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## Planing Waterbirds

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Waterbirds, aquatic mammals, and boaters share the freedom afforded by travelling across the surface of water. They also share the constraints of the waves that such travel produces.

Something moving across a water surface pushes a mound of water before it and leaves a trough of water behind it. The mound is the crest of the bow wave and in its wake lies a train of waves extending alongside and behind. Of necessity, these waves all travel at the speed of the object producing them. It is these waves that cause trouble for travellers at a water surface.

The difficulties arise because the wavelength (distance between crests) changes with the speed of travel, indeed the wavelength grows as the square of that speed. The strange consequence is that there is an effective speed limit for a swimmer or boat which occurs when it is traveling at a speed such that the wavelength in the water is equal to the length of the body or hull. This speed is called the hull speed.

A problem faces a duck, or kayaker, when either attempts to move faster than its hull speed. As the bow sits at the crest of the wave it creates, an increase in wavelength to twice the hull length, say, causes the duck to ceaselessly have to swim uphill from a wave trough to a wave crest of its own making. This situation may not pose an absolute barrier to going faster than the hull speed providing there is sufficient power, but the practical consequence is that the impediment is usually insurmountable. So, many swimming animals or watercraft just cannot move faster than their hull speeds.

Certainly, a boat with a powerful engine may be able to overcome the limitation of the hull speed and move from displacement to planing mode. In displacement mode, the boat is (primarily) supported in the water by its buoyancy (static pressure). In planing mode, it is (primarily) supported by the lift provided by the rush of water against its sloping hull (dynamic pressure). This is the same mechanism that supports a flying bird or airplane (and why it is called an *airplane*). When it attains planing, a boat

can move much faster than its hull speed, something that is often advantageous. While some, but not all, boats can plane, it is reasonable to ask whether planing lies within the capabilities of aquatic mammals and waterbirds? Can either exceed the hull speed limit?

The first place to look for planing is among the smallest waterbirds — chicks rather than adults. It is easier for a chick to plane as it does not need to propel itself as quickly to do so as does an adult. Just as the weight of an airplane is supported by the air pushing against the area of the sloping wing, so the weight of a planing duck is supported by the water rushing against the area of its sloping underside. The greater the weight, the greater the product of area and the square of the speed required to support it.

The supporting area will vary as the square of the duck's length. But, the weight to be supported will vary as the cube of the duck's length. The result is that with increasing size, a duck's weight climbs faster than does the area needed to support it and this means that a larger duck requires a higher speed for it to plane. Chicks have an advantage over adults by not needing to propel themselves as rapidly when planing.

Not surprisingly, when chicks emerge in the spring, it is not uncommon to see them plane; I have seen the planing chicks of Mallards, Common Mergansers and Hooded Mergansers.

What about the much heavier adults? Can they plane? I have seen adult Common Mergansers and Common Loons do it, and others have seen the adult Common Eider plane. These are all divers, as distinct from dabblers, and it is reasonable to speculate their rear-mounted legs will aid in giving them the power needed to plane. However, on one occasion I watched an adult Mallard plane so as to intercept a dog harassing her chicks, so when urgency demands, an adult dabbler can plane. Even though a muskrat has almost the same weight as the adult merganser its feet differ; certainly, I have never seen one plane.

A reasonable question to ask is: Why might a swimming bird want to exceed its hull speed limit and start planing? The chicks I have seen plane often do so to catch up with mommy after becoming separated. Adult birds

have used planing to chase prey, such as fish, to attack a competitor, or even to chase a potential mate, and in the case of the Mallard, to protect chicks. There seem to be multiple reasons why a swimming bird sometimes wants to move across the water with dispatch.

Of course, planing is one of three ways to get around the hull speed limit. Planing involves staying on the surface of the water, the other two methods involve avoiding the water surface, one going above it, the other below. Only birds can go significantly above the surface by lifting off and flying. The first step in doing this is to use feet and wings to lift the body out of the water so as to avoid the limitations of the hull speed while gaining flight speed. The bird runs across the water, pushing with its feet and flapping its wings. However, as the body has been lifted above the water, it is flying rather than planing. Many birds with webbed or lobbed feet do this. The third way to avoid the hull speed limit is to dive. Much greater speeds are possible by swimming underwater than remaining at the surface. Many animals, from diving birds to otters, take advantage of the underwater workaround.

One might think that the story of planing birds would end here, but to my mind, the most interesting part is what follows.

Some boats are incapable of planing no matter how much power is applied: shape is crucial. Boat designers have long known that planing requires an immersed and sharp transition between the transom and the hull. This enables a separation of the water from the boat as it sweeps past the stern. The boat can now plane across the water in an only slightly tilted position. If there were a (longitudinally) rounded or upswept stern, the boat just keeps tipping up farther as it attempts to climb the crest of the bow wave. On the other hand, displacement hulls, such as old rowboats, favour an upswept stern with the transom above the waterline as this reduces drag for them.

So, the longitudinal shape of the ventral surface (boat bottom or animal butt) is crucial. Swimming mammals, such as muskrats, have rounded butts which is one of the reasons that planing is beyond their capability.

The problem here is that waterbirds also have rounded butts, and yet a number of them can plane. How can this be?

For me, the resolution of this discrepancy had to await springtime observations of Mallard chicks. They showed me how they game the physics to attain planing speeds: they alter their body shape. Having seen how the Mallard chicks did it, I looked back through older pictures and discovered that other birds employ the same shape-shifting device.

When these ducks are swimming in displacement mode, they do indeed have a rounded stern. That changes when they switch to planing mode, at which time they force their tails down into the water to create the sharp transition needed for the separation of the flow under their bodies. But, the shape modification does not stop there. Designers of planing boats speak of a hard chine, the sharp transition along the sides of the hull that improves both directional stability and the handling of spray. It seems that some birds are also aware of this nicety as they press their wings against their sides to achieve the requisite hard chine.

Some waterbirds gain an advantage by swimming faster than their hull speeds. But, making the transition from displacement mode to planing mode depends upon size, power, and shape.

- Size: It is easier for a small bird to plane as they can do so at lower speeds than a large bird.
- Power: Even with birds of comparable size, divers, with their more powerful rear-mounted legs, seem to have an advantage over dabblers.
- Shape: The rounded butts of swimming mammals is one reason that prevents any of them from ever planing. Although birds also have rounded butts, some have learned to press tail feathers into the water them into the water to attain the requisite shape for planing. It seems that others, such as grebes, accomplish the same thing with their feet.

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## Images



Image 1: An adult female Common Merganser swims in displacement mode at just below her hull speed. Her tail is up making her stern upswept, which reduces drag in this mode.



Image 2: Another adult female Common Merganser swims in planing mode. She has pressed her tail down to make a sharp underwater transition at the stern which enables a separation of flow. She holds her wings at her sides to provide a hard chine.



Image 3: For these merganser chicks to plane, each first forced its tail down into the water.