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Editorial

Hydropower development and fish management: a food–water–energy nexus requiring international and multidisciplinary approach

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The environmental impacts of dams have been recognised globally as one of the major threats for aquatic biota, particularly riverine species (Poff and Schmidt 2016). Indeed, freshwater environments are deemed to be experiencing greater biodiversity decline than terrestrial ecosystems (Dudgeon *et al.* 2006) in part due to increasing human demand for water. In this sense, dams for hydropower production have gained substantial traction in the balance between freshwater usage and biodiversity conservation, creating various disputes worldwide. For instance, given recent development and the current boom of new dams in mega diverse rivers such as the Amazon, Mekong and Congo (Winemiller *et al.* 2016), hydropower plants have been recently highlighted as imperilling one-third of freshwater fish worldwide.

This scenario of conflict between hydropower development and fish management and conservation defines the energy–water–food nexus (Poff and Olden 2017). It is also directly related to at least six United Nations Sustainable Development Goals (Goals 7, 15, 13, 8, 2 and 3 – for details see https://www.un.org/sustainabledevelopment/, accessed 26 September 2018), making this a contemporary topic of global significance. For instance, hydropower development has been considered a key component to meet increasing energy demands associated with economic development and rapid population growth with a renewable energy source (Zhou *et al.* 2015; Romanelli *et al.* 2018). In contrast, the threats and impacts on freshwater fish, particularly on migratory and riverine species, from development in this sector have already contributed to the decline of many fish populations (Agostinho *et al.* 2016). For many rivers and basins around the globe, fish are a primary source of protein, providing food security for the population (Sabo *et al.* 2017) and declines of this important food resource can severely affect livelihoods, creating challenging environmental and social conflicts that have to be addressed for future development and system sustainability.

Such complex conflicts, involving environmental, social, economic and technological components, require multidisciplinary approaches to (*a*) provide a comprehensive understanding of the problem and (*b*) contribute to the development of well-informed decisions and management plans for hydropower and fisheries management globally. In this sense, the International Energy Agency launched the ANNEX XIII – Hydropower and Fish initiative (see https://www.ieahydro.org/annex-xiii-hydropower-and-fish, accessed 26 September 2018) seeking to integrate experts of member countries into discussions to develop a best-practice guidance for future hydropower development and improvements on the operation of current facilities. The ANNEX XIII represents a global collaboration to share knowledge on fish and hydropower interactions. The group has been active for several years and members have been jointly sharing knowledge and experience to help develop practical solutions to these challenging problems.

This special issue of *Marine and Freshwater Research* demonstrates the significant international effort to systematise and disclose scientific information on fish management and ecology applied to hydropower issues, aiming to provide some guidance for current and future development. The articles in this issue represent an opportunity to increase the understanding of both hydropower impacts on fish and to document mitigation options for various impacts, particularly those associated with migratory movements. The impact of hydropower development on fish movements is long-standing (Nieminen *et al.* 2017) and it is a primary example of the need to integrate different areas, such as engineering, fish biology, and ecology to develop environmental mitigation approaches (Williams *et al.* 2012).

The majority of the manuscripts in this special issue are related to studies associated with upstream and downstream passage of fish through hydropower structures, providing evidence that this topic is in the forefront of hydropower and fish management research. This special issue has also been linked to the 1st International Symposium on Hydropower and Fish Management jointly organised with the 2018 International Conference on River Connectivity – Fish Passage 2018 and this may have contributed to the majority of the manuscripts having a fish passage focus. It is interesting to note there is a current trend for research associated with hydropower and fish management that focus on fish passage issues, although it was compelling to see that ~45% of the manuscripts were related to downstream fish passage, an often-neglected topic in hydropower studies, particularly in tropical regions (Pompeu *et al.* 2015).

The special issue contains 20 articles that will advance knowledge on various aspects of fish and hydropower interactions. These include:

- information on the efficiency of fish ladders, or fishways, at hydropower dams to improve passage of upstream-migrating fish (Amaral *et al.* 2018*a*; Baumgartner and Wibowo 2018; Bido *et al.* 2018; Dodd *et al.* 2018; Fjeldstad *et al.* 2018; Gutfreund *et al.* 2018; Meulenbroek *et al.* 2018);
- several key technologies to improve operation of bypass systems to ensure downstream-migrating fish avoid passage through turbines (Amaral *et al.* 2018*b*; Fjeldstad *et al.* 2018; Klopries *et al.* 2018; Nyqvist *et al.* 2018);
- new and improved monitoring technologies, especially those that improve understanding of factors that lead to injury and mortality (Egg *et al.* 2018; Silva *et al.* 2018);
- understanding the hydraulic conditions in and around hydropower plants and the effects in fish (Beirão *et al.* 2018; Boys *et al.* 2018; Colotelo *et al.* 2018; Pflugrath *et al.* 2018; Santos *et al.* 2018); and
- determining long-term ecological impacts of hydropower plants and associated reservoirs (Cowx *et al.* 2018; Loures and Pompeu 2018; Naughton *et al.* 2018)

These topics represent significant issues for hydropower developers and the content and solutions presented in these articles will help address key knowledge gaps in both tropical and temperate systems.

We finally acknowledge all the authors and institutions for the great effort undertaking the research and preparing the manuscripts for this special issue. This issue, associated with the 1st International Symposium on Hydropower and Fish Management, will significantly contribute to the literature and offer a systematised volume of information for a broader audience, from researchers to stakeholders, managers and the general public. The editors are grateful to Hydro Tasmania and the Australian Renewable Energy Agency (ARENA) for the support to this special issue and for making it available in print for all delegates attending the conference. The scientific systematisation of available information on fish biology and ecology benefits areas under pressure because of rapid hydropower expansion is of paramount importance to inform management decisions and alleviate the impacts on fish.

We hope you will enjoy your reading and we seek your for support to further develop this initiative, potentially through a 2nd International Symposium on Hydropower and Fish Management and a second special issue compilation of manuscripts targeted to cover additional areas research of relevance to hydropower development and fish management.

Conflicts of interest

L. G. M. Silva, L. J. Baumgartner and Z. D. Deng are Associate Editors for *Marine and Freshwater Research* and all authors are the Handling Editors for this special issue. The authors declare that they have no conflicts of interest.

References

Agostinho, A. A., Gomes, L. C., Santos, N. C. L., Ortega, J. C. G., and Pelicice, F. M. (2016). Fish assemblages in Neotropical reservoirs: colonization patterns, impacts and management. *Fisheries Research* **173**, 26–36. doi:10.1016/J.FISHRES.2015.04.006

Amaral, S. D., Branco, P., Romão, F., Viseu, T., Ferreira, M. T., Pinheiro, A. N., and Santos, J. M. (2018*a*). The effect of weir crest width and discharge on passage performance of a potamodromous cyprinid. *Marine and Freshwater Research* **69**(12), 1795–1804. doi:10.1071/MF18075

Amaral, S. V., Coleman, B. S., Rackovan, J. L., Withers, K., and Mater, B. (2018*b*). Survival of fish passing downstream at a small hydropower facility. *Marine and Freshwater Research* **69**(12), 1870–1881. doi:10.1071/MF18123

Baumgartner, L. J., and Wibowo, A. (2018). Addressing fish-passage issues at hydropower and irrigation infrastructure projects in Indonesia. *Marine and Freshwater Research* **69**(12), 1805–1813. doi:10.1071/MF18088

Beirão, B. V., Silva, L. G. M., Brown, R. S., and Walker, R. W. (2018). Determining barotrauma in the Amazonian catfish *Pimelodus pictus* experimentally exposed to simulated hydropower turbine passage. *Marine and Freshwater Research* **69**(12), 1913–1921. doi:10.1071/MF18142

Bido, A. F., Urbinati, E. C., Makrakis, M. C., Celestino, L. F., Serra, M., and Makrakis, S. (2018). Stress indicators for *Prochilodus lineatus* (Characiformes: Prochilodontidae) breeders during passage through a fish ladder. *Marine and Freshwater Research* **69**(12), 1814–1821. doi:10.1071/MF18087

Boys, C. A., Pflugrath, B. D., Mueller, M., Pander, J., Deng, Z. D., and Geist, J. (2018). Physical and hydraulic forces experienced by fish passing through three different low-head hydropower turbines. *Marine and Freshwater Research* **69**(12), 1934–1944. doi:10.1071/MF18100

Colotelo, A. H., Mueller, R. P., Harnish, R. A., Martinez, J. J., Phommavong, T., Phommachanh, K., Thorncraft, G., Baumgartner, L. J., Hubbard, J. M., Rhode, B. M., and Deng, Z. D. (2018). Injury and mortality of two Mekong River species exposed to turbulent shear forces. *Marine and Freshwater Research* **69**(12), 1945–1953. doi:10.1071/MF18126

Cowx, I. G., Lungu, A., and Kalonga, M. (2018). Optimising hydropower development and ecosystem services in the Kafue River, Zambia. *Marine and Freshwater Research* **69**(12), 1974–1982. doi:10.1071/MF18132

Dodd, J. R., Bolland, J. D., Hateley, J., Cowx, I. G., Walton, S. E., Cattaneo, M. E. G. V., and Noble, R. A. A. (2018). Upstream passage of adult sea trout (*Salmo trutta*) at a low-head weir with an Archimedean screw hydropower turbine and co-located fish pass. *Marine and Freshwater Research* **69**(12), 1822–1833. doi:10.1071/MF18125

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z., Knowler, D. J., Leveque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D., Stiassny, M. L., and Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews of the*

Cambridge Philosophical Society **81**(2), 163–182. doi:10.1017/S1464793105006950

Egg, L., Pander, J., Mueller, M., and Geist, J. (2018). Comparison of sonar-, camera- and net-based methods in detecting riverine fish-movement patterns. *Marine and Freshwater Research* **69**(12), 1905–1912. doi:10.1071/MF18068

Fjeldstad, H. P., Pulg, U., and Forseth, T. (2018). Safe two-way migration for salmonids and eel past hydropower structures in Europe – a review and recommendations for best practice solutions. *Marine and Freshwater Research* **69**(12), 1834–1847. doi:10.1071/MF18120

Gutfreund, C., Makrakis, S., Castro-Santos, T., Celestino, L. F., Dias, J. H. P., and Makrakis, M. C. (2018). Effectiveness of a fish ladder for two Neotropical migratory species in the Paraná River. *Marine and Freshwater Research* **69**(12), 1848–1856. doi:10.1071/MF18129

Klopries, E.-M., Deng, Z. D., Lachmann, T. U., Schüttrumpf, H., and Trumbo, B. A. (2018). Surface bypass as a means of protecting downstream-migrating fish: lack of standardised evaluation criteria complicates evaluation of efficacy. *Marine and Freshwater Research* **69**(12), 1882–1983. doi:10.1071/MF18097

Loures, R. C., and Pompeu, P. S. (2018). Long-term study of reservoir cascade in south-eastern Brazil reveals spatio-temporal gradient in fish assemblages. *Marine and Freshwater Research* **69**(12), 1983–1994. doi:10.1071/MF18109

Meulenbroek, P., Drexler, S., Nagel, C., Geistler, M., and Waidbacher, H. (2018). The importance of a constructed near-nature-like Danube fish by-pass as a lifecycle fish habitat for spawning, nurseries, growing and feeding: a long-term view with remarks on management. *Marine and Freshwater Research* **69**(12), 1857–1869. doi:10.1071/MF18121

Naughton, G. P., Keefer, M. L., Clabough, T. S., Knoff, M. J., Blubaugh, T. J., Sharpe, C., and Caudill, C. C. (2018). Reservoir provides cool-water refuge for adult Chinook salmon in a trap-and-haul reintroduction program. *Marine and Freshwater Research* **69**(12), 1995–2007. doi:10.1071/MF18124

Nieminen, E., Hyytiäinen, K., and Lindroos, M. (2017). Economic and policy considerations regarding hydropower and migratory fish. *Fish and Fisheries* **18**(1), 54–78. doi:10.1111/FAF.12167

Nyqvist, D., Elghagen, J., Heiss, M., and Calles, O. (2018). An angled rack with a bypass and a nature-like fishway pass Atlantic salmon smolts downstream at a hydropower dam. *Marine and Freshwater Research* **69**(12), 1894–1904. doi:10.1071/MF18065

Pflugrath, B. D., Boys, C. A., and Cathers, B. (2018). Predicting hydraulic structure-induced barotrauma in Australian fish species. *Marine and Freshwater Research* **69**(12), 1954–1961. doi:10.1071/MF18137

Poff, N. L., and Olden, J. D. (2017). Can dams be designed for sustainability? *Science* **358**(6368), 1252–1253. doi:10.1126/SCIENCE.AAQ1422

Poff, N. L., and Schmidt, J. C. (2016). How dams can go with the flow. *Science* **353**(6304), 1099–1100. doi:10.1126/SCIENCE.AAH4926

Pompeu, P., Suzuki, F., Prado, I., and Souza, R. (2015). Downstream fish passage: the new challenge of the hydropower sector for the conservation of the Brazilian fish fauna. *American Journal of Hydropower, Water and Environment Systems* **2**, 45–47. doi:10.14268/AJHWES.2015.00028

Romanelli, J. P., Silva, L. G. M., Horta, A., and Picoli, R. A. (2018). Site selection for hydropower development: a GIS-based framework to improve planning in Brazil. *Journal of Environmental Engineering* **144**(7), 04018051. doi:10.1061/(ASCE)EE.1943-7870.0001381

Sabo, J. L., Ruhi, A., Holtgrieve, G. W., Elliott, V., Arias, M. E., Ngor, P. B., Rasanen, T. A., and Nam, S. (2017). Designing river flows to improve food security futures in the Lower Mekong Basin. *Science* **358**(6368), eaao1053. doi:10.1126/SCIENCE.AAO1053

Santos, H. A., Duarte, B., Abgail, P., Cruz, D., and Souza, G. (2018). Flow characteristics in tailrace: understanding how hydrodynamics may attract fish to hydropower plant in South America. *Marine and Freshwater Research* **69**(12), 1962–1973. doi:10.1071/MF18135

Silva, L. G. M., Beirão, B. V., Falcão, R. C., Castro, A. L. F., and Dias, E. W. (2018). It's a catfish! Novel approaches are needed to study the effects of rapid decompression on benthic species. *Marine and Freshwater Research* **69**(12), 1922–1933. doi:10.1071/MF18267

Williams, J. G., Armstrong, G., Katopodis, C., Larinier, M., and Travade, F. (2012). Thinking like a fish: a key ingredient for development of effective fish passage facilities at river obstructions. *River Research and Applications* **28**(4), 407–417. doi:10.1002/RRA.1551

Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny, M. L., Silvano, R. A., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M. Jr, Zarfl, C., Mulligan, M., Sullivan, J. P., Arantes, C. C., Sousa, L. M., Koning, A. A., Hoeinghaus, D. J., Sabaj, M., Lundberg, J. G., Armbruster, J., Thieme, M. L., Petry, P., Zuanon, J., Torrente Vilara, G., Snoeks, J., Ou, C., Rainboth, W., Pavanelli, C. S., Akama, A., van Soesbergen, A., and Saenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science* **351**(6269), 128–129. doi:10.1126/SCIENCE.AAC7082

Zhou, Y., Hejazi, M., Smith, S., Edmonds, J., Li, H., Clarke, L., Calvin, K., and Thomson, A. (2015). A comprehensive view of global potential for hydro-generated electricity. *Energy & Environmental Science* **8**(9), 2622–2633. doi:10.1039/C5EE00888C