tropical-like moist and hot conditions prevailed in the polar regions and inland seas flooded vast areas of the continents[4]. Unlike today, this and similar past hot-houses were accompanied by CO_2 build-up rates that were much smaller than what we are witnessing now. The current 100 ppm increase in the last century would have taken tens of thousands of years then.

What is the concern now? In December 2009 at Copenhagen, world governments agreed to limit global warming to 2°C above the preindustrial period. If climate change is to be stabilized at 2°C above preindustrial level – models tell us – CO_2 concentration cannot exceed 450 ppm. Reaching the symbolic milestone of 400 ppm is just another grim reminder about how fast we are approaching 450 ppm. At the current rate of CO_2 emissions, we could reach the 450 ppm target as early as 2035. It should not be surprising if we reach the target earlier than this date given the accelerating emissions in recent years.

Why is the target focused on CO_2 while there are other climate warming agents like black carbon or methane? The trouble with CO_2 is that it has a long lifetime in the atmosphere. While black carbon has a lifetime of 2 weeks and methane about 10 years, CO_2 is estimated to have a lifetime of about 100–300 years. This refers to the time for CO_2 to get into the deep ocean where it is permanently sheltered from the atmosphere. But the climate system is too complex and the deep ocean does exchange its water with the surface ocean on thousands of years timescale. Recent studies[5] show that about 10–25% of emitted CO_2 will be still around in the atmosphere even after 10,000 years. Therefore, large emissions could take the planet back to one of those hot-house conditions that prevailed in the geologic past when global mean temperatures were 5–10°C warmer than today. Sea levels in such a hot-house world with ice-free poles will be higher by 120 m. This should worry anyone who is concerned about the long-term habitability and fate of human civilization on this planet.

1. Monastersky, R., *Nature*, 2013, **497**, 13–14.
2. Ballantyne *et al*., *Nature*, 2012, **488**, 70–73.
3. Global Carbon budget, 2012; http://www.globalcarbonproject.org/carbonbudget/
4. Caldeira, K., *Sci. Am.*, September 2012, 78–83.
5. Archer, D. *et al*., *Annu. Rev. Earth Planet. Sci*., 2009, **37**, 117–134.

G. Bala is in the Divecha Centre for Climate Change, Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bangalore 560 012, India.
e-mail: gbala@caos.iisc.ernet.in

COMMENTARY

Conserving the endangered Mahseers (*Tor* spp.) of India: the positive role of recreational fisheries

Adrian C. Pinder and Rajeev Raghavan

A third of all freshwater fishes globally are threatened with extinction[1,2] making them one of the most important vertebrate groups in need of urgent conservation attention. Freshwater fishes are increasingly threatened by a range of factors, including habitat loss, over-exploitation and biological invasions[1,3]. Conserving freshwater fishes is therefore a complex challenge requiring a combination of proactive strategies, on a continuous and sustained basis[4,5]. To be successful, conservation measures also require the political will of national and regional authorities, and the participation of local communities[6].

Many countries, especially those in the tropics where much of the freshwater fish diversity is concentrated, invest little time and effort on their conservation. For example, in India, freshwater fishes have been 'out of sight' and 'out of mind' of the policy makers and general public[7]. This is in spite of the fact that the country harbours the greatest number of endemic freshwater fishes in continental Asia[8], many of which are threatened[4,9] and some probably extinct[10,11].

Mahseers of the genus *Tor* are large cyprinids endemic to continental Asia, and popular cultural icons of economic, recreational and conservation interest in their native range[12,13]. Due to the large sizes they attain, mahseers find a place among the 20 'mega fishes' of the world[14], and have often been called the 'tiger of the water'[15], and the world's hardest fighting fish[16]. There are no reliable estimates of the number of *Tor* species found in Indian waters, mainly due to the taxonomic uncertainties within this genus[12]. However, they comprise one of the most threatened groups of freshwater fish in the country. Of the currently valid species, five are listed as 'Endangered' (*Tor khudree*, *T. kulkarni*, *T. malabaricus*, *T. mussullah* (see Note 1) and *T. putitora*) and two as 'Near Threatened' (*T. tor* and *T. progenius*) in the IUCN Red List of Threatened Species[17].

The report of the National Commission on Agriculture (NCA) in 1976 was probably the first to highlight the plight of the mahseers and the need for their conservation[18]. Several studies have since revealed that overfishing and habitat alteration have resulted in severe population decline of different *Tor* species, including the golden mahseer, *T. putitora* and the tor mahseer, *T. tor* in the Himalayan rivers[19,20] and the Deccan mahseer, *T. khudree* in the Western Ghats[21]. More recently, the escalating list of anthropogenic threats to mahseer populations has been synthesized to include a broad range of individual and combined effects such as catchment fragmentation, water and aggregate abstraction, and the prevalence of illegal and highly destructive fishing methods such as small mesh nets, plant-derived toxins, electricity and dynamite[22].

The Wildlife Association of South India (WASI), an NGO based in Bangalore, Karnataka, came into existence in 1972 with a mandate 'to conserve and preserve the wildlife of South India'. The association also obtained a lease of a 22 km reach of the River Cauvery with the aim to conserve native mahseer populations. While this initiative lacked influence over catchment-scale developments impacting either directly or indirectly on habitat quality and longitudinal and lateral connectivity, the focus of the WASI effort was to control illegal fishing and replenish wild stocks using captive bred fish[23]. The WASI also set up small seasonal fishing camps to promote responsible 'catch and release' mahseer fisheries. The success of WASI encouraged other NGOs such as the Coorg Wildlife Society[23], private individuals[24], and the State Government-owned Jungle Lodges and Resorts (JLR)[25] to set up both seasonal and full-time angling camps on the River Cauvery during the 1980s and 1990s. The income generated from recreational fisheries effectively controlled illegal fishing of mahseer through the establishment of anti-poaching camps, as well as rehabilitation of former poachers as 'Ghillies' or fishing guides, thus providing alternative employment and associated societal benefits. Catch records maintained at these fishing camps show that between 1989 and 1996, the large-sized mahseer captured by anglers ranged from 21.6 to 48.1 kg (ref. 23). Such success was to later capture the attention of international tour operators, and in 2006 a British-based angling tourism specialist, Angling Direct Holidays (ADH), secured an agreement with JLR for a block booking at the Galibore Camp between mid-January and mid-March of each year. Activity during this period has been restricted to a maximum of ten anglers practising a strict 'catch and release' policy. Catch data from Galibore (number, weight, phenotype notes, etc.) and fishing effort (time) were recorded in daily logs. Preliminary analyses of data collected between 1996 and 2012 demonstrate a dramatic increase in the total number of fish caught over time along with a reducing trend in individual mean weights. These data form the basis of a manuscript in preparation, but indicate elevated levels of recruitment in response to the reduction/elimination of poaching activities[26] and possibly assisted through stocking[27].

While the main focus of mahseer angling in South India has been on the River Cauvery, there is also considerable interest in recreational fisheries and conservation of golden mahseer, *T. putitora* in the rivers draining south from the Himalayan watershed[26–29]. Since 2007, Adventure Expedition Travels Pvt Ltd, through its subsidiary, India Angling (www.india-angling.com) adapted an 'integrated catchment value systems' model[30] and applied it for angling tourism in the Ramganga River at Bikhyasen in the Himalayan foothills. Local people were employed as helpers for the anglers, and the local temple at Sarna benefitted financially for providing accommodation. Furthermore, in association with the temple, fishing prohibition signboards were erected on the two prime pools holding large specimens of mahseer[29]. This model which provides incentives to local people to protect rivers through economic benefits acquired from recreational services has helped improve the conservation of *T. putitora* in the region[29].

Apart from the positive role played by recreational fishing, the success of these efforts also demonstrated the importance of engaging local communities in the conservation of endemic and threatened freshwater fish species. Recreational fishers constitute a social group that offers unique potential to enhance fish conservation. They have a vested interest in preserving or enhancing the resources they depend on and there is ample evidence to demonstrate that anglers work proactively to conserve, and where possible enhance, aquatic biodiversity[31], as well as motivating others to do so[32]. In addition, anglers have also been known to participate in developing pro-environmental legislations, and in taking legal action to oppose developments likely to be environmentally damaging[33,34].

The Indian Wildlife (Protection) Act 1972 (IWPA)[35] was enacted to provide the much needed legal protection to flora and fauna within areas set aside for protection (Protected Areas (PA)). While this item of legislation affords little attention to freshwater fish[4,36], the Act clearly states that 'No person shall hunt any "wild animal" specified in Schedule, I, II, III and IV, except under the provisions defined in Sections 11 and 12'. Despite fishes being included within the definition of 'wildlife', under Section 2(1), the Act does not explicitly draw attention to fish under the definition of 'wild animal', which is defined as including amphibians, birds, mammals, and reptiles, and their young, and in the case of birds and reptiles, their eggs. The only specific reference to protected fish species is restricted to Part IIA of Schedule I, which includes the following marine species, whale shark (*Rhinocodon typus*), shark and ray (all *Elasmobranchii*), sea horse (all *Sygnathidians*) and giant grouper (*Epinephelus lanceolatus*).

Despite this lack of clarity, the IWPA has previously been highlighted as a

Large Mahseer, Galibore Fishing Camp, River Cauvery (February 2010).

major factor constraining the effective conservation of declining mahseer populations throughout India due of the constraints placed on the development of recreational fisheries being managed to harmonize with conservation objectives[28]. Perhaps ironically, the Act has also been implicated in seriously impeding the access of scientists to conduct scientific research within the PAs[37].

Despite the effective participation-based conservation model practised on the River Cauvery, on 17 April 2009, a legal notice was issued under Section 55 of the IWPA. It questioned the construction (albeit temporary) of the privately owned Bush Betta fishing camp[24] within the Cauvery Wildlife Sanctuary, without prior approval from the National Wildlife Board (NWB) and the Supreme Court[38]. This was followed by the issue of a further legal notice to the Central Empowerment Committee (CEC) of the Supreme Court, drawing attention to the further violation of the IWPA by permitting angling within the boundaries of the Cauvery Wildlife Sanctuary. Under Section 2(16a) of the IWPA, the Ministry of Environment and Forests (MoEF), New Delhi has considered angling to be aligned with hunting; an activity which is prohibited within protected areas. As a result, all angling activity has recently been prohibited throughout the Cauvery Wildlife Sanctuary.

In spite of several decades of research on mahseers, there remain significant knowledge gaps in our understanding of basic biology and population dynamics of important species in Indian waters. Uncertainties exist on even the total number of mahseer species that occur in India, and also on the exact species status of the *Tor* found in the Cauvery. A recent gathering of experts agreed that these were immediate research priorities[22].

Due to the fact that many of the areas where mahseers are distributed are either physically remote or dispersed, often falling within protected forest areas, the involvement of local communities and other relevant stakeholders is vital for advancing both science and conservation. Engaging community and stakeholder participation in research is not only cost-effective, but also lays the foundation for co-management[39]. For example, with regard to recreational fisheries of mahseers, collaboration between scientists and anglers can provide valuable data that can inform future conservation actions. This has been successfully demonstrated in the case of the world's largest salmonid, the threatened Eurasian giant trout or the taimen, *Hucho taimen* in Mongolia[31].

Monitoring population performance of mahseers in monsoonal rivers is problematic due to the logistical difficulties in sampling such large fishes in challenging environments. Thus, there is a paucity of available data to assess the current status and vulnerability of stocks within the Cauvery and other rivers. The value of catch data collected by the Galibore angling camp on the River Cauvery has only recently been realized (manuscript in prep.). Despite potential sampling biases, these data provide temporal and spatial information on fish numbers, weights and phenotypes over a period of 15+ years. Within-year sample size can also be substantial, thus enhancing statistical validity of observations. For example, considering that the Cauvery angling season typically extends between October and April, in any one week, a group of ten anglers would typically amass a sample of 500 hours fishing.

While the promotion of 'catch and release' fisheries may assist in effecting conservation objectives, consideration should also be afforded to the potentially damaging influence of poorly informed fisheries management actions such as stocking to artificially enhance and maintain populations. In the case of the Cauvery, no baseline exists to describe the original mahseer community prior to the advancement of mahseer culture methods pioneered by Tata Electric Company[27] and the implications for future genetic integrity of populations. There also remain a host of anthropogenic catchment pressures which impact on stocks less directly by influencing fish movement, habitat and water quality. Until practising ichthyologists are in a position to quantify these impacts, there remains an urgent need to focus on the collection and collation of biological data to determine the current gene pool, and improve understanding of the biology and ecological requirements of these fishes.

Despite the current contentions of whether 'catch and release' angling constitutes 'hunting', provision exists within the IWPA to override the prohibition of hunting in PA's. Under Section 12, Chief Wildlife Wardens have the authority to grant hunting permits for specified animals, provided their capture is for the purpose of (a) education; 4(b) scientific research; (bb) scientific management. The 'Act' further defines clause (bb), the expression, 'scientific management' means (i) translocation of any wild animal to an alternative suitable habitat; or (ii) population management of wildlife, without killing or poisoning or destroying any wild animals.

In light of the perilous status of mahseer stocks and the evidence presented to support the positive role of recreational fisheries, it is recommended that 'catch and release' angling be actively encouraged throughout India. Furthermore, within well-managed fisheries, such as the Cauvery Wildlife Sanctuary, structured data collection programmes should constitute a condition of angling permits being issued to advance scientific research. A further recommendation is that all stocking activity within the Cauvery Wildlife Sanctuary and elsewhere in peninsular Indian river systems should be strictly prohibited until the current gene pool has been defined and an understanding of stock/wild fish interactions gained.

While there is little doubt that 'catch and release' practices are less likely to limit population performance than indiscriminate fishing methods such as dynamite fishing, a number of researchers have highlighted a range of risks which may be associated with recreational fishing methods. Risks have been synthesized to include a range of impacts from delayed post-release mortality[40,41] through to subtle physiological and behavioural effects[42] which could potentially impair predator avoidance capabilities of released fish, particularly in the presence of other apex predators such as crocodile (*Crocodylus palustris* and *Gavialis gangeticus*) and otter (*Lutrogale perspicillata*). In balancing the perceived benefits of 'catch and release' angling, there also remains a requirement to quantify any such factors which have the potential to impair conservation objectives.

Note

1. Although the species status of *T. mussullah* is ambiguous[43], for the sake of the present commentary, we consider 'mussullah' as a species of *Tor*.

1. Dudgeon, D., In *The Status and Distribution of Freshwater Biodiversity in Indo-*

Burma (compilers: Allen, D. J. *et al*.), IUCN, Cambridge, UK and Gland, Switzerland, 2012, p. 158.
2. Gray, R., *The Telegraph*, 30 July 2011; http://www.telegraph.co.uk/earth/wildlife/8672417/Third-of-freshwater-fish-threatened-with-extinction.html (accessed 10 February 2013).
3. Gozlan, R. E. *et al*., *Nature*, 2005, **435**, 1046.
4. Dahanukar, N. *et al*., In *The Status and Distribution of Freshwater Biodiversity of the Western Ghats* (compilers: Molur, S. *et al*.), IUCN, Cambridge, UK and Gland, Switzerland and Zoo Outreach Organization, Coimbatore, 2011, p. 116.
5. Dudgeon, D. *et al*., *Biol. Rev.*, 2006, **81**, 163–182.
6. Kottelat, M. *et al*., In *The Status and Distribution of Freshwater Biodiversity in Indo-Burma* (compilers: Allen, D. J. *et al*.), IUCN, Cambridge, UK and Gland, Switzerland, 2012, p. 158.
7. Gadgil, M., Chandrashekahariah, H. N. and Bhat, A., *The Hindu Survey of the Environment*, 2001, pp. 137–142.
8. de Silva, S. S., Abery, N. W. and Nguyen, T. T. T., *Divers. Distrib.*, 2007, **13**, 172–184.
9. Vishwanath, W. *et al*., In *The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya* (compilers: Allen, D. *et al*.), IUCN, Cambridge, UK and Gland, Switzerland and Zoo Outreach Organization, Coimbatore, 2011, p. 88.
10. Raghavan, R. and Ali, A., *Hypselobarbus lithopidos*. In IUCN Red List of Threatened Species, Version 2012.2; www.iucnredlist.org (accessed 16 February 2013).
11. Raghavan, R. and Ali, A., *Puntius deccanensis*. In IUCN Red List of Threatened Species. Version 2012.2; www.iucnredlist.org (accessed 16 February 2013).
12. Siraj, S. S. *et al.* (eds), *Mahseer: The Biology, Culture and Conservation*, Malaysian Fisheries Society, Serdang, Malaysia, 2007, p. 235.
13. Nguyen, T. T. T., Na-Nakorn, U., Sukmanomon, S. and Ziming, C., *Mol. Phylogenet. Evol.*, 2008, **48**, 1223–1231.
14. Stone, R., *Science*, 2007, **316**, 1684–1688.
15. Nautiyal, P., *Curr. Sci.*, 2006, **91**, 1604.
16. Trans World Fishing Team, *Quest for a Legendary Fish*, International Book Distributors, Dehra Dun, India, 1984, p. 154.
17. IUCN, The IUCN Red List of Threatened Species, Version 2012.2; http://www.iucnredlist.org (downloaded on 17 October 2012).
18. National Commission on Agriculture, Report on Fisheries, Government of India, 1976, vol. 8, p. 270.
19. Bhatt, J. P., Nautiyal, P. and Singh, H. R., *J. Asian Fish. Soc.*, 2004, **17**, 341–355.
20. Bhatt, J. P., Nautiyal, P. and Singh, H. R., *Fish. Res.*, 2000, **44**, 267–271.
21. Raghavan, R., Ali, A., Dahanukar, N. and Rosser, A., *Fish. Res.*, 2011, **110**, 29–38.
22. WWF, http://www.mahseerconservancy.org/blog/2012/09/26/wwf-workshop-in-delhi-mahseer-conservancy-program/ (accessed on 17 February 2013).
23. Sehgal, K. L., In *Fish and Fisheries at Higher Altitudes: Asia* (ed. Petr, T.), FAO Fisheries Technical Paper, No. 385, FAO, Rome, 1999, p. 304.
24. Jung, S. B., *Subhan and I: My Adventures with the Angling Legend of India*, Roli Books, 2012, p. 223.
25. www.junglelodges.com (accessed 16 February 2013).
26. Dinesh, K., Nandeesha, M. C., Nautiyal, P. and Aiyappa, P., *Indian J. Anim. Sci.*, 2010, **80**, 26–38.
27. http://www.fao.org/docrep/005/y3994e/y3994e0p.htm (accessed 26 February 2013).
28. Johnsingh, A. J. T., Negi, A. S. and Mohan, D., Report, Nature Conservation Foundation, Mysore and Wildlife Institute of India, Dehradun, p. 22.
29. Everard, M. and Kataria, G., *Aquat. Conserv. – Mar. Freshwater Ecosyst.*, 2011, **21**, 101–108.
30. Everard, M. *et al*., *J. Water Res. Prot.*, 2009, **3**, 174–187.
31. Granek, E. F. *et al*., *Conserv. Biol.*, 2008, **22**, 1125–1134.
32. Parkkila, K. *et al*., EIFAC Occasional Paper No. 46, FAO, Ankara, 2010, p. 112.
33. Bate, R., *Saving our Streams: The Role of the Anglers' Conservation Association in Protecting English and Welsh Rivers*, The Institute of Economic Affairs and Profile Books, London, 2001.
34. Kirchhofer, A., In *Conservation of Freshwater Fish: Options for the Future* (eds Collares-Pereira, M. J., Cowx, I. G. and Coelho, M. M.), Fishing News Books, Blackwell Science, Oxford, UK.
35. http://envfor.nic.in/modules/rules-and-regulations/wildlife/ (accessed 26 February 2013).
36. Sarkar, U. K., Pathak, A. K. and Lakra, W. S., *Biodiver. Conserv.*, 2008, **10**, 2495–2511.
37. Madhusudan, M. D. *et al*., *Curr. Sci.*, 2006, **91**, 1015–1019.
38. Nair, S., http://www.civilsocietyonline.com/Archive/dec10/dec101.asp (accessed on 24 February 2013).
39. Bene, C. *et al*., World Fish Center Technical Manual No. 1951, The World Fish Center, Penang, Malaysia, 2009, p. 23.
40. Arlinghaus, R. *et al*., *Rev. Fish. Sci.*, 2007, **15**, 75–167.
41. Cooke, S. J. and Cowx, I. G., *BioScience*, 2004, **54**, 857–859.
42. Arlinghaus, R. *et al*., *Fish. Res.*, 2009, **97**, 223–233.
43. Dahanukar, N. and Raghavan, R., In IUCN Red List of Threatened Species, Version 2012.2; www.iucnredlist.org. (accessed on 28 February 2013).

The opinions expressed in this commentary are those of the authors and not necessarily of the organizations they represent. The authors are also not funded or supported by any commercial angling/recreational fishing company or enterprise.

Adrian C. Pinder is in The School of Applied Sciences, Bournemouth University, and also in the Mahseer Trust, Fern Barrow, Poole, Dorset, BH12 5BB, UK; Rajeev Raghavan is in the Conservation Research Group, St Albert's College, Kochi 682 018, India.*
**e-mail: adrian@mahseertrust.com*