This section is intended to be read in conjunction with:

6. The *WindFly Rig* – Mounting on a planing or semi-planing boat – Simple keel-rudder
7. The *WINDFLY Rig* – Mounting on a planing boat – Keel-rudders and hydrofoil

8. The *WINDFLY Rig* - Planing upwind as well as downwind compared with conventional sail boats

In dinghy sailing the crew hikes out to counter-balance the heeling moment of the wind on the sails. The crew act as moveable ballast. Since the ballast is moveable less ballast is required: and some dinghys have a [Length / Displacement$^{1/3}$] ratio of more than 5.7[1], many of these dinghys can plane going downwind on a broad reach or run. However no sail dinghies plane going upwind.

Kiteboards and many windsurfers are able to plane going upwind and downwind. This demonstrates that wind driven craft can plane upwind.

Section 6 "The *WindFly Rig* – Mounting on a planing or semi-planing boat – Simple Rudder" and Section 7. "The *WINDFLY Rig* – Mounting on a planing boat – Rudder and hydrofoil" consider planing action by a boat using the *WINDFLY Rig*.

There is no difference in the operation of the *WINDFLY Rig* whether the boat is travelling downwind or upwind. Unlike conventional sail boats, boats using the *WINDFLY Rig* can plane going upwind as well as downwind.

This section considers why it is sometimes possible for a conventional sail boat to plane downwind and yet conventional sail boats are not able to plane upwind.

1. *"… the high speed range can only be reached if the length displacement ratio is large enough. Exactly how large the ratio has to be is impossible to say, since other parameters, as well as section shape, stability, etc also play a role. However, values around 5.7 are often quoted in the literature. Hulls with lower values are likely to run into the 'barrier' at around Froude Number = 0.45, while those with a larger ratio may pass the hump and reach higher speeds. The larger the ratio the higher the speed possible. Unfortunately, it is very difficult to build standard yachts with a length displacement ratio larger than about 5.2, due to structural problems. Extreme racers such as the America's Cup yachts may, however, reach values up to 7.5 … "*
Larsson & Eliasson, Principles of Yacht Design, 3rd Edition 2007

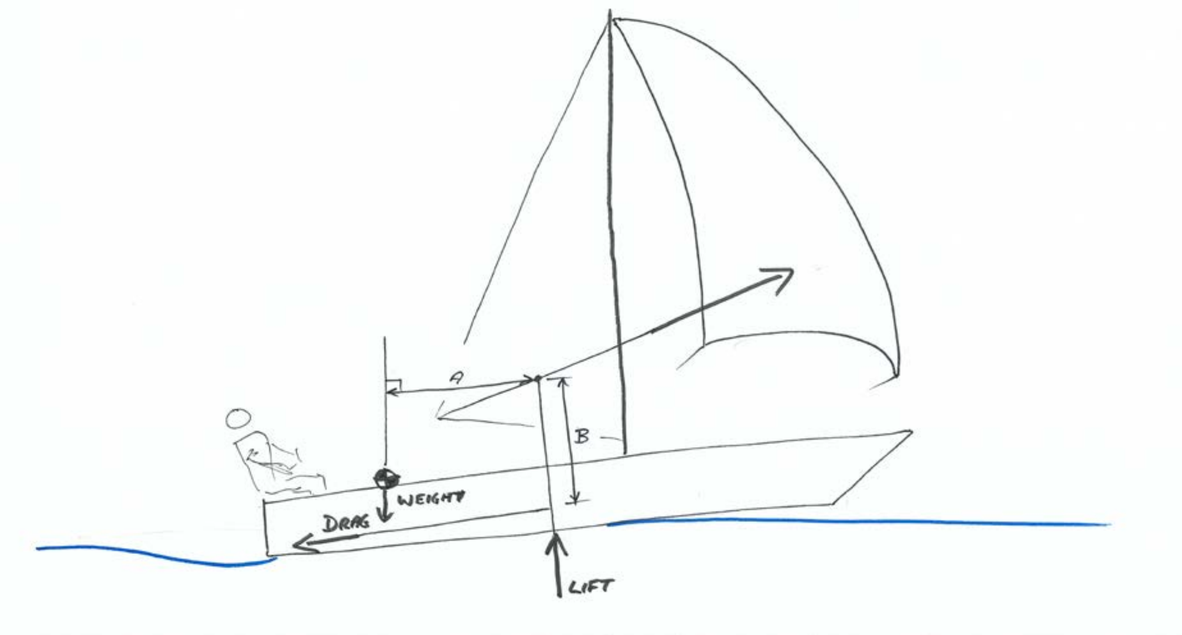

Figure 8.1.1 Analysis model for a sail boat planing downwind

Figure 8.1.2 Sail dinghys planing downwind

8.1 Analysis of a planing sail boat - going downwind

Section 6.3 describes the method usually used for the analysis of a planing motorboat. The same analysis method can be applied to a conventional sail boat.

Moments are taken about the point where the vector representing the longitudinal drive from the sails intersects with the vector representing the hydrodynamic lift. To establish the trim angle and power required the moments due to water resistance on the hull and appendages must be balanced by the moments due to the self weight of the vessel so that:

(weight) . A = (drag) . B

Moving the crew towards the stern increases the moment to counterbalance the drag moment.

Going downwind on a broad reach or run there is typically a small upward vertical component to the sail load. This limits the length of the lever arm between the intersection point and the drag vector, and therefore limits the drag moment.

The photos demonstrate that some conventional sail boats are able to plane going down wind.

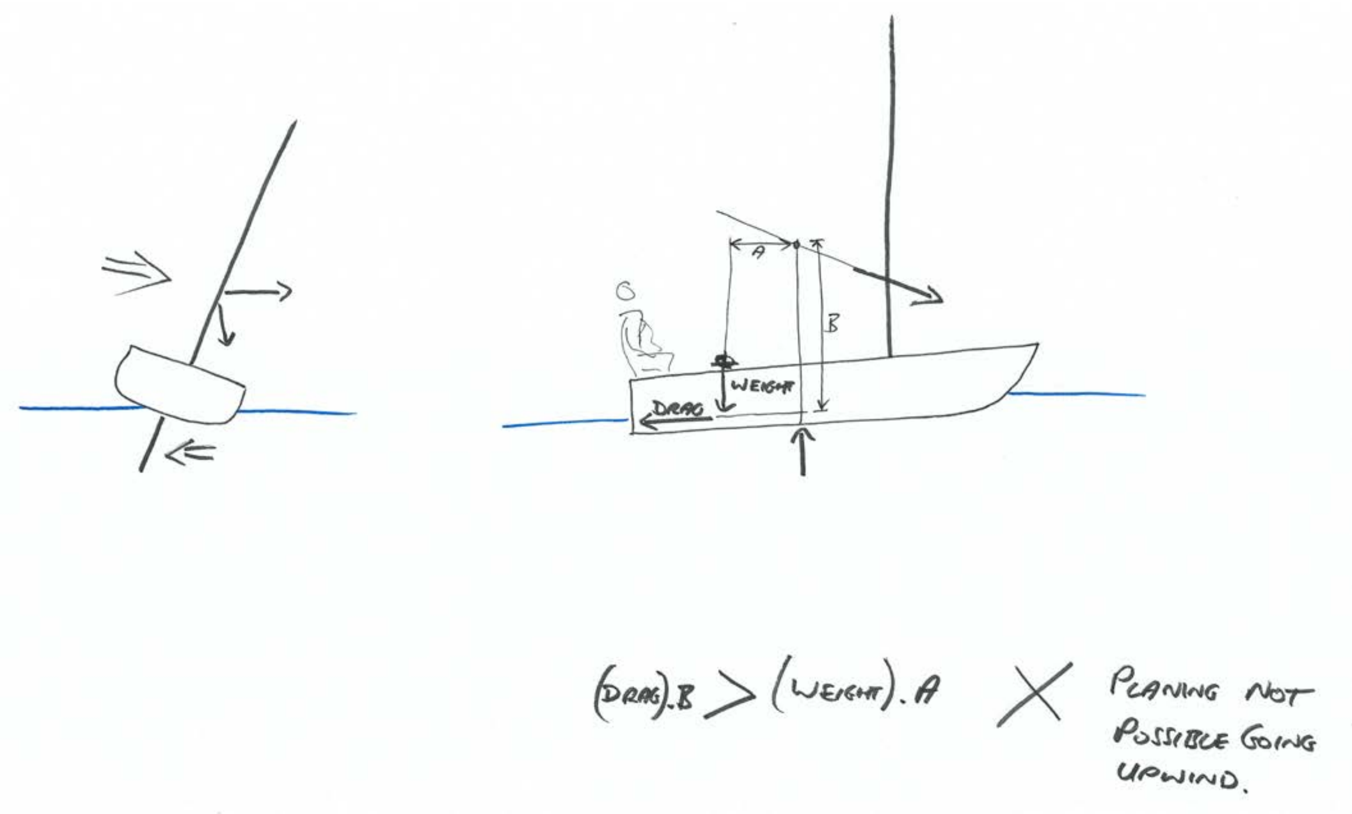

Figure 8.2 Analysis model for a sail boat planing upwind

8.2 Analysis of a planing sail boat - going upwind

Going upwind the sail acts as an aerofoil to generate "lift" which is used to drive the boat forwards. The "lift" acts perpendicular to the longitudinal axis of the mast.

Going upwind the wind causes the boat to heel away from the wind. The heel introduces a vertically downward component to the sail load. This increases the lever arm B between the intersection point and the drag vector, which in turn increases the drag moment. As the drag moment increases a larger moment from the weight is required to balance the drag moment.

In practice, the lever arm B between the intersection point P and the drag vector is so large that the weight moment is insufficient to balance the drag moment, therefore the boat pitches forwards lowering the bow into the water further increasing the drag and slowing the boat.

Therefore traditional sail boats do not plane upwind.

Note that if sufficient ballast were provided to heel the boat towards the wind the vertical component of the sail load would be vertically upwards and the analysis would be the same as was considered above for a sail boat going downwind. This is in fact the case for windsurfing, the sail is leant into the wind - which is why windsurfers do plane going upwind. A similar condition applies for kite surfing: the kite provides a vertically upward component.

However a sail boat would have to have appreciable upwind heel to plane upwind. To achieve this a large quantity of moveable ballast would be required to roll the boat into the wind against the heeling action of the sails. It appears that in practice the weight of ballast would be so great that it would not be possible to plane.

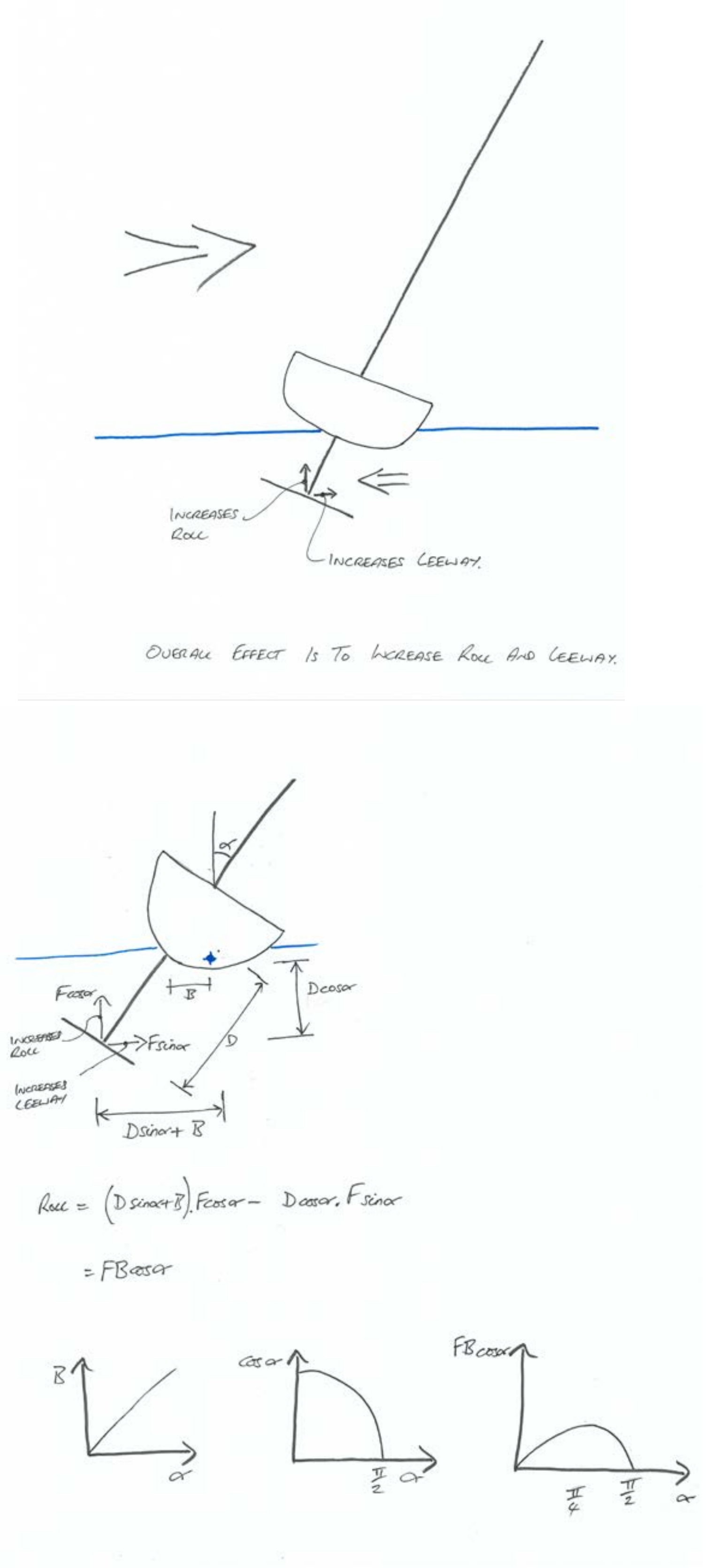

Figure 8.3

8.3 Why a hydrofoil is not suitable to provide vertical lift for a sail boat to plane

As discussed above planing boats using the *WINDFLY Rig* may include a hydrofoil to provide a vertical load which balances the vertical component of the kite load so that drive force is applied at approximately the same location and inclination relative to the hull as the drive force applied by an outboard motor. The *WINDFLY Rig* can therefore be mounted on any hull designed to plane using an outboard motor. There is no difference to the operation of the *WINDFLY Rig* whether the boat is travelling downwind or upwind: using a *WINDFLY Rig* a boat can plane upwind as well as downwind.

At first sight it appears that a similar arrangement could be fitted to a sail boat to provide a vertically upward load, lower the intersection point and so reduce the lever arm for the drag vector and hence reduce the drag moment. However:

i) Due to the heel of the boat the vertical component of the lift would be reduced so that the vertical component = (total lift) . cos(heel angle).

ii) Due to the heel the vertical component increases the heeling moment causing the boat to heel further.

iii) Due to the heel of the boat a component of the lift would act downwind tending to counter the effect of the keel and increase leeway. This downwind component = (total lift) . sin(heel angle).

Therefore, while a hydrofoil arrangement is suitable for the small angles of heel which may occur for boats using the *WINDFLY Rig* the arrangement is generally unsuitable for traditional sail boats - if it were to be applied a pair of hydrofoils would be required with a large spacing across the boat ... which leads to different design solutions such as those adopted for the foiling sail boat Hydroptere.

8.4 Conclusion

In conclusion: Boats using the *WINDFLY Rig* can plane upwind. Windsurfers and kitesurfers are also able to plane upwind. However sailing boats using a traditional rig are not able to plane upwind.