Maximizing A Trawler's Range

Or...What A Difference A Propeller Makes!

by Gary Danielson

Having sailed for years, my wife and I decided it was time to transition from sail to power. Our next planned adventure would be well-suited to a trawler—a cruise from the Great Lakes down to the Amazon River in South America.

Given the primitive wilderness of the Amazon region, we determined that we needed a trawler with plenty of living space, the ability to power long distances without refueling, as well as the ability to be self sufficient without shoreside amenities for long periods of time.

These criteria resulted in the creation of our trawler, *Hemisphere Dancer*, Hull #1 of the Great Harbour 37 series.

She has proven to be exactly what we wanted for such a journey.

Increasing Her Range

Once a boat has been designed and built, the number of things that owners can do to enhance the range of that boat are somewhat limited. Routine activities, such as keeping the engines in good operating condition, and the bottom and running gear clean, will do much to enhance the boat's long range capability.

Beyond that, however, the only other significant options that can impact a vessel's range is to reduce the overall weight as much as possible, and to install a propeller that most efficiently matches the boat.

Since long distance capability was such an important element in our intended use of *Hemisphere Dancer*, we have spent a great deal of time measuring the impact these factors would have on our plans. And it was important to test these factors after the boat was launched and delivered home, so that we could know what she would really do, before we got too deep into planning our South American adventure.

Prior to actually conducting tests and measurements on the boat, I held several assumptions related to the issue of a trawler's range. They were:

• In a full displacement hull, such as *Hemisphere Dancer*, the addition of weight has

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little, if any, effect on the vessel's range.

• On a long passage, running the boat on one engine gives greater range than running it on two engines.

• Changing props makes little actual difference in the vessel's range in the real world.

As it turned out, all three of my assumptions were incorrect.

The Autoprop is a clever device that adjusts blade pitch according to shaft speed and water pressure.

COURTESY OF AUTOPROP

Effects Of Weight On Range

Hemisphere Dancer was designed to weigh 43,000 pounds when her tanks are full and when fully stocked for a long cruise.

When the boat was first launched, she carried no additional ballast, and she initially traveled with just a few personal effects and supplies. With approximately a half-load of fuel and water, *Hemisphere Dancer* weighed in at 31,000 pounds.

After cruising the boat several thousand miles, we decided to add ballast to the boat, for a couple of reasons.

First, the boat had a "snappy" roll that was just too quick to be comfortable. We knew that strategic placement of ballast would slow the roll rate to a much more comfortable level.

We also determined that ballast placed low in the bilges would contribute to the boat's ability to resist and recover from a knockdown. (With the ballast, the boat can now self-right from a calculated heel angle of 110 degrees.)

Lastly, ballast helped trim the boat, as she sat significantly stern down when first launched.

Ultimately, we added 9,000 pounds of ballast to *Hemisphere Dancer*.

Once we completed our ballast project, and, after some basic cruising gear was brought aboard, the displacement of the boat (still with a half load of fuel and water) increased from 31,000 pounds to 41,000 pounds.

Since the boat is a full displacement hull form, designed for a displacement of 43,000 pounds, I'd assumed that a change in displacement from 31,000 to 41,000 pounds would have little, if any, effect on the fuel efficiency and resulting range of the boat. I was wrong.

It's All In The Numbers

We were fortunate to have taken extensive speed and fuel use measurements, both before and after the addition of the ballast. Other than the increased weight of the boat and the addition of an 8-inch bow thruster tube, everything between the two sets of tests was identical.

Chart 1 outlines the impact that weight had on the actual mileage of *Hemisphere Dancer*.

When I saw the negative impact the additional weight had on the mileage figures for our trawler, I was both surprised and intrigued. My assumption was clearly wrong.

So I reviewed all of the technical literature I could find to see if this effect on mileage was normal, and further, if it could be predicted and/or quantified. I soon learned that all of the technical information agreed that the addition of weight does indeed have an adverse, yet predictable, impact on mileage.

Chart 2 shows the predicted fuel use for my

Chart 1 Actual Fuel Use Measured with Two Engines and Fixed-Pitch Propellers

SPEED (KTS)	GALLONS PER HOUR (31,000 POUNDS)	GALLONS PER HOUR (41,000 POUNDS)
5.4	0.75	0.7
6.0	0.92	1.0
6.3	1.10	1.3
6.6	1.3	1.6
6.9	1.5	2.1
7.2	1.6	2.7
7.5	1.85	3.2 (at 7.4 knots)
8.05	2.4	NA

boat. As you can see, adding weight of any kind, even if it is to bring a full displacement hull down to its designed waterline, has a negative impact on the mileage of a vessel. This was proven in our own testing, as well as the predictions from the technical models.

All other things being equal, a lighter boat generally requires less power, roughly in proportion to its weight. For example, a 36,000-pound boat needs 10 percent less power to reach a given speed than a 40,000-pound boat.

The obvious conclusion here is that you should strive to keep your boat as light as possible if you are really concerned about maximizing the range potential of your boat.

Chart 2 Predicted Fuel Use

SPEED (KTS)	GALLONS PER HOUR (31,000 POUNDS)	GALLONS PER HOUR (41,000 POUNDS)
5.4	0.53	0.73
6.0	0.79	1.1
6.3	0.93	1.3
6.6	1.1	1.5
6.9	1.4	1.9
7.2	1.7	2.3
7.5	2.1	2.9
8.05	2.9	4.0

Effects Of Propeller On Range

Despite their worldwide and universal use, propellers are not particularly efficient at transforming an engine's horsepower into forward motion in water. Much of the energy generated by the engine is lost before it even reaches the propeller, and the propeller's inherent inefficiency consumes much of what's left.

However, it's true that thrust increases directly in proportion with an increase in propeller design efficiency. The higher a propeller's efficiency, the faster a vessel will go using the same amount of horsepower. So it seems natural that another good way to increase range is by increasing the efficiency of the propeller.

Overall, prop efficiency can range from as low as 40 percent (in a very inefficient installation), to as high as 70 percent (in a finely-tuned system using the best equipment available). The standard fixed-pitch, three or four-blade propellers that are commonly installed as original equipment on production trawlers probably have an efficiency of about 50 percent.

A self-pitching propeller, one that is properly matched to the boat and engine, will probably have an efficiency of around 60 percent.

The ultimate set-up, of course, is to have a controllable pitch propeller (CPP), along with full measurement instrumentation, so that the propeller can constantly be adjusted to remain at its maximum efficiency, despite changing speeds, sea states, and loads. A CPP installation can yield propeller efficiency as high as 70 percent.

Put in absolute terms, if you need 50 effective horsepower to propel the boat, a system with an efficiency of 40 percent will require a 125-shaft horsepower engine, while a more-efficient system (approaching 70 percent) will only require an engine rated at 72 shaft horsepower.

Fixed Propellers

The majority of propellers on trawlers are fixed-pitch, with either three or four blades. Fixed-pitch means that the shape, angle and pitch of the propeller can not be changed on demand. The reason they are so common is their relative low cost, while still providing an acceptable level of performance.

Unless your builder has spent a great deal of time optimizing a propeller to your boat, it is likely that some amount of improved efficiency can be achieved by working with your current fixed-pitch propeller, optimizing the angle of the blade to find the sweet spot for your boat in normal running conditions.

Remember, however, the actual modification of your prop is a job best left to a professional. Any out-of-balance condition will lead to reduced performance, increased vibration and a whole new set of headaches.

Other Propeller Options

If you are really serious about getting maximum range out of your boat, the next step up in propeller efficiency comes through the use of a self-governing, self-pitching propeller.

With this type of propeller there is no pitch control mechanism. Instead, the geometry of the blades and their pivoting attachment to the hub are designed so the blades automatically adjust pitch, in response to changes in torque, shaft speed and water pressure.

Unfortunately, these are production propellers, and are therefore meant to be mounted on a variety of boats. The self-governing mechanism is engineered to fit different boats and applications, so such a propeller may not always pitch the blade "perfectly" for your boat at any given time.

But from the available data, I believe this type

of propeller is substantially superior to any fixed-pitch installation. One such propeller is the Autoprop, made by Brunton's Propellers Ltd., in England.

Cost aside, the ultimate set-up is without question a CPP. If the boat has sufficient instrumentation to measure all of the important temperature and pressure variables, the ship's operator will be able to continuously adjust the propeller for maximum efficiency in all conditions.

This is certainly the most effective propeller set-up, but a CPP is expensive, and it also requires a high degree of operator involvement to gain maximum efficiency.

Self-Pitching *Hemisphere Dancer*

When our boat was built, it was fitted with a pair of fixed-pitch, three-blade propellers. They worked reasonably well while we got used to the new boat.

However, maximizing the range of our vessel has always been a key goal, so we naturally began exploring ways to increase the propeller efficiency in *Hemisphere Dancer*.

It was clear after we looked into CPPs that refitting a set of controllable pitch propellers would be cost prohibitive.

That left us two options: look into a new set of fixed-pitch propellers, or buying self-pitching propellers. After much discussion, we arranged with Brunton's to test a set of their Autoprops, so we could compare them to our boat's current set of fixed-pitch propellers.

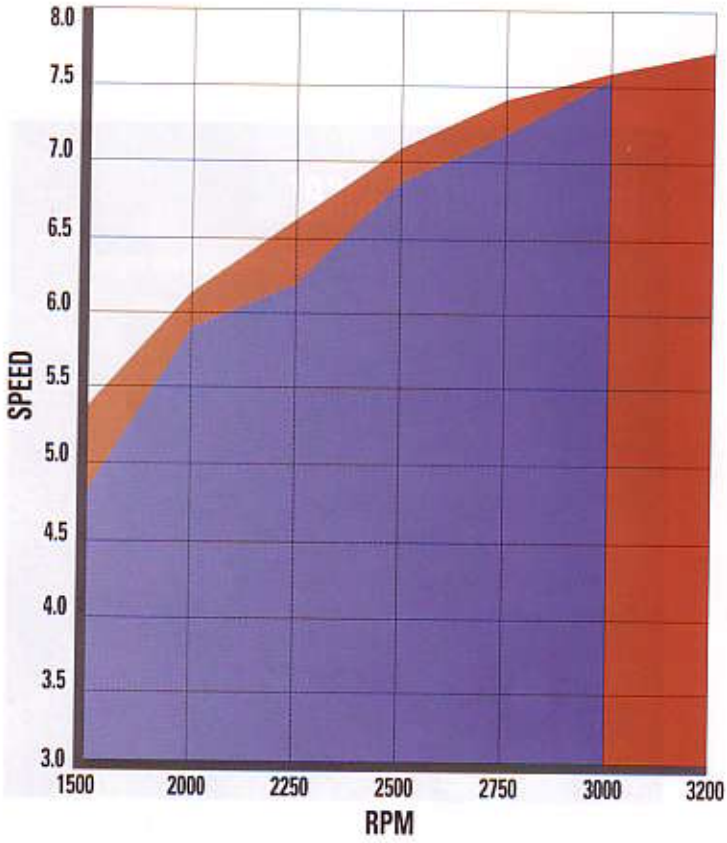
(Please note that at no time have I had any relationship with any propeller manufacturer, and am not in any marine-related business. This was to be a test conducted by me, solely to determine the most efficient propeller for use on our boat, within the budget constraints that I have to work with.)

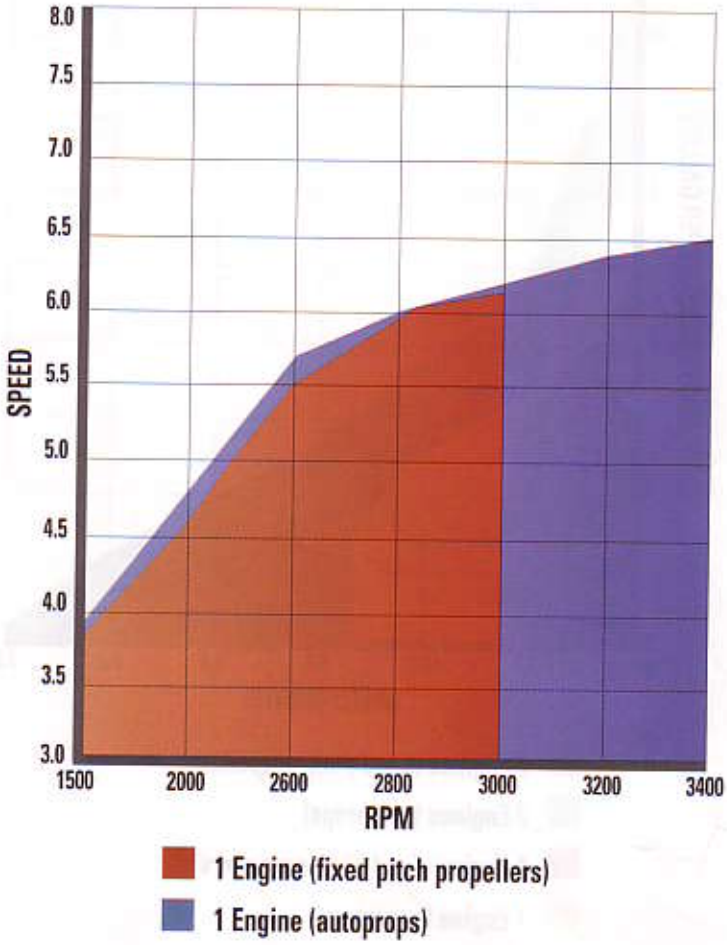
Our fixed-pitch propellers had a diameter of 21 inches, with a pitch of 12 inches. The Autoprops I tested had a diameter of 19 inches and the pitch is continuously variable.

These comparisons were conducted on *Hemisphere Dancer* after she weighed 41,000 pounds.

I read the engineering materials and test reports for the Autoprops prior to conducting our own comparison tests, so I really wasn't surprised to find that the Autoprops *were* superior to our previous set of fixed-pitch propellers.

The Autoprops propelled the boat through the water at a higher speed at the same engine rpm, and we burned less fuel at the same time. As you can see from Graph 1, the Autoprops increased range by about 20 percent at our

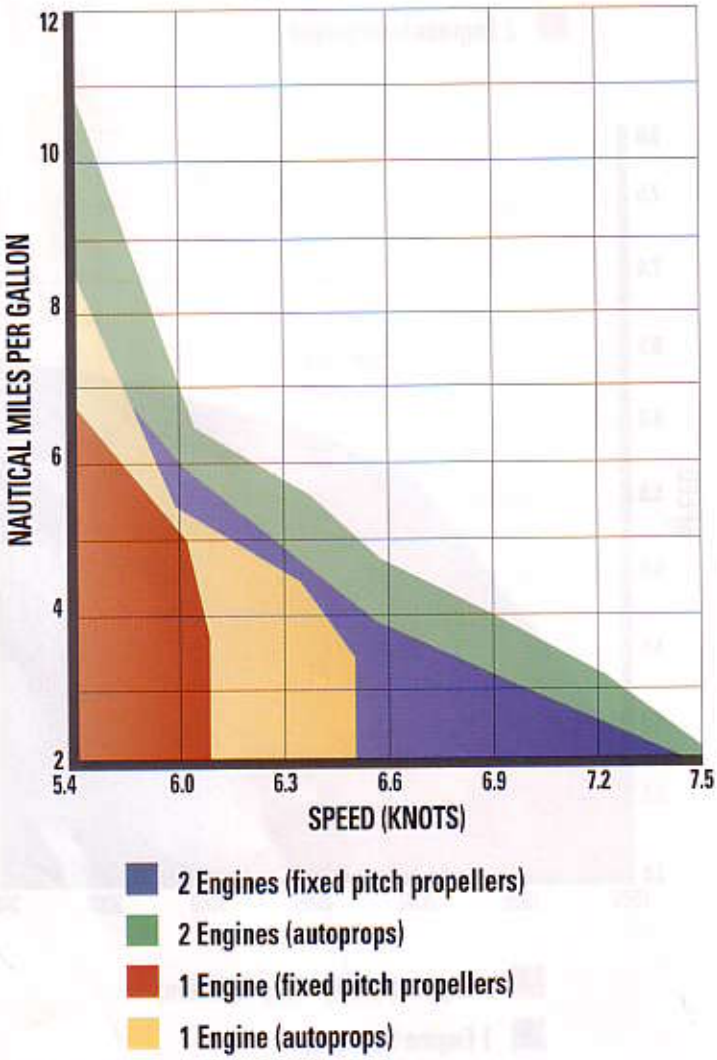




Hemisphere Dancer

Hemisphere Dancer is a full displacement, fiberglass, twin engine trawler. Its relevant statistics are as follows:

LOA:	36' 8"
Beam:	15' 10"
Draft (at full load):	2' 11"
Displacement (at full load):	43,000 lbs.
Disp./Length Ratio:	411
Power:	Twin Yanmar diesels, each rated at 34.9 hp
Reduction Ratio:	2.83



normal 6.6–7.2-knot cruising speed (S/L ratio of 1.1–1.2).

I was surprised to note that in all cases *Hemisphere Dancer* is more fuel efficient using two engines than when running on just one engine. Another wrong assumption.

But the tests *did* show we could run her on just one engine at speeds of up to 6.5 knots, if we had to, which was good to know from a safety standpoint.

Evaluating The Autoprops

Pros:

- Increase in cruising range.
- Same speed at lower rpm means that speed can be achieved with less noise and vibration.
- Reduced engine wear due to lower rpm and burning less fuel.
- A self-pitching propeller reduces propeller pitch in a heavy head sea, thereby maintaining proper engine loading upswell.
- More efficient running on one engine in a two-engine boat because non-driven Autoprop automatically feathers when not under load, dramatically reducing drag. (Autoprops are very popular on sailboats for this reason).

Cons:

- Cost: list price of $3,000 each for an Autoprop, as opposed to $850 for a Nickel/Bronze/Aluminum three-blade, fixed-pitch propeller.
- Maintenance: must lubricate bearings annually and replace bearings every 2,000 hours or so.
- Autoprops are not more efficient than fixed-pitch props above 15 knots, so they would offer limited advantage on a "fast trawler."

Putting It All Together

Most trawler owners will not have access to the significant measuring equipment necessary to conduct accurate speed and fuel consumption use tests like those we conducted on *Hemisphere Dancer*.

However, even without such test equipment, you can still construct a speed and fuel use chart for your own trawler. There are mathematical formulas available which allow you to calculate this information. (See sidebar.)

Some of the variables that impact the accuracy of any theoretical calculation include the efficiency of the engine and the efficiency of the propeller. Also keep in mind that speed and fuel use is different in flat water, without wind or current, when the boat has a clean bottom, or at times when you are not using a generator. These variables always need to be taken into account when estimating the range of one's vessel on an actual passage.

Lessons Learned

I've since readjusted my earlier assumptions, and offer these enlightened comments:

- Adding weight reduces range
- The higher your speed, the shorter your range will be
- A more efficient propeller will increase both speed *and* range. Automatic variable-pitch propellers and controllable pitch propellers are more efficient than fixed-pitch propellers.
- At least in the case of *Hemisphere Dancer*, the boat travels farther using both engines than when using just one engine at the same speed.

After all was said and done, and the testing completed, I decided that the advantages outweighed the disadvantages and we purchased a set of Autoprops. I'll keep the original props as spares.

Now we're one step closer to our South American adventure! ●

I want to thank Mike's Marine of St. Clair Shores, Mich. for loaning me all of the test measurement equipment—GD.

For more information

Voyaging Under Power, Volume III, published by International Marine. Written by Robert Beebe and revised by Jim Leishman in 1994, the book contains fundamental information on S/L ratios, how to develop fuel curves, and is a good, basic resource for anyone interested in cruising in powerboats.

The Propeller Handbook, published by International Marine, by Dave Gerr. All you need to know about the technical details of propellers.

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