ABSTRACT

Impacts of river damming to the three fish guilds in the Mekong Basin, according to their migratory behaviors viz., “white”, “black” and “grey” fishes were investigated by “before–after control–impact” method. Samplings were conducted every 2 months for one year. The period of “before intervention” was between August and October 2009, meanwhile the period of “after intervention” was between December 2009 and June 2010. The control- and impacted- sites were the Songkhram and Mun Rivers, respectively, which are in the middle migratory system of the Mekong
Basin. The intervention was the closing of all sluice gates of the Pak Mun Dam in the Mun River. There were 2 variables used in the study viz., numbers and species richness of each fish guild. The results showed that there were highly significant impacts of river damming ($P$-value < 0.01) to both variables of white fish but insignificance to the remaining 2 guilds. Benefit of the sluice-gate management of the Pak Mun Dam to the white fish was also discussed.

Introduction

Blockages of fish migratory routes both within the river mainstream and/or between the mainstream and tributaries, due to river damming, are now becoming the major concern in the Lower Mekong Basin (LMB, Dugan et al., 2010). Eighty-seven percent of the Mekong fish species, for which ecological information is available, are believed to be migratory during their life cycles (Baran et al., 2007). Some of the migratory fish species or “white fish”, as generally called in the Mekong, undertake long-distance longitudinal migration of several hundred kilometers, such as *Pangasius krempfi* (Hogan et al., 2007), in search of suitable habitats that enhance their survival, growth and reproduction success (Dugan et al., 2010). Most white-fish species venture into flooded areas in the tributaries during a monsoon season for spawning or feeding, and then returning to river habitats as the flood season ends (Poulsen et al., 2002). This “white fish” guild includes many species of Cyprinidae as well as species of Balitoridae, Cobitidae and Pangasiidae. Between 40 and 70 percent of the catches in the LMB are composed of fish species that migrate long distances along the mainstream and tributaries (Barlow et al., 2008), for example, it is estimated that white fish constitute 63% of the catch (i.e. around 150,000 metric tonnes a year) in the Tonle Sap (van Zalinge et al., 2000).

Two other fish guilds, according to their migratory behaviors, known in the LMB are “black fish” and “grey fish”. Black fish are able to survive in swamps and other water bodies in the floodplain during a dry season and occasionally perform limited, lateral migrations. These fish have often adapted to adverse environmental conditions in the floodplain, such as low dissolved oxygen. They are mainly carnivores and detritivores such as species of Channidae, Claridae, Bagridae and Anabantidae (Valbo-Jørgensen et al., 2009). Grey fish are ecologically intermediate between the two aforementioned guilds, including fishes that do not spend dry seasons in the floodplain but do not undertake long distance migrations either (Dugan, 2010; Valbo-Jørgensen et al., 2009).

To alleviate the adverse effect of river damming to fish migration, there is a technique of the “opening – closing sluice gates” for a certain period to mitigate the impact of dam to fish migrations. This measure is suitable for the regulated river that contains many fish species with varieties of migratory behaviors as in LMB, where fish ladder shows ineffective performance (Jutagate et al.,
This sluice gate management scheme has never been applied anywhere but in Thailand. The technique was first implemented in 2003 in the regulated Mun River, where the “run-of-the-river” Pak Mun Dam, which is located near the mouth of Mun River to the Mekong Mainstream, following the results from the scientific findings during the one-year trial of opening all sluice gates (see details in Jutagate et al., 2003; 2005). This measure allows opening all sluice gates approximately for four months during the rainy season, which is adjusted each year according to the rainfall intensity and water level, and then closed for eight months for hydroelectric generation. According to the opening-closing of the sluice gates, it is an opportunity to re-confirm scientifically on the impact of damming the Mekong tributary to fishes, particularly in terms of migration. Therefore, the aim of this study is to evaluate the responses of fishes according to the “opening – closing sluice gates” technique. Three fish guilds viz., the “white”, “black” and “grey” fishes were classified and used in the study. The “before–after control–impact (BACI)” quasi-experimental sampling was applied and data was analyzed by “randomized intervention analysis” (RIA: Carpenter et al., 1989) for detecting the changes of the observed variables, i.e. numbers and species richness.

**Material and methods**

*Data collections*

Sampling sites were the intact Songkhram River (as “control-site”) and the Mun River (as “impact-site”). Both rivers are similar in ecoregion and physical features, i.e. the Mun-Chi Sub-basin of the LMB but different levels of water regulations. The two rivers are also located in the middle migration system of the Mekong Basin (ICEM, 2010). Samplings were conducted every 2 months between August 2009 and June 2010. Sampling stations were in the lower portions that connected to the Mekong mainstem and selection was on the basis of accessibility and each station is about 20 km apart and there were 5 stations in each river, where all the stations of the impact-site were in the upstream of the dam. During the sampling period, “before” was referred to before the closing all sluice gates of the Pak Mun Dam (i.e. August and October 2009) and, thus,”after” when the gates were closed (i.e. December 2009 to June 2010).

Fish samples were collected by using electro-fishing by using an AC shocker (Honda EM 650, 650 watts and DC 220 V), together with the seine net, covered the area of 1,600 m$^2$. Sampling at each occasion was conducted at least three times because this could be yielded over 90% of the asymptotic number of species of the studied station (Arthur et al., 2010). Fishes were identified and counted. Individual samples were measured for total length (mm) and weight (g).
Data processing

Fishes, of each taxon, were grouped into “guilds”, i.e. white, black or grey. Samples from the five stations, of each sampling event, were kept separate but defined as one sampling unit in this study. BACI analysis subtracts the mean difference between control and impact units before intervention from the mean difference after intervention (Bried and Ervin, 2011). In RIA, the difference statistic, or effect size, is evaluated against many (≥100) possible sequences of the control-impact differences to random permutations of the impact-control data to generate a P-value (Edgington and Onghena, 2007; Bried and Ervin, 2011; Mullowney et al., 2012). In this study, 999 iterations were applied and the tested variables were numbers and species richness (i.e. number of fish species) of each guild. Statistical analyses were performed by using Program R (R Development Core Team, 2012), in which the scripts for RIA calculation and graphics were developed by Dr. M. Fukushima, National Institute for Environmental Studies, Japan.

Results

The total weight of fish samples were 862 kg from 29,646 fish, which the size spectra ranged from 15 to 541 mm. was total of 124 fish species belonging to 74 genera and 25 families was captured from the overall samplings. The most diverse families were Cyprinidae (63 species) followed by Cobitidae and Pangasiidae (7 species each). It is worthy to note that only one fish sample of Pangasiid fish (i.e. Pseudolais pleurotaenia) was caught during the intervention in the impacted site (i.e. the Mun River). The collected species were, then, classified into white, black and grey-fishes for 45, 27 and 52 species, respectively. Among of all the collected species, 41 species appeared in both rivers either before or after intervention, for example Clupeichthys aesarnensis, Rasbora dusonenensis, R. borapetensis, Barbounymus gonionotus, Hampala spp., Labiobarbus lineatus, Henicorhynchus siamensis, Osteochilus hasselti, Macrognathus siamensis, Channa striata and Parambassis siamensis. Detail of the samples viz., presence and absence of individual species both before and after intervention as well as numbers, total weights and size spectra of individual species in each river, during the experiment, can be downloaded at http://www.agri.ubu.ac.th/fishery/.

Significant differences between before and after intervention were found in numbers (P-value < 0.01, Fig. 1A) and species richness (P-value < 0.01, Fig. 1B) of white fish. Numbers of white fish in the impact-site responded significantly to the intervention and were sharply decline after the intervention was applied. Meanwhile, numbers of white fish in the control-site (i.e. the Songkhram River) were slightly dropped just after the intervention period, between December and February, but continuously increased in numbers since then. Species richness values in the control-site were higher
than those in the impact-site in every sampling occasion, which the great differences were observed during the period before intervention.

The insignificant results of RIA were found in the numbers (P-value = 0.872, Fig. 2A) and species richness (P-value = 0.616, Fig. 2B) of black fish as well as the grey fish, which P-values were equal 0.06 and 0.88 for the numbers and species richness, respectively (Fig. 3A and 3C). This indicated that there has been no either positive or negative effect of the intervention, i.e. gate-closing, to both fish guilds. Numbers of black fish in both rivers were changed in the same trend except in April, when a sharp decline was observed in the impact-site. Species richness of black fish in the impact-site was quite constant but fluctuated in control-site during the whole studied period. Numbers and species richness of grey fish were changed in the similar pattern in both rivers. Although insignificant, numbers of grey fish in the impact-site in October were substantially higher than the control-site. Meanwhile it was in December that species richness in the control-site substantially higher than the impact-site.

**Figure 1** The RIA results to (1A) numbers and (1B) species richness of the white fish.
Discussion

Changes in fish communities both upstream and downstream of the dam-site are inevitable, which mainly caused by changes in hydrological and ecological of the river (Kite, 2001). Classification of LMB fishes into “white” “black” and “grey” fish guilds, though by local fisher folk, is highly related to the “ecological” sense and can be used to explain their reaction to changes due to river damming (Welcomme et al., 2006). In this study, RIA was applied to a time series of response measures, which obtained from two ecological units, the regulated Mun River as an impact-site and the intact Songkram River as a control-site. Meanwhile, the intervention was the closing of all the sluice gates of the Pak Mun Dam in Mun River. Differences in the observed variable between the two
sites, comparing between before and after intervention, were used in calculation, in which large differences provide possible evidence of an effect of the intervention (Murtaugh, 2002).

![Figure 3](image)

**Figure 3** The RIA results to (3A) numbers and (3B) species richness of the grey fish.

Sharp decline of white fish was observed in both rivers after the intervention and could be attributed to the hydrological cycle. The water level in the Mekong tributaries always start to recede and the floodplain dries up from October, therefore, most fish leave the floodplain and the white fish goes back to the Mekong mainstem to seek refuge in permanent water bodies (Valbo-Jørgensen et al., 2009). Increases in numbers and species richness of white fish during the intervention period could imply the migration of small Cyprinids such as *Raiamas guttatus*, *Mystacoleucus mariginatus*, *Rasbora dusoensis* and *Paraluabuca riveroi*. These fish species are found to immigrate and emigrate between the Mekong mainstream and her tributary all year round (Jutagate et al., 2005). Moreover,
there are some medium to large Cyprinids, which start to migrate to the tributaries during the early rainy season, i.e. May, once there is a cue of strong flow from the tributary (Jutagate et al., 2005; Baran, 2006). Thus, *en masse* migration of these fish, which occurred in the control-site, made significant difference between the two rivers.

Blockage the river has no effect to the black fish either in terms of abundance or species richness. Fishes in this guild are limnophilic and proliferate in the reservoir condition and/or lowland river-floodplain systems (Hortle, 2009). As the floodplain residents, blockage along the longitudinal river course could not make any harm to them as far as the connectivity between the river and extent of inundated floodplain is still intact (Baran et al., 2007; Welcomme et al., 2006). Decline during April to June could imply that they moved to the floodplains, meanwhile only one observation of high numbers at the control-site in April suggesting it might be a type I error on data collection. The trend in decline in numbers of grey fish after the intervention was similar to those white fish in both rivers, implying that they were also regulated by hydrological cycle as those white fish. However, insignificant in differences of before and after intervention implying that they are tributary inhabitants and are able to adapt behaviorally to altered hydrograph (Welcombe et al., 2006) such as *Barbonymus altus, Hampala dispar, Dangila lineata* and *Osteochilus lini*.

In conclusion, numbers and specie richness of white fish adversely responded to the intervention at the impact-site, i.e. both variables sharply decline after closing the sluice gates. But there was no significant impact to numbers and species richness of black- and grey-fishes. Intervention by damming the river would eventually result in different in species composition between the intact- and regulated- tributaries, particularly the white fish. Therefore, the technique of opening the sluice gate for a certain period is benefit to the white fish to immigrate and emigrate between the Mekong mainstream and her tributaries. The technique could be also applied to other dams in the basin as an option other than fish ladder. This is because fish ladder has just proved to be success only for low-head dams in the basin (Baumgartner et al., 2012), but there has not yet any evidence, showing that the fish ladder can be performed effectively to large dam since the structure need to cope with massive migrations of the extremely diverse fish species as in the Mekong (Dugan et al., 2010).

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