Short Communication

A watershed moment for the Mekong: newly announced community use and conservation areas for the Tonle Sap Lake may boost sustainability of the world's largest inland fishery

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Paper submitted 25 July 2012, revised manuscript accepted 9 December 2012.

Freshwater biodiversity and ecosystem services are critically important to human wellbeing throughout the Lower Mekong River watershed and particularly so around the Tonle Sap Great Lake of Cambodia (hereafter the Tonle Sap Lake). Though seemingly lacustrine, the Tonle Sap Lake is actually an enormous wetland within a major tributary of the Lower Mekong River. The wetland is the largest natural freshwater body in Southeast Asia, a UNESCO Biosphere Reserve, the epicenter of the region's incredible freshwater biodiversity, and the foundation of food security for Cambodia. Its fisheries directly yield ~350,000 tonnes of the 2.6 million-tonne annual fresh-

CITATION: Cooperman, M.S., So N., Arias, M., Cochrane, T.A., Elliott, V., Hand, T., Hannah, L., Holtgrieve, G.W., Kaufman, L., Koning, A.A., Koponen, J., Kum V., McCann, K.S., McIntyre, P.B., Min B., Ou C., Rooney, N., Rose, K.A., Sabo, J.L. & Winemiller, K.O. (2012) A watershed moment for the Mekong: newly announced community use and conservation areas for the Tonle Sap Lake may boost sustainability of the world's largest inland fishery. *Cambodian Journal of Natural History*, **2012,** 101–106.

water fish harvest of the Lower Mekong watershed and the Tonle Sap Lake serves as a crucial nursery ground for migratory fish populations throughout the 606,000 km^2 watershed (Hortle, 2007; MRC, 2010). The importance of this fishery is immense. Mekong fishes provide the majority of the animal protein consumed by >50 million people in the basin (Hortle, 2007) and ~2 million Cambodians are directly involved in the Tonle Sap Lake fishery (Nam & Song, 2011). However, multiple indicators — including declining fish size and catch-per-unit-effort, elimination of the largest and most valuable species, and increasing prevalence of less desirable species in the catch (Enomoto *et al.*, 2011) — reveal severe challenges to the sustainability of the fishery.

Amid growing concerns over the present status and potential future impacts on Cambodia's freshwater fisheries from hydropower dams, expanding agro-industry in the upper watershed, climate change, a rapidly increasing human population, and inequity in the distribution of benefits derived from these fisheries, in February 2012 Prime Minister Hun Sen announced the permanent cancellation of all 80 commercial fishing lots in the Lower Mekong watershed in Cambodia. Of the lots closed, 38 were in the Tonle Sap Lake (Fig. 1). These 38 fenced lots have been fished intensively for decades, resulting in the nearly complete removal of fish from approximately 20% of the area of the Tonle Sap Lake every year. From 10 April 2012, the Tonle Sap Lake lots will be apportioned as community-use areas (~76%) and conservation areas (no-harvest reserves, ~24%).

This bold move may prove to be an essential first step toward maintaining fishery productivity and protecting the biological diversity that supports it. Yet the new management regime will be beset with challenges as it makes the transition from delineated fishing concessions with strict enforcement of boundaries, a closed season, and habitat protection, to a diffuse and mobile fleet of tens of thousands of fishers using a vast diversity of gear types and organised into hundreds of fishing communities overseen by officials with limited enforcement capacity. We suggest the odds of success — i.e. protecting and enhancing the sustainability of the fishery — will be enhanced if the new system draws upon lessons from marine protected areas, adds auxiliary protections for migratory species, and actively governs against a "tragedy of the commons" scenario.

The proposed network of conservation areas totals ~600 km^2, comparable in size to the largest intensively-studied marine protected areas (MPAs) (Lester *et al.*, 2009). Management of this unparalleled collection of freshwater conservation areas should start with lessons learned from its marine counterparts. Perhaps the most notable lesson from MPAs is that size and location of conservation areas (also known as no-harvest zones or reserves) are crucial decisions. The benefits to both fisheries yield and biodiversity conservation from MPAs have been shown to increase with reserve size (Claudet *et al.*, 2008), and enforcement is more straightforward in a few large reserves than in many small ones. The efficacy of such reserves also depends on protecting both a range of habitat types and the connections among them (Sala *et al.*, 2002), and fisheries benefits may be optimised when habitat type is consistent on both sides of a conservation area boundary (Forcada *et al.*, 2008). Unlike MPAs, the Tonle Sap Lake conservation areas must account for seasonal fluctuations in water level. Provision of an adequate quantity and quality of low water habitats is critical, lest protected fishes be flushed from conservation areas by annual changes in water levels.

Hence, detailed spatial planning should play a central role in designing the Tonle Sap Lake reserve network. We suggest that the conservation portions of the 38 lots be consolidated into a smaller number of large reserves distributed along the Southeast-Northwest axis of the Tonle Sap Lake and include the mouth of the Tonle Sap River and other large tributaries (i.e., Pursat River, Sangkea River, etc.) to ensure there is biological connectivity to the rest of the watershed. The proposed conservation areas should encompass the best remnants of forests and other riparian habitats that flood seasonally because these areas are important for fish recruitment. Lake circulation patterns should also be accounted for, as they likely dictate where larval settlement, retention, and survival rates are highest. If large reserves are embedded within community-managed fishing areas, "spill-over" benefits may accrue from the export of post-reproductive adults and new recruits (Halpern *et al.*, 2010).

Another lesson from MPAs is that fish life history strategies matter. Almost all of the several hundred fish species known or suspected to use the Tonle Sap Lake are harvested, but only some are likely to benefit from the conservation areas in the absence of other forms of protection. In general, species with long-lived sedentary adults and dispersing progeny usually benefit from no-harvest areas while migratory species are more problematic (Russ & Alcala, 1996). Winemiller (2005) provides a framework for predicting how the fishes of the lake will respond to the conservation area network (Fig. 2). *Opportunistic species* are small, rapidly-maturing and have a high reproductive effort and a relatively short lifespan. This group of species comprises the bulk of both species diversity and catch in the current Mekong fishery, and these species should respond rapidly to reserves. However, they typically have low market value.

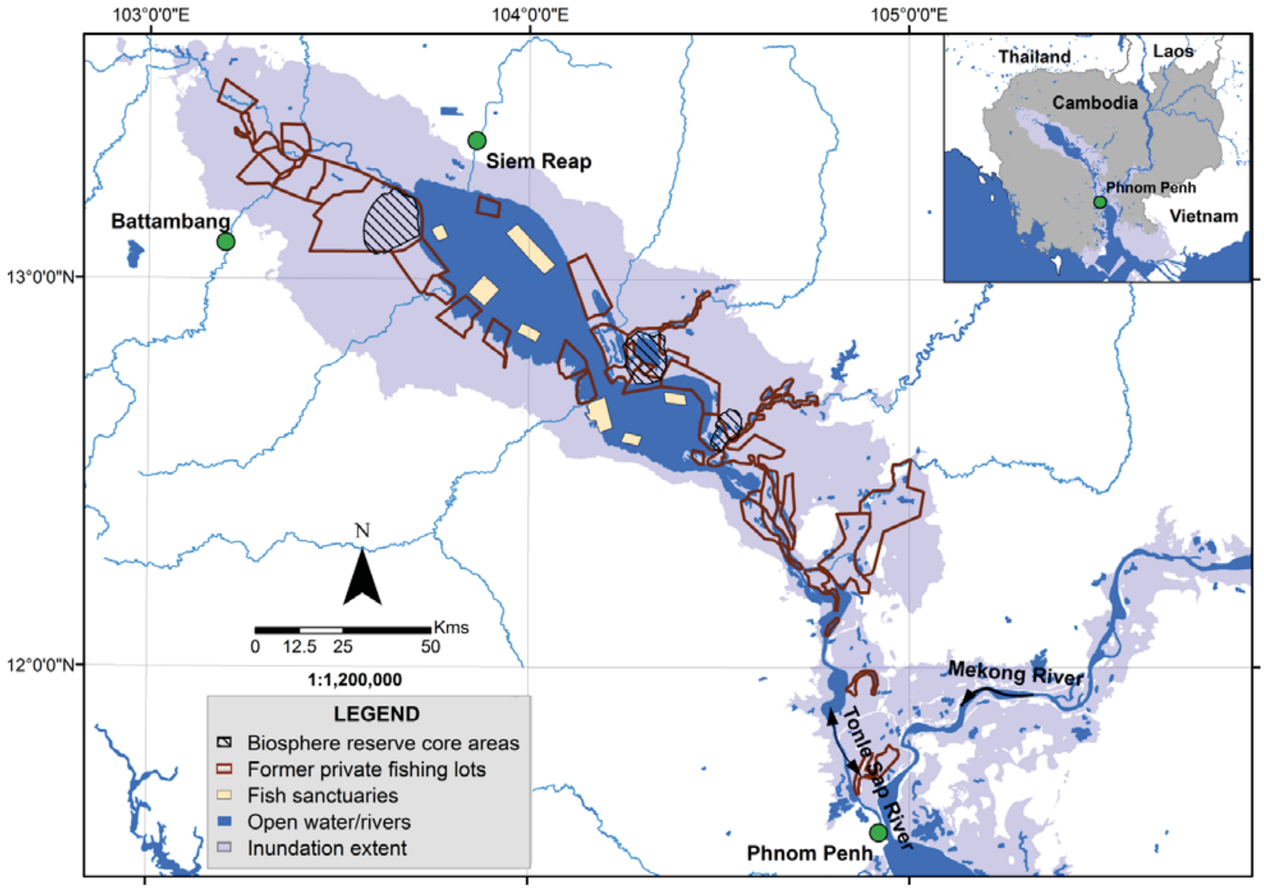

Fig. 1 The Tonle Sap Lake ecosystem of Central Cambodia, showing the tremendous annual change in lake surface area between dry and wet seasons and locations of the now-closed fishing lots.

Equilibrium strategists have relatively low fecundity, high parental investment per offspring, and tend to be sedentary. Despite low demographic resilience, these species should benefit from reserves both via adults in reserves surviving to older ages with greater fecundity, and via juveniles that seed fished areas where growth rates will be high due to low competition for resources. Finally, *periodic strategists* tend to be larger and migrate long distances to exploit spatial and temporal variation in the environment. They mature at larger sizes and ages, and they release huge batches of tiny eggs during discrete spawning periods. Many periodic breeders spawn in the Lower Mekong or Tonle Sap rivers with their young transported into the Tonle Sap Lake during annual floods. Conservation areas in flooded forests and shrublands of the Tonle Sap Lake may aid smaller and rapidly maturing periodic-type species by increasing survival of early life stages. However, the far-ranging movements of these species will keep them vulnerable to over-exploitation as they move beyond the boundaries of reserves. Indeed, the most valuable species in the fishery are periodic breeders that mature at older ages, and these species are unlikely to benefit from the Tonle Sap Lake reserves unless granted additional protection outside the reserve network.

Harvest regulations to complement the Tonle Sap Lake conservation areas are therefore essential for protecting economically-valuable migratory fishes. Currently, the dai fishery in the Tonle Sap River uses rows of barge-mounted drift nets to non-selectively harvest fishes migrating between the Tonle Sap Lake and the Mekong River. This fishery harvests ~15,000 tonnes annually, including harvest rates of up to 500 kg of small 'trey riel' (*Henicorhynchus siamensis* and *H. lobatus*) per 15-minute set for each individual net from December–February (Halls *et al.*, in press). Nearby, the barrage system of river-spanning fences guides fish of all sizes into nets as they move downstream. Together, these methods reduce escapement of adults and recruits to the point that some large, migratory species are on the brink of extinction (e.g. giant catfish *Pangasianodon gigas*,

Fig. 2 Sorting the fish catch from the barrage fishery of the Tonle Sap River. Insets: (Top) *Paralaubuca typus*, an example of fish with an opportunistic life history strategy; (Middle) *Channa micropeltes*, a fish with an equilibrium life history strategy; (Bottom) *Pangasius larnaudii*, a fish with a periodic life history strategy.

and giant barb *Catlocarpio siamensis*), and the fishery is dominated by a handful of resilient, small and low value species. We support the recommendation of both Cambodia's Inland Fisheries Research and Development Institute (INFReDI) and the Mekong River Commission to Cambodia's Fisheries Administration that the Tonle Sap River fisheries be closed periodically to enhance escapement (Nam, 2010). Expanding harvest restrictions and reserve-style protections to deep pools of the Mekong River would also benefit the migratory fishes of the Tonle Sap Lake (Baird, 2006).

Experience shows that no-harvest reserves are most effective when coupled with active management of fished areas (Hilborn *et al.*, 2006). Curtailing the use of poisons, explosives and ultra-effective gear that catch entire schools of migrating fishes is essential. Such measures have proven successful elsewhere in the Lower Mekong, as have seasonal closures to protect spawning aggregations (Coates *et al.*, 2003). Regulating the mesh size of gill nets to limit harvest of either small or exceptionally large fishes is another potential approach. Support for gear exchange programmes (i.e. a "trade-in" programme whereby "undesirable" fishing equipment is exchanged for approved gear at no or low cost to the owner) is one way the international community could assist Tonle Sap Lake management. Low household income within local fishing communities would make it difficult to prohibit existing fishing gears in the absence of such support.

Both community acceptance and enforcement will need to be put in place rapidly to prevent the new conservation and community use areas from turning into de facto open-access fisheries because even low levels of poaching within these areas will erode their benefits to legal fishers (Sethi & Hilborn, 2008). Procedures for garnering community support for no-harvest reserves include: involving the affected communities within a participatory planning process; clearly articulating broad goals and specific catch quotas; acknowledging trade-offs between maximising economic benefits, food production, and biodiversity; recognising strong community leaders coupled with building local capacity (Gutierrez *et al.*, 2011); and empowering the fishing community via property rights and representation in future management (Ostrom, 2009).

Managing public expectations through education is particularly important due to the unavoidable time lag between establishing conservation areas and observing demographic responses in the long-lived fish species that are prized by commercial and community fisheries (Halpern, 2003). The transition from commercial lots to community fisheries also increases the need for communication among fishers and managers, because the mobility of the target fishes vastly exceeds the area governed by any single authority. Boosting capacities for this coordination is a potential role for international nongovernmental organisations.

At present, the governance structure that will emerge for the new conservation and community use areas is unclear. Adequately defining the responsibilities of the numerous government institutions and community organisations active within the Tonle Sap Lake ecosystem will be critical to the success of the newly established community use and conservation areas. A comprehensive assessment of Tonle Sap Lake governance is beyond the scope of this paper, but we note that a recent review describes a history of competing mandates and professional rivalries amongst multiple government agencies which collectively have retarded the emergence of a unified vision for the ecosystem and its resources (Keskinen & Varis, 2012). Given its importance and recent history, it appears reasonable that addressing the questions of how and for what purposes the Tonle Sap Lake will be managed is a compelling need. As above, this may be an area where international nongovernmental organisations could provide assistance.

Prime Minister Hun Sen should be applauded for moving boldly to address impending threats to Cambodia's freshwater fisheries. The decision to eliminate harvest from a substantial portion of the Tonle Sap Lake ecosystem and transition to community-based fisheries and conservation areas is a laudable first step towards protecting the globally-recognised resources of this ecosystem. However, if these actions are not supported by complementary measures – including optimising the design of the conservation area network, designing enforceable fishery laws and regulations that include explicit protection for migratory fishes, and cultivating support within local communities – they are likely to realise only part of their promise. Momentous decisions remain to be made, and recent insights into the hallmarks of successful fishery management provide clear guidance that can readily be applied to the Tonle Sap Great Lake of Cambodia.

References

Baird, I.D. (2006) Strength in diversity: fish sanctuaries and deep-water pools in Lao PDR. *Fisheries Ecology and Management*, **13,** 1–8.

Claudet, J., Osenberg, C.W., Benedetti-Cecchi, L., Domenici, P., Garcia-Charton, J.A., Perez-Ruzafa, A., Badalamenti, F., Bayle-Sempere, J., Britio, A., Bulleri, F., Culioli, J.M., Dimech, M., Falcon, J.M., Guala, I., Milazzo, M., Sanchez-Meca, J., Somerfield, P.J., Stobart, B., Vandeperre, F., Valle, C. & Planes, S. (2008) Marine reserves: size and age do matter. *Ecology Letters*, **115,** 481–489.

Coates, D., Poeu O., Suntornratana, U., Tung N.T. & Viravong, S. (2003) *Biodiversity and Fisheries in the Mekong River Basin*. Mekong Development Series no. 2, Mekong River Commission, Phnom Penh, Cambodia.

Enomoto, K., Ishikawa, S., Hori, M., Hort S., Song, S.L., Nao T. & Kurokura, H. (2011) Data mining and stock assessment of fisheries resources in Tonle Sap Lake, Cambodia. *Fisheries Science*, **77,** 713–722.

Forcada, A., Bayle-Sempere, J.T., Valle, C. & Sanchez-Jerez, P. (2008) Habitat continuity effects on gradients of fish biomass across marine protected area boundaries. *Marine Environmental Research*, **66,** 536–547.

Gutierrez, N.L., Hilborn, R. & Defeo, O. (2011) Leadership, social capital and incentives promote successful fisheries.

Nature, **470,** 386–389.

Halls, A.S., Paxton, B.R., Hall, N., Pengbun, N., Lieng S., Pengby, N.& Nam S. (in press) *The Stationary Trawl (Dai) Fishery of the Tonle Sap-Great Lake, Cambodia*. Mekong River Commission Technical Paper, Mekong River Commission, Phnom Penh, Cambodia.

Halpern, B.S. (2003) The impact of marine reserves: do reserves work and does reserve size matter? *Ecological Applications*, **13,** S117–S137.

Halpern, B.S., Lester, S.E. & Kellner, J.B. (2010) Spillover from marine reserves and the replenishment of fished stocks. *Environmental Conservation*, **36,** 268–276.

Hilborn, R., Micheli, F. & de Leo, G.A. (2006) Integrating marine protected areas with catch regulation. *Canadian Journal of Fisheries and Aquatic Sciences*, **63,** 642–649.

Hortle, K.G. (2007) *Consumption and Yield of Fish and Other Aquatic Animals From the Lower Mekong Basin*. Mekong River Commission technical paper no. 16, Mekong River Commission Vientiane, Lao PDR.

Keskinen, M. & Varis, O. (2012) Institutional cooperation at a basin level: for what, by whom? Lessons learned from Cambodia's Tonle Sap Lake. *Natural Resource Forum*, **36,** 50–60.

Lester, S.E., Halpern, B.S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B.I., Gaines, S.D., Airame, S. & Warner, R.R. (2009) Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology-Progress Series*, **384,** 33–46.

MRC – Mekong River Commission (2010) *Fisheries Baseline Assessment Working Paper, v. II*. Mekong River Commission and the International Centre for Environmental Management.

Nam S. (2010) *Recommendations for the Management of Tonle Sap River Dai Fishery*. Report by Cambodia's Inland Fisheries Research and Development Institute for the Fisheries Administration of Cambodia. [In Khmer, verbal translation provided by Nam S.].

Nam S. & Song, S.L. (2011) Fisheries management and development in Tonle Sap Great Lake, Cambodia. *Paper presented to the Consultation on Development Trends in Fisheries and Aquaculture in Asian Lakes and Reservoirs, 20–23 September 2011, Wuhan, China*.

Ostrom, E. (2009) A general framework for analyzing sustainability of social-ecological systems. *Science*, **325,** 419–422.

Russ, G.R. & Alcala, A.C. (1996) Do marine reserves export adult fish biomass? Evidence from Apo Island, Central Philippines. *Marine Ecology–Progress Series*, **132,** 1–9.

Sala, E., Aburto-Oropeza, O., Paredes, G., Parra, I., Barrera, J.C. & Dayton, P.K. (2002) A general model for designing networks of marine reserves. *Science*, **298,** 1991–1993.

Sethi, S.A. & Hilborn, R. (2008) Interactions between poaching and management policy affect marine reserves as conservation tools. *Biological Conservation*, **141,** 506–516.

Winemiller, K.O. (2005) Life history strategies, population regulation, and implications for fisheries management. *Canadian Journal of Fisheries and Aquatic Sciences*, **62,** 872–885.

