Rowboat design

The science of rowboat design is easily understood. Once mastered it can be used to improve choice of craft and rowing technique.

John Gardner in his excellent book "Building Classic Small Craft" does not include science because traditional craft were developed before general scientific literacy. On this issue a famous Norwegian yacht designer, Colin Archer, observed: "Most features of good hull design have been discovered from experience by generations of boat builders, and science must be content to explain their results."

A major interest for a rowing boat lays in its slipperiness though the water. There are two main factors affecting its slipperiness in the water, **wave-making** and **wetted surface**. The speed of the boat is related to its waterline length, which is in turn related to the wavelength of a water wave. The greater the wavelength of water wave the faster it travels.

Rowboat at (maximum) displacement speed. A displacement hull sits in the water rather than planing on top of it. It displaces water equal to its own weight.

Notice, in the picture of the rowboat above, the crest of a wave at the bow and stern and a trough in the middle. Any attempt to go faster will compel the boat to try to climb the bow wave as it leaves the crest at the stern behind. This can be done with a powerful motor but for a rower will require unsustainable effort. It is also why champion swimmers should be tall and why they can only make marginal improvements to speed records. This leads to rule number one.

1. **The speed of a displacement hull is limited by its waterline length**. The boat cannot be rowed faster than a speed given by the formula: Speed in Knots[1]= 1.4 times the square root of the waterline length in feet. For example the maximum speed, of the boat shown above, with a 16 foot waterline length is given by: speed = 1.4x $\sqrt{16}$ = 1.4x4 = 5.6 knots.

Motorboats are also limited to displacement speed unless very powerful. Notice the crests at bow and stern and trough in the middle. The trough causes the boat to sink a somewhat in the water.

2. **The frictional resistance is proportional to the area in contact with the water and the square of the speed of the boat.** Hence a boat travelling at 4 knots will have four times the resistance of a boat travelling at 2 knots. Since the relative speed is 2 then the relative resistance is $2^2 = 4$. This frictional resistance also increases with the area of boat in contact with the water (wetted surface area).

3. **The power required to row a boat is proportional to the cube of the speed.** At double the speed the boat is covering twice the distance against 4 times the resistance. So four times the force is applied over twice the distance in the same time. Thus relative power to double the speed = $2^2 x2 = 2^3 = 8$. **That is: 8 times the power is needed to row at twice the speed.** This is extraordinary and seems counter intuitive but emphasises the need to reduce wetted surface area. The cube rule implies that the speed of a rowing boat should be kept as constant as possible and explains why racing sculls employ quick recovery strokes.

The racing skiff cheats on the first rule. Its hull is pencil thin so that it makes negligible waves and can go faster than its theoretical displacement speed. It's semicircular cross section keeps wetted surface to a minimum, but its extreme length cancels this out somewhat. In spite of the extreme nature of its design a bicycle rider can easily keep up with a racing eight rowed by super fit athletes, testifying to the limiting effect of skin friction.

Racing sculls, showing hemispherical pencil thin hull.

Speed: A very fit young fella, Asher Ashwood, has averaged 5.6 knots (race record) around Dangar Island in the 16 foot waterline Swift dory. An old fella like myself (72) can average 5 knots. If we look at these figures using the cube rule we can deduce that Asher has an average power 40% greater than mine but probably more as he must have been exceeding displacement speed at times.

This matters little as we normally intend to travel more casually. For instance: **it requires very nearly twice as much power to row at 5 knots than 4 knots ($5^3/4^3$=125/64=1.95). To travel at 3.5 knots (4mph) we will require only a third of the power required to travel at 5 knots.**

Slow? I often began my row to Dangar Island as another was setting up their tinnie, removing security devices etc., and arrived before them.

“Well” I would ask, “Why do you need a 50hp outboard to get to the Island?

“I just want to get away from the rat race as fast as I can.” Came the smug reply.

“But you didn’t cobber, you’ve just brought the rat race with you.”

How long should your rowing boat be: This is a compromise between two factors affecting speed. Too short and your speed will have too low a maximum speed and too long, the extra wetted surface will offer too much skin friction. Experience tells us that a waterline length of about 16 feet (4.9m) is right. This will give a maximum speed of 5.6 knots and a reasonable cruising speed of 3.5-4 knots (4-4.5 mph). If this seems slow then consider that that the average walking speed is 3 mph. Since we tend to seek favourable tides and wind when cruising we will be going about 50% faster than walking speed.

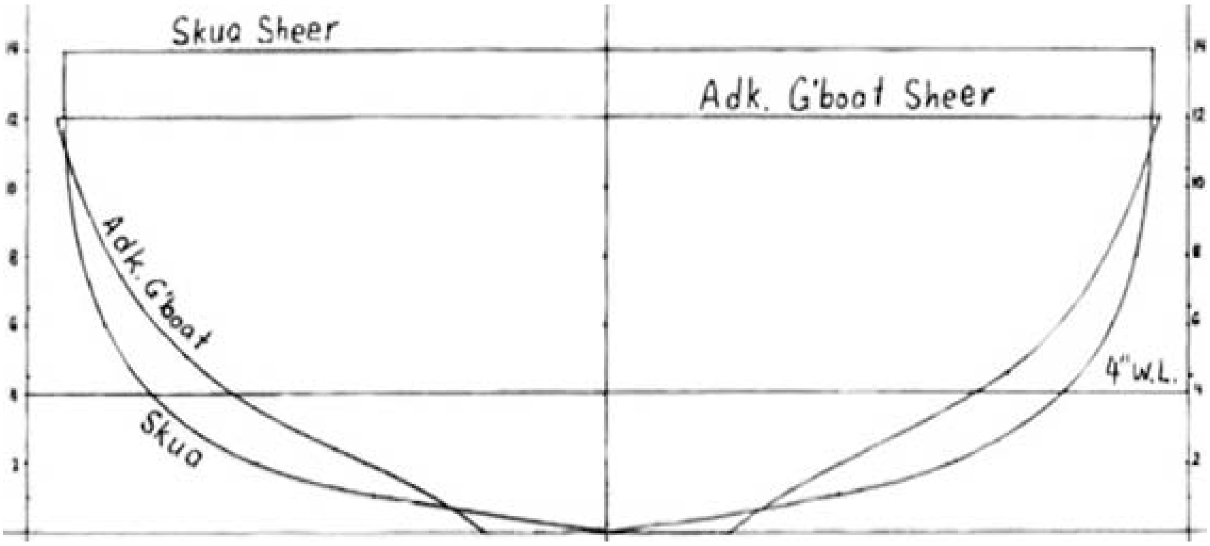
The overall length should therefore be between 16 and 18 feet. Anything longer than this will be blown around too much in a breeze. It will also result in a heavier boat than necessary. A large strong person may benefit from a longer hull (say 18’) and a more lightly built person might go down to a 15-foot hull. The shorter hull will be lighter and have less wetted surface. It will have a lower top speed but will be easier to row at lower speeds.

I can well remember the rowing boats for hire when I was a young fella. Rowing boats for singles were 14ft. and doubles 16 feet. Considering these were more heavily built and beamier and waterlogged clinkers, their lengths were probably about right.

The shape of the boat

Ideally, a hemispherical cross section will give minimum wetted surface and less wave making resistance. However it will be too unstable for recreational rowing and its beam (width) will be inadequate to accommodate a decent set of oars. Consequently the designs over the years have incorporated all sorts of different compromises. The racing scull employs a hemispherical cross section with outriggers for the oars, and ignores its instability, but we are in a quandary as to which compromise will suit us best.

Consider the midship sections of the Skua made by Middle Path Boats and the Traditional Adironback guide boat.



Midship sections of the Skua against the midship section of the Adironback guide boat (inside lines).

In theory the Guideboat should be faster as it has a narrower waterline and less wetted surface. However it will certainly be less stable and may make the newcomer nervous. An acquaintance has described it as “not very stable”. These are the sorts of compromises that must be considered in selecting design. However, there are more important considerations in selecting a rowing boat.

John Gardner comments on this issue as follows; “Small pulling boats, mostly under 18 or 19 feet in length, cut through the water rather than skim over it. To knife along with as little fuss as possible, the hull requires a sharp, thin entrance and an equally sharp exit with long easy flowing lines between. If the boat has a transom, this must sit high above the water for best results.

The high transom of this Ian Oughtred design easily clears the water while the waterline length is maintained at the Keel. The clinker hull does however add a little to wetted surface while a good beam allows for a decent set of oars.

To the extent that the transom is immersed, it will drag, cutting down rowing speed. This is the principal reason why boats with wide low sterns to support outboard motors row poorly.

A deep, sharp forefoot at the bottom of a perpendicular stem such as is characteristic of a Whitehall turns slowly, tows badly, and is dangerous in surf. A more raking stem, and a rounder, more cut away forefoot is required for quick manoeuvring in broken water."

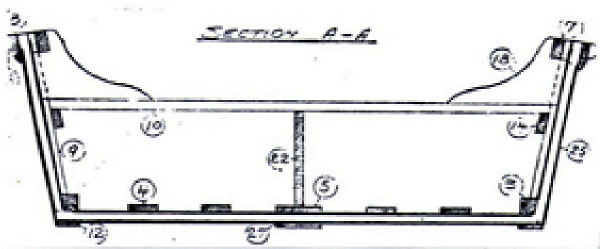
This beautiful Whitehall made of wood weighs a rather impractical 350lbs. Notice the deep forefoot of the stem. This does have the advantage of slicing through waves and reducing pounding in steep chop. Recreational rowing seeks to avoid these conditions however.

The portion of the hull above the water must be taken into account. Windage, that is the force of the wind against the topsides, can cut rowing speed markedly and make the boat difficult to manage, yet adequate freeboard is required to keep the boat from swamping."

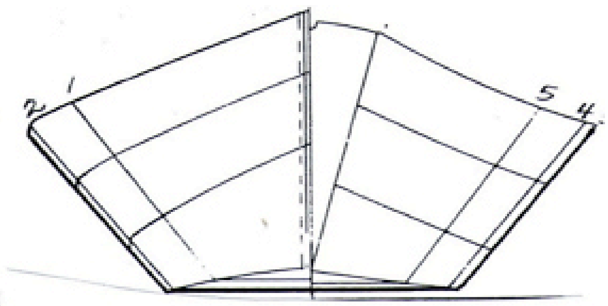
The author has rowed the Whitehall and indeed found it difficult to manoeuvre. However the Whitehall was used as a pilot boat and as such it was important for the hull to slice through the waves in all weathers, in its race to acquire a piloting job.

It is interesting to note that John Gardner at no stage mentions the importance of keeping wetted surface to a minimum and in this he may be reflecting ignorance of its importance to early designers. For instance no yacht designer worth his salt today would include the long deep keels of yore because of the wetted surface drag on performance. Keelsons to protect the bottom of skiffs not only make them more difficult to manoeuvre but add to wetted surface and weight. Modern light hulls can be lifted rather than dragged up the beach.

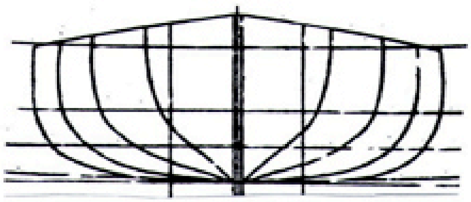
Shown below are drawings the midship section of eight different types of rowboats. It is obvious that the punt, which is designed as a short haul workboat has sacrificed performance for ease of build and stability. The grand banks dory that has a reasonable rowing performance, but terrible windage unloaded, is designed for ease of build and large fish loads. They fit into each other like cup cakes on the decks of the grand banks schooners. The straight sides and bottoms need healthy scantlings increasing the weight. Peter Evans in the 2014 Summer edition of Ash Breeze estimates his 18 ft. Grand Banks dory weighs 250-300 lbs. This causes larger wetted surface and the sharp turn of the bilge gives poor streamline flow. To see these historic craft in action watch an old movie “Captains Courageous” with Spencer Tracy.



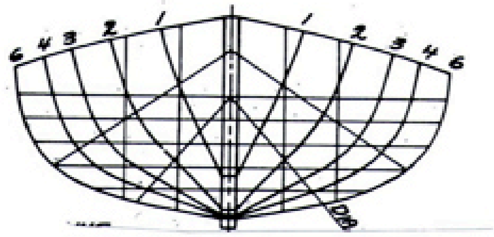
Common Punt



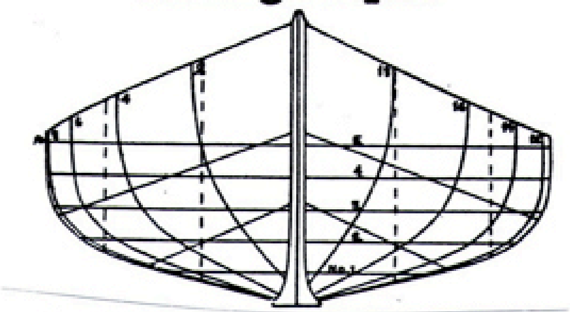
Grand Banks Dory



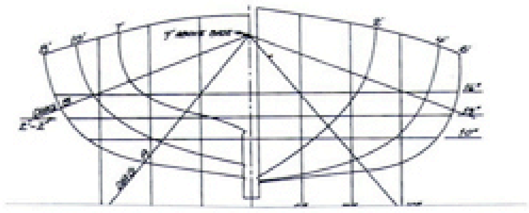
Sailing Peapod



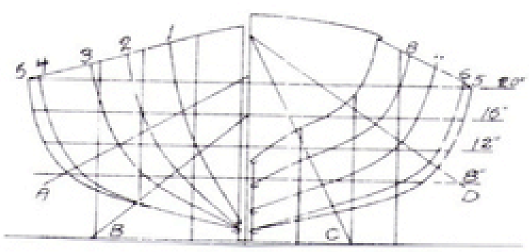
Rowing Peapod



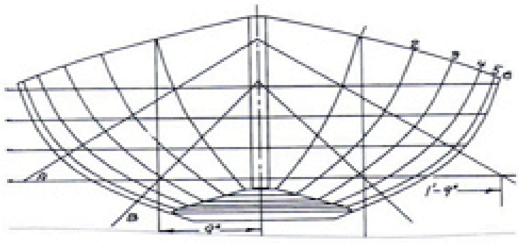
St. Lawrence river skiff



Spurling rowboat



Whitehall



Herreshoff Rowboat

The sailing peapod is the only skiff with a distinctly flat bottom. This provides stability against the heeling effect of the sails but it illustrates why sailing skiffs do not make good rowing boats. They have too much wetted surface and present a less streamlined hull to the water. The remaining skiffs present a variation of the angle of rise of the bilge (bottom). The steeper the angle the greater the depth of keel. A steep angle will increase directional stability but reduce stability. The Herreshoff rowboat, also described as a semi dory employs a flat bottom section that increases stability somewhat while also marginally decreasing wetted surface.

The Wherry and the Adirondack guide boat also employ partially flat bottoms so it is instructive to understand why this is so.

Francis Herreshoff justifies his flat bottom as follows: “You see she (the Herreshoff rowboat) is quite different from the so called St. Lawrence skiff which has been the usual rowboat for the last sixty years, but the St. Lawrence skiff is too straight along the garboard to row easily or to turn quickly into a sea. She is too narrow at the gunwale (3’6”) to use with long oars.” As for the Adirondack guide boat, it seems that the narrow flat bottom is designed to enable a narrow waterline beam and lower wetted surface. However this is at the expense of initial stability. The beam of both these boats at less than 42”(1m) seems inadequate and would require overlapping oars which even experienced rowers may feel awkward. A full four-foot beam as shown below is necessary to utilise a decent set of 7 to 7 ½ foot oars.

A four foot beam allows the rower to comfortably use a good set of 7 ½ foot oars.

John Gardner in his book makes the following comment: “I consider 45”(115cm.) to be adequate although Daniel S Connelly, a knowledgeable connoisseur of small craft, whose opinions I value and respect, feels that a 48”(120cm.) rowing span is better.”

The Adirondack Guide boat: Beam (38”) is described as suitable for “Slow rivers and flat waters.”

Seaworthiness: this brings to mind the comment that the most dangerous part of a car is the nut that holds the wheel. In other words the most “seaworthy craft” will put an incompetent or careless rower into danger. A careful reading of John Gardner’s book will come across little comment when it comes to seaworthiness. He does not describe any of the designs as being unseaworthy. Here are some generalisations relating to safety in rowing.

1. Enter the boat with one foot in the centre and one hand on the gunwale. Losing balance is the best way of falling in the water or swamping a boat.
2. Make sure of reasonable buoyancy and little weight in the ends of the boat in rough water.
3. Avoid if possible rowing in wind against tide conditions especially when both are strong.
4. Make sure the oars and rowlocks are in good condition. From a standing start pull on the oars with all you strength, try to break them, because you don’t want to break them in dangerous and trying conditions. In rough weather make sure the oars are secured into the rowlocks and the rowlocks secured into the boat.
5. Get a weather report before going on the water.
6. Wear a safety vest.

(Also read “Bad Timing” a cautionary tale on this website)

I can report that in almost 30 years of rowing in all weathers none of our Herreshoff rowboats (aka Swift Dories) have had an accident. By contrast two lives have been lost in tinnies. Do not fall into the trap of believing a high sided boat is more seaworthy. It is more likely to become uncontrollable in strong winds and can even be blown over. The large amount of sheer (upwardly curving ends) of some boats may cause problems in handling and of heeling in strong winds. By contrast the Herreshoff rowboat has powderhorn sheer. This design feature assumes that the rising bow wave will enter the boat aft of the bow and keeps unnecessary windage and weight down.

Powderhorn sheer: The rising sheer from amidships goes into a slight reverse to cut weight and windage but still disperse waves. The author is exhausted and over heated, but not naked, from a rowing race.

I will leave the last words to John Gardner; “Safety in a small rowboat must not be judged by its absence of motion, but rather by its control. Only a boat which responds freely, lightly, quickly and easily to the motion of water can be considered safe. The sea is much too powerful to fight. Safety lies in being able to avoid the sea like a sea duck riding the crests and dipping easily into the troughs, the superior small rowboat can take an amazing amount of weather.”

Lightness and strength

There exists in many quarters a prejudice against fibreglass boats that is quite damaging to the sport. Wooden boats require maintenance and can die fairly quickly of neglect. Canoes on the other hand are mostly made out of plastic or fibreglass and are going from strength to strength, in spite of their unseaworthiness and lack of versatility. The modern carbon fibre canoe paddle is symbolic of the forward-looking design associated with canoes. Especially when compared with the flat blade oar offered for some rowing boats.

John Gardner complains that: “Fibreglass is a much heavier material than cedar or pine. A hull thickness required obtaining a stiffness equivalent to wood means extra weight which, if added in the wrong place, can spoil the balance of the hull.” He is quite right, but the problems he reveals can be overcome. How this is done I will reveal by describing the building of the “Swift dory” which very closely resembles the Herreshoff rowboat in design.

The “problem” with fibreglass is that in spite of its strength it is about three times as dense as cedar. This means that, in the thin layups used, it lacks stiffness and this is the problem that must be addressed. This problem is greatest in the flat section at the bottom of the Swift dory. It is resolved by inserting a layer of coremat or foam plastic (such as Klegecell) between two or more layers of glass. This stiffens the bottom section immeasurably without adding much weight.

Coremat layer visible at the bottom, in the layup. Latterly Klegecell has replaced the coremat.

The curve in the rest of the hull provides strength in the same way as its curved shape strengthens the eggshell. Nevertheless all fittings fibre glassed into the hull strengthen it. The seats and foot stretchers, for instance, serve the additional function of providing buoyancy and rigidity to the hull. These and the Klegecell foam provide 220lb. (100kg.) of buoyancy. The gunwales and front and back rests further add stiffness and buoyancy. It is possible to swamp this boat and recover by bailing from inside it.

Fitments including seats, foot stretchers, front and back rests and gunwales contribute to the rigidity of the hull. Inboard fore and aft seats keep weight out of the ends.

Buying considerations: based on ease of transport, storage, rowing, durability and general utility.

1. The boat should not weigh much more than 70lbs. (32 kg.) to facilitate transport.
2. It should be between 16 and 18 feet long (5-5.5m).
3. The beam should not be much less than 4 ft. (1.2m)
4. It must have adjustable foot stretchers to brace against.
5. The rowlock sockets should be about 9"(23cm.) above the seat and 9" (23cm.) behind the rear edge of the seat. These measurements allow for a decent back stroke and clearance of the knees by the handles on the return stroke.
6. If made of fibreglass, vinyl ester rather than polyester resin should be used. Vinyl ester is lighter more flexible, has better adhesion and better water resistance.

Handling characteristics of the Herreshoff/Gardner rowboat (aka Swift Dory)

One of the minor changes in the Swift dory is the addition of a 3"(8cm. skeg). Without it the boat yaws when rowing ceases and is a little too subject to beam winds. This is a better solution than a long keel that makes the boat difficult to manoeuvre and adds to wetted surface and weight. The skeg serves an additional function of securing a dinghy dolly for single person handling.

The robust stainless skeg helps the boat track and provides a cleat for easy attachment of a dory dolly.

Although Herreshoff designed the boat as "a good sea boat", its ends were too fine and rowing into chop tended to bring water on board. Gardner, after a lot of thought, modified the design to give fuller ends and fortunately widened the beam to 48" at the same time. John quotes Buzz Nicholls on the boat as follows: "While in California, I made a number of crossings from Catalina Island to Long

Beach a distance of 28 miles. I made one trip rowing single in 5 hrs. 47 minutes. The boat is excellent in the open ocean." It is a fact, however, that for a small boat, rivers and lakes with their vicious chops, shallow waters, and wind against tide conditions can be more dangerous that the open ocean.

One of the extraordinary characteristics of the boat is its ability to handle beam powerboat wash and chop. It seems that the side of the hull fits the oncoming wave beautifully and the boat allows the wave to slide under it with ease. The boat does not rock but stays quite up right I assume because of a combination of its shape and the inertia of the rower. Beam waves are inclined to slap into slab sided hulls and spill on board, by contrast.

In most conditions the bow rises willingly to chop but with a load on board and heavy chop it may be necessary to slow down. In quite rough conditions however I have seen a family of mum and two daughters happily rowing across from Dangar Is. disappearing completely from view in the troughs whilst waving arms in animated conversation. I have rowed home from work at night in strong with waves standing on end from the opposing tide, and surfed down them while throwing my self rearwards onto my knees, for fun, while grabbing hold of the gunwales (I am a strong swimmer). The boat would surf then broach and then I would repeat the fun. The more conservative rower may have ceased rowing or dug his oars in if he thought catching the wave might cause trouble. On other occasions I have surfed on small waves into the shore but the boat must be made to sit in the wave rather than slide down the front of it causing a broach. But I have never felt myself in Danger and nor has many of my fellow rowers.

Last word on seaworthiness comes from Bill Cannell (a boat builder from Maine quoted by Gardner): "As for seaworthiness, a boat of this type can handle any conditions which would either be fun or rational for the recreational oarsman to go out in."

And Finally: don't forget the oars. Please read the article, "Efficient rowing" on this website. A D-section oar in the appropriate rowlock will not try to twist with each stroke. Use spoon oars that are not excessively long. Set up properly with adjustable foot stretchers and light efficient oars, rowing is an absolute pleasure.

Try before you buy, forget about the dolly with the brolly in the back and go for a practical boat rather than a pretty one.

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Sometimes speed is unimportant, time to smell the roses.

Footnotes:

1. A knot is a nautical mile per hour. A nautical mile is equal to 1 1/7 or 1.15 miles. It is also equal to 1.85 Kilometers. This business of different countries and individuals using different measurements is a pain in the backside. We have the following methods of measuring speed.
    a. Knots (nautical miles per hour)
    b. Miles per hour. (USA and UK)
    c. Kilometres per hour. (Europe and Australia)
    d. Meters per second. (Scientific or MKS system)

    The last would be the most satisfactory as a fast runner can do ten meters per second. This makes it easier to conceptualise the meaning of different speeds.

    N.B. A nautical mile is the arc on the earth's surface subtended by an angle of one second of degree at the earth's centre. One degree of latitude is equal to 60 nautical miles. It is a unit of length that makes navigational calculations much simpler.If the waterline length is measured in metres then displacement speed in knots = 2.55√water line length (m)

2. Fibreglass stretches 4% before failure. Since polyester fails at 2% stretch it can audibly crack while the hull remains intact. However almost invisible micro cracks weaken the hull and allow some water penetration. Vinyl ester, which is 10% lighter, stretches 4% with the glass and is thus more durable and flexible. It also has better adhesive qualities and water resistance.