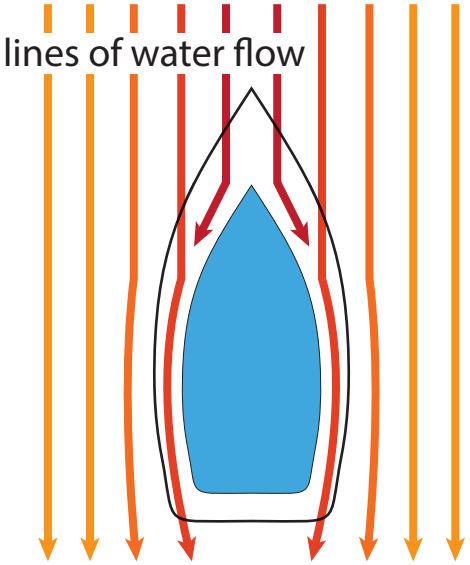
Wetted Area and Heel

You may have noticed that when skippering the boat, there is often a force on the tiller, trying to pull or push it from off-center. You may also have noticed that these forces occur most often when the boat isn't flat.

When the boat is not level in the water, we say it is heeled. Heeling the boat changes what part of the hull is in the water. Figures A and B on the following page, show how the wetted area of the hull (the part that's in the water) changes as the boat heels. These changes to the wetted area cause the boat to want to turn one way or the other, and are responsible for some of the forces the skipper feels through the tiller.

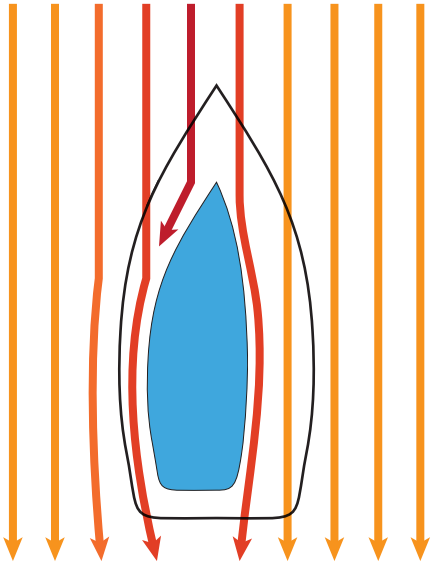
First, let's consider a flat boat - example (i) on the following page:



When the boat is flat, water is deflected in equal amounts around both sides of the hull. The deflected water is briefly piled-up adjacent to the hull, applying excess pressure to the hull (relative to a stationary boat). Because equal amounts of water are deflected around both sides of the hull, the excess pressure is equal on both sides of the hull.

The boat therefore tracks in a straight line.

Now, let's consider a heeled boat - example (ii) on the following page:



When the boat is heeled, water is deflected in unequal amounts around each side of the hull. In this example, the boat is heeled towards the left hand side. So, water is deflected to a greater extent around the left hand side of the hull. This leads to greater water pressure on the left hand side of the hull than on the right.

This difference in water pressure causes the boat to turn towards the right.

Fig A

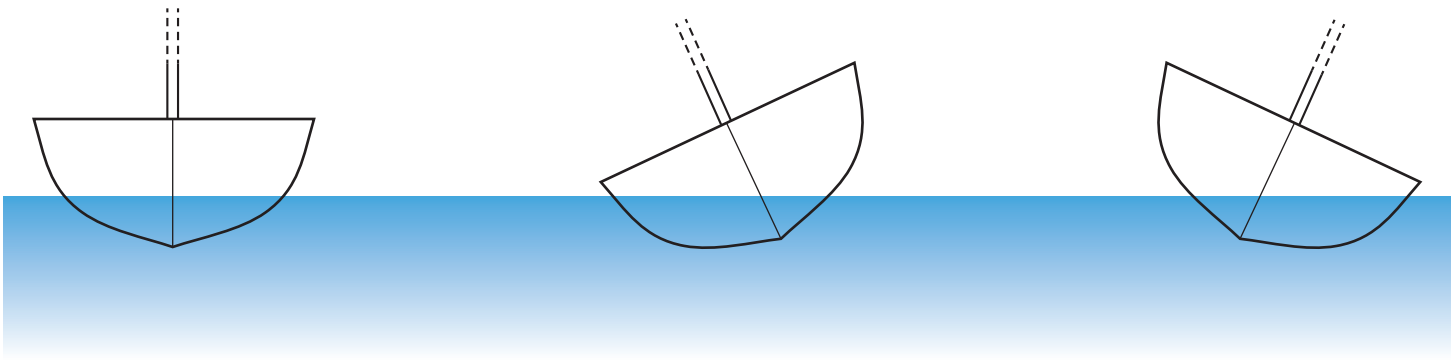


Fig B

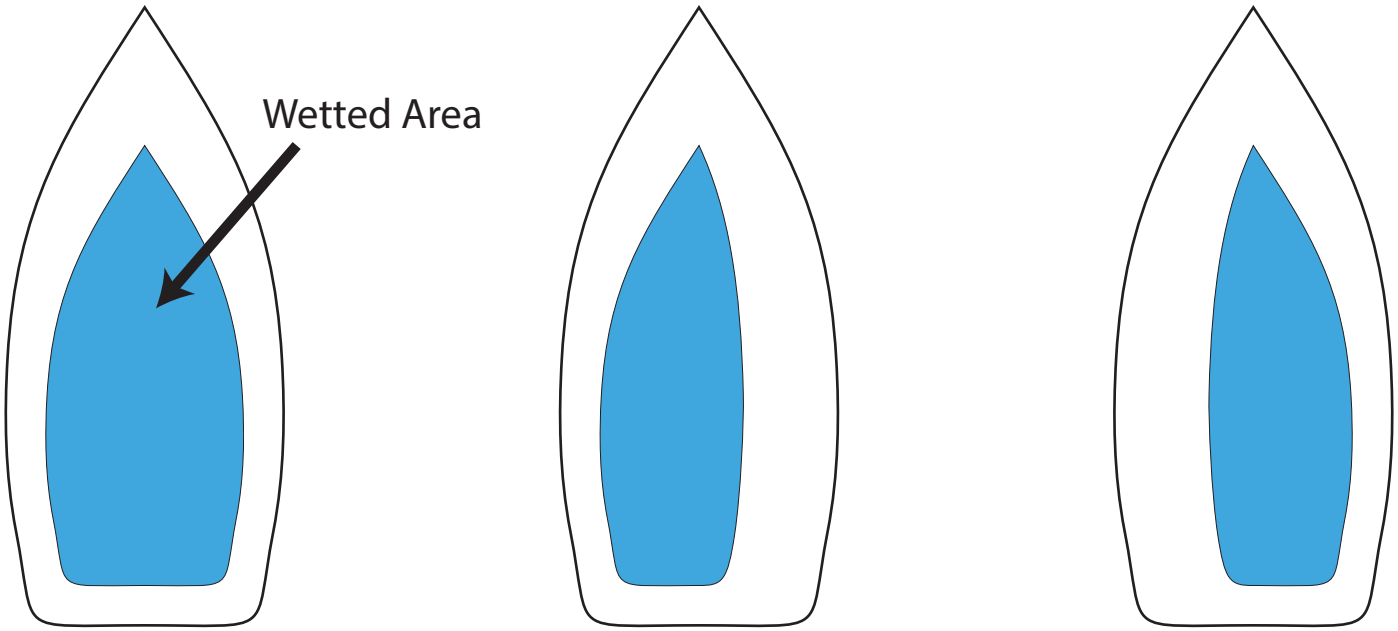
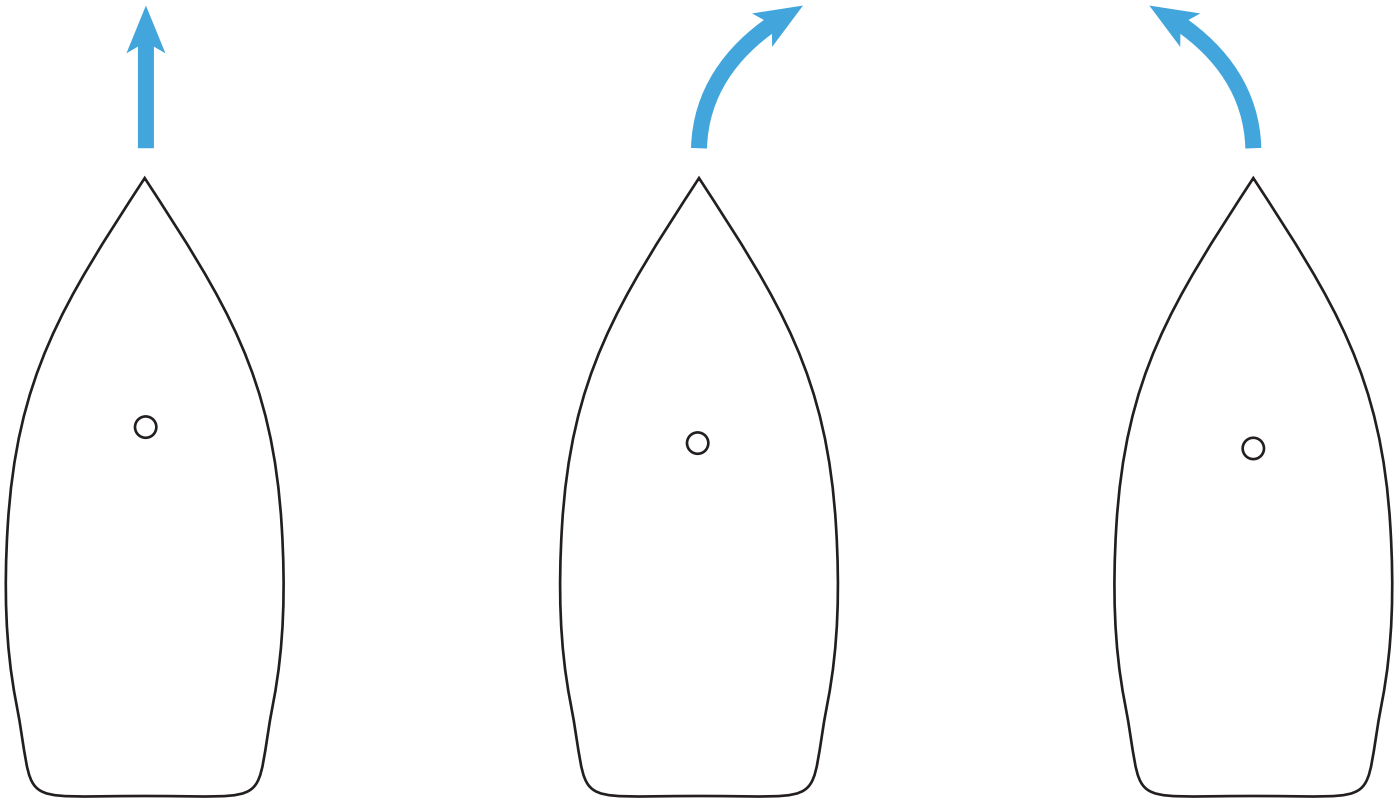


Fig C



Weather Helm Due to Heel

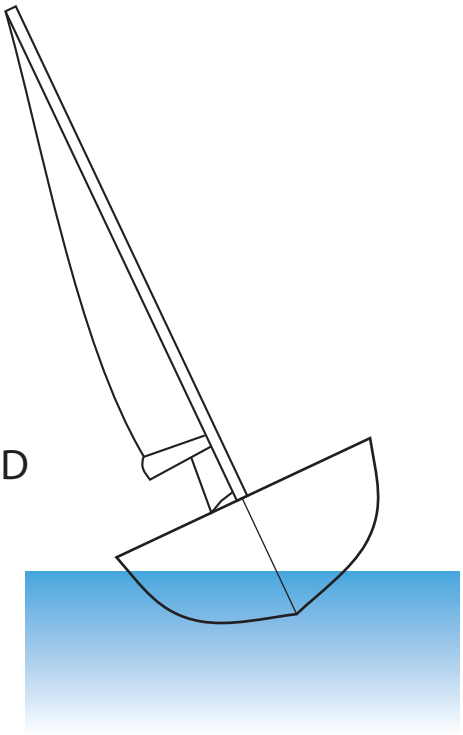
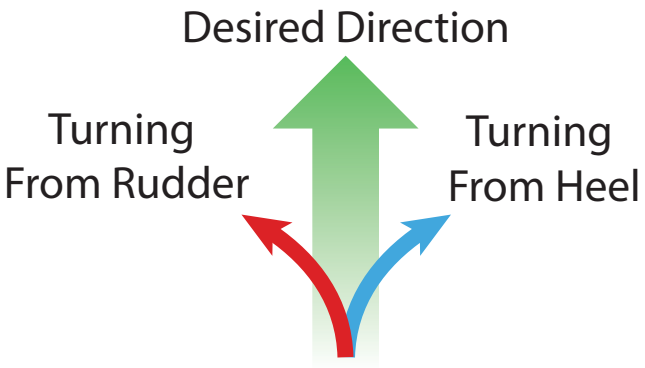


Fig D



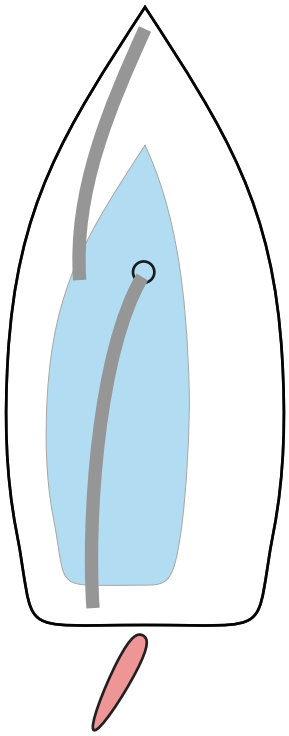


Fig E

Situation: The force of wind in the sails causes the boat to heel to leeward. In this example, the boat is on starboard tack (Fig D).

The leeward heel changes the shape of the wetted surface, leading to a force that turns the boat towards the wind - also known as "to weather."

This is great if you want to turn the boat towards the wind, but if you want to maintain a straight course, it needs to be corrected.

Common Mistake: Many skippers will counteract this turning force from heel using the rudder, as shown in Fig E. This might keep you in a straight line, but the drag it creates slows the boat down, doesn't help if you need to bear away (fall off), and in extreme cases can damage the rudder or tiller.

Solution: Aim to bring the boat back to a level position by:

- Having the crew hike out harder

- Easing the sheets to de-power the sails

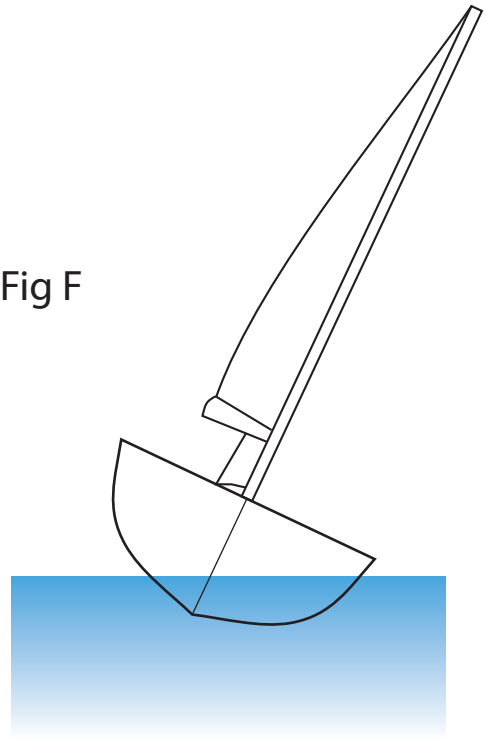
- If close-hauled, luff the sails by sailing into the edge of the no-go zone.

- Adjust sail controls (outhaul/vang/cunningham) to de-power the sail.

- If constantly over-powered, reef the sails.

Lee Helm Due to Heel

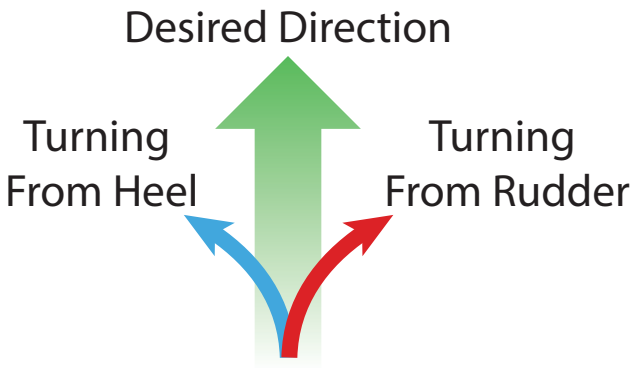
Fig F



Situation: The wind drops, reducing the force in the sails and causing the boat to heel to windward. In this example, the boat is on starboard tack (Fig F).

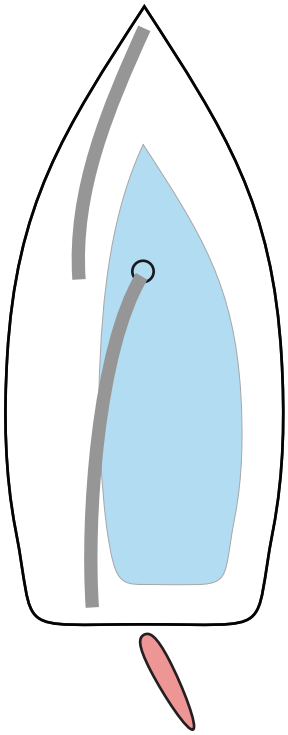
The windward heel changes the shape of the wetted surface, leading to a force that turns the boat away from the wind.

This is great if you want to turn the boat away from the wind, such as when rounding the windward buoy of a race course. However, it is not desirable when trying to maintain a straight course or if you want to turn to windward.



Common Mistake: Many skippers will counteract the turning force from heel using the rudder, as shown in Fig G. This possesses the same problem as using this solution to combat weather helm. However, lee helm is generally encoutered less often than weather helm.

Fig G



Solution: Aim to bring the boat back to a level position by:

- Having the crew move inboard to balance the boat

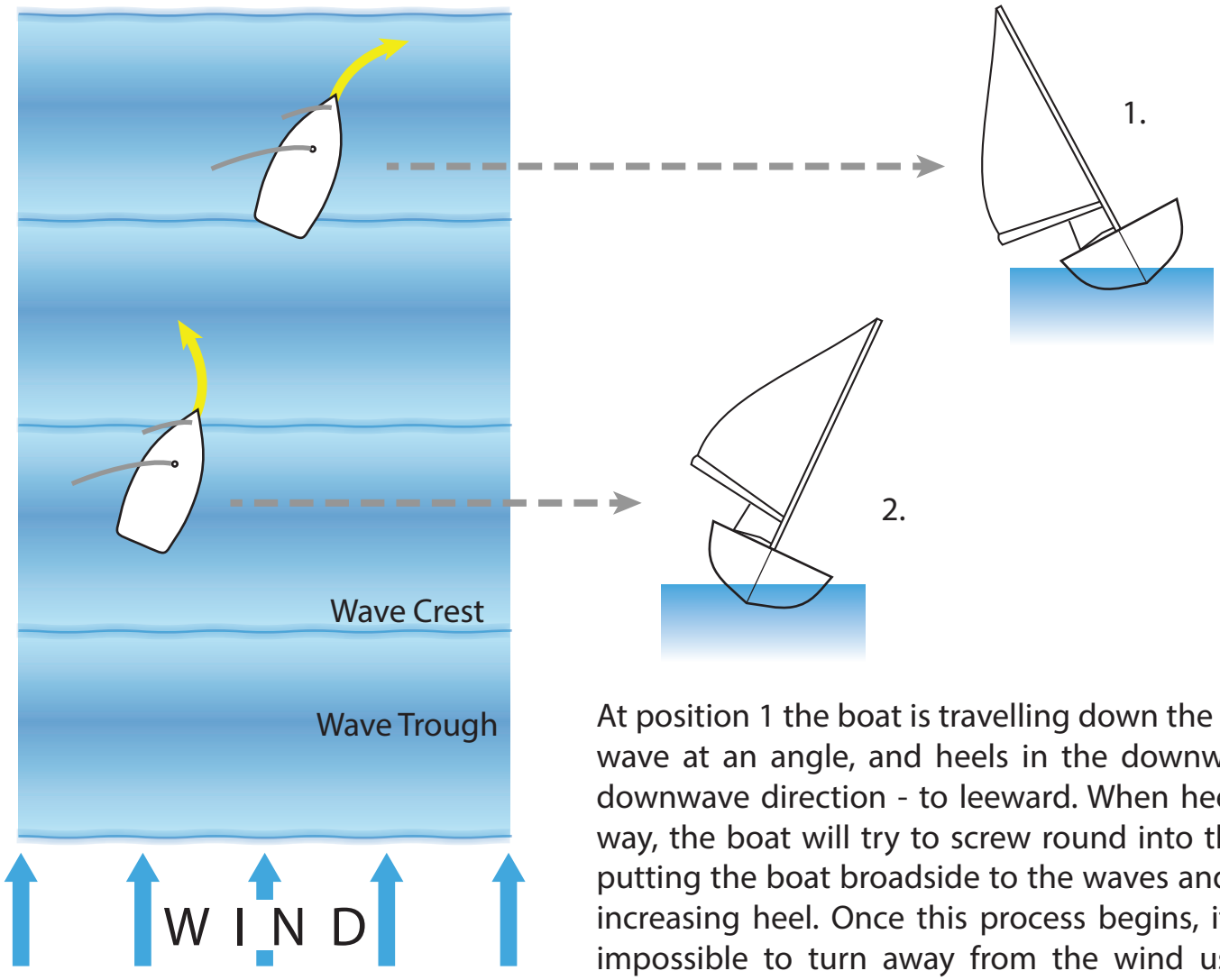
- Check your sails are trimmed for maximnum power

- Adjust sail controls (outhaul/vang/cunningham) to power-up the sail.

Boat Heel, Steering, Waves, and Gybes.....

You will probably have noticed when sailing downwind in waves (most obvious when sailing on a broad reach) that the boat can experience significant alternating windward and leeward heel. The boat will therefore try to turn away from and toward the wind respectively. The skipper will feel these turning forces through the tiller, which can make controlling the boat a challenge, especially when leading up to a gybe.

By understanding how the boat will roll in the waves, we can steer the boat to minimize problems:



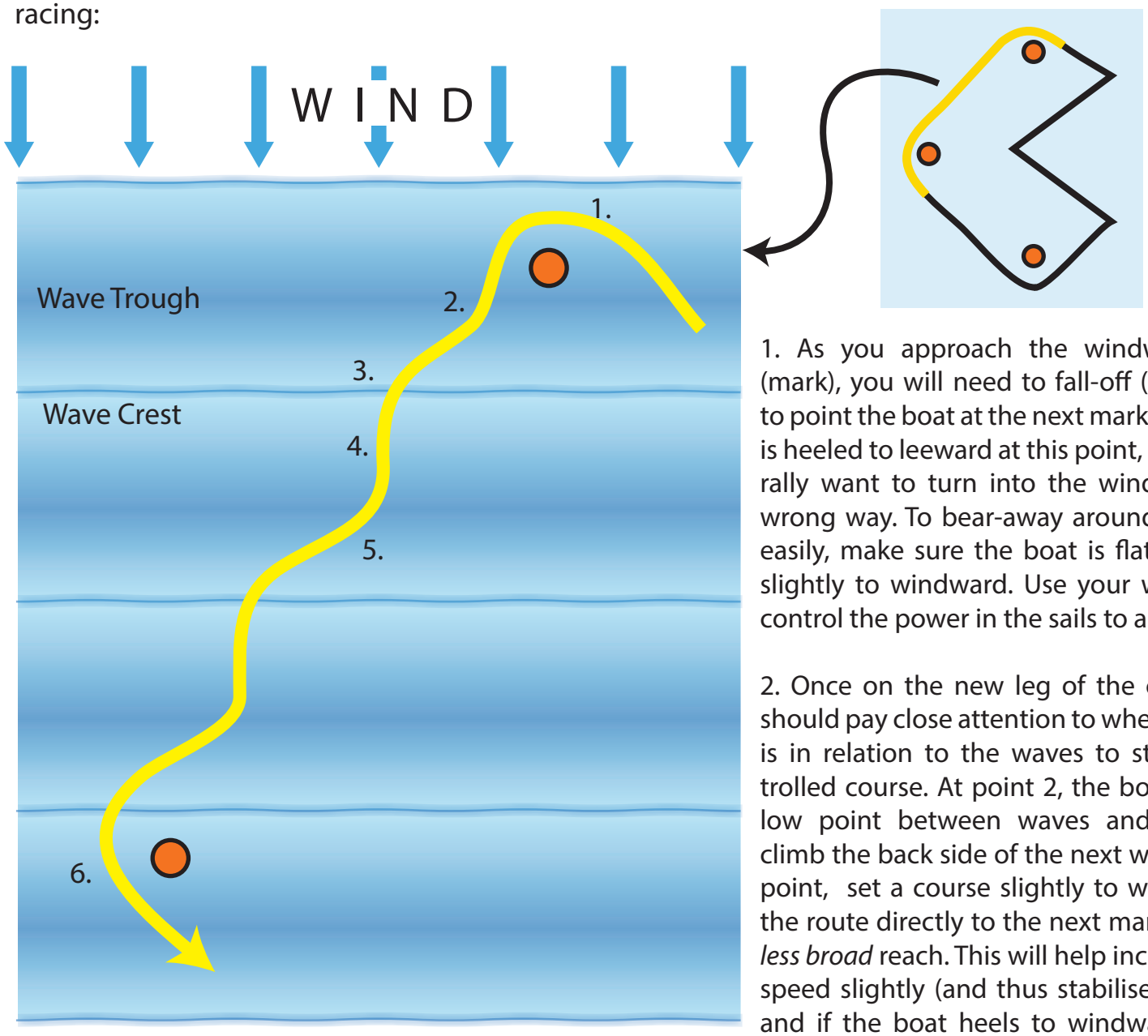
At position 1 the boat is travelling down the face of a wave at an angle, and heels in the downwind and downwave direction - to leeward. When heeled this way, the boat will try to screw round into the wind, putting the boat broadside to the waves and further increasing heel. Once this process begins, it will be impossible to turn away from the wind using the rudder.

At position 2 the boat is on the back of a wave, and will heel to windward, which is again in the downwave direction. When heeled this way, the boat will try to turn away from the wind. Turning this way aligns the boat with the direction the waves are travelling, which reduces heel and the associated turning force. This effect therefore tends to be easier to control than the situation described in position 1. However, if left unchecked, it can lead to an unexpected gybe.

When at the very top or bottom of a wave, where the boat is flatter, the tiller will feel more neutral to the helm, and and turning the boat using the rudder will be easier.

Boat Heel, Steering, Waves, and Gybes.....

Let's look at part of a course you will often sail during the internediate sailing classes and when racing:



1. As you approach the windward buoy (mark), you will need to fall-off (bear-away) to point the boat at the next mark. If the boat is heeled to leeward at this point, it will naturally want to turn into the wind - i.e., the wrong way. To bear-away around this mark easily, make sure the boat is flat or heeled slightly to windward. Use your weight and control the power in the sails to achieve this.

2. Once on the new leg of the course you should pay close attention to where the boat is in relation to the waves to steer a controlled course. At point 2, the boat is at the low point between waves and about to climb the back side of the next wave. At this point, set a course slightly to windward of the route directly to the next mark, i.e., on a *less broad* reach. This will help increase boatspeed slightly (and thus stabilise the boat), and if the boat heels to windward on the back of a wave, you will be turned towards the direction you want to go.

3. At the crest of the wave, turn the boat so that it is aligned straight down the face of the next wave, i.e., onto a *more broad* reach or a run (the exact point of sail will depend on how well aligned the wind and waves are). This will prevent heeling as the boat accelerates down the face of the wave.

4. If you've got everything right, you should be surfing down the face of the wave on a relatively level boat - this is the fun part!

5. As you enter the lowest part of the trough, the boat will slow down and you should turn back onto a less broad reach to increase boat speed and climb up the back of the next wave. Repeat these steps as each wave passes.

6. You've reached the next mark and need to gybe. More about this on the next page.....

Boat Heel, Steering, Waves, and Gybes.....

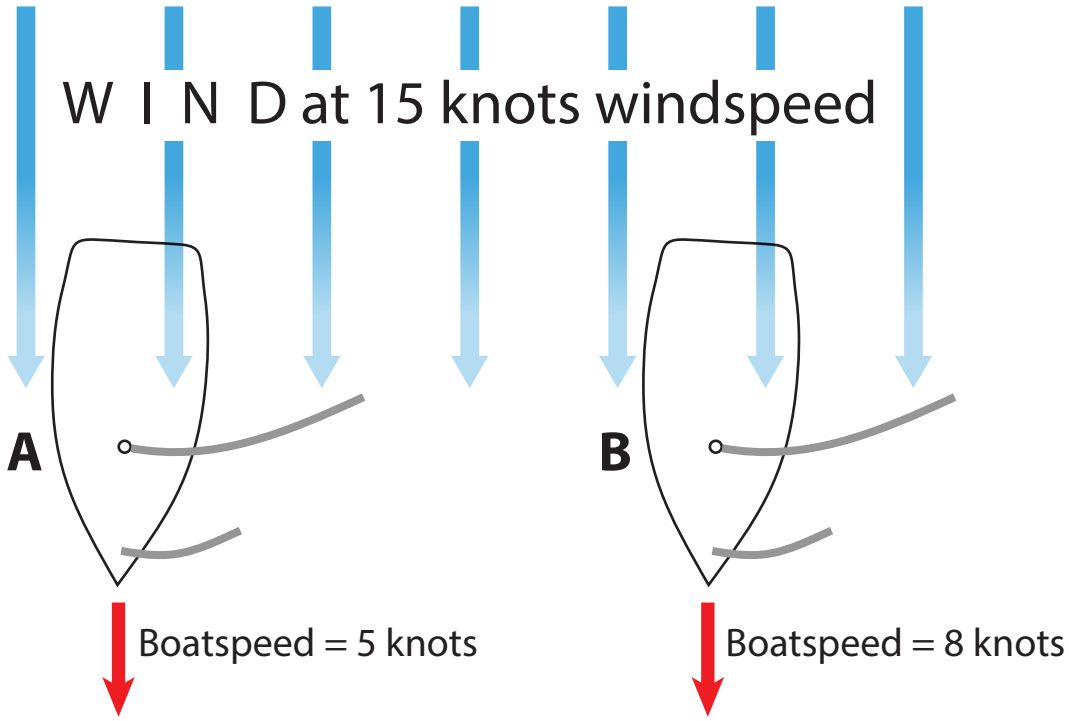
As you might have already discovered, gybing a sailboat in strong wind and waves is not easy! Getting this manouver wrong can easily lead to a capsize and increases the risk of a crew member going home with a badly bruised head.

Several common mistakes when performing this manouver are:

- Entering the gybe without enough boatspeed
- Turning the tiller through too large an angle
- Trying to begin the gybe when the boat is heeled to leeward

Let's look at the first of these issues and how it relates to our earlier discussion of sailing in waves. The intution of many new sailors is to wait until the boat is moving at it's slowest before begining the gybe, as this feels safest. In reality, it makes the gybe considerably more difficult to control. We can understand this by considering two boats running downwind at different speeds in 15 knots of windspeed.

When the wind hits the sails of boat A, it is forced to slow from 15 knots to 5 knots; a 10 knot change in velocity. When wind hits the sails of boat B, it only has to slow from 15 to 8 knots. A change of 7 knots in velocity. If this change in wind velocity takes just 0.01 seconds in both cases and we consider a mass of air hitting the sails that is 10 cm deep, we can use the simple formula: force = mass x acceleration, to calculate the force on the sails of each boat:

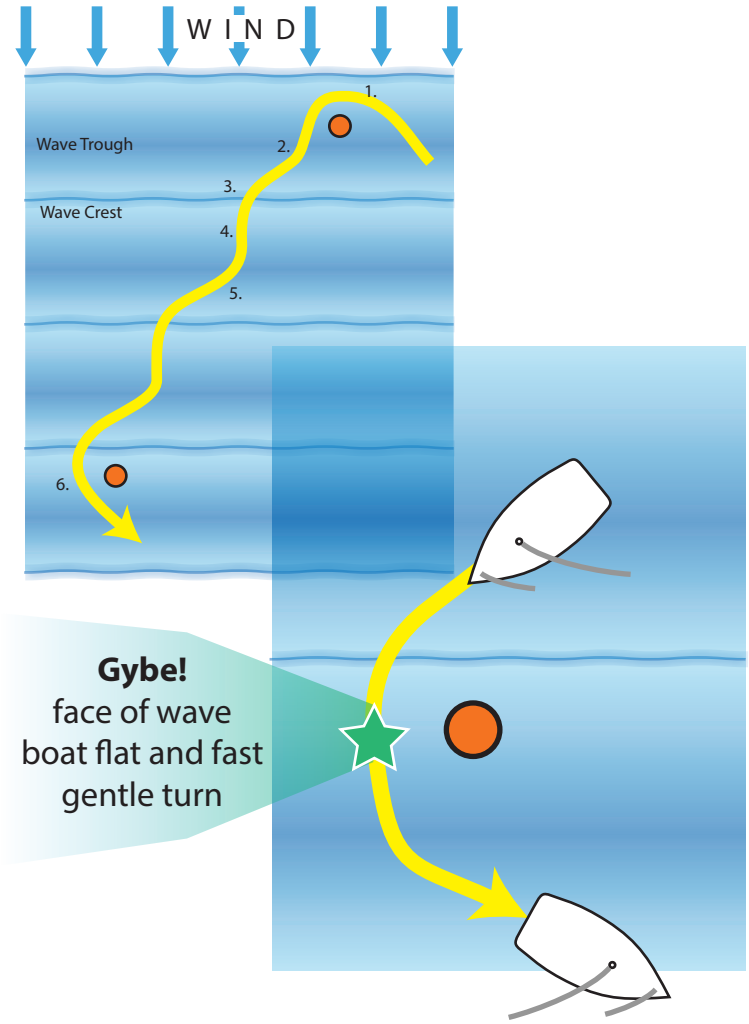


Coronado sail area = 11.42 m^2
Volume of air (10cm deep) = 1.142 m^2
Density of air = 1.225 kg/m^3
Mass of air = 1.4 kg
Decceleration of air = 514.0 m/s^2
Force = 359.8*1.4 = **719 N**

Coronado sail area = 11.42 m^2
Volume of air (10cm deep) = 1.142 m^2
Density of air = 1.225 kg/m^3
Mass of air = 1.4 kg
Decceleration of air = 359.8 m/s^2
Force = 359.8*1.4 = **503 N**

These numbers are somewhat arbitrary, but suffice to demonstrate that there is more load on the sails of the slower boat. Therefore, during the gybe, the force that will cause the boom to crash over onto the new side will be increased if the boat is travelling slowly. The shift forwards in apparent wind due to travelling quickly may also help aid the gybe, but we will not discuss that further here.

Boat Heel, Steering, Waves, and Gybes.....



We now know that to execute a successful gybe, we need to:

- maintain the best boatspeed possible through the gybe

- turn the boat through a small angle by not turning the tiller hard over

- make sure the boat is level before beginning the turn. Don't attempt to begin a gybe if the boat is heeling to leeward!

Returning to our figure that describes how to sail downwind in waves, we can see that the boat is going to be level and moving at it's fastest when surfing down the front of a wave. This is where we should aim to execute our gybe:

Tips to execute a successful gybe:

1) Communicate with your crew. Let them know you're getting ready to perform the gybe, tell them you plan to do it on the face of the next wave, wait until they respond that they're ready.

2) Prepare your tiller and sheets. Make sure that you yourself are ready - untangle and uncleat any sheets and get your tiller exention in the correct position so that it doesn't catch on anything during the gybe

3) Be aware of your surroundings. Make sure you're clear of all boats and always assume things might go wrong and you could lose control. If you're not confident you have room to manouvre, wait.

4) Bring in a couple of armfuls of sheet just before the gybe. This will make it easier to pre-gybe the main by grabbing the falls and tugging the boom across, and limit how far the boom swings out on the new side.

5) Use small tiller movements. Unlike a tack, you don't have to use momentum to pass through a no-go zone. You will only need a few degrees change in direction to go from a run to a run by gybing.

6) Practice. This is a hard manouver in strong winds that even experienced sailors regularly get wrong. There is no substitute for practice!

Useful Video Links:

Tacking: https://www.youtube.com/watch?v=JZAPz9BCqJM

Gybing/Jibing: https://www.youtube.com/watch?v=dMb6UEZ0pvE

A good demonstration of gybing in high winds (starts at ~3:50). Note how little tiller movement is required, and the way the helmsman orients the tiller extension to the new side in advance of the gybe:

https://www.youtube.com/watch?v=uUD1mjwie_k

An excellent presentation of some aspects of rig tuning and the effect of sail controls. Much of this isn't worth worrying about at this stage, but the sections on sail controls (kicker/vang, cunningham, outhaul) are a good demonstration of how each control affects sail shape:

https://www.youtube.com/watch?v=mVFnnHGUlOs&t=2s

Demonstration of how tell-tales can me used to find the appropriate close-hauled course at the edge of the no-go zone:

https://www.youtube.com/watch?v=hnOO5Z0zOfs

A good example of how far outboard you can get your body weight when hiking to balance the boat, and avoid muscle strain in the long term:

https://www.youtube.com/watch?v=-TbfX7gYILE

Some right-of-way rules and examples of they can be applied:

https://www.youtube.com/watch?v=iS8dO0QjU5Q