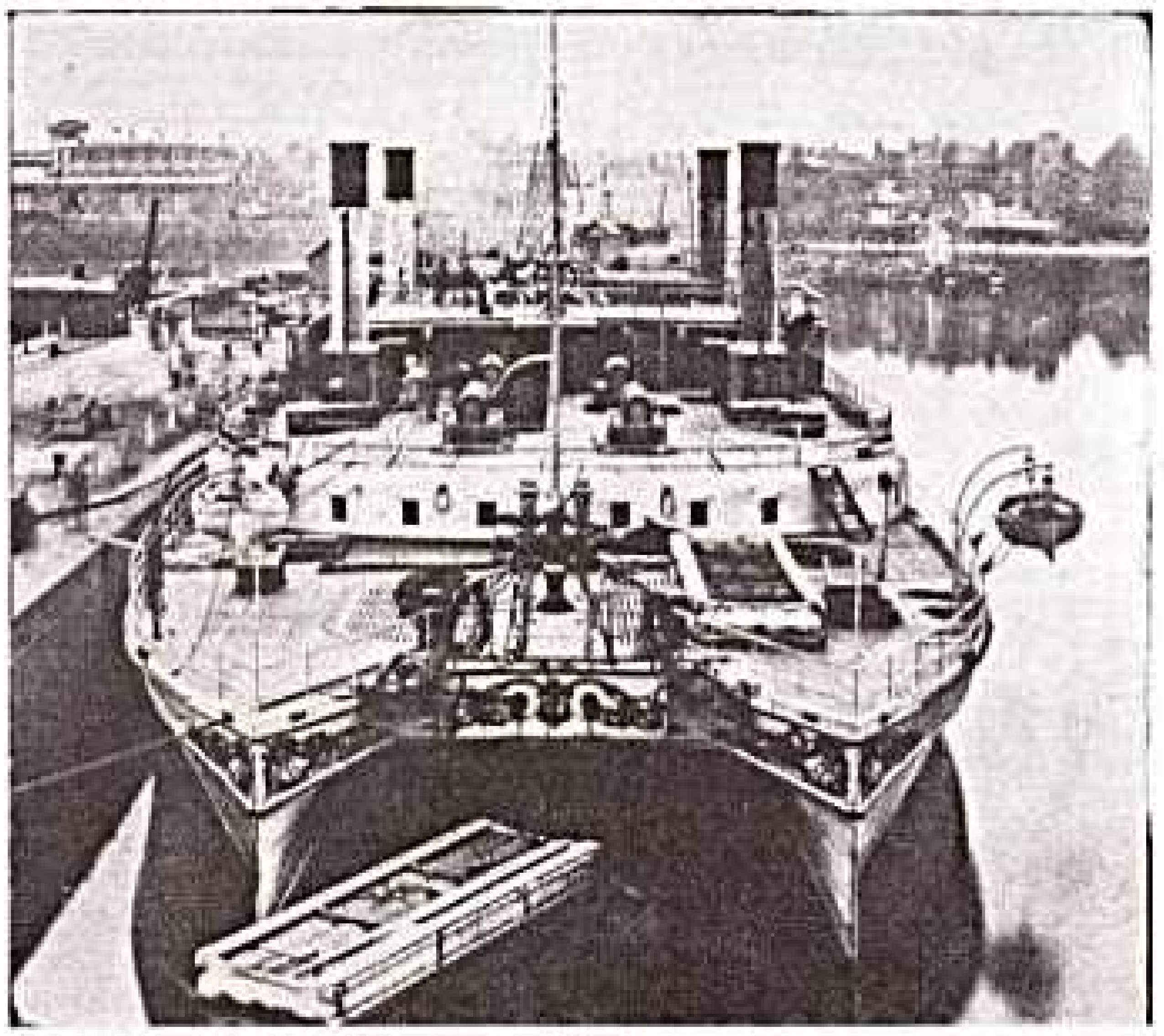
Catamarans

After nearly a hundred years of pioneering experiments these twin-hulled boats have now established themselves in modern guise among sailing enthusiasts. Much research and development are being devoted to exploiting their advantages to the full and overcoming difficulties

by K. C. Barnaby



A catamaran-type Channel paddle-steamer, the Castalia, *appeared in 1874. (Photograph by courtesy British Railways Southern Region.)*

SMALL double-hulled sailing yachts—once derided as a "savage invention only suitable for the South Seas"—are now appearing in rapidly increasing numbers all over the sheltered waters of Europe and the United States. The main reason for their surprisingly sudden rise into favour is a rediscovery that, in favourable circumstances, a well-designed catamaran is one of the fastest sailing craft afloat. It may therefore be of interest to examine something of the history as well as the pros and cons of an erstwhile "savage invention" that is now the subject of research by leading experts in both sailing and in hydrodynamics. Nor are experiment and research unnecessary, for a badly designed catamaran can be slow, reluctant to "go about" and even dangerous in heavy weather.

Although double-hulled vessels are universally called catamarans the term is really a misnomer, since it means "logs tied together". These logs were assembled in groups of usually three to five, or the centre logs could be omitted and replaced by cross pieces. Log catamarans of this type are really very narrow rafts and can still be found in many parts of the world. Thus the Brazilian *jangada*, the Singhalese catamaran and the Formosan *tek-pai* are all true catamarans. The timbers normally used for these craft are respectively balsa, mahogany and bamboo. Balsa wood is the lightest known timber and comes from a very remarkable tree which has a normal rate of growth of 10 feet a year; instances of over double this rate have been recorded. The density varies from 2½ lb to 24 lb per cu. ft; for comparison, cork weighs 15 lb per cu. ft. The great variation in the weight of balsa is due to the increase of density with age. Thus the outer sapwood is denser and stronger than the inner heartwood, since it comes from a more mature tree.

The famous *Kon-Tiki* raft was built of balsa logs, and its gradual absorption of water was a source of great anxiety to Thor Heyerdahl and his crew of four Norwegians and one Swede on their trip from Peru to Polynesia. The Brazilian *jangada* is beached at frequent intervals to allow the wood to dry out and recover its original buoyancy—a precaution that was obviously impossible on an ocean voyage lasting some 3½ months.

The modern catamaran, as the term is now universally understood, consists of two similar or "handed" hulls joined together by a shallow platform or trunk of considerable width and forming a rigid connection between the two hulls. In catamarans intended for cruising rather than "round the buoy" racing, a cabin structure replaces the shallow well or platform of the normal type. Modern catamarans are thus very different from those of the raft type previously considered, as in place of solid logs, they are hollow boat-shaped structures, built as lightly as possible so as to provide the maximum buoyancy on the minimum weight. In shape these twin hulls may vary from mere pontoons to forms that are most carefully designed in accordance with hydrodynamic principles and, what is perhaps even more important, to comply with actual sailing experience with catamaran types.

The Polynesian double canoe was undoubtedly the ancestor of the modern catamaran. Early travellers to the South Seas were deeply impressed by the great speed of these craft when compared with that of their slow-going ships. Sir William Petty, the statistician, was such a man, and he became a firm believer in the catamaran principle. During his lifetime (1623-1687) he built several double-hulled vessels, but achieved ridicule rather than success. The largest of these craft was intended for service from Liverpool to Ireland; she broke up on her second passage.

Catamaran-type cross-Channel steamers.—The building of two double-hulled paddle-steamers for the Dover-Calais crossing formed the next notable attempts to popularize the catamaran principle. Unfortunately the principle was being applied quite wrongly, but the failure is worth recording as showing what should *not* be done in catamaran design. The first vessel was the *Castalia* which appeared in 1874 and was followed by the *Calais-Douvres* three years later. Both ships had two paddle-wheels placed in the gap between the two hulls. It was trustingly expected that water would flow between the hulls and supply the paddle wheels in a normal way. Unfortunately the water in the gap ahead of the first wheel proved to be stationary in relation to the moving vessel and was merely being carried along as additional deadweight. This was clearly shown when the vessel was moored and the paddle-wheels run up to full revolutions, for there was found to be no current at all in the fore part of the central passage! All the water supply to the wheels had to be drawn diagonally under the twin hulls, thus adding to the resistance. The expected speed was 14 knots on about 1,250 i.h.p. The actual speed was only 11 knots despite about 1,500 i.h.p. This was too slow to be acceptable for the service, and the ship was also stigmatized as being a "dirty" sea boat (in nautical terminology this means that she was too prone to taking water aboard her decks). The *Castalia* was condemned as a failure and sold to the Metropolitan Asylums Board, who converted her into an isolation hospital for infectious diseases and moored her in Long Reach of the river Thames.

The *Calais-Douvres* was more successful; she ran for some nine years before being scrapped. By virtue of increased length and nearly three times the power of the *Castalia*, she attained a trial speed of 14 knots. Her sea speed of 13 knots soon proved too slow in comparison with the orthodox 18½ knot paddle-steamers with which she had to compete. Withdrawn from service, she ended her days as a coal hulk, also in the Thames. The idea behind the design of both the *Castalia* and the *Calais-Douvres* was the prevention of rolling and, as the promoters hopefully termed it, "reducing the horrors of the middle passage to a minimum". This was of course a forlorn hope. All that happened was a shorter but much quicker and jerkier roll. When the other channel packets were rolling through perhaps 15 degrees in about ten seconds, the *Calais-Douvres* was moving through only, say, 5 degrees—but in much quicker time, and this jerky and rapid roll proved equally productive of seasickness. One observer even claimed that he had seen about 400 of her 460 passengers seasick during bad weather, though this was probably a gross exaggeration.

The main lesson to be drawn from these powered catamarans is the necessity for adequate separation of the twin hulls if an excessive resistance is to be avoided. It would appear that a gap of about twice the beam of each hull is needed. Fortunately, about this amount of separation is usually required in order to provide a sufficient amount of stability for sail carrying, a point that will be discussed in due course. It also follows that the twin hull principle is useful only for moderate lengths, since the weight of the connecting structure soon becomes uneconomic if it is to stand up to the heavy stresses imposed by waves. It seems probable that an upper limit of about 70 ft in length is not likely to be exceeded, special circumstances apart.

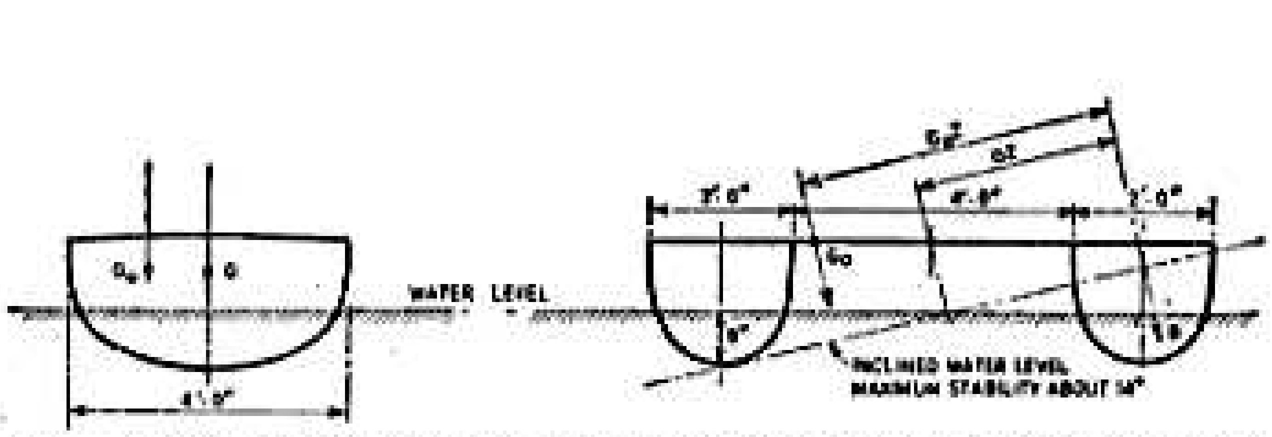


FIGURE 1 *(left). Single hull. Crew on gunwale. Weight of hull 400 lb. Weight of crew (2) 300 lb.* FIGURE 2 *(right). Double hull. Weight of hull and crew as for single hull.*

The Herreshoff catamarans.—Nathaniel Herreshoff, once termed the "wizard of Bristol", is best known for having designed and built the yachts that successfully defended the *America*'s Cup six times in succession. It is less well known that between 1877 and 1881, he designed and built a number of sailing catamarans. These craft were among the fastest sailers of the day in fresh to moderate winds. Having accepted a challenge from the New York Yacht Club, Herreshoff was only too successful, for he beat all comers so soundly that catamarans were termed freaks and barred from all future races. Since most sailing enthusiasts wish to race, this veto stopped almost all catamaran building until quite recently.

Most of the Herreshoff catamarans were over 30 ft in length with elliptical underbodies. The absence of centreboards must have made them slow performers to windward. Unlike modern catamarans, the connecting structures terminated in ball and socket joints, thus allowing some vertical play between the hulls. This was a dangerous feature as the depressed lee hull tended to bury itself in a head sea. This meant that the craft would not luff into the wind, but tended to fall away with a grave risk of a longitudinal capsize and structural damage if occurring at high speed. A specially large headsail was very advisable, so that in emergency this could be let fly and thus rapidly increase the "ardency", as a tendency to turn into the wind is termed.

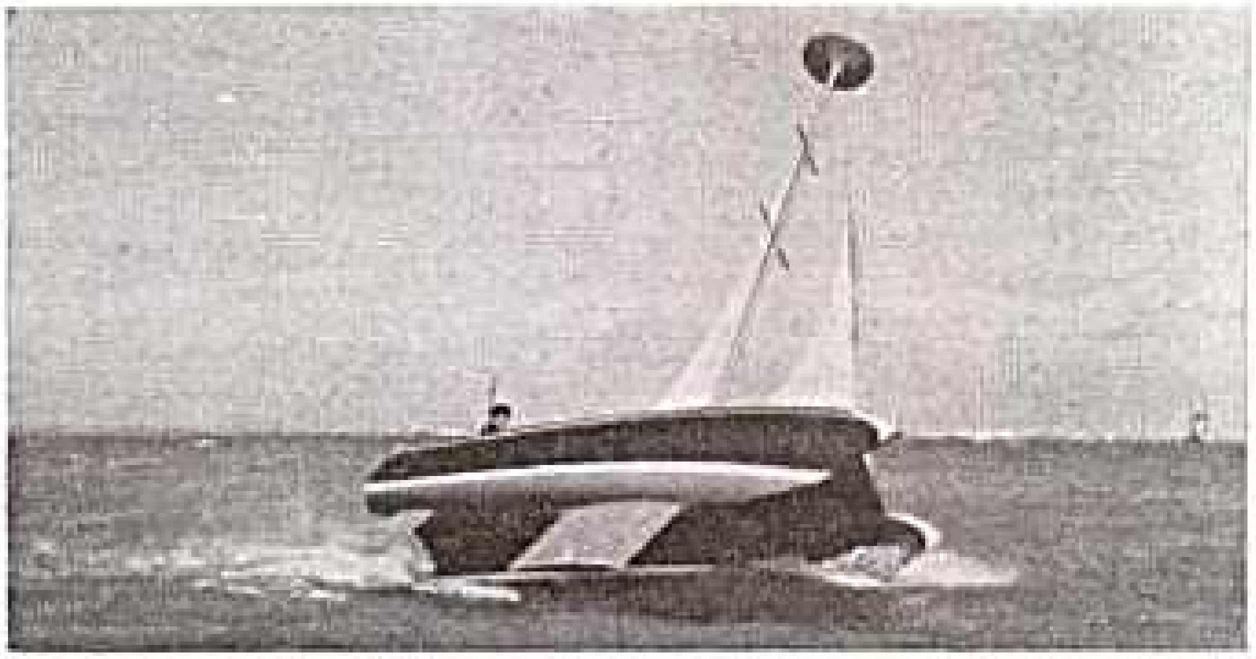
Long after Nathaniel Herreshoff had ceased to experiment with catamarans, some rather spasmodic attempts to evolve improved models were made by two of his sons, L. Francis and Sydney De Witt Herreshoff, who were both noted yacht designers in their own right. These attempts were not too successful and aroused little interest. One reason was probably a belief in their father's dictum that successful catamarans must have a length of at least 30 ft. This may have been true in 1880, when water-restistant plywoods and glues were not available and long hulls were needed to reduce the weight/length ratio. It is certainly not true today, when some of the most successful types are only about 16 ft in length.

It may well be asked, why go to the trouble of building two separate hulls and incur these design difficulties? Could not a much beamier single hull serve the same purpose? The short answer is that in order to get a similar righting moment, the beam would have to be so great as to involve excessive weight and resistance to motion. This point is illustrated in the Figures 1 and 2. In order to balance the upsetting moment of the wind pressure on the sail area, there must obviously be an equivalent righting moment. This is supplied by the weight of the boat and crew acting through a lever termed the "GZ", which can be defined as the separation between verticals through the combined centre of gravity of craft and crew and through the centre of buoyancy of the displaced water. In the case of a single hull (Figure 1) the latter centre can not move very far from its original position. About one-eighth of the beam would be a probable limit. With a double hull (Figure 2) the maximum movement occurs when the windward float is just touching the water and the whole buoyancy supporting the craft is concentrated in the leeward float. The movement of the centre of buoyancy is now approximately half the separation of the centres of the floats.

For the case shown in the diagrams, the maximum righting moment for a dinghy of 4 ft beam and the crew positioned amidships is only about 300 ft-lb. With the crew of two sitting out on the gunwale, the combined centre of gravity moves from G to G_1 and the righting moment is increased to about 450 ft-lb. Similar figures for the double hull of Figure 2 are about 1,680 and 2,940 ft-lb respectively, thus showing an enormous improvement over a single hull.

The new catamarans.—The revival of interest in catamarans and the successful "breakthrough" in design and construction

Catamarans *continued*



GOLDEN MILLER. *Note the circular cork float at the masthead. (Photograph by Beken and Sons.)*

has occurred only in the last few years. It is largely due to three apparently unrelated events, coupled with new lightweight boat-building methods and materials.

In Hawaii, Woodbridge Brown, a former glider pilot, had built the catamaran *Manu Kai* on traditional Polynesian lines but with a very light aeroplane-type construction. Although some 40 ft overall and 31 ft 6 in. on the waterline, this craft weighed only about 3,000 lb and carried 500 sq. ft of sail. Her best speed is reported to have been 28 knots in winds of 30 to 35 knots.

In England, on the river Thames, the graveyard of the ill-fated *Castalia* and *Calais-Douvres*, the boatbuilding brothers Francis and Roland Prout turned their talents to catamarans, based on their very considerable experience in producing and sailing racing canoes. Their first models were in fact twin canoes joined together with planks and later with bamboo poles. These prototypes were too slow in tacking, though very fast on a reach. The Prouts then decided to abandon canoes for floats and to design more suitable hulls. These were given more beam and the keels were "rockered"—that is, they were given a shape curving upwards to bows and sterns, in order to make the craft come about more readily. The bows were also given a slight flare to reduce the risk of their diving under when hard pressed. These changes worked out very well, and *Shearwater III* produced in 1956 proved such a success that 250 replicas were sold during the first twelve months.

In Scotland, Hugh Barkla had been studying the hydrodynamic and aerodynamic requirements for high-speed sailing. In 1951 he read a paper on this subject before the Royal Institution of Naval Architects which aroused wide interest. The two factors which limit sailing speeds with conventional craft are the necessity for a heavy ballast keel to get sufficient stability, and the induced drag of this keel. The small planing dinghy, it is true, dispenses with a ballast keel, but in lieu requires a wide beam and movable ballast in the shape of an athletic crew who endeavour to get as far outside the boat as possible. Barkla showed that to reach planing speeds in winds of about 15 to 20 knots, a vessel must carry a sail area of the order of 400 sq. ft per ton of displacement. Given this, he considered that speeds of 40 knots or more were possible, provided the stability was enough to meet a thrust on the sails about equal to the vessel's own weight.

Neither of these conditions is possible with a single hull, and it is necessary to adopt the catamaran principle of light hulls winged out a sufficient distance to give the required stability without fixed ballast. The solution favoured by Barkla was a three hull "triscaph", or "trimaran", as it is often termed. This type has a single main hull with short floats on either side, and is thus a modern version of the Polynesian double outrigger canoe.

Barkla's scientific approach has been followed up by a considerable amount of research and testing by members of the Amateur Yacht Research Society and by various designers. This is essential since the modern catamaran is very much in its infancy, despite its historic ancestry. Many points, such as the best shape for the float underbodies and the most effective methods for augmenting the lateral resistance, are still the subject of controversy. The lateral resistance of the floats is always poor, owing to their shallow immersion, and centreboards or dagger-plates are usually essential for going to windward. Without these appendages or specially-shaped floats, the catamaran would merely drift away to leeward.

The very different shapes adopted for the underbodies are largely due to the unfortunate fact that it is quite impossible to devise the ideal form for all speeds. At low speeds a fine bow and fine stern are preferable. As speeds increase, the stern waterlines require broadening out and the buttocks to be kept as flat as possible to avoid "squat". At still higher speeds it is advantageous to have enough flat or nearly flat surface to provide a measure of dynamic lift and initiate planing. It is commonly claimed that the advantage of planing lies in the reduction of wave-making. This is a very natural belief, but unfortunately the dynamic lift which replaces static buoyancy brings in its train a large induced drag. The real saving then comes from the reduced surface friction on the smaller area in contact with the water.

These differing requirements are precisely the same for single hulls, and consequently no one form can be equally suitable for all weather conditions. In very light airs, a fine-lined "X" boat may take the lead. As winds strengthen, she will be overtaken by a racing dinghy which in turn will be passed by the potentially much faster catamaran.

The capsizing risk.—A deep-keeled sailing yacht reaches her maximum righting moment only at a considerable angle of heel and may still retain a small moment at 90 degrees. At this point the mast and sails will be flat on the water with no further upsetting wind moment. With small yachts and dinghies, it is usually possible to right the craft without undue difficulty. It is very different with a catamaran. Although there will be much greater relative stability, the maximum righting moment is reached at a small angle of heel and then rapidly decreases. At 90 degrees there is not only no righting moment, but the upturned float and connecting platform still present a considerable surface to the wind. This may result in a complete capsize to 180 degrees, and from this position it will be impossible to right the craft without aid from a large vessel. The circular cork float seen at the mast head of *Golden Miller* (see photograph) is intended to avoid this dire calamity by providing a buoyancy moment at 90 degrees.

It is reasonable to design a racing catamaran so that full sail can be carried in winds of up to 20 knots without the windward float leaving the water. Rather less sail area or greater stability is desirable on cruising catamarans and on those used by children. Such craft are then extremely safe.

Powered catamarans.—Although the catamaran type has been seen to be very suitable for high speed sailing, it has no advantage for craft propelled by engine power alone. The twin hulls add to the wetted surface and the resistance. The motion in a seaway is jerky and unpleasant, while the connecting structure is a source of weakness in heavy weather. Small outboards are, however, very useful auxiliary units on cruising catamarans.