Design Brief

Long Rangers

The author tries a different approach to designing efficient passagemakers, sportfishermen, and other deepwater motoryachts.

by Patrick Bray

There's a strong desire among the boating public to do something positive for our environment—while still enjoying, yes, the comforts of modern-day life. Every month we see proposals, in the consumer boating press, for Star Wars–styled craft that utilize emerging technology, able to do wondrous things. As exotic and impressive as they seem, the truth is most of those boats are decades away from consumer availability.

More than 15 years ago I initiated a research project with the goal of reducing the powering requirements of long-range motoryachts. Even then, the rising cost of fuel was a concern, but the goal wasn't just fuel savings; it was seakeeping and economy of construction as well. My intent was to design a hullform that would be efficient over a wide band of displacement and semi-displacement speeds. This long-range motoryacht needed to be capable of serious ocean passages at displacement speed, along with a comfortable motion, good stability characteristics, and good fuel economy. After cruising to the Mediterranean or other faraway waters, the vessel could power around at semi-displacement speeds to keep up with faster local yachts, while still maintaining the high degree of comfort with good fuel efficiency, and then return across the Atlantic in displacement mode.

Simply put, my aim was to refine small-ship design by reinventing the then-current technology in order to reduce resistance.

Engine Analogy

The development of the internal combustion engine provides a simple analogy. The first version, appearing in 1890, although workable, was not very efficient. The Daimler/Maybach 1.1-liter (67-cu-in) motor was capable of 4 hp (3 kW) at 900 rpm. Today that same size production motor—with modern efficient carburetors, turbochargers, header exhaust, fuel injection, and careful intake and exhaust porting—can develop over 100 bhp (75 kW) at 6,000 rpm, and is still lighter and more fuel efficient than the original model. The principles of combustion and the general design have not changed greatly from the initial concept, but fine-tuning the design has made a big difference. Much has been achieved by bolting on additional parts to improve motor function. Better carburetion, tuned air intake and exhaust systems, and the like have resulted in power gains traditionally seen only with racecars. In the same spirit, I evaluated the principles of good basic hull design and then looked at methods to increase efficiency with enhanced "bolt-on" appendages.

The growing interest in long-range motoryachts offered a commercial focus for this research. As so-called baby boomers retire with record wealth, good health, and a thirst for adventure, they look to travel the globe in a vessel under their own control. More environmentally aware, these adventurous owners have even purchased converted fishing trawlers in an effort to find the efficiencies and seaworthiness of a passagemaker. Those single-screw displacement commercial vessels venture into open ocean year after year off the coasts of North America and Europe, in some of the worst weather imaginable.

Hull Design

We started by looking at overall hull design. First, we compared relative efficiencies and seaworthiness of published hullforms, using standard resistance curves for a wide variety of displacement and semi-displacement hulls to: (a) establish their "sweet spots"; and (b) see how this applied to the targeted speed/length ratios. From this exercise I concentrated on a lobsterboat-type hull, as it was the most efficient over the desired range of speed (8–18 knots).

Then we looked at various features to further enhance performance:

- a finer bow for low resistance and low bow wave;
- high, wide spray knockers to add substantial volume when pitching into a seaway;
- low transom immersion to reduce drag at low speeds; and
- wide spray chines above the waterline to give trim control at higher speeds (**Figure 1**).

These enhancements brought out, I believe, the best of the lobster-hull breed. I then looked at additional ways to further improve performance. Appendages like the bulbous bow held promise, and that's when the engine analogy came to me. I've been able to incorporate numerous innovations into our vessels with conventional styling, and that makes these boats real sleepers, disguising their efficiency to the point that their abilities are often disbelieved.

Our hullform-and-appendage combination has no noticeable wave train at 6 knots. At 15 knots there is considerably less wave than most moderate-displacement trawlers (**Figure 2**). At 20

Figure 1.

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Figure 2.

CAPE SCOTT MARINE

Figure 3.

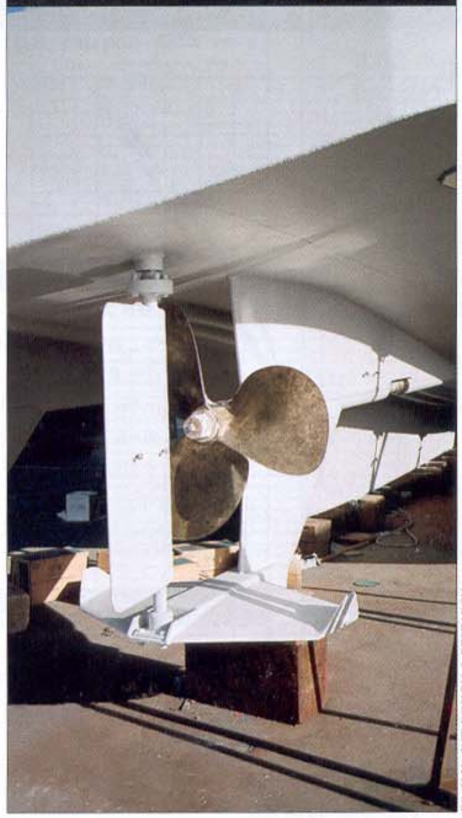

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Fig. 1*—A Fox 86 (26.2m) demonstrates key design elements of a motoryacht that is efficient in displacement and semi-displacement modes: bulb coupled to a fine bow; buoyant, spray-deflecting topsides forward; low transom immersion; and a wide chine flat above the waterline.*
Fig. 2*—The Cape Scott 86 at 15 knots produces less wave train than typical trawlers.*
Fig. 3*—So-called bifoil skeg was inspired by commercial fishing boats.*

knots, the form is equal to chined, fully planing hulls for resistance and wave profile.

More details on appendages follow.

Bulbous Bow

Our bulb design work was inspired by the application of bulbous bows on commercial fishing boats in the early 1980s. From this published work we refined the concept in a bulb effective from 8 knots to 20 knots, and produced a drop in resistance of over 12% at its maximum efficiency. In retrofitting bulbs to more than three dozen existing vessels during the past eight years, we found that the attachment of a bulb would produce an immediate ¾-knot increase in speed, or a minimum 10% fuel savings.

Here's a quote from a report on the Fox Project (see the **sidebar** on page 26) model-test program conducted at the Ocean Engineering Centre at the University of British Columbia: "From the resistance and EHP *[effective horsepower]* plots it is evident that the bulb reduces the required power throughout the range of speeds from 9 to 19 knots, with crossover at 20 knots. The reduction is accomplished through wave cancellation and by reduction of the running trim due to the hydrodynamic forces acting on the bulb."

In addition to the fuel savings, there is close to 50% reduction in pitching motion—quite an advance in itself.

Bifoil Skeg

The bifoil skeg was also inspired by work developed for commercial fishing fleets (**Figure 3**). It utilizes

Figure 4.

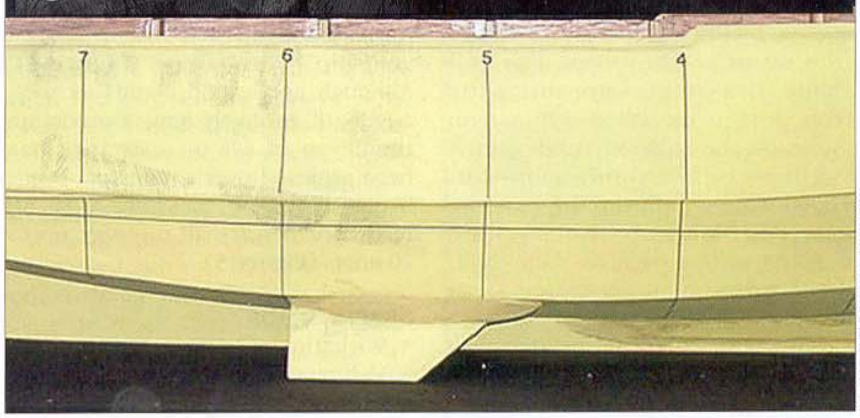

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Fig. 4*—According to the author, his 'midship hydro-fairing appendage reduces the 'midship hollow created by a displacement vessel at speed, thereby reducing resistance as well—by as much as 6%.*

Figure 5. Effective Horsepower vs. Speed—Fox 86

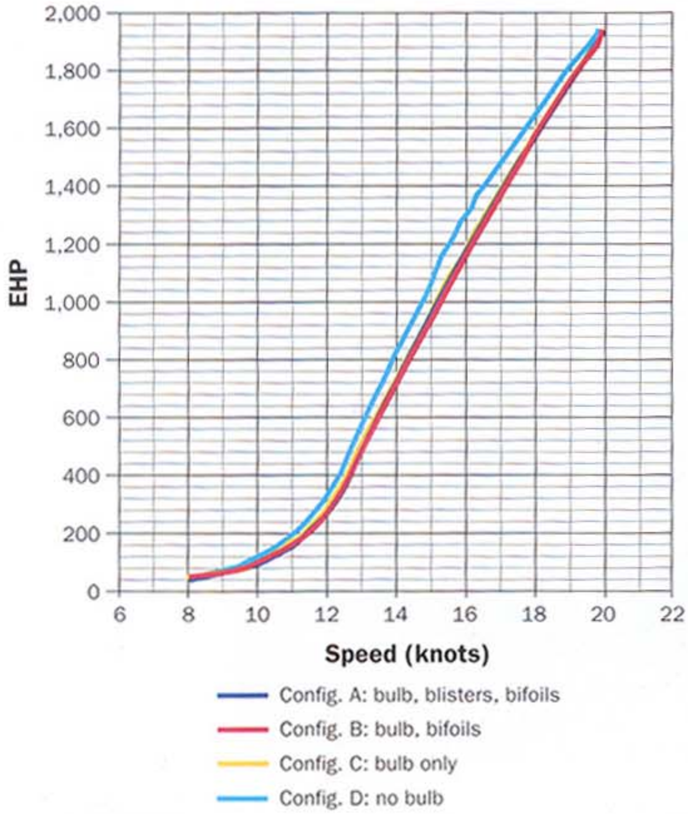

Figure 6a.

Figure 6b.

Figure 6c.

Figure 6d.

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*Tank tests at the Ocean Engineering Centre, University of British Columbia. **Fig. 6a**—A typical trawler hull at 10 knots. **6b**—The Fox 86 at 10 knots. **6c**—Typical trawler at 13 knots. **6d**—Fox 86 at 13 knots.*

'80s "green" technology, which applied drag reduction to the pipe-frame net guard (typically referred to as a beaver tail) fitted under the propeller on seiners. By optimizing the planform and utilizing a hydrodynamic foil section, it reduces drag and increases propeller thrust. This is done by driving clean, turbulence-free water to the prop. The foil shape also acts as an automatic trim device: as stern-down trim increases, the angle of attack on the foil increases, creating more lift. That lift then reduces the running trim and dampens the pitching motions at the stern as well. And, the prop is more protected from logs and lines.

This work is still under development and shows considerable promise. Already an increase in thrust has been achieved along with a 0.5° reduction in stern trim, both of which help reduce resistance.

'Midship Hydro-Fairings

One of the most recent advances comes from 'midship appendage fairings. Having reduced the bow wave with a fine entrance angle, plus a bow bulb, we needed to reduce drag by reducing the overall wave train, and increase stability under way by reducing the 'midship hollow—with a 'midship hydro-fairing (**Figure 4**). Although application of this technology is still relatively new, a maximum reduction of 6% in resistance has been achieved over a range of speeds from 8 knots to 16 knots, with no resistance penalty all the way up to 20 knots (**Figure 5**).

Stern Bulbs

With the reduction in bow and 'midship waves, it is only natural to next look aft for a similar reduction in the stern wave. Preliminary published work on stern bulbs shows a 7% reduction in resistance. Production of a successful stern-bulb appendage could yield results similar to those of the bow or 'midship appendages, yielding significant overall gains in propulsion economy.

Comparison to a Typical Trawler

In comparison to existing vessels *without* the technology described above (hullform, bow bulb, stern bifoil), our tested designs proved 30% more efficient and also operate over a wider range of speeds (**Figures 6a–d**). The result has been ocean-proven in full-size vessels on long offshore passages.

Also, lower fuel consumption means less fuel to carry. Less fuel means less weight. Less weight means a smaller engine and less structural weight to accommodate it. Which means less overall weight and less power to move it, lower fuel consumption, etc. The usual vicious circle of increasing

Figure 7a. Performance Figures of a Typical Trawler vs. the Fox 86

Speed (knots)	SHP		GPH (U.S. gal)		Range (nautical miles)		Gal/mile (U.S. gal/nm)		% Difference
	Typical	Fox 86	Typical	Fox 86	Typical	Fox 86	Typical	Fox 86	
8	100	108	4.0	4.2	13,905	13,568	0.50	0.52	–92.6
10	316	238	13.3	9.6	5,279	7,696	1.33	0.91	132.8
12	808	615	33.9	24.7	2,476	3,546	2.83	1.97	131.4
14	2,266	1,725	95.2	69.2	956	1,476	7.4	4.74	131.3

Figure 7b

	Typical	Fox 86
LOA	85.35′ (26.0m)	85.75′ (26.14m)
LWL	77.5′ (23.62m)	77.5′ (23.62m)
Beam O.A.	23.38′ (6.52m)	24.5′ (7.47m)
Beam WL	21.2′ (6.46m)	21.17′ (6.45m)
Draft hull	6.83′ (2.1m)	4.92′ (1.5m)
Draft	7.28′ (2.22m)	6.5′ (1.98m)
Displacement	150 tons (136.11 tonnes)	125 tons (113.66 tonnes)

Figure 8. Seakeeping Comparisons

Sea state	Speed (knots)	Bow accelerations (g-rms)	CG accelerations (g-rms)	Stern accelerations (g-rms)
Config. A: bulb and bifoil				
SS 3	10	0.254	0.109	0.138
SS 3	12	0.256	0.122	0.154
SS 5	8	0.298	0.127	0.164
SS 5	10	0.352	0.160	0.200
Config. D: no bulb, no bifoil				
SS 3	8	0.247	0.091	0.124
SS 3	10	0.275	0.109	0.145
SS 3	12	0.273	0.115	0.159
SS 5	6	0.281	0.106	0.148
SS 5	8	0.349	0.138	0.185
SS 5	10	0.374	0.159	0.210

penalties (more fuel for greater range requiring more displacement and more power that consumes the extra fuel) has become instead a spiral of benefits (**Figures 7a, b**). Once we complete development of the stern bulb, we anticipate savings of up to 50% overall.

Seakeeping

The added appendages (bow bulb, 'midship hydro-fairing, bifoil) and efficient hullform also render superior seakeeping characteristics (**Figure 8**). Not only can the vessel operate economically at a higher speed, the reduction in pitching means there is no loss of comfort at that speed. The reduced bow wave height means that when the bow enters a wave, less water is pushed aside, so there is less water to come on deck. Clients have confirmed that these appendages produce a very dry boat overall.

With all the boats that we've now retrofitted with a bulb, it is the reduction in pitching that owners notice the most. Over time they notice fuel savings, but their initial reaction is to the improvement in seakeeping.

You can see from Figure 8 that with the addition of appendages the subject vessel has virtually the same degree of comfort at 10 knots in Sea

Three Examples

Here's a sampling of Bray-designed boats that illustrate the concepts discussed in the main text.

Amnesia IV

One of our first large fiberglass motoryachts to take advantage of some of the technology described in this article was the Cape Scott–built *Amnesia IV*—86′/26.2m x 23′/7m x 6′/1.8m, powered with a single 1,300-hp (975-kW) MAN diesel. Top speed is 15 knots. At 210,000 lbs (95,130 kg) displacement (half load), the vessel is characterized as medium weight. It has a 7,000-nm range at 9 knots on 6,000 U.S. gal (22,710 l) of fuel. As reported by her captain, on a trip from Vancouver, British Columbia, to San Diego, California, *Amnesia IV* averaged 9 knots in big seas and high winds, burning less than a gallon per nautical mile, or 3.8 l/nm (including generator run time)—in comfort.

Kookaburra

The chined, all steel, 76′ (23m) trawler yacht has a 22′ (6.7m) beam and 6.5′ (2m) draft. Fitted with twin 330-hp (248-kW) diesels, the boat's top speed is 12 knots. At 225,000 lbs (101,925 kg) displacement (half load) it is moderately heavy. *Kookaburra* has a 3,500-nm range at 9 knots on 3,300 gal (12,491 l) of fuel. The owner reported that on her first trip from Vancouver to Mexico she averaged 9 knots in reasonable weather. Although the initial intention was not to cruise that fast, the crew started out at that pace, found it comfortable, and never throttled back. They burned about 1 gallon of fuel per nautical mile, including running the generator three hours per day.

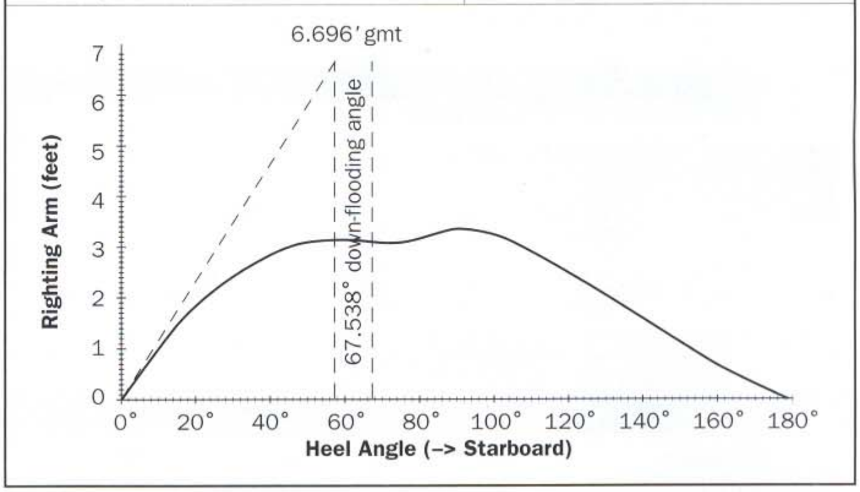
The Fox Project

Launched in the summer of 2006, the Fox 86 (26.2m) was extensively tank-tested at the Ocean Engineering Centre at the University of British Columbia, and won a design award at the Barcelona Boat Show. Much of the data cited here is taken from that test report. *No Boundaries* is an 86′ long-range sportfisherman with a 24.5′ (7.5m) beam and 6.5′ (2m) draft. Built with a chined steel hull and fiberglass superstructure, the boat displaces 250,000 lbs (113,250 kg) at half load. Twin 550-hp (413-kW) diesels will push her up to 15 knots with a range of 5,000 nm on 4,750 gal (27,979 l) of fuel.

—Patrick Bray

Figure 9a. Fox Sports 86 Intact Static Stability on Waves (half-load condition)

Displacement	106.067 lton	Wave height	9.684′
LCG (+ fwd mid)	–1.343'	Wave ctr (+ aft)	0.000'
TCG (+ stbd cl)	0.000'	Wave length/lbp	1.000
VCG (+ abv bl)	8.433'	Water sp gr	1.025



State 3 (seas 3.5′–4′/1.1m–1.2m) as it does at 8 knots in the same sea without the appendages. An increase in speed to 12 knots causes very little increase in pitching motion. This 2-knot speed advantage continues at Sea State 5 (seas 8′–12′/2.4m–3.7m) as well. So, the appendages allow a 2-knot increase in speed with no real increase in vessel motions.

Stability

In addition to the features above, the improved hullform has better-than-average stability characteristics. Not only is there a comfortable roll period in a seaway, but a strong range of positive stability makes the vessel very safe for ocean cruising. The hullform exceeds the minimum requirements of international authorities, and achieves a good, healthy range of stability in steep seas (**Figures 9a, b**)—without resorting to more than minor amounts of trim ballast.

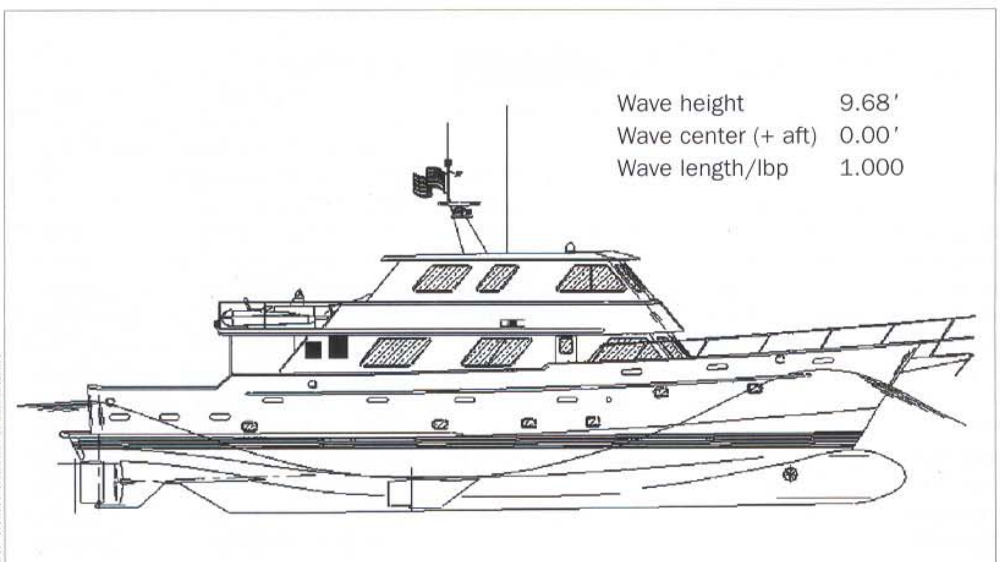


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***Fig. 9b**—Wave profiles for the Fox 86.*

As mentioned earlier, we've retrofitted bulbous bows to more than three dozen vessels from 40′ to 95′ (12.2m to 29m), and fitted them to our own hullform on completed vessels up to 86′, with model tests on hulls to 160′ (49m). The full-scale boats have never reported any slamming, and the bulb seldom comes clear of the water. The design parameters and real-time results (50% reduction in pitching and up to 12% reduction in resistance) have been well established by feedback from numerous clients and their captains and crew.

The bifoil skeg has increased thrust, reduced pitching motions, and improved trim control. This appendage is a relative newcomer, so we're still compiling data from in-service reports. At its present state of development, when combined with the bulbous bow, we show an advantage of 30% over most similar vessels.

The 'midship hydro-fairings, which give an initial 6% drop in resistance, need further study to develop their full potential and determine the exact proportions necessary for maximum benefits. Our goal is to achieve a 10% drop in resistance and a significant reduction in the 'midship wave hollow. In combination with the wave reduction of a bulbous bow, the hydo-fairings bring a reduction in the stern wave through an overall shallower wave train, and also contribute to increased stability under way, since there is less 'midship trough for the vessel to heel into.

The stern bulb shows potential; reductions in resistance as much as 10%–12% may be achieved soon. There should also be further reductions in pitching motions.

By combining these separate appendages, we expect a 15%–20% reduction beyond the 30% already seen. Computational fluid dynamics and model testing will be required to optimize the many possible combinations, especially with so many different parts, locations, and sizes to be considered. All these appendages create additional buoyancy, so we'll update the hullform to maximize the benefits. Added displacement of the appendages allows finer beam-to-length and draft-to-length ratios, which will contribute to lower resistance numbers through reduced hull volume.

Our ideal is a vessel that will slip through the water without any disturbance to mark its passing—the ultimate interface vehicle. PBB

About the Author: *Patrick Bray's design work over the past 32 years has included cruising sailboats, power catamarans, 14-knot motorsailers, 8,000-mile-range passagemakers, and luxury superyachts. Based in White Rock, British Columbia, he remains actively involved in research and development, particularly on appendages, bulbous bows, and specialized hullforms.*