AMBIO (2010) 39:344–348
DOI 10.1007/s13280-010-0036-1

SYNOPSIS

Fish Migration, Dams, and Loss of Ecosystem Services in the Mekong Basin

Patrick J. Dugan, Chris Barlow, Angelo A. Agostinho, Eric Baran, Glenn F. Cada, Daqing Chen, Ian G. Cowx, John W. Ferguson, Tuantong Jutagate, Martin Mallen-Cooper, Gerd Marmulla, John Nestler, Miguel Petrere, Robin L. Welcomme, Kirk O. Winemiller

Received: 24 January 2010 / Accepted: 3 February 2010 / Published online: 3 June 2010

Abstract The past decade has seen increased international recognition of the importance of the services provided by natural ecosystems. It is unclear however whether such international awareness will lead to improved environmental management in many regions. We explore this issue by examining the specific case of fish migration and dams on the Mekong river. We determine that dams on the Mekong mainstem and major tributaries will have a major impact on the basin's fisheries and the people who depend upon them for food and income. We find no evidence that current moves towards dam construction will stop, and consider two scenarios for the future of the fisheries and other ecosystems of the basin. We conclude that major investment is required in innovative technology to reduce the loss of ecosystem services, and alternative livelihood strategies to cope with the losses that do occur.

Keywords Mekong · Inland fisheries · Fish migration · Dams · Ecosystem services · River development

This synopsis was not peer reviewed.

INTRODUCTION

The economic and social transformation of the twentieth century saw a dramatic increase in human population, economic activity and demand for natural resources (Costanza et al. 2007). In particular, the end of World War II was followed by a marked acceleration in the scope, scale and intensity of human impacts on the environment (Costanza et al. 2007). The Millennium Ecosystem Assessment documented these impacts, and concluded that they had fundamental consequences for human well-being (MEA (Millennium Ecosystem Assessment) 2005).

There is some evidence that a reduction in the rate of anthropogenic impacts on natural ecosystems is occurring due to declining fertility and birth rates, the emergence of environmental institutions and governance, and changing values and behaviours (Hibbard et al. 2007). This deceleration, however, is still modest, is confined largely to the post-industrial economies, and it remains unclear whether and when signs of deceleration will emerge in other regions (Hibbard et al. 2007).

We considered this issue through study of the fisheries of the Mekong river, a biologically diverse and highly productive ecosystem (Campbell 2009) that is the focus of intense development attention (Molle et al. 2009). We examined the potential impacts of proposed dam developments on fish migrations in the Mekong and their implications for the basin's fisheries. These are amongst the most important of the river ecosystem's provisioning services (MEA (Millennium Ecosystem Assessment) 2005), and their condition and future prospects provide important insights into the basin states' capacity to pursue economic development while maintaining natural ecosystems and the services they provide.

DAMS AND FISHERIES ON THE MEKONG

The social and environmental impacts of dams have attracted considerable concern (McCully 2001; Scudder 2005). In response, the World Commission on Dams produced policy principles and guidelines (Scudder 2005; WCD (World Commission on Dams) 2000), the hydropower industry developed sustainability guidelines (IHA (International Hydropower Association 2003), and dams

have been decommissioned and removed in some countries (Doyle et al. 2003). Although these changes have been accompanied by a global decline in new dam construction, many dams still continue to be built in Africa, Asia and Latin America in response to demographic and economic growth, and rising demand for energy.

This continued focus on hydropower investment is clearly evident in Southeast Asia and especially in the Mekong river basin. China completed the first dam across the mainstem of the Mekong in 1995 (Li and He 2008), followed by two others completed in 2003 and 2008, and a further five are planned (Barlow et al. 2008). Further downstream, there are over 100 proposals for new dams in the lower basin that lies within Cambodia, Laos, Thailand and Vietnam. Of these, 11 are scheduled to be installed on the mainstem of the river within the next decade. Seven of these are located in Laos, two in Cambodia and two will be shared between Laos and Thailand (MRC (Mekong River Commission) 2008).

This massive acceleration in plans for hydropower development in the Mekong has led to growing concern over the potential environmental, economic and social costs; in particular, there is acute concern over the impact on the basin's fisheries. With an estimated annual harvest of 2.2 million tonnes of wild fish, the Mekong supports the world's largest inland fishery, annually worth US$2.2–3.9 thousand million at first sale and between US$4.3 and US$7.8 thousand million on retail markets (Hortle 2009). This catch is essential for livelihoods, nutrition and food security, with annual consumption in the lower basin between 29 and 39 kg per capita and accounting for 47–80% of total animal protein consumed (Hortle 2007). It also sustains livelihoods for millions of people. In Lao PDR more than 3 million people fish, mainly from the Mekong and its tributaries. In Cambodia, 80% of the 1.2 million people living around Tonle Sap use the lake and its rivers for fishing (Ahmed et al. 1998).

Dams will bring a range of changes to the river and its fish habitats (Postel 1997). In particular, altered flow regimes will degrade the feeding and breeding habitats along the river (Kummu and Sarkkula 2008), and the physical barrier of the dam wall will stop migration (Barlow et al. 2008; Baran and Myschowoda 2008). Because 40–70% of fish catch in the Mekong depends on species that migrate long distances along the Mekong mainstream and into its tributaries (Barlow et al. 2008; Baran and Myschowoda 2008), these fish stocks will be especially vulnerable to dams built on the mainstem or lower reaches of tributaries.

DAMS AND FISH MIGRATION

In view of these concerns and the special importance of migratory fish in the Mekong, we conducted an assessment of the potential impact of mainstem dams on fish migration and recruitment in the Mekong and on the fisheries that depend upon migratory species (Dugan 2008). We did so under the auspices of the Mekong River Commission and brought together expertise covering dams and fisheries in over 20 river systems in Asia, Africa, Australia, Latin America, North America and Europe. We reviewed available information on ecological and population characteristics for important fish species in the Mekong and comparable rivers, as well as experience in designing and operating hydroelectric dams to minimize impacts on migratory fish populations.

We concluded that the dams currently planned for the Mekong will have a major impact on the fisheries of the basin. In particular, we concluded that the barriers created by the dams will disrupt upstream spawning migration of economically and biologically important species (Dugan 2008). In addition, the downstream drift of fish eggs and larval stages that sustain fisheries recruitment will be compromised, mainly because juvenile life stages will be trapped in the impoundments. Dams in the middle and lower reaches of the lower Mekong basin, including in the major tributaries, will stop the longest migrations and disrupt recruitment to the lower reaches of the river. Although the impacts of dams higher in the basin and on individual tributaries will be restricted to the fish populations that use these reaches, these populations contribute substantially to fish production along large stretches of the river (Poulsen et al. 2002).

In other regions of the world, a suite of fish passage technologies has been developed to partially mitigate the impacts of dams. However, our assessment concluded that existing mitigation technology in the form of fishways, locks and lifts cannot cope with the scale of fish migration on the Mekong mainstream, which involves over 50 species, many tens of millions of individuals, and biomass that is much greater than that found today in the rivers of Europe and North America (Dugan 2008; Baran et al. 2001; Halls 2009). In addition, fish passage mitigation measures for dams in North America and Europe necessitated research and development conducted over decades, and relied on teams of experienced biologists and fish passage engineers. Similar investments would be needed in the Mekong before any level of certainty on their effectiveness could be determined. Furthermore, specific mitigation measures adapted to the species and hydrological conditions of the Mekong would need to be designed from the start and integrated into dam engineering and operation. Given the lack of investment so far, it is unlikely that any substantial mitigation measures will be available in the foreseeable future.

WILL MORE DAMS BE BUILT?

There is strong evidence that dams on the Mekong mainstem will stop a significant portion of the longitudinal fish

migration required to sustain the river's fisheries at present levels. In contrast, we see no evidence that the drivers of environmental sustainability (Hibbard et al. 2007) have enough traction in the Mekong region to have an impact on the forces currently driving investment in dam construction. For this to change, increased awareness is needed at multiple levels, together with adequate technical capacity, and better environmental governance (Hibbard et al. 2007; Lambin 2005). These factors are today only present in the Mekong basin to a limited degree. Although many of the 60 million people who live in the lower Mekong basin are keenly aware of the importance of the river's fisheries, and those who fish recognize changes in catch (Baran and Myschowoda 2008), they generally have little knowledge of the potential impacts that future dams may have on their livelihoods and food security (Osborne 2009). Public engagement in environmental assessment activities, in particular, remains limited (UNEP et al. 2006), fisheries rarely appear in the discourse of politicians (Friend et al. 2009), and most water resource developers are unaware of the importance of the fisheries or the impacts of dams (Osborne 2009).

Similarly the limited science capacity in the basin constrains the emergence and use of new technology, as does the tendency of current national planning approaches to focus on the benefits of dams and give little attention to impacts (Dore 2003; Molle 2005). Moreover, governance conditions within the basin are not conducive to robust debate of these and other issues (Lebel and Garden 2005; Öjendal and Mathur 2002). Cooperation between government agencies and NGOs in particular is limited, and with the exception of Thailand few domestic NGOs are able to represent local community interests independently (UNEP et al. 2006; United Nations 2008). The impact of the Mekong River Commission, the one institution charged with facilitating regional cooperation in management of the river, is also limited (Dore 2003; Ratner 2003), as is debate of sustainable development options at the national level.

CONCLUSION

Our assessment provides no evidence to suggest that the current drive towards dams on the mainstem of the Mekong will stop. We conclude that if this proves correct a large part of the river's fish production, and the economic, nutritional and social benefits of this ecosystem service will be lost in the coming decades. Given this grim prognosis for Mekong fisheries, we consider two broad scenarios for the future well-being of people who depend upon these resources. In the first institutions and communities are unable to adapt to dams, with the significant loss of fisheries and other benefits that we foresee. This will in turn result in large scale loss of livelihoods and nutrition and social disruption for millions of people in the basin, and especially in the low income communities of Cambodia, Laos and Vietnam. This pessimistic scenario dominates the international environmental discourse on the Mekong (McCully 2001; Rivers 2009). It raises the prospect of increased social conflict and rural-to-urban migration in search of employment (Osborne 2006). Given that 80% of the basin remains rural and urban employment is still limited, this scenario also raises the risk of increased movement of people beyond the confines of the basin (Homer-Dixon 2001).

In the second scenario, the basin's institutions and communities adapt successfully to the environmental, economic and social changes that arise as a result of dam construction and the loss of fisheries. This optimistic scenario dominates the discourse of dam proponents who argue that hydroelectric power will help drive economic diversification, and the income generated through the export of electricity will provide for other investments in the national economy (World Bank 2009). These will provide for enterprise development in both rural and urban settings and employment for those who can no longer earn income from fishing. These are plausible arguments, and Asia's economic growth in recent decades provides reason for optimism. In contrast, substantial international experience of dam development suggests that the probability of successful adaptation by fishing communities in the face of ecosystem degradation is low (Scudder 2005; WCD (World Commission on Dams) 2000), especially without first investing in diversifying and strengthening livelihoods so that the poor are better able to cope with the changes arising from dam development. This will be especially difficult for the Mekong given the limited capacity of national institutions to pursue integrated approaches to basin development (UNEP et al. 2006), and the marginal participation of poor stakeholders in political decision making (Dore 2003).

Future innovations may help society meet challenges currently believed to be insurmountable (Hibbard et al. 2007). In the Mekong investments to identify, develop and apply such innovations are now required urgently. These will need to tailor the planning, design and operation of dams to sustain river fisheries and other ecosystem services. This has so far proved elusive in all other major rivers with hydropower developments similar to those proposed for the Mekong, and doing so in the Mekong presents a formidable challenge. In the absence of such a breakthrough, current best evidence suggests significant and rapid loss of natural ecosystems and their services in the basin, leading to major social and economic impacts. The search for innovative solutions that avoid such impacts therefore needs to accelerate, while being accompanied by

investments that build capacity to adapt to the prospect of declining fisheries and other ecosystem services. Such adaptation will inter alia need to consider new livelihood strategies for large numbers of people living along the Mekong and its tributaries. Only by pursuing this dual approach will it be possible to minimize the negative impacts of future basin development on the poor who depend on the basin's natural ecosystems.

Acknowledgements We thank E. Allison, N. Andrew, L, Baumgartner, M. Beveridge, A. Brooks, S. Hall, and B. Ratner for their comments on drafts of this paper.

REFERENCES

Ahmed, M., N. Hap, V. Ly, and M. Tiongco. 1998. *Socioeconomic assessment of freshwater capture fisheries in Cambodia: Report on a household survey*. Phnom Penh: MRC.

Baran, E., and C. Myschowoda. 2008a. Dams and fisheries in the Mekong basin. *Aquatic Ecosystem Health and Management* 12: 227–234.

Baran, E., and C. Myschowoda. 2008b. Have fish catches been declining in the Mekong river basin. In *Modern Myths of the Mekong: A critical review of water and development concepts, principles and policies*, ed. M. Kummu, M. Keskinen, and O. Varis, 55–64. Helsinki: Helsinki University of Technology.

Baran, E., N. van Zalinge, P.B. Ngor, I.G. Baird, and D. Coates. 2001. *Fish resource and hydrobiological modelling approaches in the Mekong Basin*. Penang: ICLARM.

Barlow, C., E. Baran, A. Halls, and M. Kshatriya. 2008. How much of the Mekong fish catch is at risk from mainstem dam development? *Catch and Culture* 14: 16–21.

Campbell, I.C. 2009. *The Mekong. Biophysical environment of a transboundary river*. New York: Elsevier.

Costanza, R., L. Graumlich, and W. Steffen. 2007a. *Sustainability or collapse? An integrated history and future of people on earth*. Cambridge: MIT Press.

Costanza, R., L. Graumlich, W. Steffen, C. Crumley, J. Dearing, K. Hibbard, R. Leemans, C. Redman, and D. Schimel. 2007b. Sustainability or collapse: What can we learn from integrating the history of humans and the rest of nature? *Ambio* 36: 522–527.

Dore, J. 2003. The governance of increasing Mekong regionalism. In *Social challenges for the Mekong region*, ed. M. Kaosaard, and J. Dore, 405–440. Bangkok: White Lotus.

Doyle, M.W., E.H. Stanley, J.M. Harbor, and G.S. Grant. 2003. Dam removal in the United States: Emerging needs for science and policy. *Eos, Transactions, American Geophysical Union* 84: 29–36.

Dugan, P. 2008. Mainstream dams as barriers to fish migration: International learning and implications for the Mekong. *Catch and Culture* 14: 9–15.

Friend, R., A. Arthur, and M. Keskinen. 2009. Songs of the doomed: The continuing neglect of capture fisheries in hydropower development in the Mekong. In *Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance*, ed. F. Molle, T. Foran, and M. Käkönen. London: Earthscan.

Halls, A.S., and M. Kshatriya. 2009. *Modeling the cumulative effects of mainstream hydropower dams on migratory fish populations in the lower Mekong basin*. Final report to the Mekong River Commission Secretariat.

Hibbard, K.A., P. Crutzen, E.F. Lambin, D. Liverman, N.J. Mantua, J.R. McNeill, B. Messerli, and W. Steffen. 2007. The great acceleration. In *Sustainability or collapse? An integrated history and future of people on earth*, ed. R. Costanza, L.J. Graumlich, and W. Steffen, 341–378. Cambridge: MIT Press.

Homer-Dixon, T.F. 2001. *Environment, scarcity and violence*. Princeton: Princeton University Press.

Hortle, K.G. 2007. *Consumption and yield of fish and other aquatic animals from the lower Mekong Basin*. MRC technical paper no. 16. MRC: Vientiane.

Hortle, K.G. 2009. Fisheries of the Mekong river basin. In *The Mekong. Biophysical environment of a transboundary river*, ed. I.C. Campbell. New York: Elsevier.

IHA (International Hydropower Association). 2003. *The role of hydropower in sustainable development.* Sutton: IHA.

International Rivers. 2009. *Mekong Mainstream Dams: Threatening southeast Asia's food security*. Berkeley: International Rivers.

Kummu, M., and J. Sarkkula. 2008. Impact of the Mekong river flow alteration on the Tonle Sap flood pulse. *Ambio* 37: 185–192.

Lambin, E.F. 2005. Conditions for sustainability of human-environment systems: information, motivation, and capacity. *Global Environment Change* 15: 177–180.

Lebel, L., P. Garden, and M. Imamura. 2005. The politics of scale, position, and place in the governance of water resources in the Mekong region. *Ecology and Society* 10(2):18. http://www.ecologyandsociety.org/vol10/iss2/art18.

Li, S., and D. He. 2008. Water level response to hydropower development in the upper Mekong river. *Ambio* 37: 170–177.

McCully, P. 2001. *Silenced rivers: The ecology and politics of large dams*. London: Zed Books.

MEA (Millennium Ecosystem Assessment). 2005. *Ecosystems and human well-being: Synthesis*. Washington, DC: Island Press.

Molle, F. 2005. *Irrigation and water policies in the Mekong region: Current discourses and practices*. Colombo: IWMI.

Molle, F., T. Foran, and M. Käkönen. 2009. *Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance*. London: Earthscan.

MRC (Mekong River Commission). 2008. Proposed and operational dams on the mainstream Mekong. http://www.mrcmekong.org/ish/map.htm.

Öjendal, J., V. Mathur, and M. Sithirith. 2002. *Environmental governance in the Mekong: Hydropower site selection processes in the Se San and Sre Pok Basins*. SEI/REPSI report series no. 4. Stockholm: Stockholm Environment Institute.

Osborne, M. 2006. *The Mekong: Turbulent past, uncertain future*. Sydney: Allen and Unwin.

Osborne, M. 2009. *The Mekong: River under threat*. Sydney: Lowy Institute.

Postel, S., and C. Carpenter. 1997. Freshwater ecosystem services. In *Nature's services: Societal dependence on natural ecosystems*, ed. G.C. Daily. Washington, DC: Island Press.

Poulsen, A.F., P. Ouch, V. Sintavong, S. Ubolratana, and T.T. Nguyen. 2002. *Fish migrations of the Lower Mekong River Basin: Implications for development, planning and environmental management*. MRC technical paper no. 8. Phnom Penh: MRC.

Ratner, B.D. 2003. The politics of regional governance in the Mekong river basin. *Global Change* 15: 51–76.

Scudder, T. 2005. *The future of large dams: Dealing with social environmental, institutional, and political costs*. London: Earthscan.

UNEP, A. Snidvongs, and S.-K. Teng. 2006. *Mekong River: GIWA regional assessment 55*. Kalmar: University of Kalmar.

United Nations. 2008. Report of the special representative of the Secretary-General for human rights in Cambodia, Yash Ghai. United Nations General Assembly, Human Rights Council (29 February 2008). http://daccessdds.un.org/doc/UNDOC/GEN/G08/115/04/PDF/G0811504.pdf?OpenElement.

WCD (World Commission on Dams). 2000. *Dams and development: A new framework for decision-making*. London: Earthscan.
World Bank. 2009. *Directions in hydropower*. Washington, DC: World Bank.

Patrick J. Dugan (✉)
Address: WorldFish Center, 10670 Penang, Malaysia.
e-mail: p.dugan@cgiar.org

Chris Barlow
Address: Australian Centre for International Agricultural Research, Canberra, ACT 2601, Australia.

Angelo A. Agostinho
Address: Fundação Universidade Estadual de Maringá, CEP 87020-900 Maringá, Brazil.

Eric Baran
Address: WorldFish Center, Phnom Penh, Cambodia.

Glenn F. Cada
Address: Oak Ridge National Laboratory, Oak Ridge, TN 37831-6036, USA.

Daqing Chen
Address: Yangtze River Fisheries Research Institute, Jingzhou City, China.

Ian G. Cowx
Address: Hull International Fisheries Institute, Hull, UK.

John W. Ferguson
Address: Northwest Fisheries Science Center, Seattle, WA 98112, USA.

Tuantong Jutagate
Address: Ubon Ratchathani University, Ubon Ratchathani, Thailand.

Martin Mallen-Cooper
Address: Fishway Consulting Services, St Ives Chase, NSW 2075, Australia.

Gerd Marmulla
Address: Food and Agriculture Organization of the United Nations, Rome, Italy.

John Nestler
Address: US Army Corps of Engineers, Concord, MA, USA.

Miguel Petrere
Address: Universidade Estadual Paulista, 13506-900 Rio Claro, Brazil.

Robin L. Welcomme
Address: Stoke by Clare CO10 8HJ, UK.

Kirk O. Winemiller
Address: Texas A&M University, College Station, TX 77843-2258, USA.