

Supplementary material

**Tolerable ranges of fluid shear for early life-stage fishes:
implications for safe fish passage at hydropower and irrigation infrastructure**

*Anna Navarro^{A,B}, Craig A. Boys^{A,C,G}, Wayne Robinson^{A,B}, Lee J. Baumgartner^{A,B}, Brett Miller^D,
Zhiqun D. Deng^E and C. Max Finlayson^{A,F}*

^AInstitute of Land, Water and Society, Charles Sturt University, Elizabeth Mitchell Drive,
Thurgoona, NSW 2640, Australia.

^BNew South Wales Department of Primary Industries, Narrandera Fisheries Centre,
64 Buckingbong Road, Narrandera, NSW 2700, Australia.

^CNew South Wales Department of Primary Industries, Port Stephens Fisheries Institute,
Taylors Beach Road, Taylors Beach, NSW 2316, Australia.

^DUniversity of New South Wales Water Research Laboratory, 110 King Street,
Manly Vale, NSW 2093, Australia.

^EPacific Northwest National Laboratory, Richland, WA 99354, USA.

^FIHE Delft, Institute for Water Education, NL-2601 DA, Delft, Netherlands.

^GCorresponding author. Email: craig.boys@dpi.nsw.gov.au

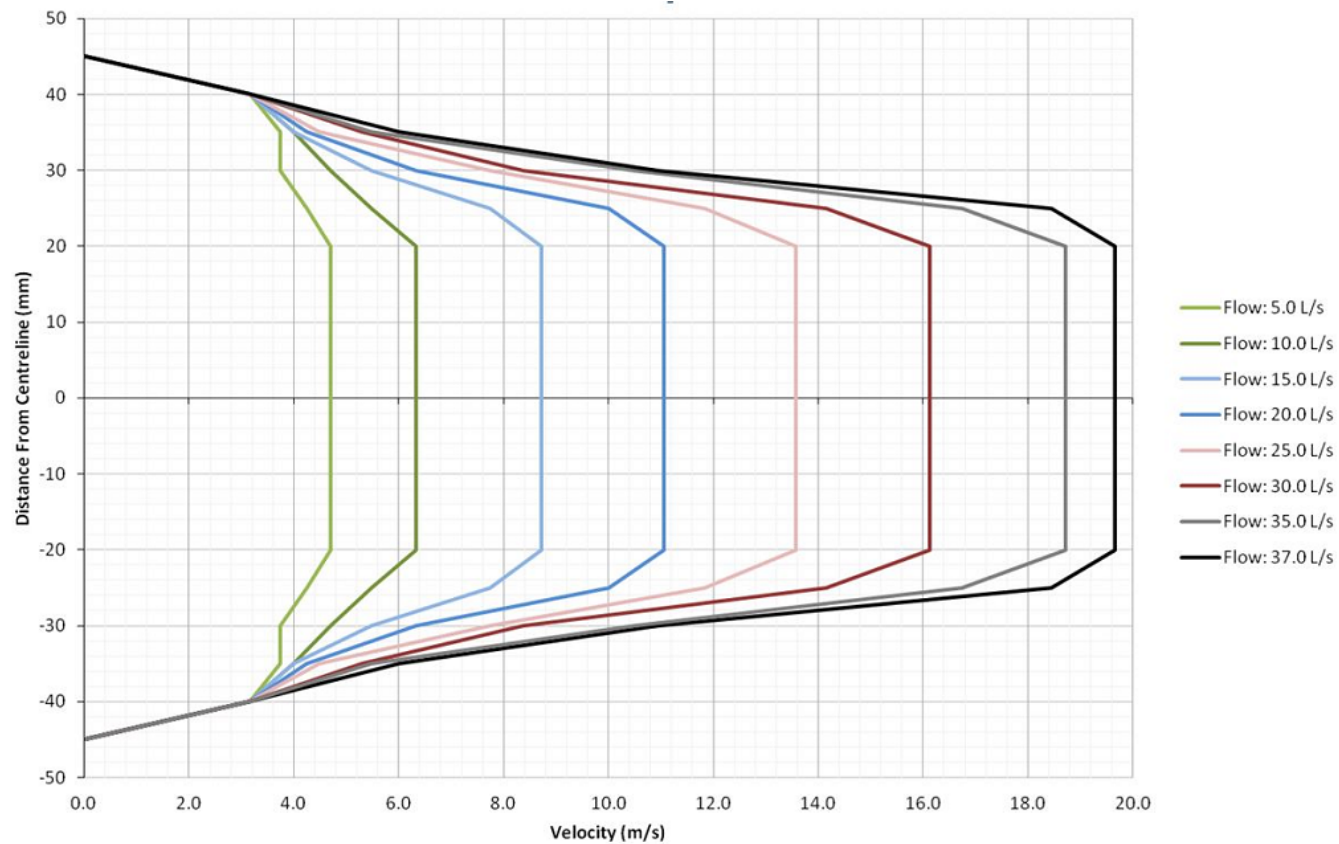


Fig. S1. Velocity profile of the flow-establishment zone of the shear flume. Measurements (m s^{-1}) were taken 90 mm in front of the nozzle and incrementally radiating out (mm) from the centreline of the jet stream. Velocity profiles for all the flow rates tested are shown (source: Boys *et al.* 2013, reproduced with permission).

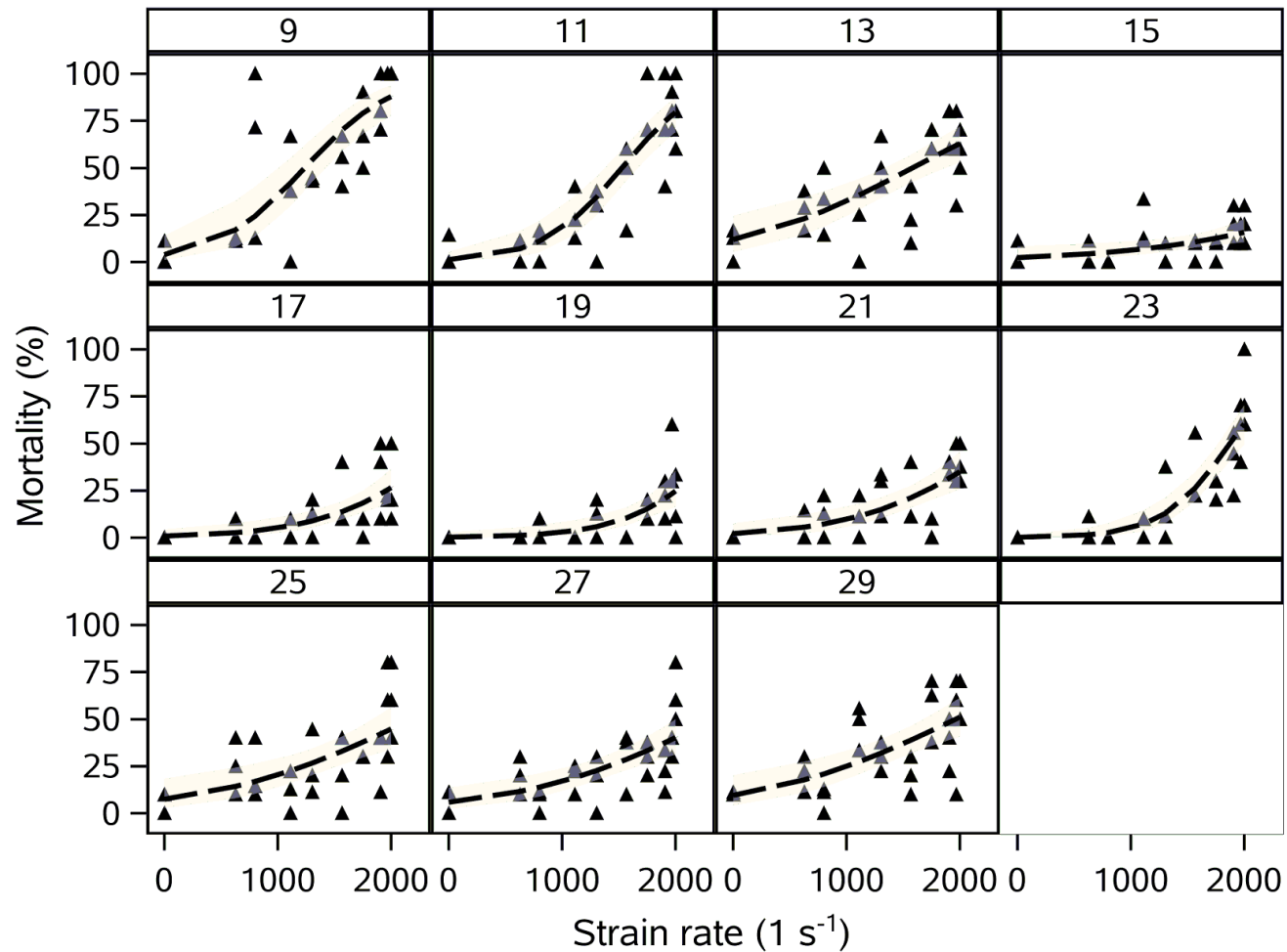


Fig. S2. Percentage mortality of Murray cod larvae at different days post-hatch (9–29) when exposed to varying strain rates. The triangle markers show the results from each replicate, the dashed line represents the probability of mortality as predicted by a binary logistic regression model and the shaded region shows the 95% confidence limits.

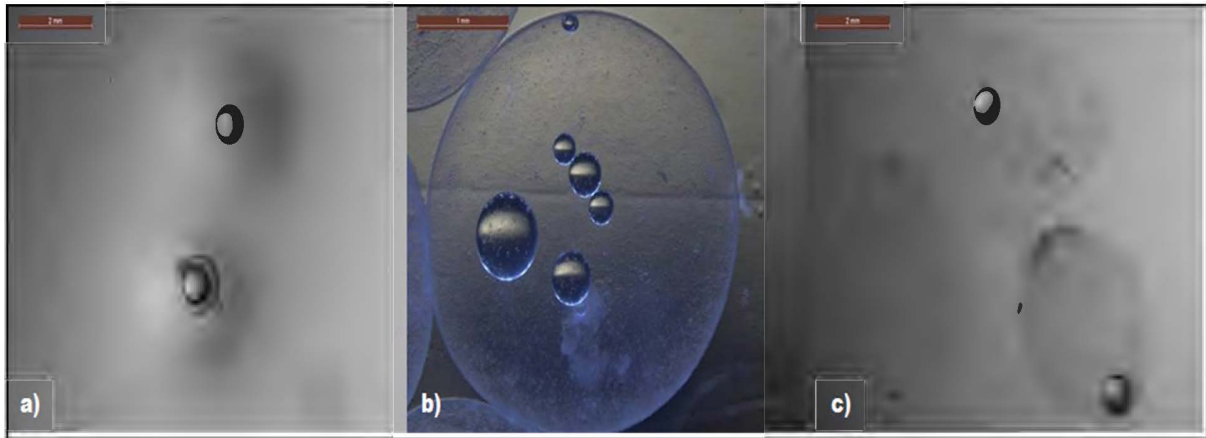


Fig. S3. Golden perch eggs showing (a) no injury, (b) the disruption of cellular protein and (c) torn chorion (source: Boys *et al.* 2014, reproduced with permission).



Fig. S4. Examples of different injuries observed in larvae following exposure to elevated strain rates: (a) spinal injury, (b) missing eye, (c) rupture of the yolk sac and (d) decapitation. These fish are 9-days post-hatch Murray cod after exposure to a strain rate of 1906 s^{-1} (source: Boys *et al.* 2014, reproduced with permission).

References

- Boys, C. A., Baumgartner, L., Miller, B., Deng, Z. D., Brown, R., and Pflugrath, B. (2013). Protecting downstream migrating fish at mini hydropower and other river infrastructure. Fisheries Final Report Series Number 137, NSW Department of Primary Industries, Sydney, NSW, Australia.
- Boys, C. A., Navarro, A., Robinson, W., Fowler, T., Chilcott, S., Miller, B., Pflugrath, B., Baumgartner, L. J., McPherson, J., Brown, R., and Deng, Z. (2014). Downstream fish passage criteria for hydropower and irrigation infrastructure in the Murray–Darling Basin. Fisheries Final Report Series Number 141, NSW Department of Primary Industries, Nelson Bay, NSW, Australia.