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What!? How *Small* a Wave Can Capsize My Boat!?

We've covered many seamanship topics here over the past several years. Topics such as what to do if you're sinking (see SSP, "We're Sinking!", 12/13/06), how to handle heavy seas (see SSP, "Skippering in Heavy Weather",11/24/10) and what to do if you've run her aground (see SSP, "Hard Aground – Now What?", 7/09/08) have been among the literally hundreds of topics we've covered. One topic we haven't covered is the general topic of capsizing. There is a tremendous amount of data on "righting moments", centers of buoyancy and gravity, thanks to the US Navy and the US Coast Guard, amongst many institutions who literally live and die by these metrics. We've also seen a couple of columns here about wind and waves, which are the agents of capsizing (see SSP, "Wave Theory and Practice", 3/23/11 and "Wave Theory and Practice, Part II", 7/21/10.) But there has been very little direct data on what that translates into in terms of my 25' boat and 8' seas at the Inlet. This column is about that.

Some Background

To understand the forces of a capsizing, and how those forces changes when you load the boat (see SSP, "We All Get Heavier With Age – Including Our Boats", 3/02/11), let's get some terms under our belt.

Most of us understand "center of gravity" (G) instinctively. But what is the center of buoyancy? The center of buoyancy (B) is the center of the volume of water which the hull

Diagram A – Courtesy of US Coast Guard – click to enlarge

Diagram B – Courtesy of US Coast Guard – click to enlarge

displaces. When a ship is stable, the center of buoyancy is vertically in-line with the center of gravity of the ship. So, as long as the center of gravity (G), pushing the boat down, is above the center of buoyancy (B), pushing the boat up, we're good. How good? That is a *very* good question and as with many good questions, it requires more information to answer properly. Take a look at diagram A. What is that "M" sitting up there above our trusty center of "G"ravity and the center of "B"uoyancy? That is something very important called the "M"etacenter. The metacenter remains directly above the center of buoyancy regardless of the heeling (tilting caused by external factors like wind or waves) or listing (tilting caused by internal factors such as poorly stowed cargo or on-boarding of water by wind or waves) of a boat. Take a look at Diagram B. If you are starting to worry about the distance between "G" and "M", called the "Metacentric height" (or "GM" in naval architecture parlance), you've catching on quickly. The math gets pretty complicated from here but suffice it to say that the ability of the boat to right herself, i.e,, her "righting arm" or "righting moment", has a lot to do with GM. The larger the GM acting as a lever, the better.

Sail boats are designed to operate with a higher degree of heel (greater GM) than motor boats but the principles are exactly the same.

From This to Wave Height?

Yes. You can infer that your motor boat's center of gravity and center of buoyancy can't be too far apart when the entire distance from the keel to the floor boards is probably something like 2' or 3'. Think of her draft. It isn't a big number, even for a 40'er. No reason to panic but you now realize that M, G and B can't be that far apart – which means that GM just can't be that great either. And GM is a surrogate for the righting ability of your boat.

But wait. I've been out in some pretty steep seas and I think the boat handled it well. Yes, because studies conducted by the Society of Naval Architects and Marine Engineers (SNAME) determined that 3 things must exist for a capsizing to occur:

1. The boat is broadside to the wave. Yes, a boat can be pitch-poled (tossed end-over-end), but the size of the wave needed to do that greatly exceeds the size of the smaller wave needed to

knock a boat down when broadside to a wave.
2. The boat is struck by a breaking wave.

3. Wave height must exceed a certain percentage of the boat's length.

At this point the wave contains enough energy to overcome a boat's righting moment.

So, what is that "certain percentage?" At only 30% of your boat's length, (about 6' from tough to crest for a 20' boat), things enter directly into the realm of high danger. At 60%, it is nearly certain that one wave will catch you and then you, the crew and the boat may well come to grief.

So, before trying to transit these inlets and bars that control much of our access to the open sea (see SSP, "Mastering the Inlet", 12/12/07), think about just how much of a righting arm your boat can possibly have…