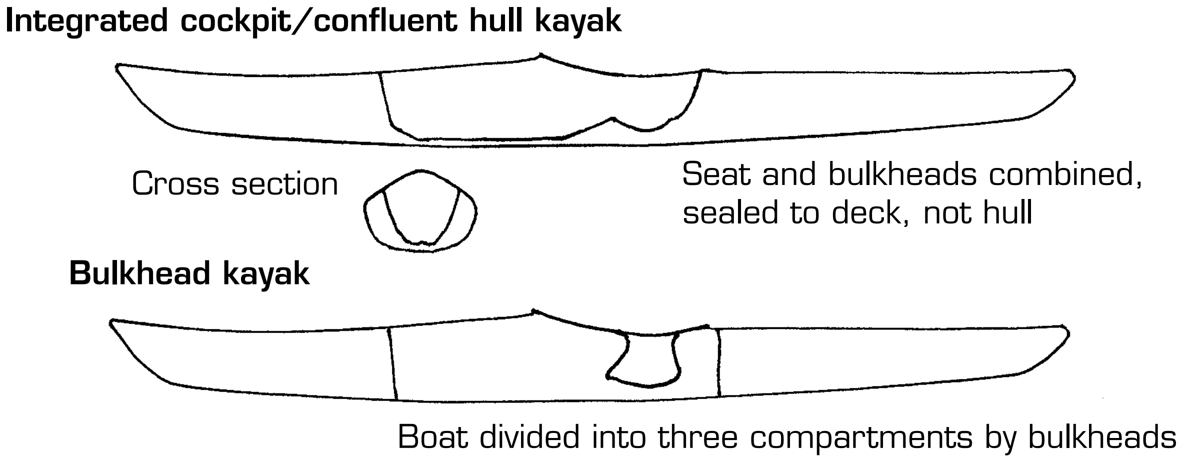
A kayak flooding experiment

Peter Carter

Background

The behaviour of flooded sea kayaks became a matter of controversy after the paddler of a Sea Tiger was rescued off Anglesey in the UK in May 1988. Advocates of the Sea Tiger, and integrated cockpit[1] craft in general, point to the incident as an example of the enhanced safety of such craft, while detractors, some (falsely) invoking free surface effects, claim that bulkhead craft are safer. The argument continued for some time in the *ISKA Newsletter* and private correspondence.

Structural differences between the two types are shown in this diagram:



Several things should be apparent:

- the volume of the integrated cockpit is less than that of the bulkhead cockpit, while hull volume for equipment/buoyancy is greater
- water is able to settle evenly, with no loss of trim.

The integrated cockpit craft is more difficult to develop: the cockpit is a complex three dimensional shape, while bulkheads are simply flat sheets. Assembly is rather different, but no more difficult. Voyager cockpits are based on an Alan Byde original, and are shaped like a small bathtub. The Puffin cockpit is more shoe-like, since it includes some deck area. Early Puffins had no bulkhead and water could flow from bow to stern; later versions were sealed just aft of the cockpit.

Some comparison with ships may be in order, especially as the safety of ro-ro ferries has been under discussion in the naval architecture literature of late[2]. Ships, ro-ro ferries excepted, are generally divided into a large number of compartments. Should one compartment be flooded the effect on the ship is small, since the compartment is much smaller, relatively, than the compartment of a bulkhead kayak.

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1 integrated cockpit: a kayak cockpit in which the seat and bulkheads are combined in one unit and sealed to the deck to form a cockpit which is isolated from the rest of the internal space in the boat. The concept was devised and promoted by Alan Byde, whose initial motivation was to reduce 'fold and hold' accidents in whitewater, but the main application has been in sea kayaks. Examples include Sea Tiger (UK), Nimbus Puffin (Canada), kayaks by Aquadynamic Watercraft (Canada), and Voyager (Australia).

2 This paper was written in 1991, when memories of the *Herald of Free Enterprise* sinking off Zeebrugge were still fresh

Protagonists of bulkhead kayaks might note that for comparable performance a kayak would need a dozen or so bulkheads: obviously impractical. Numerous equipment bags or pieces of buoyancy are their equivalent.

Previous investigations

Two carefully controlled experiments had already been conducted, the first by Peter Lamont (Lamont, 1989) who used Sea Tiger and Nordkapp kayaks, the second, under BCU auspices, by Duncan Winning (Winning, 1990) with Sea Tiger, Nordkapp, Hebrides and KW7 craft. In both investigations, measured quantities of water were added to the boats, which were then photographed. Winning also recorded the paddlers' comments as the boats were paddled over a short course. As would be expected, bulkhead craft went bow or stern down with relatively small amounts of water, while integrated cockpit craft remained substantially level, and controllable, with quantities of water up to 200 litres. Winning also comments that the presence of equipment bags or buoyancy material both reduces the amount of water that a boat may take on, and restricts its movement so that it does not affect stability.

One criticism made against those experiments was that they did not compare 'like with like', in other words, the tests should have been made with integrated cockpit and (nonexistent) bulkhead Sea Tigers, and standard and (nonexistent) integrated cockpit Nordkapps, etc. Why such a comment should be made is difficult to understand, as it appears to betray either a misunderstanding of the physics involved, or perversity in the face of unwelcome evidence. Loss of trim on flooding is not a function of hull shape, but depends on water position and movement within the hull.

This investigation

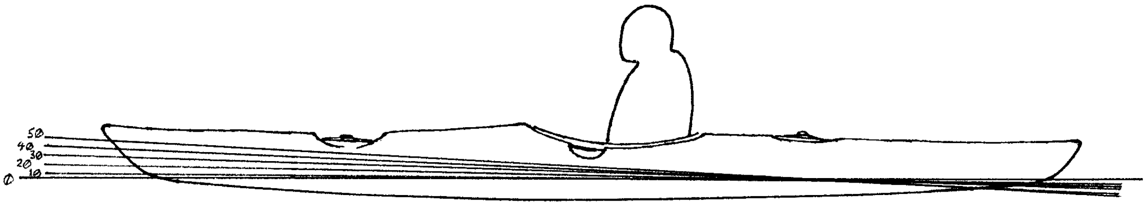
The experiment recorded here is an attempt to compare 'like with like', and also to examine the behaviour of craft not previously tested. Two boats used were early model Voyagers: the first prototype with bulkheads, and a later boat with integrated cockpit. Apart from the cockpits and different fins, the boats were identical. The other two boats were a Nimbus Puffin and the prototype Voyager 4, a double sea kayak. The tests were conducted in calm conditions at West Lakes, a recreational/ornamental lake in the Adelaide metropolitan area. Two paddlers were involved, Graham Fowler and Trevor Rossack, both experienced sea paddlers. Directing and assisting were myself and David Turner, owner of the Puffin.

As in the previous investigations, measured quantities of water were added to the hulls and cockpits, and the boats were photographed. Numbered cards were held in the boats' deck shock cords to indicate the amount of water on board. To keep the scale of the photographs as constant as possible the boats were placed bow on to a buoy. From the photographs, waterlines were drawn on diagrams.

All the boats were packed with buoyancy materials, inflated 20 and 5 litre wine cask liners in the case of the Voyagers. There was more than sufficient buoyancy in the boats to prevent their sinking, either completely or by one end, as had occurred with the earlier experiments. Aft hatches on the integrated cockpit boats were sealed, but others were open, and spraycovers were not worn.

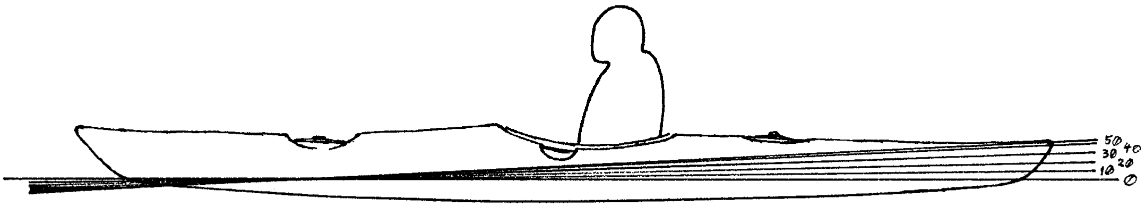
The Voyagers

Water was added to the bulkhead example 10 litres at a time. The maximum put into the bow was 50 litres, for which some buoyancy material had to be removed:



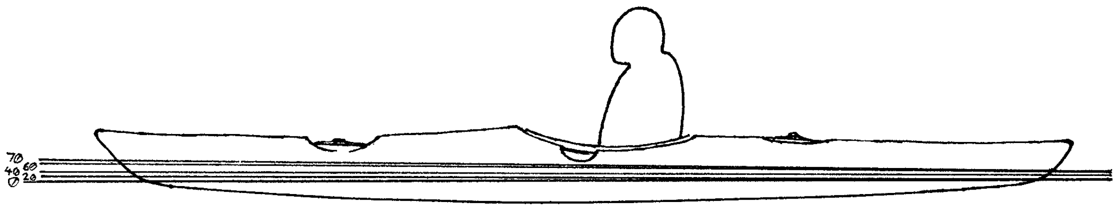
0–50 litres

In the stern, water was again added 10 litres at a time to a maximum of 50 litres:



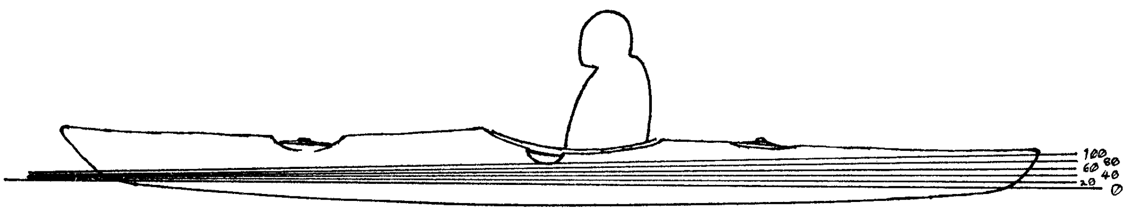
0–50 litres

The cockpit was flooded 20 litres at a time to 60 litres, and was then taken to a maximum of 70 litres. This boat has side bulkheads, and a conventional cockpit would have held rather more, with 120 to 150 litres being the normal range:

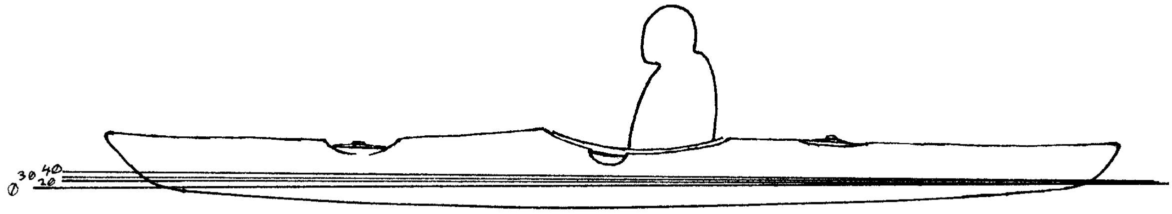


0–70 litres

The integrated cockpit boat was given 20 litres at a time to 100 litres, with the maximum load being 105 litres. Its increasing stern down trim is a sign of uneven buoyancy distribution:



0–105 litres



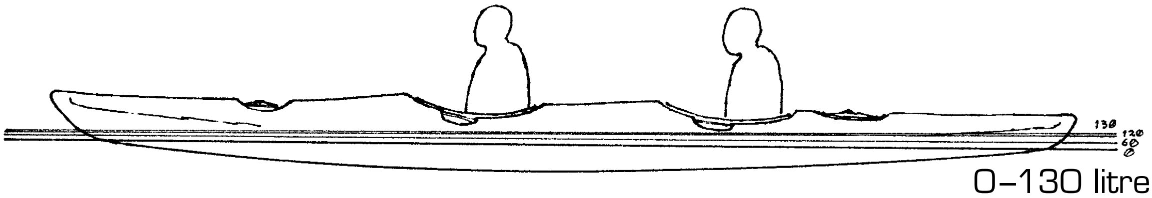
0–40 litres

The maximum amount of water added to the cockpit was 40 litres, at which stage it was full (actual capacity of a Voyager cockpit is about 80 litres):

Comment on the differences is hardly required.

Voyager 4

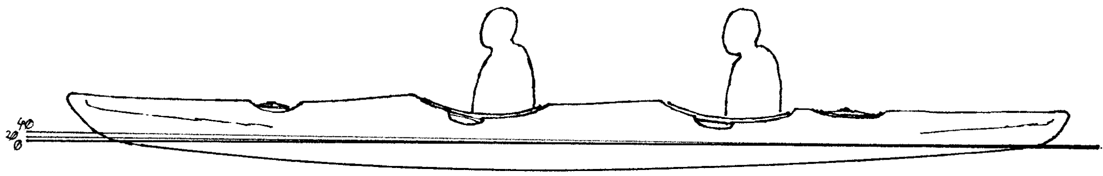
Twenty litre quantities were poured into the hull at a time, with the maximum being 130 litres. At this stage water was up to the hatches because of the amount of buoyancy in the boat:



0–130 litres

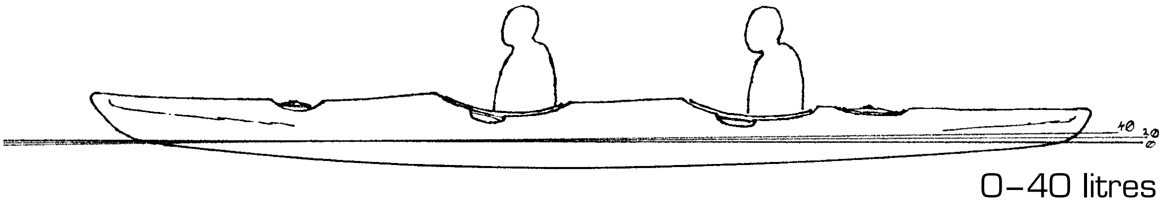
The cockpits were tested separately, with 20 and 40 litres, and their flooding did affect trim. Some thought had been given during the development process to connecting them, but to date this has not been done. At sea the boat has often had 5 litres or so in the forward cockpit and none in the aft without causing any concern[3]. (Both cockpits now have foot pumps.)

Forward



0–40 litres

Aft



0–40 litres

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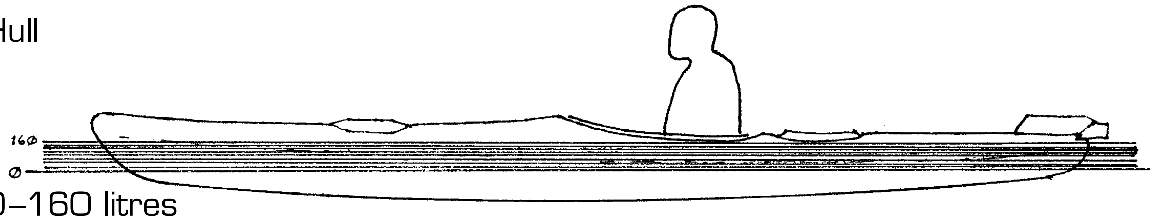
3 In January 2001 this boat was paddled as far as King Island as part of Davis Williamson's Bass Strait crossing. At some stage, the aft cockpit was damaged, and the boat took on water in heavy conditions. Despite this, it remained controllable.

Nimbus Puffin

Twenty litre increments were again used, to a maximum of 160 litres (There was less buoyancy material in the Puffin than in the other boats). The boat was clearly very sluggish, but controllable: Even with hull and cockpit flooded the paddler was able to perform a succession of high support strokes:

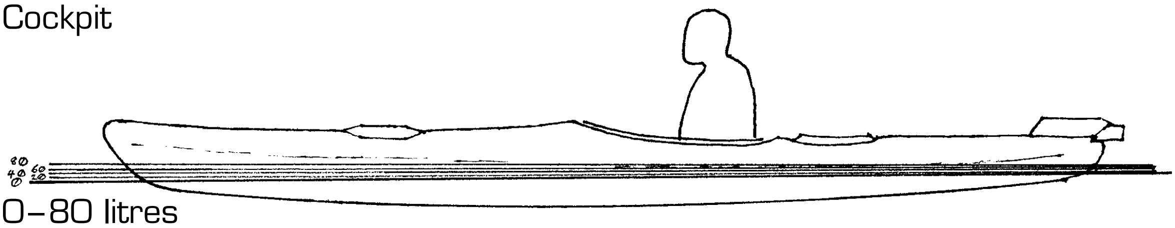
The maximum amount placed in the cockpit was 80 litres, reflecting its greater volume compared to the Voyager cockpits. With this amount it was possible to lean the boat and have water spill out:

Hull



0–160 litres

Cockpit



0–80 litres

We were favourably impressed by the Puffin's behaviour. It certainly had adequate performance in these tests, and several owners report that reentry and roll rescues are straightforward despite the lack of cockpit handrails.

The Slow Leak

The two single Voyagers had veen prepared for a further experiment by having 6 mm holes drilled in their hulls beneath the forward hatch, and then temporarily sealed with tape. The experiment, based on an idea from Peter Lamont, was to simulate a kayak being paddled with a leak. The boats were drained, had full buoyancy installed and old vinyl hatchcovers fitted. The tape was removed simultaneously from both boats and they were then paddled around a triangular course, each lap taking a little under 5 minutes. A breeze, 5–10 kn, was now blowing.

After the first lap, the bulkhead boat's behaviour was described as 'silly', and after the second (at 8 and a half minutes) the paddler reported that it 'fails to respond to bow rudder.' At the end of the third lap there were obvious problems on the crosswind sections of the course, while the integrated cockpit craft was described as 'OK'.

The experiment was halted after 19 minutes. By this time the bulkhead boat's bow was some 5 cm lower than that of the integrated cockpit version, and in heavier conditions would undoubtedly have been in difficulties. When the hatchcover was removed it was found that the internal and external water levels were equal. No more water was entering, and the boat was supported by its buoyancy material.

Water was still entering the integrated cockpit boat and the internal level was lower than in the other kayak. The total quantity was greater, however, than in the bulkhead craft. This suggests that a leaking integrated cockpit craft will take on more water than a bulkhead craft with similar damage. At first sight, this may appear to be a disadvantage, however as this experiment and experience elsewhere show, these craft remain controllable, whereas bulkhead boats rapidly lose directional, then lateral stability. Although the quantity of water is greater, the effect on boat handling is minimal compared to the effects on a conventional kayak. Integrated cockpit Voyagers have several times been paddled at sea with 10–15 litres of water in their hulls (mainly through leaking hatchcovers) without problems, in conditions up to 25 kn and 2 m seas.

Conclusions

There were no real surprises from any of these tests. The differences between integrated cockpit and bulkhead kayaks were exactly those that would be predicted from previous experience or theory: that the integrated cockpit/confluent hull system is more tolerant of flooding, both of the cockpit and the hull. Rescues after capsize, either solo or assisted, are much quicker and easier. It is therefore potentially the safer of the two systems. It is not a panacea however: the boat must be properly packed with equipment and/or buoyancy, it must be maintained, and the paddler must operate it in conditions within his or her experience and skill.

Acknowledgements

My thanks to Graham Fowler and Trevor Rossack for their assistance, and to David Turner for the use of his Puffin.

References

Lamont, P, *Experimental Progressive Flooding of Two Sea Kayaks,* 1989 (unpublished)

Winning, D, *Sea Tiger Report,* British Canoe Union, 1990

Bows of the integrated cockpit (left) and bulkhead (right) Voyagers at the end of the slow leak experiment. The bulkhead boat is noticeably down by the bow.

Appendix: The photographs

Bulkhead Voyager

Water in bow compartment

Bulkhead Voyager

Water in bow compartment

Water in stern compartment

Water in stern compartment

Water in cockpit

20 litres

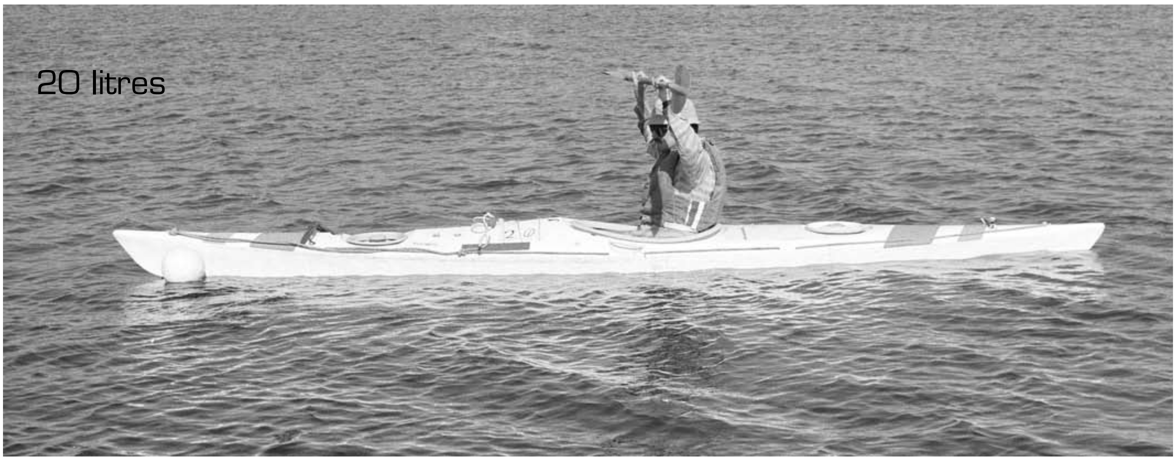
40 litres

60 litres

70 litres

Integrated cockpit Voyager

Water in hull



Water in hull

Water in cockpit

Voyager 4
Water in hull


0 litres


20 litres


40 litres


60 litres


80 litres

Water in hull

Voyager 4

Water in forward cockpit

Water in aft cockpit

Nimbus Puffin

Water in hull

Water in hull

Nimbus Puffin

Water in cockpit