610 - 8.36\frac{s_a}{\sqrt[3]{D}} + \frac{s_a^2}{19608} - 30.8\sqrt{l} - 55\frac{P}{J+E} - 602\frac{d^2}{s_a} \quad (10)$$

P, E and J are rig measurements, which may be familiar to anyone who has filled in the information for an IRC certificate. I is also used here, although not for an IRC certificate. The measurements are defined in Table 6. The term s_a is sail area calculated as the sum of the base main and forward triangles, $s_a = (PE + IJ)/2$. Essentially we are simplifying, assuming that the sails are right angle triangles. It is thought that the Schell formula has formed the basis of Byron.

Unfortunately it has not been possible to trace any publications by Schell on this topic. The coefficients in the equation are from two web citations [Paul Kamen, undated] and [Portland Yacht Club, undated].

$\mathcal{L}$	the hull length from the for (*sic*) most part of the stem to the aft most point of the transom excluding any hull spar such as a bow sprit.
P	the length of the mast track from the point where the top edge of the boom intersects the mast to the lower edge of the black band at the top of the mast.
E	the boom length from the point where the aft edge of the mast intersects the boom and the inner edge of the blackband on the outer end of the boom.
I	the distance from the point where the bottom of the forward face of the mast and the deck meet and the point where the forestay intersects the mast.
J	the distance between the forward face of the mast and the forward most part of the bowesprit (*sic*) (if fitted)
D	the weight of water displaced by the boat
design year	the year the boat was first commissioned
$\mathcal{S}$	the upwind sail area. If this is used the rig dimensions, P, E, I and J should not be entered.

Table 7: The measurements used in the RYA base number calculator. While most of the measurements are familiar, note that water line length does not appear. The formula uses the length overall, the hull length from stem to stern.

Yachtsnet	`www.yachtsnet.co.uk/archives.htm`	in Imperial units, gives actual sail area $\mathcal{S}$
Performance Yacht Systems	`www.pyacht.com/rig-dimensions.htm`	in Imperial units, gives P, E, I and J
Sailboatdata.com	`sailboatdata.com`	metric and Imperial, gives sail area as $(PE + IJ)/2$

Table 8: Possible sources of data

D RYA Base List Calculator

The base list calculator is not intended for general consumption: it "should not be distributed to club members or other 3rd parties". It is in the form of a spreadsheet calculation which takes the information listed in Table 7. In any case it is *only* to be used where a base number is not already in the RYA's base number list.

E Sources of data

A number of websites (Table 8) have aggregated boat data. Sometimes it is necessary to consult all of them in order to establish the required measurements. Caution must be exercised in the interpretation of the data. Sadly the terms and values are not always interchangeable.

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