FISH for the PEOPLE

A Special Publication for the Promotion of Sustainable Fisheries for Food Security in the ASEAN Region

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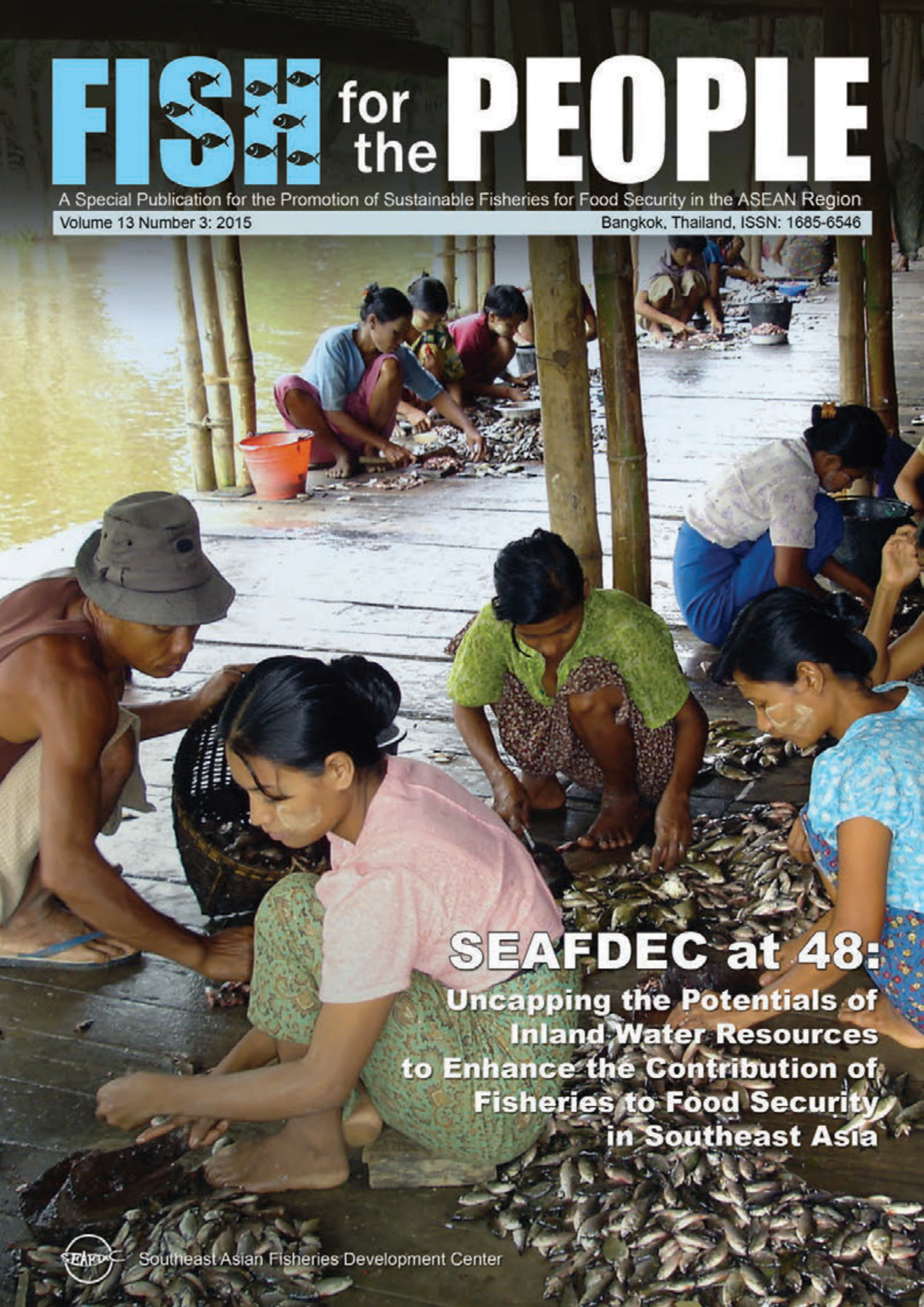

SEAFDEC at 48:

Uncapping the Potentials of Inland Water Resources to Enhance the Contribution of Fisheries to Food Security in Southeast Asia

Southeast Asian Fisheries Development Center

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Editorial

The series of Conferences on the economic development of Southeast Asia convened in early 60s that substantiated the development of fisheries as means of improving the food situation of the region, had given rise to the eventual establishment of the Southeast Asian Fisheries Development Center (SEAFDEC) in December 1967. While discussions on the importance of inland water fisheries continued to take place, during the latter Conferences, SEAFDEC was asked to also address the region's concern on ***the need for multiplication and conservation of inland water fishery resources***. Such proposition came into view as SEAFDEC had focused its activities on marine fisheries development since the start of its operations, through its Training Department (TD) and Marine Fisheries Research Department (MFRD), and later its Aquaculture Department (AQD) and Marine Fishery Resources Development and Management Department (MFRDMD), notwithstanding the efforts of AQD in conducting research on freshwater aquaculture at its Binangonan Freshwater Station since 1978.

As the attention given to inland fisheries had escalated considering its potential to supply fish for the growing food needs of the populace, especially the region's rural poor, the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium "Fish for the People" in November 2001 devoted a session on Inland Fisheries Development and Management. Thus, the Resolution and Plan of Action adopted during the 2001 Conference encouraged the ASEAN countries to also consider the importance of inland fisheries and freshwater aquaculture in policy formulations to improve food security and livelihoods of rural people. Meanwhile, SEAFDEC has continued to promote co-management and resources enhancement for inland capture fisheries through TD, inland aquaculture through AQD and value-adding of freshwater fish catch through MFRD as means of improving the livelihoods in fishing communities, and to a certain extent, inland fisheries development through MFRDMD while awaiting appropriate platform within SEAFDEC that would deal with inland fisheries.

As fisheries development continued to flourish in Southeast Asia, concerns on the development of sustainable inland fisheries in the region also became apparent, *i.e.* the continued undervaluation of the contribution of inland fisheries to food security, inadequate understanding of the importance of inland fisheries in terms of providing livelihoods to local fishers in rural areas, and the uncontrolled exploitation of inland resources that has manifested in the region, among

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others. Such a scenario therefore called for the development of ways and means of promoting the sustainable development and management of inland fisheries for food security in the Southeast Asian region. In the subsequent ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" in June 2011, inland fisheries was given prominence in the adopted new Resolution and Plan of Action by encouraging the ASEAN countries to enhance their understanding and awareness of the potentials of inland fisheries to contribute to food security and sustainable livelihoods in the region. It was also during the 2011 Conference that the Minister of Marine Affairs and Fisheries of Indonesia expressed his view on the relevance of inland fisheries to the region's food security, and suggested that SEAFDEC could consider taking on a new core of activities focusing on freshwater fisheries through the establishment of a Regional Center for Inland Fisheries as part of its organization, and offered his country to host the said center. Thus, during the 44th Meeting of the SEAFDEC Council in 2012, the proposal of Indonesia was considered and the Council agreed in principle to establish the said center.

After a series of assessments and consultations, the necessary documents were finally signed on **2 September 2014** marking the official launching of the establishment of the said center which has been renamed as the **Inland Fishery Resources Development and Management Department (IFRDMD)** of SEAFDEC. The establishment of IFRDMD therefore makes SEAFDEC competent in working towards a holistic approach to sustainable fisheries development and management in Southeast Asia, *i.e.* on marine capture fisheries, aquaculture, fisheries post-harvest technology, and inland capture fisheries. Thus, the functions of IFRDMD that focus on establishing guidelines for the sustainable development and management of inland fisheries in Southeast Asia are meant to uncap the potentials of the region's inland water resources for enhancing the contribution of fisheries to food security together with those of aquaculture and marine capture fisheries. In order to achieve such colossal goal, the initial Working Program of IFRDMD had been crafted to include the development of baseline information on policies and regulations on inland fisheries in Southeast Asia, increasing awareness on the status of inland fisheries in the region, and formulation of policy recommendations and guidelines on inland fisheries management in coordination with the ASEAN Member States.

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FISH for the PEOPLE is a special publication produced by the Southeast Asian Fisheries Development Center (SEAFDEC) to promote sustainable fisheries for food security in the ASEAN region.

Matching-up the Population Dynamics of Mekong Giant Catfish with Conservation and Management Strategies

Naruepon Sukumasavin, K. Lorenzen and *Z. S. Hogan*

A charismatic aquatic species revered throughout the Mekong River, the Mekong giant catfish (*Pangasianodon gigas*) is one of the world's largest freshwater fishes and is considered critically endangered (IUCN Red List, 2003). A range of conservation initiatives for the giant catfish are being carried out, and this article assesses the conservation status of the Mekong giant catfish and evaluates the likely effectiveness of such conservation measures. The synthesis and analysis of detailed data that were collected intermittently since the late 1960s, through the application of mathematical models, seemed to suggest that very low level of targeted fishing could be allowed to provide long-term monitoring of population data, and that public awareness of the species and the wider Mekong ecosystem should be enhanced. Maintaining the overall Mekong ecosystem (flows, physical habitats and connectivity) is however important to ensure the long-term survival of the species in the wild. Although the captive population of the catfish appears to be sustainable, safeguarding the survival of the species should be ensured before this species becomes extinct in the wild. Captive population should also be managed carefully to conserve its genetic diversity, in the event that re-introduction might become necessary. While the wild population carrying capacity appears to be quite low, releases of even low numbers of captive-bred fish could create significant impacts on the wild population. Moreover, considering that escapes of catfish grown in commercial aquaculture could pose significant threat to the wild population, measures should be taken to minimize the occurrence of such escapes.

The Mekong giant catfish (*Pangasianodon gigas*) or MGC is listed as critically endangered in the IUCN Red List as a result of excessive targeted fishery and incidental harvesting over the past twenty years, and to a lesser extent habitat degradation. Given the critical state of the MGC population, conservation and eventual recovery would require a combination of measures such as captive breeding, reduced harvesting, and conservation/restoration of critical habitats. Although a number of conservation initiatives and programs focusing on the MGC had been carried out, an overall conservation and recovery strategy has not been established. Meanwhile, the effectiveness of measures taken so far is largely unknown, and some measures are even believed to be conflicting or detrimental (Sukumasavin, *et al*., 2014).

Giant Catfish Fishery and Environmental Changes in the Mekong Region

Giant catfish fishing

Historically, the MGC is being captured in targeted fishery in various parts of the Lower Mekong Basin (**Fig. 1**). Targeted fishery for the species has generally been associated with festivals of spiritual significance. Although occurring only in

A
Regular catches in Chiang Khong/Huay Xai drift net fishery

B
Tonle Sap bag net fishery

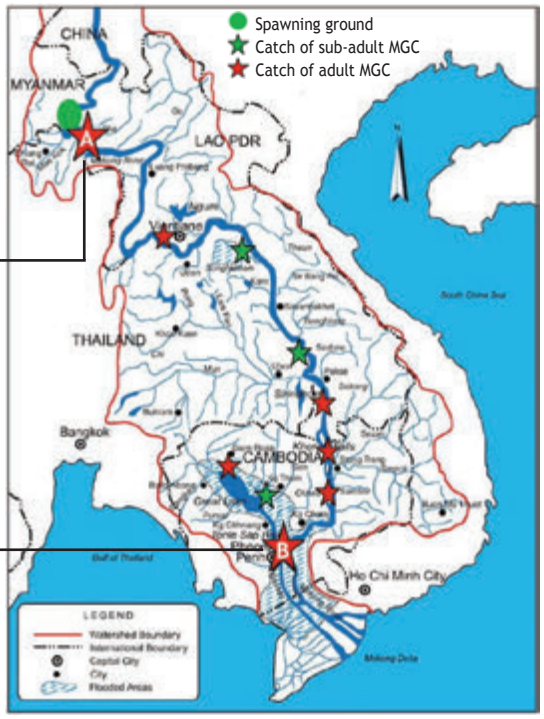

Fig. 1. Map of the Lower Mekong Basin (big stars indicating locations where Mekong giant catfish have been regularly caught in fisheries in recent years: (**A**) Chiang Khong/Huay Xai in Northern Thailand and Lao PDR, and the Tonle Sap River in Cambodia (**B**))

certain locations and making use of specially constructed very large-mesh nets, such fishery targets the MGC during their spawning migration through narrow channels at low water level where MGC becomes prone to harvesting.

Thus, incidental catches of MGC are relatively rare as the fishery is largely confined to what is known as migratory 'bottlenecks'. For example, the most regular incidental catches are taken in just one Dai net in the Tonle Sap River in Cambodia, at a location where the Dai blocks virtually the entire cross-section of the river, while low incidental catches have also been reported from the Khone Falls area. Incidental catches elsewhere are extremely rare and do not appear to follow any identifiable pattern. The history of MGC fishing at various locations in the Mekong River could be gleaned from **Fig. 1**. Nevertheless, insufficient information on the MGC fishing prior to about 1930 has made the analysis of the pre-1970 data difficult to undertake due to lack of continuity.

Nonetheless, most accounts provide only snapshots of catches in particular locations, sometimes with vague references to previous 'average' catch levels. Although several reports mentioned catch declines, such reports do not clearly state whether these refer to overall, long-term decline or 'boom and bust' cycles in the fishery. As a matter of fact, 'high' local catches of about 50 individuals followed by declines in catch and catch per unit of effort have been reported for various locations. Such reports however do not indicate whether catches of such magnitude have ever been sustained in the long term.

In interpreting the catch data, it is important to consider that catches are influenced by both fish abundance and fishing effort, and that catch declines are not necessarily indicative of population decline. The armed conflict throughout the region in the 1970s, particularly the Khmer Rouge regime in Cambodia resulted in the virtual cessation of MGC fishing in many locations. Fishing that time was considered dangerous in the Mekong River Basin especially the area that borders Thailand and Lao PDR, including many traditional fishing grounds such as the Chiang Khong/Huay Xai and the Nong Khai/Vientiane areas. In Cambodia, large-scale fishing became very restricted during the civil war and ceased completely during the Khmer Rouge period.

Fishing history at Chiang Khong District, Chiang Rai Province in Northern Thailand

The targeted fisheries in Chiang Khong District of Northern Thailand and in neighboring Huay Xai of Lao PDR, is a particularly important element of MGC exploitation and assessment. Such fisheries dominated the overall catches since 1980s providing the most detailed data on the currently available population. There is however, no clear record when MGC fishing begun in Chiang Khong District of Chiang Rai Province in Thailand. Nonetheless, based on interviews with local fishers, fishing for the MGC has been practiced for more than 70 years, and fishing period is about one (1) month from April to May every year when the fish migrate to their spawning grounds, which is somewhere around the "Golden Triangle," the area that overlaps the mountain ranges of Myanmar, Lao PDR and Thailand. Meanwhile, the catch statistics for MGC from Chiang Khong/Huay Xai area from 1973 to 1995 were recorded by Borkeo Province of Lao PDR. In Thailand, the Department of Fisheries (DOF) recorded the MGC catches since 1983, when its program on the artificial breeding of the Mekong giant catfish was started.

Based on recorded data from 1973 to 1983, the catches varied from 1 to 6 heads per year with an average of 3 heads per year. After 1983, when the DOF Thailand had succeeded in the artificial spawning of wild-caught MGC from the Mekong River, catches from 1984 to 2000 increased to an average of 29 heads per year, with a maximum of 71 heads. This dramatic increase in MGC catches reflected a massive increase in fishing effort between 1983 and 1990, fuelled by the high demand for MGC of DOF Thailand for its captive breeding program, as well as from the local tourism industry. This developed as public awareness about the fisheries and on the captive breeding program had increased, and massive promotion campaign dwelling on local people's belief that eating MGC would lengthen one's life, had been intensified. Furthermore, catch rates (CPUE) in the fishery declined to a minimum in the mid-1990s while the effort also diminished resulting from both low catch rates and alternative economic opportunities. Nevertheless, from 2000 to 2003, no MGC were caught at Chiang Khong District which was attributed to rapid blasting in the mainstream of the Mekong River for navigation and construction of a port in Chiang Khong. When the said construction was completed, 7 heads were caught in 2004, and 4 heads in 2005. However, a conservation campaign

advocated by both local and international NGOs led to reduced fishing in 2005 and 2006, with a near-complete cessation of MGC fishing in 2006 when the NGOs bought the fishing gear from all registered MGC fishers in Thailand and Lao PDR.

Environmental changes in the Mekong River Basin

Environmental changes in the Mekong River Basin had been observed to be gradual and considered moderate in magnitude until the very recent past. Land had also gradually become more agricultural and the hydrology showed no marked changes since the start of a systematic recording in 1960, contrary to widespread perceptions that dams cause significant changes in the water flow. Although access to some tributaries and the upper Mekong/Lancang might have been restricted by the dams, the total area potentially lost accounted for only a moderate proportion of the basin. Nonetheless, more dramatic changes may have occurred in the very recent past with the 'rapid blasting' and the commissioning of several dams in the upper river, but any effects of these changes on the MGC population have not been visible in the data. Therefore, fishing has been identified as the main driver of the past changes in the population abundance and structure of MGC in the Mekong River Basin.

Assessment of the Wild Population of Mekong Giant Catfish

Population model and parameter estimation

Length-structured matrix population model was adopted as the main assessment tool for determining the status of the wild population of MGC. The recruited population was divided into length groups, and the model population and catch numbers grouped into length over time. The detailed data collected intermittently since the late 1960s were then synthesized and analyzed with the use of a mathematical model, taking into consideration certain assumptions that underlie the baseline model (**Box 1**). An overview of the model parameters and their baseline values is shown in **Table 1**.

Box 1. Assumptions on the parameters considered for the baseline population model

Assumptions	Means of verification
MGC in the Mekong Basin form a single population	All catches have been taken from the same population
Full population is vulnerable to fishing	No reports on un-fished and unobserved local populations
Reporting of MGC catches is near-complete and not size-biased	There is no unreported harvest of small MGC

Assessment of the population status of MGC: Model Fitting

Most of the parameters used for model fitting were estimated from the subsets of data or comparative information shown in **Table 1**, but only the level of recruitment R_0 in the unexploited population B_0 and the catchability coefficient **c** (a constant proportionally relating CPUE to the absolute abundance) were estimated by fitting the model into a time series for fisheries data. The data set used for model fitting was the CPUE time series for the Chiang Khong/Huay Xai fisheries. Fitting the model to CPUE data started with equilibrium solutions for a variety of plausible exploitation scenarios during 1960s-70s and levels of recruitment compensation running forward through 1973-2005. In each year, the model population was reduced by the actual (reconstructed) catches and the action of natural mortality but new recruits were also gained based on the stock-recruitment relationship. Recruitment of the unexploited population R_0 and the catchability coefficient **c** were then estimated by numerically searching for values that provide the best fit to the CPUE data. As previously highlighted, key uncertainties in population assessment include the level of natural mortality such as exploitation rate prior to the Chiang Khong fishing boom, and the level of recruitment compensation. A variety of scenarios, *i.e.* E1970s and K, allowed acceptable model fits based on the available catch and CPUE data (**Table 2**). However, there is no strong basis for discriminating among the fits those that

Table 1. Model parameters and their baseline values

Parameter	Definition	Value				
Life cycle						
• L_r	• Length at recruitment	100 cm				
• a_r	• Age at recruitment	10 years				
Growth						
• L_∞	• Asymptotic length	290 cm				
• K	• Growth rate	0.1 $year^{-1}$				
• α	• Coefficient of l-w relationship	4.0 x 10^{-5} cm				
• β	• Exponent of l-w relationship	2.8				
Natural mortality						
• M_r	• Natural mortality rate at L_r	0.15 $year^{-1}$				
• L_r	• Reference length for M_r	200 cm				
Reproduction						
• L_m	• Length at maturity	224 cm				
• p	• Steepness of maturity curve	-0.2				
Recruitment for M_r at 250 cm		0.12	0.12	0.12	0.06	0.06
• K	• Recruitment compensation	5	2	100	5	100
• B_0	• Unexploited spawner biomass	95 t	179 t	81 t	544 t	180 t
• R_0	• Recruitment at B_0	345	650	296	320	106 t
Fishing						
• F	• Fishing mortality rate in fully exploited size groups	Variable				
• L_c	• Gear selection length	224 cm				
• q	• Steepness of selectivity curve	-0.1				
• c	• Catchability coefficient	0.00417 $boat^{-1}$				

Source: *Adapted from Sukumasavin,* et al. *(2014)*

were associated with these alternative scenarios. As a result, all acceptable model fits predicted a spawner abundance of about 250 heads which could have been possible at the start of the Chiang Khong 'fishing boom.' At any rate, the estimates of unexploited spawner abundance vary from 355 to 2,200 heads (**Table 2**). Hence, the abundance at the start of the Chiang Khong 'fishing boom' represented between 11% and 71% of the unexploited abundance. Furthermore, natural mortality rate $M_r = 0.12$ year^{-1} at l_r=250 cm which was used as baseline (grey column in **Table 2**), while some predictions were made for $M_r = 0.06$ year^{-1} at l_r=250 cm (blue column in **Table 2**). The results indicated that the models provide a good overall fit to the observed CPUE time series as shown in **Fig. 2**. The models which provided very similar CPUE and abundance estimates for much of the period but diverged somewhat towards the end, thus predicted the same abundance prior to the Chiang Khong 'fishing boom' of about 250 spawners and similar pattern of reduction during the 'fishing boom' but differ in the predicted recovery pattern. The model also reproduced the catch length distribution in 1999-2005 as shown in **Fig. 3**.

Reconstructed Population and Fishing History

The reconstructed spawner abundance (**Fig. 4**) shows a relatively stable spawner population of about 250 heads prior to 1983 (11-71% of unexploited abundance). The population then declined dramatically to just 50 spawners in 1995 (2-14% of unexploited abundance).

The Chiang Khong 'fishing boom' therefore led to the reduction of spawner abundance by about 80% in just ten

Table 2. Equilibrium catch, unexploited spawner population (N_0) and relative spawner population prior to the Chiang Khong fishing boom (Rel N) estimated for different combinations of exploitation rate in the 1970s and recruitment compensation K. Combinations marked in red lead to predictions that are inconsistent with the available data. The scenarios used in predictions are highlighted in grey (M_r=0.12 year^{-1}) and in blue (M_r=0.06 year^{-1})

M_r at L_r=250cm	0.04	0.06	0.08	0.10	0.12	0.14	0.16
E (1970s)	0.8	0.7	0.6	0.5	0.4	0.3	0.2
K=100							
Catch	-	27	29	24	20	15	-
N_0	-	860	622	501	414	355	-
Rel N	-	0.294186	0.406752	0.50499	0.611111	0.712676	-
K=5							
Catch	-	23	29	24	20	15	-
N_0	-	2200	1149	694	490	404	-
Rel N	-	0.114948	0.220191	0.364553	0.516327	0.626238	-
K=2							
Catch	-	-	-	-	20	15	-
N_0	-	-	-	-	1480	745	-
Rel N	-	-	-	-	0.170946	0.339597	-

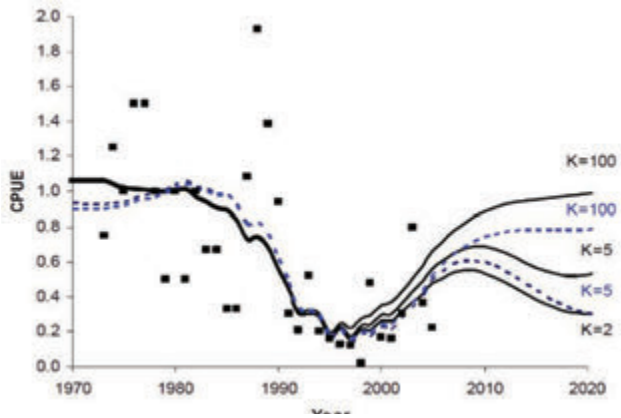

Fig. 2. Observed (*squares*) and predicted (*lines*) catch per unit of effort in the Mekong giant catfish fishery, predictions are for M_r = 0.12 year^{-1} (*black solid lines*) and M_r = 0.06 year^{-1} (*blue broken lines*)

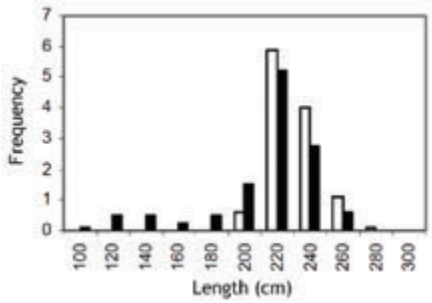

Fig. 3. Observed (*solid bars*) and predicted (*open bars*) size distribution of MGC catch in 1999-2005

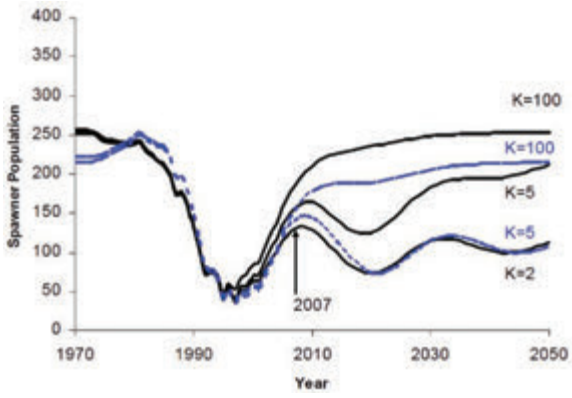

Fig. 4. Spawner population abundance reconstructed by the population model, and predicted recovery trajectories for different levels of compensatory density-dependence in recruitment, predictions are for M_r = 0.12 year^{-1} (*black solid lines*) and M_r = 0.06 year^{-1} (*blue broken lines*)

years, although the model also predicted that the population has since recovered significantly. The predicted current (2006) level of spawner abundance is estimated at 145 heads or 7-40% of the unexploited abundance.

The predicted recovery of spawners until about 2010 is based largely on growth and maturation of the fish that spawned before the period of intensive fishing, which would still occur although there was no successful reproduction since 1990, and even if subsequent population development would

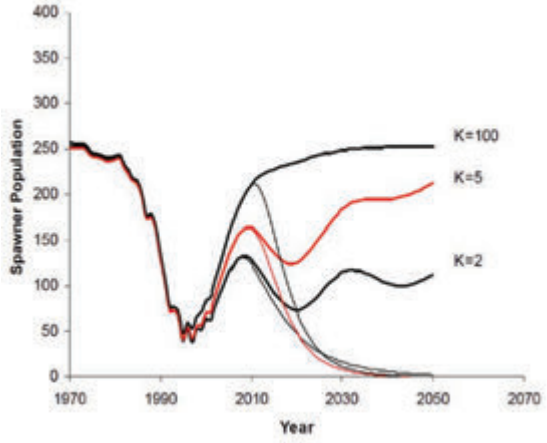

Fig. 5. Spawner population abundance predicted by the population model assuming normal recruitment or complete reproductive failure since 1990, predictions for M_r = 0.12 year^{-1}

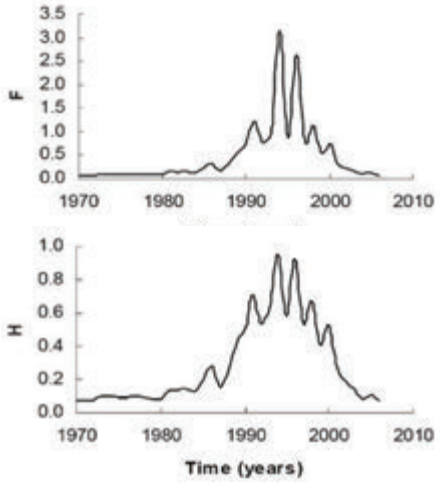

Fig. 6. Reconstructed fishing mortality **F** (*above*) and corresponding proportion of the available population harvested **H** (*below*) from 1970 to 2006, reconstruction for 1970s exploitation rate of 0.4

depend on reproduction during and after the period of very low spawner abundance. Unless recruitment compensation is extremely high (K=100, **Fig. 4**), spawner abundance is predicted to decline again between 2010 and 2020 as a result of low spawner abundance and reproduction output during the 1990s. However, even if reproduction failed entirely from 1990 onwards (*e.g.* as a result of the Allee effects or due to environmental factors), the effect would only become apparent after 2010 (**Fig. 5**). This implies that the basic life history of MGC should be taken into consideration when interpreting catch and abundance trends, and that long-term monitoring would be necessary. The model-based population reconstruction had also provided direct estimates of fishing mortality rates, where the fishing mortality pattern for M_r = 0.12 year^{-1} clearly shows a dramatic increase in fishing pressure on the mature population between 1983 and the early 1990s (**Fig. 6**). Fishing mortality rates then declined and returned to pre-1983 levels by 2004. Instantaneous fishing mortality rates **F** can be translated into proportional harvest rates **H**, *i.e.* proportion of the available population harvested in the fishery. Thus, the pre-1983 and post-2004 fisheries had removed about 10% of the population per year, and in 1990-2000, over 50% of the available population was harvested annually at a maximum rate of 96% in 1995.

Potentials for Sustainable Exploitation

In assessing the potentials for sustainable exploitation of the MGC, the equilibrium (=sustainable) catch and the corresponding spawner abundance of the population were calculated, given different levels of natural mortality and recruitment compensation as shown in **Fig. 7**.

The level of natural mortality and pre-boom exploitation assumed major implications for the assessment of the

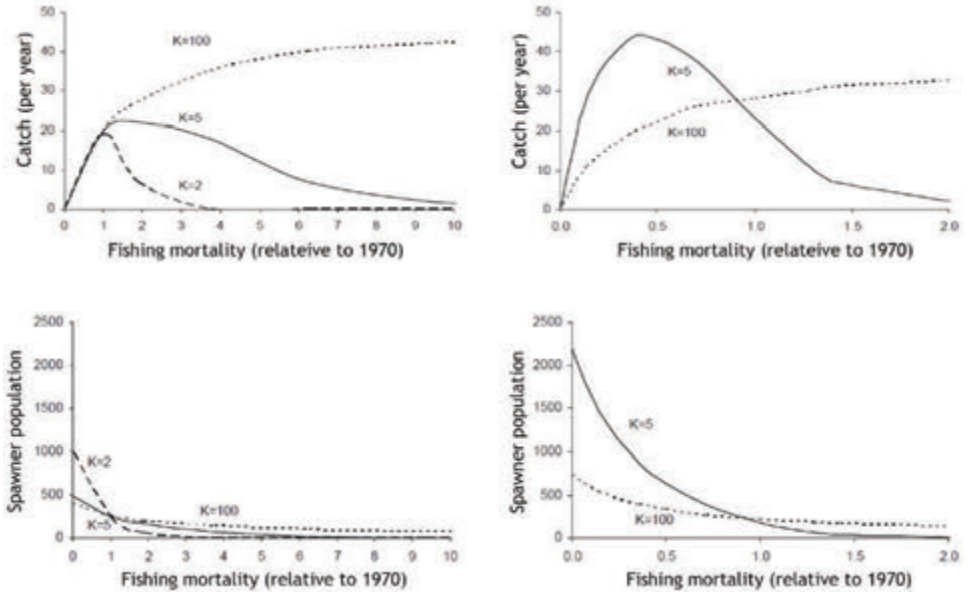

Fig. 7. Equilibrium catch (*top*) and spawner population abundance (*bottom*) of MGC in relation to fishing mortality rate F, predictions are for M_r = 0.12 year^{-1} (*left hand side*) and M_r = 0.06 year^{-1} (*right hand side*)

'traditional' (pre-boom) level of fishing. For M_r = 0.12 year^{-1} at l_r=250 cm (E1970s=0.4), traditional fishing conducted at or below the effort level provided the maximum sustainable catch. For M_r = 0.06 year^{-1} at l_r=250 cm (E1970s=0.7), traditional fishery overexploits the population if K=5, and represents a very high level of exploitation if K=100, although it is not possible at present to discriminate between these scenarios, as the true level of natural mortality and pre-boom exploitation is unknown. Such a situation however does not present a major problem for management in the short-to-medium term because the population is currently depleted and unlikely to rebound to levels at which the maximum sustainable catch could be attained, even for the next at least 2-3 decades. Nonetheless, the different models have very similar implications for population management in the medium term.

Release of captive-bred fish

Captive-bred MGC could be released to raise recruitment to the level estimated for the unexploited population, thereby speeding up recovery without exceeding the estimated carrying capacity for recruits. If 'traditional' levels of fishing are maintained and captive-bred fish are released from 2010 onwards at a level commensurate with the natural carrying capacity, this would raise the abundance of spawner population starting from about 2025 onwards but only with medium-low recruitment compensation (**Fig. 8**). Nonetheless, in all cases except for very low recruitment compensation (K=2), complete cessation of MGC fishing would lead to faster recovery than releasing captive-bred fish.

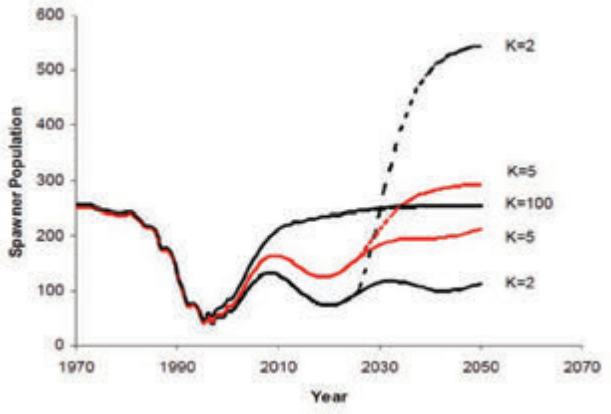

Fig. 8. Impact of releases of captive-bred recruits on predicted spawner population change, at 'traditional' levels of fishing mortality, where broken lines show the effect of releasing captive-bred recruits at a rate that raises the total recruitment to R_0 (recruitment in the unexploited population), predictions for M_r = 0.12 year^{-1} only

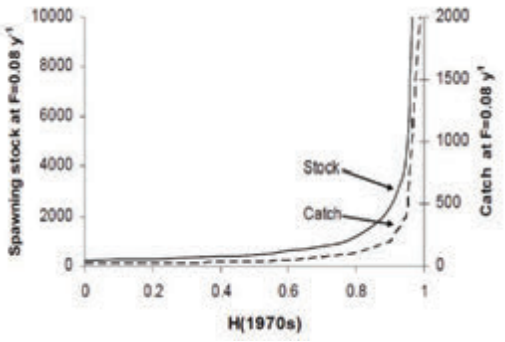

Fig. 9. Spawner population size and sustainable yield at the 'traditional' level of targeted fishing (**F**=0.08 year^{-1}) in the absence of juvenile exploitation, given different assumed juvenile harvest rates H_j(1970s) in the 1970s

Implications of possible exploitation of small juveniles

Exploitation of MGC juveniles less than 100 cm in length has remained unknown. However, any exploitation occurring at this stage would affect recruitment to the population of large MGC (>100 cm in length) that are exploited by known fishery. Thus, it is also necessary to model the effect of juvenile exploitation by introducing a juvenile harvest rate $\mathbf{H_j}$ into the stock-recruitment function, *i.e.* **Recruitment of large juveniles = recruitment of small juveniles x (1-juvenile harvest rate $\mathbf{H_j}$)**. The juvenile harvest rate $_{Hj}$ acts simply as a scaling factor to recruitment and does not affect the analysis of the population dynamics as long as **H** remains constant. Baseline analysis estimated that the level of maximum recruitment of about 345 fish (100 cm in length) corresponds to that of the Chiang Khong 'fishing boom' and the level of recruitment in the 1970s. If this recruitment level had been influenced by juvenile harvesting at the rate of $\mathbf{H_j}$ (1970s), then the natural recruitment level in the absence of juvenile harvesting would be higher by 1/(1-$\mathbf{H_j}$). Likewise the spawner population abundance and sustainable yield in the absence of juvenile fishing would be proportionately higher as shown in **Fig. 9**.

Future Population Change

From the abovementioned results, the future population trends have been predicted for several different scenarios, especially with respect to fishing, releases of captive-bred fish, and reproductive failure.

Fishing

Predictions had been given for 'traditional' level of fishing mortality and a scenario where all fishing for MGC is stopped from 2007. Although 'traditional' fishing scenario is deemed most likely in the medium term, closure of the Chiang Khong/Huay Xai fisheries and decommissioning of the Dai net fisheries responsible for the bulk of MGC catches in the Tonle Sap River would lead to a 'no fishing' scenario.

Nevertheless, since the MGC population is expected to recover under both scenarios (**Fig. 10**), recovery would be faster towards a higher level of abundance if fishing were discontinued. For recruitment compensation K=5, the population would recover to pre-1983 abundance around 2025 in the absence of fishing, but would still be below the pre-1983 abundance in 2050 if fishing is continued at the 'traditional' level.

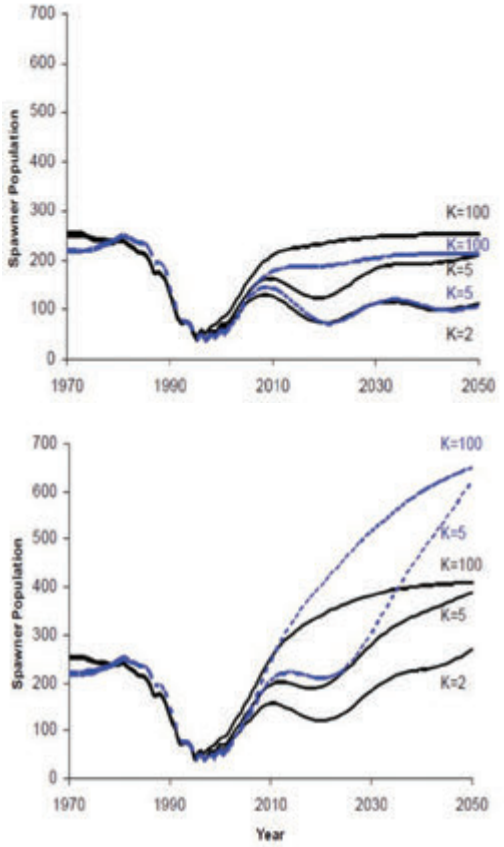

Fig. 10. Predicted spawner population change given 'traditional' levels of fishing mortality (above) or no fishing (below), predictions for M_r = 0.12 year^{-1} (*black solid lines*) and M_r = 0.06 year^{-1} (*blue broken lines*)

Recruitment failure

Recruitment failure could be a result of destruction of spawning and juvenile habitats or from depensatory (Allee) effect at low spawner abundance. However, the effects of recruitment failure could be visible only after some 15-20 years since its first occurrence (**Fig. 5**).

Role of captive-bred and culture fish

Captive-bred and cultured fish could play an important role in future population change, whether the fish comes from deliberate releases or accidental escape from aquaculture facilities. While examining the impacts of captive releases on the recovery of spawner population, the survival and growth parameters for MGC released into semi-natural environments or reservoirs could also be estimated although the impacts of such releases on the wild population should be taken into consideration.

Potential effects of releases on wild population

In assessing the impacts of deliberate or accidental releases of cultured fish on the wild population, the fisheries enhancement model of Lorenzen (2005) in the EnhanceFish package could be used, with the assumption that captive-bred and cultured fish show the same growth and mortality patterns as wild fish, as well as in terms of reproductive competence. Using such package, the impacts of releasing large 'recruits' (100 cm in length) as shown in **Fig. 11** indicate that although releases are predicted to increase the total fisheries yield and population biomass, the wild population component could be depressed. Even if a moderate release of about 300 recruits would result in a significant wild population impact as a result of the estimation, the wild population carrying capacity would be very low combined with the wild-like fitness of released fish.

In the deliberate releases of MGC, smaller fish of about 10-20 cm in length could be used but such fish could undergo relatively high and most likely, density-dependent mortality before even reaching the 100 cm length. Releases of few hundreds or even thousands of 20 cm fish per year would also have little impact on the total yield while moderately depressing the wild population biomass (**Fig. 12**). Thus limited, *e.g.* ceremonial releases of small captive-bred MGC could still be conducted without posing a major threat to the wild population.

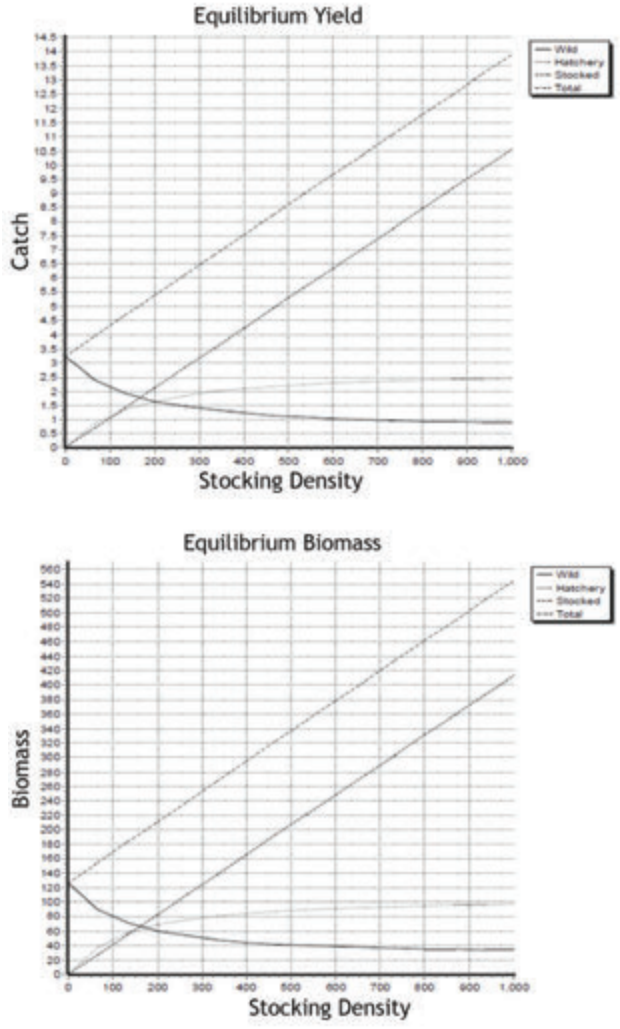

Fig. 11. Impact of releasing recruits (100 cm fish) on yield (*above*) and total biomass (*below*) of MGC population components

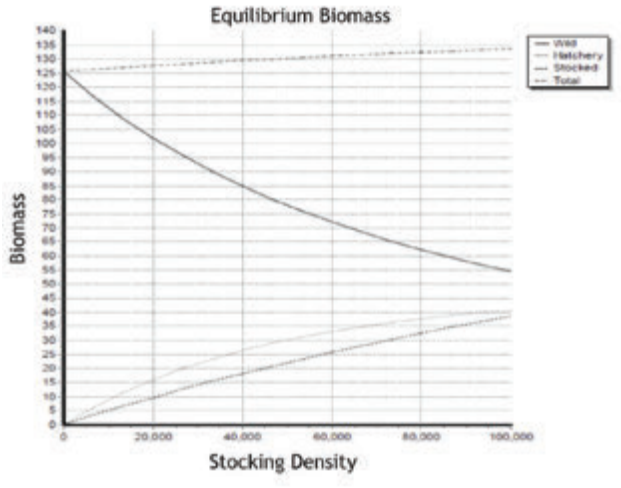

Fig. 12. Impact of releasing juveniles of 20 cm length on biomass of MGC population components

Implications for Conservation Strategy Development

Threat assessment

The factors that threaten the survival of MGC could include fishing, habitat degradation, and interactions with culture-bred fish. However, the known fishery targeting large MGC appears to be less of a threat to population persistence than previously thought. The highly size-selective nature of the fishery and low level of incidental harvesting imply that the population is quite resilient to overfishing. Thus, a moderate level of traditional fishing could still be allowed without compromising population viability. This could have an overall beneficial effect in terms of providing long-term monitoring data and maintaining public interest in the species.

Nevertheless, such effort should ensure that fishing intensity remains well below the levels seen at the height of the Chiang Khong fisheries, and that there is no increase in incidental catches (*e.g.* due to new gear development). Furthermore, the current assessment of sustainable catch levels may be revised should population dynamics be affected by other threats. Since the extent to which small juveniles of less than 100 cm length are subjected to exploitation remains unknown, and if there is significant exploitation at this stage, this could have a strong effect on population abundance. Such exploitation would however be entirely incidental, *i.e.* MGC are neither targeted nor indeed known to be caught by gill net fisheries exploiting this size range, although this is very difficult to address without placing strong restrictions on the mainstay of Mekong fisheries.

The latter of course is not a realistic proposition and therefore possible exploitation of juvenile MGC is in effect an external factor. Habitat degradation is unlikely to have played a major role in past population change, but may play a larger role in the future as population growth and economic development lead to increased utilization of the Mekong River Basin and its associated natural resources. The most important known threats are likely to be navigational improvements and hydrological change in the spawning grounds, and loss of access to juvenile habitats due to the damming of Mekong tributaries. Modification of spawning habitats may be the most acute threat, and would be detectable in the adult population only about 20 years after any impact.

While loss of access to juvenile habitats could result in reduction of carrying capacity, the small population size and low carrying capacity of the MGC make the population vulnerable to ecological and genetic interactions with released cultured fish. Nonetheless, as noted in many fora, there has been little 'hard' information on the effectiveness of any of the conservation measures. The quantitative assessment in **Box 2** could provide new insights with important implications for the prioritization of conservation measures.

Conclusion and Recommendations

Results of the reconstructed spawner abundance indicated a dramatic decline of MGC spawners to just 50 in 1995 but recovered to about 145 heads by 2006. Fishing had affected the abundance and structure of the MGC population, specifically contributing to the depletion of the MGC stock. However, very low levels of harvest (up to 10 mature fish basinwide) could still be allowed until 2030 for the population to recover from its current state, and also for long-term population monitoring of population data. Recent changes in the environment of the Mekong River Basin have not affected the population abundance of MGC but it is still necessary to maintain the overall Mekong ecosystem, *i.e.* water flows, physical habitats and connectivity, to ensure long-term survival of the species in the wild. Considering that habitat use and migration patterns of the species are largely unknown, the essential habitats of MGC could not be established except for the spawning area, which is most likely some 50 miles north of Chiang Khong District in Chiang Rai Province of Thailand. It is therefore an immediate priority that this habitat should be protected.

Box 2. Possible conservation measures that should be prioritized based on the population dynamics of MGC

- **Reducing exploitation of the wild population:** This could be the most important immediate conservation priority, and related initiatives have been targeted at the Chiang Khong and Tonle Sap River fisheries. In the analysis, fishing has been identified as the main driver of past changes in population abundance and structure. The exceptionally intensive Chiang Khong fishery in the 1980s and 90s in particular is likely to account for the dramatic population decline observed over this period. The population has since recovered slightly, but remains in depleted state. Only very low levels of harvest (up to 10 mature fish basinwide) could be sustained until 2030 if the population is to recover from its current state. Within this limit, the lower the harvest the faster population recovery would occur. A very low level of targeted fishing could be allowed to provide long-term population monitoring data and promote public awareness of the species, and the wider Mekong ecosystem. The extent to which small juveniles of less than 100 cm length are subjected to exploitation should be investigated. It is unlikely that any such incidental exploitation can be reduced significantly in the short term. In the longer term, the overall fishing effort may decline as economic development provides alternative opportunities for fishers.
- **Habitat management:** Habitat conservation was perceived to be a major priority for current and future conservation action, due to the fact that potentially detrimental activities such as rapid blasting and construction of dams on major tributaries are likely to intensify. This priority remains unchanged. Perhaps the most important habitat conservation priority concern is likely the spawning grounds of the MGC near Chiang Khong, which may be crucial to the survival of the whole wild population.
- **Supportive breeding:** captive breeding programs had been identified as an important 'insurance' for species survival in case of wild population extinction. This view remains unchanged. Captive-bred fish could be used to re-establish a wild population should this indeed become extinct. The assessment suggests, however, that at present the MGC population is undergoing natural recovery from excessive harvesting of large fish during the 1980s/90s, and that releases of captive-bred fish would make at best a very minor contribution to recovery. At worst, releases would threaten the recovery of the wild population through ecological and genetic interactions with captive fish that are likely to be moderately compromised in their fitness in the wild. Hence releases of captive-bred fish into the Mekong should not be carried out at present, or only in very small numbers.
- **Aquaculture escapees:** prevention of escapees into the Mekong mainstream from MGC aquaculture has been tentatively identified as important. The current analysis suggests that even moderate escapes of a few tens or hundreds of animals can lead to significant replacement of wild with captive/cultured fish provided that the latter survive well in the wild and are reproductively competent. Results of MGC stocking in reservoirs suggest that cultured fish can survive well in semi-natural environments. Preventing escapes should be a high conservation priority.

The efforts of the Department of Fisheries (DOF) of Thailand to maintain captive population would provide vital 'insurance' for safeguarding the survival of the species should it become extinct in the wild. However, such captive population should be managed carefully so as to conserve genetic diversity, should re-introduction become necessary. For the time being, captive-bred fish should not (even only in very low numbers) be released into the Mekong River or its tributaries because the wild population is likely to recover naturally. Although interaction with cultured fish might not have played a significant role in past population change, this might be a major issue in the future in view of both intentional and accidental releases, especially that the present cultured population is likely to exceed the wild population in terms of abundance. Nevertheless, escapes of MGC from commercial aquaculture operations could pose a significant threat to the wild population. Measures should therefore be taken to minimize the occurrence of such escapes for although the wild population carrying capacity appears to be quite low, releases of even low numbers of captive-bred fish could have significant impacts on the wild population.

References

Davidson, A. 1975. Fish and fish dishes of Laos. Imprimerie Nationale Vientiene, Lao PDR

Durand, J. 1940. Notes sur quelques poissons d'especes nouvelles ou peu connues des eaux douces Cambodgiennes. Institute oceanographique de l'Indochine, Nhatrang

Giles, F.H. 1935. An Account of The Ceremonies and Rites Performed When Catching the Pla Buk: A Species of Catfish Inhabiting the Waters of the River Mekong, the Northern and Eastern Frontier of Siam. Natural History Bulletin of the Siam Society 28:91-113

Haddon, M. 2001. Modelling and Quantitative Methods in Fisheries. Boca Raton: CRC

Hogan, Z.S., Pengbun, N. and van Zalinge, N. 2001. Status and conservation of two endangered fish species, the Mekong giant catfish *Pangasianodon gigas* and the giant carp *Catlocarpio siamensis*, in Cambodia's Tonle Sap River. Natural History Bulletin of the Siam Society 49:269-282

Fleming, I.A. and Petersson, E. 2001.The ability of released, hatchery salmonids to breed and contribute to the natural productivity of wild populations. Nordic Journal of Freshwater Research 75: 71-98

Glyki, E. 2006. Public survey on historical changes in Mekong river fisheries. Field notes

Lenormand, S. 1996. Les Pangasiidae du delta du Mekong (Viet Nam): description preliminaire des pecheries, elements de biologie, et perspectives pour une diversification des elevages, Memoire de Fin D'etudes, Ecole Nationale Superieure Agronomie de Rennes

Lorenzen, K. 1996. The relationship between body weight and natural mortality in fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49: 627-647

Lorenzen, K. 2000. Allometry of natural mortality as a basis for assessing optimal release size in fish stocking programmes. Canadian Journal of Fisheries and Aquatic Sciences 57: 2374-2381

Lorenzen, K. 2005. Population dynamics and potential of fisheries stock enhancement: practical theory for assessment and policy analysis. Philosophical Transactions of the Royal Society B 360: 171-189

Lorenzen, K. 2006. Population management in fisheries enhancement: gaining key information from release experiments through use of a size-dependent mortality model. Fisheries Research 80: 19-27

Lorenzen, K. (in press) Beyond 'stock and recruitment': density-dependent growth in recruited fish and its role in population regulation. Bulletin of Marine Science

Mattson, N., Buakhamvongsa, K., Sukumasavin, N., Tuan, N. and Vibol, O. 2002. Mekong giant fish species: on their management and biology. MRC Technical Paper No. 3, Mekong River Commission, Phnom Penh

Mitamura, H. 2005. Studies on the behaviour of Mekong giant catfish using biotelemetry. PhD Thesis, Kyoto University

Myers, R.A., Bowen, K.G. & Barrowman, N.J. 1999. Maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences 56: 2404-2419

Ngamsiri, T., Nakajima, M., Sukamanomon, S., Sukumasavin, N., Kamonrat, W., Na-Nakorn, U., Taniguchi, N. 2007. Genetic Diversity of the Wild Mekong Giant Catfish, *Pangasianodon gigas* Collected from Thailand and Cambodia. Fisheries Science 73, 792-799

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and environmental temperature in 175 fish stocks. ICES Journal du Conseil 39: 175-192

Pauly, D. 1984. Fish Population Dynamics in Tropical Waters: A Mannual for use with Programmable Calculators. Manila: ICLARM

Pholprasith, S. and Tavarutmaneegul P. 1998. Biology and culture of the Mekong giant catfish *Pangasianodon gigas* (Chevey 1930). Paper Number 31. National Inland Fisheries Institute, Bangkok

Phukasawan, T. 1969. *Pangasianodon gigas* Chevey. Inland Fisheries Division, Department of Fisheries, Bangkok

Roberts, T. R. 1993. Artisanal fisheries and fish ecology below the great waterfalls of the Mekong River in Southern Laos. Natural History Bulletin of the Siam Society 41: 31-62

Rose, K.A., Cowan, J.H., Winemiller, K.O., Myers, R.A. & Hilborn, R. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2: 293-327

Shepherd J. G. (1987) Towards a method for short-term forecasting of catch rates based on length compositions. ***In***: D. Pauly & G.P. Morgan (eds). Length-Based Methods in Fisheries Research. Manila: ICLARM, pp. 113-120

Smith, H.M. 1945. The Fresh-water fisheries of Siam or Thailand. United States Government Printing Office, Washington D.C

Sukumasavin, Nareupon, K. Lorenzen and Z. Hogan. 2014. Population Assessment and its Application on the Development of Conservation Strategies of the Mekong Giant Catfish. Paper presented during the Experts Meeting on Mekong Cooperation on Fisheries, Aquatic Resources and Wetlands: 20-year Lessons Learnt in Phnom Penh, Cambodia, 12-14 November 2014. Southeast Asian Fisheries Development Center, Bangkok, Thailand

Walters, C.J. & Martell, S.J.D. 2004. Fisheries Ecology. Princeton University Press, Princeton

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Save Our Eels: Protection or Extinction?

Takaomi Arai

Freshwater eels of Genus *Anguilla* are important aquatic species not only because of their unique catadromous life history, *i.e.* after being hatched in marine habitats, the fish migrate to freshwater areas where they spend the majority of their lives growing and maturing after which the adult fish return to the sea to spawn, but also for their value as food resource. Populations of the European, American and Japanese eels are now considered to be beyond safe biological limits and are seriously threatened with extinction. For such reason, the European eel has recently been categorized as critically endangered by the European Union and the United Nations. The drastic decline in eel populations due to overfishing, has led to increasing demand for cultured eels. As with many other aquatic species, aquaculture of eels still completely depends on wild juveniles since artificial propagation of eels has not yet been successful. Therefore, commercial eel industries are now considering tropical eels as possible replacement for the European and Japanese eels to compensate for the declining stocks. However, useful scientific research and information on the biology and stock assessments of tropical eels are inadequate, a situation which is quite different from that for other temperate freshwater eels, which have been well studied for several decades with trends and recruitment patterns being on record. Nevertheless, the present tropical eel catch has been reported as being less than half that of 20 years ago. The present trends in eel stocks and utilization for human consumption suggest that eel populations will decline to numbers that fall outside safe biological limits and will be seriously threatened with extinction without protection and conservation with strict enforcement of local and international laws. These insights are discussed in the article, where most of the contents were cited and refereed from the latest review regarding the present status of the biology and stocks of freshwater eels by Arai (2014a).

Current Status and Concerns on Eel Stocks in the World

Freshwater eels are exotic animals and despite a huge number of scientific studies conducted on eels, the crucial aspects of their biology remain a mystery. No one has yet observed eels spawning in the natural environment, as spawning areas are located in the open ocean. This distinctly contrasts with other animals, such as the anadromous salmon fish whose biology is well studied and better understood because localized spawning stocks are relatively easy to survey when the adults return to freshwater to spawn. Freshwater eels are the most important of the eel families from a conservation standpoint because they have a unique catadromous life history (**Fig. 1**) and are utilized as food resources. Recently, however, juvenile

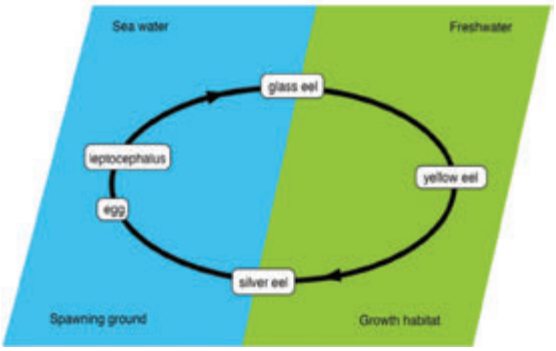

Fig. 1. Typical life history of freshwater eels of Genus *Anguilla*

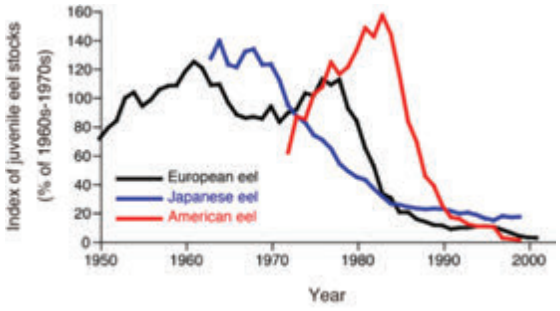

Fig. 2. Trends in juvenile stocks of the European, American and Japanese eels

Note: Data for European and Japanese eels are shown as landings of juveniles in each area and for the American eel as recruitment data from Lake Ontario at the northern limit of its distribution, the abundance of juvenile eels shows sharp decline after peaks, *i.e.* the European eel by 99%, the Japanese eel by 80%, and recruitment of the American eel has virtually ceased

Source: *Figure reference materials came from Dekker* et al. *(2003) and was drawn using original data provided by Dr. Willem Dekker (Arai, 2014a)*

abundance (**Fig. 2**) has declined dramatically by 99% for the European eel and by 80% for the Japanese eel (Dekker *et al*., 2003), while recruitment of the American eel near the species' northern limit has virtually ceased (Dekker *et al*., 2003). Other eel species, including the Australian and New Zealand eels (*Anguilla dieffenbachii* and *A. australis*) also show indications of decline (Dekker *et al*., 2003). The main problem is that all young eels used in aquaculture are wild juveniles (glass eels and elvers) captured in estuaries. Since almost all (90%) of the total world eel supply comes from aquaculture (FAO, 2010), therefore, the supply of eel resources for human consumption is completely dependent on wild catch.

The population size of wild juveniles has linearly decreased from over 200 metric tons in the early 1960s to 20 metric tons at present, and in Japanese eels, shortage of fry has become a serious problem for fish culture in recent years (Arai, 2014b). Eel stocks throughout Europe are also declining (Dekker, 2003a), and eel fishery yields have decreased in most European countries. Populations of the European,

American and Japanese eels are considered to be outside safe biological limits, and current fisheries are not sustainable (Dekker, 2003b; Dekker *et al*., 2003; Arai, 2014b). Under such circumstance, the European eel was recently categorized as critically endangered by the European Union (EU) and the United Nations (CITES, 2007), although other eel species have not yet been seriously considered for protection. Since the early 1980s, juvenile recruitment has decreased, dropping to 1.0% that of the levels in 1970s.

Nonetheless, the causes of decline in stock and recruitment are not well understood, although overfishing, habitat loss and migration barriers, increased natural predation, parasitism, ocean climate variations, and pollution might have some impacts (Knights, 2003; Marcogliese and Casselman, 2009; Bonhommeau *et al*., 2008; Friedland *et al*., 2007). Since the European eel was listed by CITES under Appendix II and came under protection in March 2009, and considering that export/import ban was already issued by the EU in 2010, the international trade of juvenile eels has changed.

Species other than the European and Japanese eels, such as several tropical species, seem to have replaced the European eel on the international market. In addition, countries including Canada, the USA, Dominican Republic, Morocco, Madagascar, Philippines, and Indonesia have now entered the market by supplying juvenile eels for the farming industry in China, Japan, Taiwan, and South Korea (Crook, 2013; Anonymous, 2013a and 2014). Since fewer studies had been conducted on tropical eels than those of the European, American, Japanese, Australian, and New Zealand eels, the unavailability of information on basic life history, stock and population of tropical eels could lead to further serious declines in such eel resources. Therefore, before tropical eel juveniles are used to replace and augment the European and Japanese eels stocks, stock assessments and recruitment studies of source stocks are necessary to determine the sustainability of tropical eels. However, consumers in the East Asian countries do not pay much attention to protection, conservation and enhancement of tropical eel populations, concentrating instead on having a stable eel supply and trade as they did with European and Japanese eels. If such *ad hoc* eel resource utilization would continue, eels around the world would become extinct in the near future, considering that artificially induced breeding techniques for eel species are not yet firmly established, unlike for salmon, blue fin tuna and livestock. This situation could accelerate the status of wild eel stocks from threatened to declining. The inadequacy of scientific research, assessment and protection would lead to the collapse of tropical eel populations and affect the sustainability of the European, American, Japanese, Australian, and New Zealand eel resources. Therefore, rapid stock assessment and continuous monitoring of recruitment in tropical eels are necessary before fully utilizing this resource to avoid eel extinctions around the world.

History and Status of Eel Aquaculture

The global demand for eels has been met largely through the aquaculture production of essentially two eel species, the Japanese eel and the European eel (**Fig. 3**). Consumers in East Asia and Europe value the nutritional properties of these eels, making it a high-value aquaculture commodity. In fact, FAO (2010) mentioned that almost all (90%) of the world's eel supply comes from aquaculture.

Aquaculture of eels has been pioneered by countries where eels are a delicacy. Eel culture in Japan began in 1879 (Matsui, 1952) and at approximately the same time in Italy and France (Gousset, 1990; Heinsbroek, 1991; Ciccotti and Frontennelle, 2000). Initially, eel was raised in polyculture systems (Gousset, 1992), but large-scale commercial production started in the early 1960s when formulated feeds became available (Liao *et al*., 2002). Eel farming depends completely on the collection from the wild of juvenile stages such as the glass eel and elvers (**Fig. 4**). Therefore, the annual recruitment of the glass eel is very important to the eel aquaculture industry. However, recent recruitments of the glass eel stage of the Japanese eel have fallen to 10% that of the early 1960s rate (Ijiri *et al*., 2011).

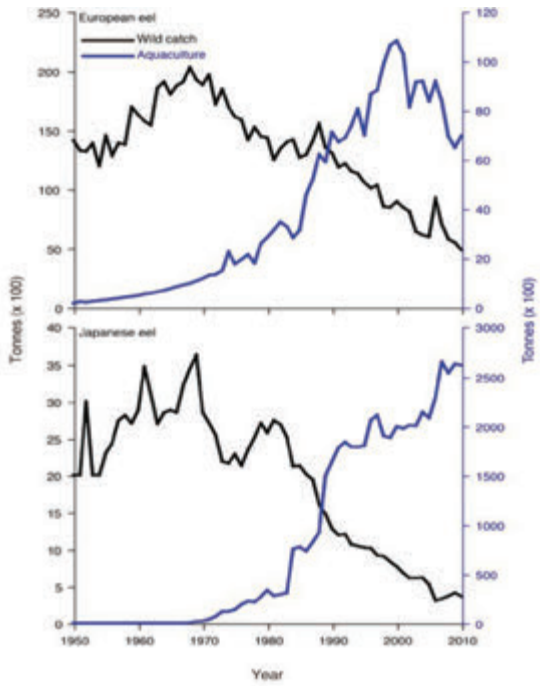

Fig. 3. Trends in global capture and aquaculture production between 1950 and 2010 for the European eel (top) and Japanese eel (bottom)
Note: Sharp declines in wild European and Japanese eel populations correspond to drastically increasing aquaculture demands for these eels after the 1970s, where peak capture of Japanese eels is less than the lowest captures of European eels, indicating a relatively low virgin biomass of Japanese eels

Source: *Arai 2014a, figure was drawn using the FAO FishFinder of the Food and Agriculture Organization of the United Nations (http://www.fao.org/fishery/fishfinder/contacts/en)*

Fig. 4. Newly recruited glass eels to Indonesian coasts (approximately 50 mm in total length), the complete dependence of eel aquaculture on wild glass eels could lead to serious declines in eel stocks

For the European eel, recruitment has also fallen, on average to <5% of the peak levels of the late 1970s and early 1980s (Dekker *et al*., 2007) as shown in **Fig. 2**, and the ICES continues to advise that the stock is outside safe biological limits and that current fisheries are not sustainable (ICES, 2006). The unstable supplies and prices for glass eels are serious concerns that confront the eel aquaculture industry. Therefore, the development of eel artificial breeding techniques is urgently necessary. In Japan, attempts to induce the artificial maturation of the Japanese eel started in the 1960s (Tanaka *et al*., 2003).

Yamamoto and Yamauchi (1974) were the first to successfully obtain fertilized eggs and larvae from the Japanese eel using hormone treatments, and after a two-week rearing period the preleptocephalus larvae reached 7 mm TL (Yamauchi *et al*., 1976). However, the larvae did not feed, and the transition into leptocephalus larvae did not occur. Although many researchers have henceforth succeeded in obtaining eel preleptocephali (Satoh, 1979; Wang *et al*., 1980), larval feeding and the production of leptocephali were not successful until 2001 (Tanaka *et al*., 2001).

For other eel species, such as the European eel (Prokhorchik, 1986) and the New Zealand short- and long-finned eels (*A. australis* and *A. dieffenbachii*, Anguillidae), experimentally produced larvae had only survived for few days (Lokman and Young, 2000), and as with the Japanese eel, did not develop into leptocephali. After much trial and error, Tanaka *et al*. (2001) found that preleptocephali were strongly attracted to and actively fed on shark egg powder. Thereafter, leptocephali have been successfully reared in aquaria using this diet for 100 days and have been raised to 22.8 mm TL, and the morphological characteristics and age of the reared leptocephali overlap with those of wild leptocephali (Tanaka *et al*., 2001). Soon after this study was performed, Tanaka *et al*. (2003) reported further progress in rearing larvae to the glass eel stage and even further to the yellow eel stage in 2003 (Ijiri *et al*., 2011).

After succeeding in rearing the eels to the leptocephalus stage (Tanaka *et al*., 2001), their diet was improved by supplementation with krill hydrolysate, soybean peptide, vitamins and minerals (Tanaka *et al*., 2003). The leptocephali that fed on this new diet grew to 50 to 60 mm TL and had begun to metamorphosis into glass eels approximately 250 days after hatching (Tanaka *et al*., 2003). The artificially produced glass eels could be grown and were artificially matured (Ijiri *et al*., 2011). Thereafter, a second generation of larvae was produced in 2010 (Ijiri *et al*., 2011). However, the techniques for producing glass eels are not yet firmly established (Tanaka *et al*., 2003). The egg quality is unstable, and the survival rates of the larvae are usually extremely low. In addition, the growth of the larvae is slower in captivity than in the wild by approximately 100 days (Arai *et al*., 1997). Under such conditions, the mass production of glass eels for use in aquaculture has not succeeded until recently.

Present Status of Trading and Biological Studies of Tropical Freshwater Eels

The present target tropical eel species is a tropical eel, *Anguilla bicolor* (*A. bicolor bicolor* and *A. bicolor pacifica*) from Indonesia and the Philippines (Anonymous, 2013a, 2014). China, Japan, Taiwan and South Korea have been importing cultured eel and selling it to consumers, using it to replace and compensate for the declining European and Japanese eel supply. Although Indonesia and the Philippines prohibit the export of juvenile eels, *i.e.* less than 150 g in weight from Indonesia and less than 15 cm in length from the Philippines to protect their resources, no regulations are enforced for juvenile fisheries in these countries (Anonymous, 2013a and 2014). All marked eels are either wild-caught eels or cultured eels from wild juveniles. Since there are no historical stock or juvenile recruitment data for eels available in these countries, fluctuation in the abundance of eels could not be well understood. The only available data in tropical eels show the three-year trend for recruitment from 1997 to 1999 based on quantitative sampling from an estuary in Indonesia (Arai *et al*., 1999; Sugeha *et al*., 2001), where juveniles were found to occur throughout each year (**Fig. 5**) with the highest recruitment occurring at the time of the new moon (Sugeha *et al*., 2001). More than 30,000 glass eels were collected

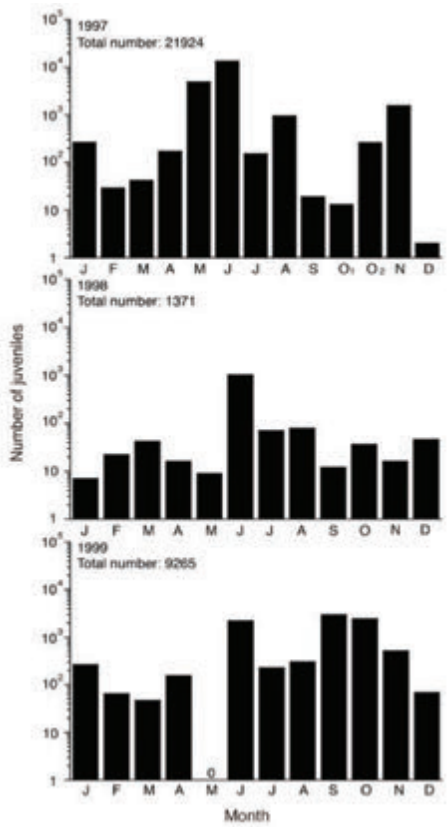

Fig. 5. Fluctuations of recruitment in tropical juvenile eels in Indonesia between 1997 and 1999

Notes: Monthly abundance of 3 tropical juvenile eels collected at the new moon in the Poigar River estuary, North Sulawesi Island of Indonesia from 1997 to 1999, where for October 1997 samples: 1 = early, 2 = late (Arai *et al.*, 1999; Sugeha *et al.*, 2001)

Juvenile eels were collected at the mouth of the tropical river, and were caught along a 10 m transect at the beach within 1.5 m from shore using 2 triangular scoop nets (mouth 0.3 m^2, 1 mm mesh), where the nets were fished simultaneously at depths of 25 to 50 cm in 10 replicate passes at hourly intervals (Arai *et al.*, 1999; Sugeha *et al.*, 2001); where the temporal patterns of juvenile catches suggest tropical juveniles recruit to the estuary throughout the year with considerable inter-annual variation in the recruitment patterns, such recruitment patterns are clearly different from those of European, American, Japanese, Australian and New Zealand eels, which have much shorter seasonal ranges in recruitment period during about half the year or less (Matsui, 1952; Haro & Krueger, 1988; Gandolfi *et al.*, 1984; Sloane, 1984; Jellyman, 1977)

This figure was drawn using the original data from Arai et al. *(1999) and Sugeha* et al. *(2001)*

quantitatively in the Poigar River estuary on north Sulawesi Island, Indonesia, with monthly collections from 1997 to 1999 (Arai *et al*., 1999; Sugeha *et al*., 2001).

The specimens identified were of three species, *Anguilla celebesensis*, *A. marmorata*, and *A. bicolor pacifica*, and were found each year in fluctuating abundances (**Fig. 6**). *A. celebesensis* was the most abundant species and comprised 73.5 %, 79.5 %, and 81.9 % of all glass eels recruiting to the estuary of the Poigar River in 1997, 1998, and 1999, respectively (**Fig. 6**) (Arai *et al*., 1999; Sugeha *et al*. 2001). This species was relatively abundant in all three years with peaks during June in 1997 and 1998 and during September in 1999 (**Fig. 6**). *A. marmorata* was the second most abundant species and comprised 23.8 %, 18.8 %, and 17.7 % of the yearly catches, respectively, and the peaks in abundance were reached during June in 1997 and 1998, and during January in 1999 (**Fig. 6**). *A. bicolor pacifica* comprised only 2.7 %, 1.7 %, and 0.3 % of the yearly catches respectively, with peak catches in June in 1997, January in 1998, and January and February in 1999 (**Fig. 6**). *A. celebesensis* and *A. marmorata* were collected almost throughout the year in 1997, 1998, and 1999, suggesting that in contrast to the temperate eels that recruit during half the year from winter to spring, these tropical eel species recruit to some degree throughout the year.

The temporal patterns of glass eel catches near the mouth of the Poigar River differed among species and years suggesting that there was considerable inter-annual variation in the recruitment patterns of glass eels in the region. However, such systematic surveys for tropical glass eels have never been conducted in other tropical regions. Further long-term surveys should be urgently needed to understand the natural (*e.g.* ambient environments such as global climate change and oceanic transportation systems) and anthropogenic impacts (*e.g.* over exploitation, habitat degradation and pollution) on the recruitment of glass eels in tropical regions. The natural reproductive ecology and spawning patterns of both tropical and temperate eel species remain a mystery, and it is thus extremely difficult to determine the nature of the migrations of freshwater eels (Arai, 2016).

Recently, Arai (2014c) found that tropical freshwater eels in Lake Poso, located in Central Sulawesi, Indonesia, had higher gonadosomatic index values than did temperate eels that were collected in coastal waters preparing for spawning migration and showed histologically fully developed gonads (**Fig. 7**). The results suggested that, in contrast to the long-distance migrations made by the Atlantic and Japanese eels, freshwater eels originally migrated only short distances, perhaps less than 100 km to local spawning areas adjacent to their freshwater growth habitats (Arai, 2014c).

Present Status of Stocks in Temperate Freshwater Eels

In contrast to the tropical eels, historical stock data for wild eels are available for European, American, Japanese, Australian, and New Zealand eels. For European and Japanese eels, wild catches fell gradually after the peak levels of the late 1970s and early 1980s in accordance with the increasing demand for eels in aquaculture (**Fig. 3**). Trends in juvenile abundance of the major eel stocks for European, American and Japanese eels also suggest that juvenile populations have declined dramatically and clearly lie outside of safe biological limits (**Fig. 2**). Moreover, the recruitment of European and Japanese eels in each distribution range declined by 99% and 80%, respectively, while recruitment of American eel at the northern limit of its distribution has ceased (**Fig. 2**).

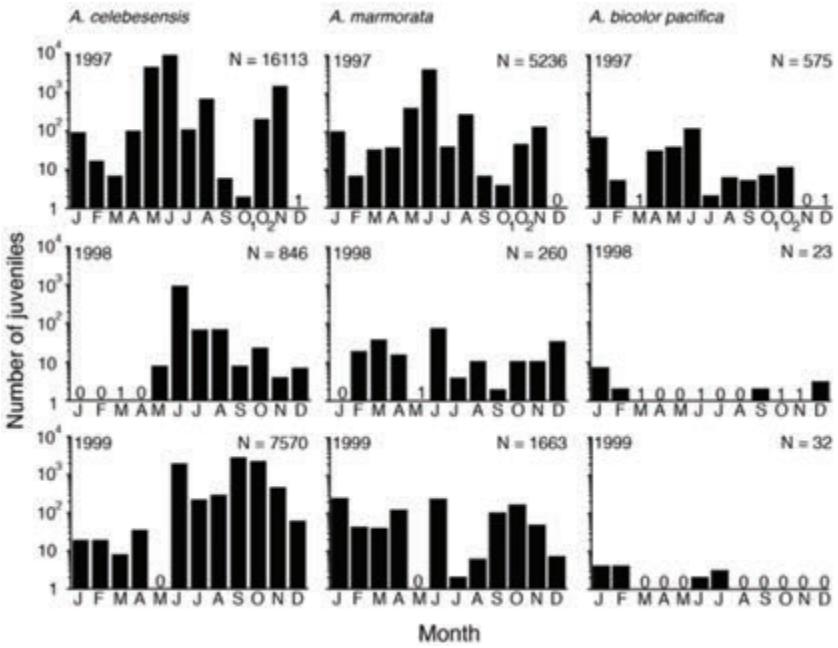

Fig. 6. Fluctuations of recruitment in tropical eels *Anguilla celebesensis*, *A. marmorata* and *A. bicolor pacifica* in Indonesia between 1997 and 1999 (Arai, 2014a)

Note: Monthly abundance of glass eels of each species collected at new moon in the Poigar River estuary from 1997 to 1999 (for October 1997 samples: O_1 = first new moon, O_2 = second new moon)

This figure was drawn using the original data from Arai et al. *(1999) and Sugeha* et al. *(2001)*

Worldwide Decline of Freshwater Eel Populations

The worldwide decline of freshwater eel populations is a major concern for animal conservation and diversity. European, American and Japanese eels have experienced sharp declines across their ranges over the last 30–40 years (ICES, 2006; Aprahamian *et al*., 2007; Castonguay *et al*., 1994; Dekker *et al*., 2003, 2007) as shown in **Fig. 2** and **Fig. 3**. In spite of the seriousness of the situation for juvenile eel recruitment, eel consumption is still increasing. To continue to supply large amounts of eels to consumers, the replacement and compensation have started to import eels from foreign countries, mainly the Philippines, Indonesia and Madagascar (Anonymous, 2013a, 2013b, 2014). The main problem with consumption of this animal is that artificial propagation has not yet succeeded as it has with other common animals, such as salmon, blue fin tuna and livestock; therefore, juvenile eels are high-value aquaculture commodities that put high fishing pressure on a natural environment. Almost all (90 %) of the world's eel supply comes from aquaculture (FAO, 2010), and the present eel aquaculture completely (100 %) depends on wild juveniles. More than 90 % of the world production of eels is cultured in East Asia, primarily Japan, Taiwan and China (Ringuet *et al*., 2002). Thus, wild juvenile eel catch will be needed in the future for these countries due to the increasing demands of aquaculture (**Fig. 3**). To enhance natural eel stocks and continue their commercial usage for human consumption, studies related to the establishment of commercial juvenile production are urgently required and should focus on this goal as a means of protecting wild eel stocks.

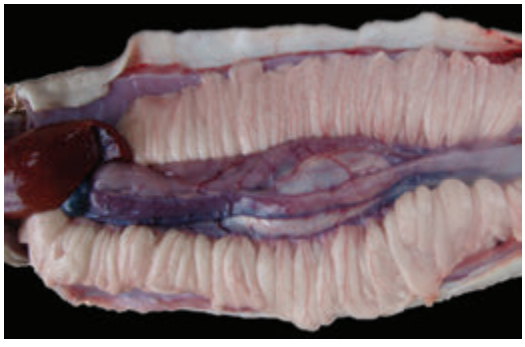

Fig. 7. Gonadal morphology of a spawning-condition tropical freshwater eel *Anguilla celebesensis* (754 mm in TL) that was collected from Lake Poso, Central Sulawesi, Indonesia

Concerns on Lack of Stock Assessment and Enhancement in Freshwater Eels

For the European eel, as a consequence of these concerns, the European Commission has agreed to an eel recovery plan, the aim of which is to return the European eel stock to sustainable levels of adult abundance and juvenile recruitment (Svedäng and Gipperth, 2012). In 2007, the European eel was listed in Appendix II of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) and Appendix II "includes species not necessarily threatened with extinction, but in which trade must be controlled to avoid utilization incompatible with their survival" (CITES, 2007). Although stock assessment and management of the European eel have received increasing attention from both the scientific community and fisheries agencies in recent years (ICES, 2006), such assessment and management of the Japanese eel have not yet been well studied. Such studies would help

with the development of a concrete conservation policy and management applications for stock enhancement.

Despite the high demand for the product, the peak capture of Japanese eels (**Fig. 3**) is less than the lowest captures of European eels (Halpin, 2007). This fact indicates a relatively low virgin biomass of Japanese eels. To make matters worse, trade in tropical eels started with no scientific assessment and management before usage in spite of our experience with severely declining stocks in European, American, Japanese, Australian and New Zealand eels. Until now, there has been no information available on historical fishing records in tropical eels and only limited biological information compared with European, American, Japanese, Australian and New Zealand eels.

Do We Allow Freshwater Eels to Extinction?

Although European, American, Japanese, Australian and New Zealand eels appeared to have much shorter seasonal ranges during the recruitment period for about half of the year or less (Matsui, 1952; Haro and Krueger, 1988; Gandolfi *et al*., 1984; Sloane, 1984; Jellyman, 1977), at least a few juveniles of the tropical eels recruited year-round. The temporal pattern of tropical juvenile recruitment (**Fig. 5** and **Fig. 6**) was found to have considerable inter-annual variation (Arai *et al*., 1999; Sugeha *et al*., 2001). Thus, continuous long-term research is needed to determine the causes of the variation. Such year-round recruitment in tropical eels might be more convenient in aquaculture, which would be able to culture eels throughout year. In fact, 70 tons of eels were exported to Japan from one eel farm in Indonesia in 2013, and this amount is estimated to double in 2014 (Anonymous, 2014). Because the present market price of juvenile eels is 150 times higher than 20 years ago, a number of village people near juvenile eel fishing grounds in Indonesia tend to concentrate on eel fishing only, whereas they used to focus on farming and fishing (Anonymous, 2014). However, the juvenile eel catch is now reported to be half that of 20 years ago (Anonymous, 2014), although the estimated decline has never been evaluated based on scientific research. The causes of decline in eel stocks and recruitment are not well understood. One of the main reasons must be overfishing, as sharp declines in wild European and Japanese eel populations correspond to drastically increased aquaculture demands for these eels since the 1970s (**Fig. 3**). Now, tropical eels may have begun to follow the same trends as the European and Japanese eels. This suggests that we cannot rule out overfishing in tropical countries. Thus, if the wild juvenile eel catch of tropical eels continues to increase without assessment and protection of the stock and regulation of the catchment, all eel populations will decline to numbers outside safe biological limits. Currently, European, American and Japanese eels are seriously threatened with extinction due to eel consumption, and demand is still increasing. After the stocks and recruitment collapse in the present target eel species and areas, we will have to seek other targets for replacement and compensation to continue eel consumption. We may not be able to see such a unique animal on earth in the near future.

References

Anonymous. 2013a. Competition on eel fishery and trading in Asia. *http://www.nhk.or.jp/ohayou/marugoto/2013/08/0801.html* (accessed March 19 2014).

Anonymous. 2013b. The danger zone for eel. *http://weekly.japantimes.co.jp/ed/the-danger-zone-for-eels*. (accessed March 28 2014)

Anonymous. 2014. Eel battle in tropical area. *http://bulo.hujiang.com/menu/110460/item/862115/* (accessed March 19 2014).

Aprahamian, M. W., Walker, A. M., Williams, B., Bark, A., Knights, B. 2007. On the application of models of European eel (*Anguilla anguilla*) production and escapement to the development of Eel Management Plans: the River Severn. *ICES Journal of Marine Science* 64: 1472–1482

Arai, T., Otake, T., Tsukamoto, K. 1997. Drastic changes in otolith microstructure and microchemistry accompanying the onset of metamorphosis in the Japanese eel *Anguilla japonica*. *Marine Ecology Progress Series* 161: 17–22

Arai, T., Aoyama, J., Limbong, D. and Tsukamoto, K. 1999. Species composition and inshore migration of the tropical eels *Anguilla* spp. recruiting to the estuary of the Poigar River, Sulawesi Island. *Marine Ecology Progress Series* 188: 299–303

Arai, T. 2014a. Do we protect freshwater eels or do we drive them to extinction? *SpringerPlus* 3: 534

Arai, T. 2014b. How have spawning ground investigations of the Japanese eel *Anguilla japonica* contributed to the stock enhancement? *Reviews in Fish Biology and Fisheries* 24: 75-88

Arai, T. 2014c. Evidence of local short-distance spawning migration of tropical freshwater eels, and implications for the evolution of freshwater eel migration. *Ecology and Evolution* 4: 3812-3819

Arai, T. 2016. Spawning ground of tropical eels. ***In***: Arai T (*ed*.) Biology and Ecology of Anguillid Eels. CRC Press, Boca Raton, FL, USA; pp. 89-107; in press

Bonhommeau, S., Chassot, E., Rivot, E. 2008. Fluctuations in European eel (*Anguilla anguilla*) recruitment resulting from environmental changes in the Sargasso Sea. *Fisheries Oceanography* 17: 32–44

Castonguay, M., Hodson, P. V., Moriarty, C., Drinkwater, K. F., Jessop, B. M. 1994. Is there a role of ocean environment in American and European eel decline? *Fisheries Oceanography* 3: 197–203

Ciccotti, E., Fontennelle, G. 2000. Aquaculture of European eel (*Anguilla anguilla*) in Europe: a review. ***In***: *Abstracts of the 3rd East Asian Symposium on Eel Research—Sustainability of Resources and Aquaculture of Eels*. Keelung: Taiwan Fisheries Research Institute, pp 9–11

CITES. 2007. Proposal: Inclusion of *Anguilla anguilla* (L) in Appendix II in accordance with Article II §2(a). ***In***: Convention on International Trade in Endangered Species of Wild Flora and Fauna. Fourteenth meeting of the Conference of the Parties, The Hague, Netherlands, 3–15 June 2007 CoP14, Prop. 18. *http://www.cites.org/common/cop/14/raw_props/EDE04-Anguilla%20anguilla.pdf* (accessed 8 Aug 2007)

Crook, V. 2013. Traffic Bulletin Vol 25, No. 1. *http://www.traffic.org/bulletin-download*

Dekker, W. 2003a. On the distribution of the European eel (*Anguilla anguilla*) and its fisheries. *Canadian Journal of Fisheries and Aquatic Sciences* 60: 787–799

Dekker, W. 2003b. Did lack of spawners cause the collapse of the European eel, *Anguilla anguilla*? *Fisheries Management and Ecology* 10: 365–376

Dekker, W., Pawson, M., Wickström, H. 2007. Is there more to eels than slime? An introduction to the papers presented at the ICES Theme Session in September 2006. IC*ES Journal of Marine Science* 64: 1366–1367

Dekker, W., Casselman, J.M., Cairns, D.K., Tsukamoto, K., Jellyman, D., Lickers, H. 2003. Québec Declaration of Concern: worldwide decline of eel resources necessitates immediate action. *Fisheries* 28, 28–30

FAO European Inland Fisheries Advisory Commission; International Council for the Exploration of the Sea. 2006. ICES Report of the Joint EIFAC/ICES Working Group on Eels. ICES Document CM 2006/ACFM: 16 (2006) *http://www.vliz.be/imisdocs/publications/230347.pdf* (accessed March 28, 2013)

FAO (Food and Agriculture Organization of the United Nations). 2010. *The state of world fisheries and aquaculture*. Food and Agriculture Organization of the United Nations, Rome; 197 p

Friedland, K. D., Miller, M. J. and Knight, B. 2007. Oceanic changes in the Sargasso Sea and declines in recruitment of the European eel. *ICES Journal of Marine Science* 64: 519–530

Gandolfi, G., Pesaro, M. and Tongiorgi, P. 1984. Environmental factors affecting the ascent of elver, *Anguilla anguilla* (L) into the Arno River. *Oebalia* 5: 17–35

Gousset, B. 1990. European eel (*Anguilla anguilla* L.) farming technologies in Europe and in Japan: application of a comparative analysis. *Aquaculture* 87, 209–235

Halpin, P. 2007. Unagi: Freshwater ''Eel''. *Anguilla japonica*, *A. anguilla*, *A. rostrata*. Seafood Watch, Seafood Report. Monterey Aquarium, Monterey *http://www.seafoodwatch.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_UnagiReport pdf.* (accessed March 28, 2013)

Haro, A. J. and Krueger, W.H. 1988. Pigmentation, size, and migration of elvers *Anguilla rostrata* (Lesueur) in a coastal Rhode Island stream. *Canadian Journal of Zoology* 66, 528:2533

Heinsbroek, L. T. N. 1991. A review of eel culture in Japan and Europe. *Aquaculture and Fishery Management* 22, 57–72

ICES. 2006. Report of the Joint EIFAC/ICES Working Group on Eels. ICES Document CM 2006/ACFM: 16: 367 p

Ijiri, S., Tsukamoto, K., Chow, S., Kurogi, H., Adachi, S., Tanaka, H. 2011. Controlled reproduction in the Japanese eel (*Anguilla japonica*), past and present. *Aquaculture Europe* 36: 13–17

Jellyman, D. J. 1977. Invasion of a New Zealand freshwater stream by glass eels of two *Anguilla* spp. *New Zealand Journal of Marine and Freshwater Research* 11: 193–209

Knights, B. 2003. A review of the possible impacts of long-term oceanic and climate changes and fishing mortality on recruitment of anguillid eels of the Northern Hemisphere. *Science of the Total Environment* 310: 237–244

Lokman, P. M., Young, G. 2000. Induced spawning and early ontogeny of New Zealand freshwater eels (*Anguilla dieffenbachii*) and (*A. australis*). *New Zealand Journal of Marine and Freshwater Research* 34: 135–145

Marcogliese, L. A., Casselman, J. M. 2009. Long-term trends in size and abundance of juvenile American eel (*Anguilla rostrata*) in the St. Lawrence River. *American Fisheries Society Symposium* 58: 197–206

Matsui, I. 1952. Study on the morphology, ecology and pond culture of the Japanese eel (*Anguilla japonica* Temminck & Schlegel). *Journal of the Shimonoseki College of Fisheries* 2: 1–245

Prokhorchik, G. A. 1986. Postembryonic development of European eel, *Anguilla anguilla*, under experimental conditions. *Journal of Ichthyology* 26: 121–127

Ringuet, S., Muto, F., Raymakers, C. 2002. Eels, their harvest in Europe and Asia. *Traffic Bulletin* 19: 2–27

Satoh, H. 1979. Try for perfect culture of the Japanese eel. *Iden* 33: 23–30

Sloane, R. D. 1984. Distribution, abundance, growth and food of freshwater eel (*Anguilla* spp.) in the Dauglass River, Tasmania. *Australian Journal of Marine and Freshwater Research* 35: 325–339

Sugeha, H. Y., Arai, T., Miller, M. J., Limbong, D., Tsukamoto, K. 2001. Inshore migration of the tropical eels *Anguilla* spp. recruiting to the Poigar River estuary on north Sulawesi Island. *Marine Ecology Progress Series* 221: 233-243

Svedäng, H., Gipperth, L. 2012. Will regionalization improve fisheries management in the EU? An analysis of the Swedish eel management plan reflects difficulties. *Marine Policy* 36: 801–808

Tanaka, H., Kagawa, H., Ohta, H. 2001. Production of leptocephali of Japanese eel (*Anguilla japonica*) in captivity. *Aquaculture* 201: 51-60

Tanaka, H., Kagawa, H., Ohta, H., Unuma, T., Nomura, K. 2003. The first production of glass eel in captivity: fish reproductive physiology facilitates great progress in aquaculture. *Fish Physiology and Biochemistry* 28: 493-497

Wang, Y., Zhao, C., Shi, Z., Tan, Y., Zhang, K., Li, T. 1980. Studies on the artificial inducement of reproduction in common eel. *Journal of Fisheries of China* 4: 147–156

Yamamoto, K., Yamauchi, K. 1974. Sexual maturation of Japanese eel and production of eel larvae in the aquarium. *Nature* 251: 220-222

Yamauchi, K., Nakamura, M., Takahashi, H., Takano, K. 1976. Cultivation of larvae of Japanese eel. *Nature* 263: 412

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Harnessing the Potentials of Inland Fishery Resources in Southeast Asia: Role of SEAFDEC/IFRDMD

Chumnarn Pongsri, Budi Iskandar Prisantoso, Virgilia T. Sulit and *Nualanong Tongdee*

Cognizant of the important role that agriculture plays in the economic development of Southeast Asia, especially on the need to increase food production for the increasing population in the region, the April 1966 Ministerial Conference for the Economic Development of Southeast Asia agreed to *develop the region's fisheries as one of the means of improving the food situation of the region*. The same Conference also sought the cooperation of Japan for the establishment of a Marine Fisheries Research and Development Center in Southeast Asia. The ensuing December 1966 Conference on Agriculture Development in Southeast Asia conformed to the prior understanding that *fisheries development should be promoted in the region* to improve nutritional standards and increase supply of animal protein, and evoked that such goal could be achieved through *research, development and expansion of fisheries techniques appropriate for the region*. While also considering that inland water fisheries is important for several countries in the region, the December 1966 Conference also agreed to *consider the need for multiplication and conservation of inland water fishery resources*. Thus, in order to jump-start the establishment of the proposed Center, a study working group consisting of fisheries experts from Southeast Asia and Japan was put together in early 1967 to assess the requirements and procedures for such undertaking. The study group's recommendations to establish the **Southeast Asian Fisheries Development Center** including the draft Agreement for establishing the proposed Center, was then considered and adopted during the Second Ministerial Conference for the Economic Development of Southeast Asia convened in the Philippines in April 1967. Also included in the adopted recommendations of the study group was the organization structure of the proposed Center which shall initially consist of the Marine Fisheries Training Department (later known as the Training Department or **TD**) and Marine Fisheries Research Department (**MFRD**), with the respective working programs of such Departments. After the draft Agreement had been finalized through the initiative of Japan, Malaysia, Philippines, Singapore, Viet Nam, and Thailand, signing of the Agreement was arranged on ***28 December 1967 in Bangkok, Thailand*** and the Inaugural Meeting of the SEAFDEC Council was convened in Thailand in March 1968, in accordance with the said Agreement establishing SEAFDEC.

One year later, the common interest of the Southeast Asian countries to improve the current fish culture technologies in order to contribute to the overall objective of increasing food production was expressed by the governments during the subsequent Third Ministerial Conference for the Economic Development of Southeast Asia in 1968. SEAFDEC was then asked to consider the establishment of a third Department to deal with freshwater and brackishwater fish culture. The study group composed of aquaculture experts from the Member Countries which was formed for this purpose, came up with a proposal which was adopted by the Fourth Ministerial Conference for the Economic Development of Southeast Asia in 1969 giving impetus to the establishment of the Aquaculture Department (**AQD**) in the Philippines which was agreed upon by the SEAFDEC Council during its Meeting in Malaysia in July 1973. Two decades after the Inaugural Meeting of the SEAFDEC Council, the Government of Malaysia proposed during the 21st Meeting of the Council in 1988, the establishment of a SEAFDEC Department for fishery resource development and management to be hosted by Malaysia, considering the declining state of the region's fishery resources and the need to match exploitation level with resource ability and regeneration. The SEAFDEC Council adopted the recommendations of the Technical Working Group that reviewed the proposal, and agreed during its 24th Meeting in 1991 to establish the Marine Fishery Resources Development and Management Department (**MFRDMD**) in Terengganu, Malaysia. In view of some technical issues including the finalization of its working programs, MFRDMD was officially established in 1992.

Meanwhile, as inland fisheries received more attention considering its potentials to supply fish required for the growing food needs of the populace, especially the region's rural poor, the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium "Fish for the People" in November 2001 included in one of the agenda, discussion on Inland Fisheries Development and Management. It was also recognized during the Conference that there is a need to compile real time data and information for the proper valuation of inland fisheries that could be used during planning and management of the inland fisheries sub-sector. Moreover, the Conference also considered it important to establish an approach that would recognize the role of inland fisheries within a multiple use water management system and foster restoration of critical habitats including fish migratory routes. As a result, the Resolution and Plan of Action adopted during the 2001 Conference included the need for the ASEAN countries to promote the importance of inland fisheries and aquaculture in planning and policy formulation, as means of improving food security and livelihoods of the rural people. Moreover, the subsequent Resolution which was adopted during the succeeding ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" in June 2011, specified that the ASEAN countries should enhance the awareness of stakeholders on the contribution of inland fisheries to food security and sustainable livelihoods, and that all concerned stakeholders should be involved in undertaking development projects that may impact the inland fisheries. As a response to the aforementioned pronouncements, SEAFDEC has sustained its efforts in promoting inland aquaculture through AQD, and inland fisheries development through the newly-established SEAFDEC Inland Fishery Development and Management Department (**IFRDMD**) in Palembang, Indonesia for the sustainable development and management of inland fisheries in Southeast Asia.

Inland Fishery Resources of Southeast Asia with Potentials for Fisheries Development

The Southeast Asian region is endowed with enormous areas of natural inland water resources that could be tapped for sustainable development of freshwater fisheries as well as man-made water bodies that could provide additional resources. Although not comprehensive enough, **Table 1** partly shows the available natural and man-made water bodies in Southeast Asia, comprising river systems, lakes, floodplains, reservoirs and dams, wetlands, and others. It is against the backdrop of such valuable gift provided by nature and in some cases enhanced by humans, with huge potentials for development but mostly remained under-utilized, that the Minister for Marine Affairs and Fisheries of Indonesia in 2011 (SEAFDEC, 2011a) offered to host a regional center for inland fisheries development as part of the SEAFDEC organization. Recognizing that inland fisheries could complement to a great extent fish production from marine capture fisheries and aquaculture, the ASEAN countries during the 2011 ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment", concurred to the proposed establishment of such inland fisheries center in Indonesia.

Based on such an agreement, the Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 which was adopted by the Ministers responsible for fisheries of the ASEAN-SEAFDEC Member Countries during the same ASEAN-SEAFDEC Conference, clearly included provisions for the sustainable development of inland fisheries in Southeast Asia (**Box 1**). This same argument had also fuelled the decision of the Minister for Marine Affairs and Fisheries of Indonesia to push through with the proposed establishment of a regional center for inland fisheries development under the SEAFDEC umbrella organization. Thus, the eventual establishment of the SEAFDEC Inland Fishery Resources Development and Management Department in Palembang, Indonesia came into force on 2 September 2014 upon subsequent consideration and endorsement by the Council of Directors of the Southeast Asian Fisheries Development Center.

Table 1. Natural as well as man-made water bodies in Southeast Asia

Country	Rivers (km^2)	Lakes (ha)	Floodplains[1] (ha)	Reservoirs (ha)	Dams (ha)	Wetlands[2] (ha)	Others (ha)
Cambodia[3]	1,482.82[a]	334,186.79[b]	727,382.10[b]	11,684.47[b]	7,805.00[c]	2,412,401.00[b]	254,796.55[b,d]
Indonesia[4]	1,899,750.00[e]	1,800,000.00[f]	33,281,155.00[g]	500,000.00[h]	26,522,193.00[h]	20,096,800.00[i]	3,852,223.09[i]
Lao PDR[5]	123,347.80	-	156,000.00	130,309.78	-	843.60	-
Malaysia[6]	312,840.67[k]	109,489.00[l]	2,979,918.00[m]	*included in lakes*		6,942,556.00[n]	-
Myanmar[7,o]	737,800.00[p]	-	6,000,000.00[p]	1,800,000.00[p]	-	-	1,300,000.00[p]
Philippines[8]	108,923.00[q]	187,168.40[q]	-	19,000.00[r]	-	246,063.00[r]	253,854.00[s]
Thailand[9]	511,311.00[t]	-	12,851,984.00[u]	645,350.62[v]	-	-	965,739.37[w]

1 *Floodplains are areas of low-lying grounds adjacent to a river, formed mainly of river sediments and subject to flooding*
2 *Wetlands are areas saturated with water, either permanently or seasonally, take on the characteristics of distinct ecosystem (e.g. swamps, marshes, bogs) and vary widely in terms of soil composition, topography, hydrology, water chemistry, vegetation, among others*
3 *General Source: Chin Leakhena (pers comm., 2015)*
a *Source: River network (JICA, 2002)*
b *Source: Land use (JICA, 2002)*
c *Source: Open Development of Cambodia (ODC, 2014)*
d *Refer to the Tonle Sap*
4 *General Source: Sevi Sawestri (pers comm., 2015)*
e *Daftar Wilayah Sungai Kementerian PU RI/Ministry of Public Works: http://sda.pu.go.id:8181/sda/index.php?act=daftar_ws*
f *Kelautan dan Perikanan Dalam Angka/Marine and Fisheries in Figures 2014, Page 42 & 165; Kartamihardja (2015)*
g *Buku Informasi Statistik Pekerjaan Umum 2013, Page III-21; 10,802,132.00 ha have potentials for agriculture, 22,479,023.00 not suitable for agriculture*
h *Buku Informasi Statistik Pekerjaan Umum 2013, Page III-10 & 12; Kartamihardja (2015)*
i *Wetlands include peatswamps (Kartamihardja, 2015); Others include mangroves*
5 *General Source: Phongsavanh Sengsomphou: Other sources: https://en.wikipedia.org/wiki/Mekong; https://lo.wikipedia.org/wiki/ແມ່ນ້ຳຂອງ; https://en.wikipedia.org/wiki/Nam_Theun_2_Dam; www.internationalrivers.org/.../study_prepared_by_fisheries; www.seafdec.or.th/.../627-report-on-the-preliminary-surve; www.poweringprogress.org/new/9.../17-se-xet-2-76mw; vahttps://en.wikipedia.org/wiki/Nam_Ngum_Damselaos.com/houaykapheu.htm; www.internationalrivers.org/campaigns/nam-ou-river; https://en.wikipedia.org/wiki/Nam_Ngum; www.mrcmekong.org/.../TB-Lao-Thai-Xe-Bang-Hieng-Na; www.icem.com.au/.../wetlands%20wshop/g.Lao_wetland_s*
6 *General Source: Hemalatha Raja Sekaran (pers comm.., 2015)*
k *Source: http://forum.mygeoportal.gov.my/smanre/sungai/lembangan_sungai_utama_kategori.php*
l *No comprehensive inventory of lake resources in Malaysia but preliminary assessment indicates more than 90 lakes (lakes+reservoirs) with total area of at least 100 000 ha; Source: http://asmic.akademisains.gov.my/download/water/Vol.1%20Main%20Report%202009.pdf*
m *Source: http://forum.mygeoportal.gov.my/smanre/sungai/kaw_banjir_msia.php*
n *Include natural and constructed wetlands (http://www.wetlands.org/Portals/0/publications/Report/WI_GRoWI-Asia_1999.pdf)*
7 *General Source: Than Than Lwin (pers comm.., 2015); FAO and NACA (2003)*
o *The total inland water bodies of Myanmar could comprise about 8.2 million ha of which about 1.3 million are permanent while the remaining are seasonally inundated floodplains*
p *Source: FAO and NACA (2003)*
8 *General Source: Marylene M. Mandreza (pers comm.., 2015)*
q *Philippine Rivers, Lakes, Coastal, and Marine Waters @ website :http://jcgregsolutions.weebly.com/blogs/philippine-rivers-lakes-coastal-and-marine-waters*
r *Philippine Fisheries Profile @ website http://www.bfar.da.gov.ph/profile (wetlands include freshwater wetlands – 106,328 ha; brackishwater wetlands – 239,323 ha)*
s *Others include fishponds (freshwater – 14,531 ha; brackishwater – 239,323 ha)*
9 *General Source: Chutima Pokhun (pers comm., 2015)*
t *Source: http://www.haii.or.th/wiki/index.php/*
u *Source: http://www.prevent.80rider.com/index.php/2014-11-13-16-14-04/2014-11-13-16-19-52*
v *Source: http://group4-51.blogspot.com/2008/09/blog-post_12.html*
w *Others include fishponds (http://www.mkh.in.th/index.php/2010-03-22-18-05-14/2010-03-26-05-51-54 (brackishwater – 320,388.75); Source: www.inlandfisheries.go.th/images/active/academic/GAP11-1.ppt (freshwater - 645,350.62)*

Box 1. Provisions on Inland Fisheries Management in the Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 (SEAFDEC, 2011b)

32. Establish and implement comprehensive policies and supporting legal and institutional frameworks for an ecosystem approach to inland fisheries management by integrating fisheries and habitat management that devolves co-management to the local authority and stakeholders, and at the same time strengthens the rights of communities and develops rights-based fisheries
33. Undertake campaigns to promote awareness of the importance of freshwater fisheries for local food security, and the importance of rehabilitating and restoring habitats for migratory freshwater fish, restocking indigenous fish species to enhance productivity and encouraging culture-based freshwater fisheries, where appropriate
34. Develop inter-agency coordination (national/sub-regional) on multiple-use water resources of the wetlands/flood-plains to sustain freshwater fisheries, mitigate conflicts between users and also encourage better coordination to address trans-boundary inland fisheries management issues
35. Ensure the sustainability of inland fisheries by maintaining ecological health of the ecosystem, particularly the inter-connectivity of habitats and the specific management needs during the dry season. Develop mitigating measures for the adverse impacts on inland fisheries that may be caused by the construction of water infrastructure and alteration of waterways
36. Encourage coordinated planning on the use of inland rivers, water-bodies and flood plains through (i) resource enhancement programs; (ii) inland wetlands and fisheries management programs; (iii) environmental impact assessment studies with regards to structures that might impact on aquatic resources; (iv) the consideration of restocking of locally and/or commercially important inland fish species; and (v) giving priority to human resources development for the implementation of such programs
37. Formulate guidelines to promote the use of practical and simple indicators for inland/floodplain fisheries within the national inland fisheries management framework, to facilitate (i) timely local level fisheries management decisions with due respect to the large number of people/farmers that take part in fishing; (ii) dialogue to ensure that the inter-connectivity of fish migration path is kept as a tool for management/conservation measures; and (iii) adaptation to the effects of climate change within catchments
38. Monitor the impact of the structures that might affect migration and spawning of fish through a consultative process that involves collaboration with the regional organizations

Production from Inland Fisheries in Southeast Asia

Inland fisheries, for the purpose of this article, comprise inland capture fisheries and freshwater aquaculture, which had been providing many countries of Southeast Asia with food fish that supply the nutritional requirements of the populace ensuring food security, especially in the rural areas. During the period from 2008 to 2013, the region's inland fisheries attained an average growth rate of 5.0% in terms of volume and about 6.0% in terms of value (**Table 2**, **Fig. 1**, **Fig. 2**). Specifically, production from inland fisheries in 2013 contributed about 25% to the total fisheries production of Southeast Asia (**Fig. 3**), indicating its valuable contribution to the region's food stability.

It could be gleaned from **Table 1** that Indonesia has more than 256 million ha of inland water bodies, followed by Myanmar with more than 82 million ha, Thailand with more than 66 million ha, and Philippines with more than 12 million ha. Although Cambodia seems to have only more than 4 million ha of inland water bodies, the Tonle Sap Great Lake could expand from 250,000 ha to more than 1.6 million ha during the wet season creating huge areas of wetlands that occupy about 30% of the country's total land area (Try and Sitha, 2011), providing vast areas of natural habitats for freshwater aquatic species. The information in **Table 1** however, is not comprehensive enough since Viet Nam could not provide the total area of its inland water bodies.

Correspondingly in 2013 (**Table 3**), Indonesia produced high volume of inland aquatic species comprising mainly

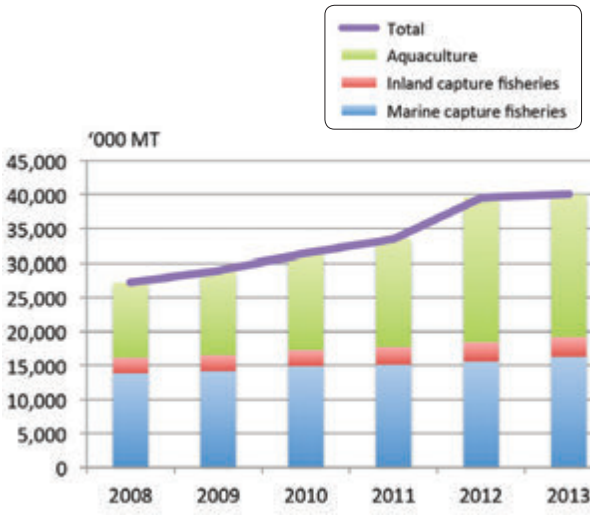

Fig. 1. Total fisheries production of Southeast Asia (2008-2013)

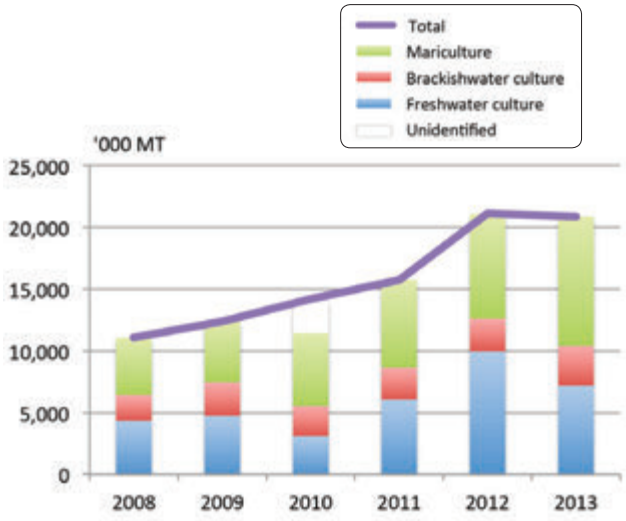

Fig. 2. Production from aquaculture of Southeast Asia (2008-2013)

Table 2. Fisheries production 2008-2013: World *vs.* Southeast Asia

	2008	2009	2010	2011	2012	2013
Total fisheries production*: World ('000 MT)	143,100	145,800	148,100	155,700	157,900	162,800
Marine capture fisheries ('000 MT)	79,900	76,600	77,800	82,600	79,700	80,900
Inland capture fisheries ('000 MT)	10,300	10,500	11,300	11,100	11,600	11,700
Aquaculture ('000 MT)	52,900	55,700	59,000	62,000	66,600	70,200
Total fisheries production: Southeast Asia**						
- Volume ('000 metric tons (MT))	27,207.8	28,917.1	31,438.4	33,487.7	39,567.2	40,040.9
- Value ('000 000 US$)	28,585.8	29,215.3	38,744.2	43,782.9	44,958.9	41,845.8
Marine capture fisheries						
- Volume ('000 MT)	13,814.4	14,140.4	14,874.5	15,095.5	15,590.7	16,256.8
- Value ('000 000 US$)	12,338.2	10,416.7	15,898.8	21,178.8	20,049.0	20.349.5
Inland capture fisheries						
- Volume ('000 MT)	2,329.5	2,397.3	2,377.3	2,646.1	2,820.0	2,884.5
- Value ('000 000 US$)	2,215.4	2,834.5	2,526.5	2,914.4	3,226.6	3,279.7
Aquaculture*						
- Volume ('000 MT)	11,063.9	12,379.5	14,186.7	15,751.2	21,160.5	20,889.6
- Value ('000 000 US$)	14,032.2	15,964.2	13,377.7	19,689.7	21,683.3	18,216.6
Freshwater culture						
- Volume ('000 MT)0	4,345.8	4,739.9	3,098.0	6,071.3	9,961.0	7,198.5
- Value ('000 000 US$)	4,716.2	6,583.4	4,186.5	5,486.5	6,322.8	7,404.6
Brackishwater culture						
- Volume ('000 MT)	2,072.0	2,694.3	2,435.2	2,557.2	2,638.4	3,191.9
- Value ('000 000 US$)	3,471.5	7,156.1	6,468.6	6,137.7	6,047.9	8,218.8
Mariculture						
- Volume ('000 MT)	4,646.1	4,945.2	5,886.6	7,122.7	8,467.1	10,509.2
- Value ('000 000 US$)	2,994.5	2,224.7	2,722.6	1,784.5	2,929.6	2,593.2
Production from inland fisheries**: Southeast Asia						
- Volume ('000 metric tons (MT))	**6,675.3**	**7,137.2**	**5,475.3**	**8,717.4**	**12,781.0**	**10,083.0**
- Value ('000 000 US$)	**6,931.6**	**9,417.9**	**6,713.0**	**8,400.9**	**9,549.5**	**10,684.3**

* **Source:** *FAO (2014)*
** **Source:** *SEAFDEC (2014)*
*** **Sources:** *SEAFDEC (2010); SEAFDEC (2011c); SEAFDEC (2012); SEAFDEC (2013);SEAFDEC (2014)*
**** **Note:** *inland fisheries comprise inland capture fisheries and freshwater aquaculture*

miscellaneous freshwater fishes followed by striped snakehead, Nile tilapia, and snakeskin gourami from inland capture fisheries, and Nile tilapia, torpedo-shaped catfishes, and *Cyprinus carpio* from freshwater aquaculture. The country's production from inland fisheries contributed about 15% to the country's total fisheries production in 2013 in terms of volume and about 25% in terms of value. For Myanmar, its high production from inland capture fisheries comprised mainly miscellaneous freshwater fishes and roho labeo from freshwater aquaculture, and accounted for 47% of the country's total fisheries production in 2013 in terms of volume and 44% in terms of value. Production from inland capture fisheries of Thailand comprised mainly miscellaneous freshwater fishes, and Nile tilapia and giant freshwater prawn from freshwater aquaculture. For Viet Nam, its main production from freshwater aquaculture comprised mainly miscellaneous freshwater fishes. Production from inland capture fisheries of the Philippines comprised mainly freshwater mollusc and tilapia, while Nile tilapia and miscellaneous freshwater fishes were produced from freshwater aquaculture. This information suggests the high diversity of the region's freshwater aquatic resources.

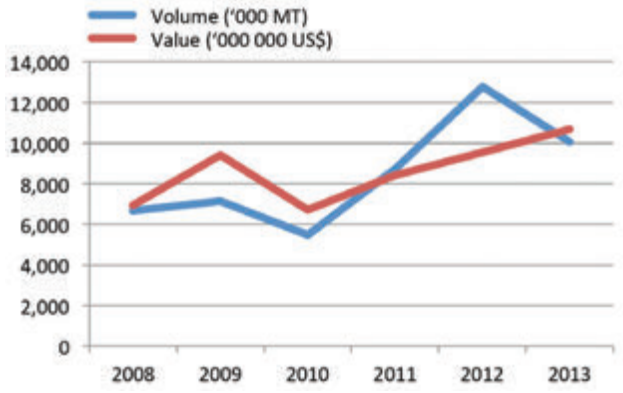

Fig. 3. Total production from inland fisheries of Southeast Asia (2008-2013)

Table 3. Total production of Southeast Asia from inland fisheries (as of 2013)

Production from:	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Thailand	Viet Nam
Inland capture fisheries								
Volume ('000 MT)	528.0	391.3	40.1	5.6	1,303.0	194.6	213.7	208.1
Value ('000 000 US$)	-	741.8	-	20.1	1,954.5	206.6	356.8	-
Freshwater aquaculture								
Volume ('000 MT)	85.3	2,412.0	124.1	132.9	922.3	276.6	490.0	2,754.4
Value ('000 000 US$)	-	4,303.5	-	279.5	1,434.4	448.2	935.8	-
Total for inland fisheries								
Volume ('000 MT)	**613.3**	**2,803.3**	**164.2**	**138.5**	**2,225.3**	**471.2**	**703.7**	**2,962.5**
Value ('000 000 US$)	**-**	**5,045.3**	**-**	**299.6**	**3,388.9**	**654.8**	**1,292.6**	**-**

**Values of production from three countries (Cambodia, Lao PDR, Viet Nam) not available*
Source: *SEAFDEC (2015), in press*

Role of SEAFDEC/IFRDMD in the Sustainable Development and Management of Inland Fisheries in Southeast Asia

As indicated in **Table 1**, the Southeast Asian region embraces very rich and most diverse inland water bodies such as river systems, lakes and others, in terms of aquatic resources and biodiversity. SEAFDEC/IFRDMD aims to harness the potentials of such water bodies through its R&D programs and activities, notwithstanding many reports demonstrating that such resources have been slowly degrading due to overexploitation and other factors both internal and external. IFRDMD considers it urgent to promote the sustainable development and management of such resources in order that their functions in ensuring food security and alleviating poverty in rural areas could be assured. One of the main challenges in sustaining the functions and services of inland water resources is the high competition for water resource utilization especially in major river systems, *e.g.* the Mekong River. Construction of hydropower and irrigation systems associated with economic development could compete for water resource utilization negatively affecting the aquatic resources, but such efforts could not be prevented for the sake of progress. It is therefore necessary that the development of inland fisheries be advocated by emphasizing the value of inland fisheries production through better data and information compilation.

A good compilation of data and information on inland fisheries would help policy makers and people from other sectors understand the contribution of inland fisheries to food security, thus, facilitating cross-sectoral coordination and high-level policy interventions to secure the sustainability of inland water resources. Construction of cross-river infrastructures could also create barriers to water flow resulting in dis-connectivity of aquatic habitats and obstructs the natural "flood pulse" necessary for fish reproduction and larval dispersion. Alternative means could still be done to protect the biodiversity of aquatic species and sustain fisheries production through such mitigating measures as construction of fish pass or fish ways that could reconnect the habitats and facilitate upstream-downstream or horizontal migration of fish.

The inland fisheries sector should therefore develop fish pass models that are suitable to support migration of aquatic species, and ensure that such models are brought up to the attention of policy makers to ensure the sustainability of inland fisheries (Pongsri, 2015). Moreover, construction of cross-water obstacles could create drastic swing of the water levels resulting in water fluctuations which could lead to disorientation on the part of aquatic organisms, threatening their spawning behavior and their ability to survive in such environment. Measures to mitigate these impacts should therefore be developed and promoted. Furthermore, inland capture fisheries and related activities are highly seasonal with peaks during the wet season, when huge volumes of fish could be harvested. Such large

Box 2. Functions of SEAFDEC/IFRDMD

IFRDMD was established to serve as a center for providing guidelines for the proper development and management of inland fishery resources of the Member Countries, which could consist of freshwater, saline water and mixture of both, and distributed throughout the land such as rivers, lakes, floodplains, reservoirs, wetlands, estuaries, and inland saline systems. The properties of such resources are dominated by permanent, seasonal or intermittent occurrence of flooding and are used for fisheries and related livelihoods.

Specifically, IFRDMD is tasked to establish partnership with relevant organizations, such as Mekong River Commission, to mobilize and extend research results to the Member Countries; develop guidelines on basic data collection for routine monitoring activities of different types of inland habitats; provide the tools for assessment and management of inland fisheries resources that could be applied in the region; monitor the state and levels of exploitation of inland fishery resources in the region; provide scientific basis for proper development and management of inland fishery resources to the Member Countries; and serve as regional forum for cooperation and consultation on research, conservation and management of inland fishery resources among the Member Countries. Moreover, IFRDMD would also coordinate and implement programs to improve the capability of the Member Countries in the development, management and conservation of inland fishery resources, through a master plan that covers the necessary programs of activities to be undertaken for sustainable inland fisheries.

Box 3. Program of Work of SEAFDEC/IFRDMD

To be able to carry out its functions, IFRDMD had initially developed its Program of Work and identified the corresponding strategies to be adopted in undertaking such programs:

1. **Compiling baseline information on policies and regulations related to inland fisheries in the ASEAN Member States (AMSs)**

   Strategy 1.1 Gather and compile information related to inland fisheries policies and regulations from the AMSs

   Strategy 1.2 Provide accessibility of such baseline information in consultation with the AMSs

2. **Enhancing the awareness of AMSs on the status of inland fishery resources in the region**

   Strategy 2.1 Assess the applicability of existing scientific data and information, and the effectiveness of data collection tools

   Strategy 2.2 Develop the mechanism for collecting scientific data on inland fisheries, and guidelines

   Strategy 2.3 Engage the AMSs and relevant agencies in collecting scientific data and in generating useful information for policy formulation

   Strategy 2.4 Increase the visibility of IFRDMD as an information hub for inland fishery research and development

3. **Formulating policy recommendations and guidelines on inland fisheries management in close coordination with the AMSs**

   Strategy 3.1 Formulate and disseminate policies and guidelines on inland fisheries management in the AMSs

   Strategy 3.2 Support the adoptability of policies and guidelines on inland fisheries management by the AMSs

volumes of harvest should be utilized in an effective manner, such as fish preservation to allow people access to year-round supply of fish products for consumption. This effort would require the promotion of improved post-harvest technologies and handling processes to ensure the quality of fish as well as development of value-added products. Another equally crucial concern is on the fact that boundary of most water bodies could not be confined within a single management area. Therefore, management of such water bodies should be done with the involvement of several sectors and stakeholders through a "catchment approach" or "ecosystem approach" taking into consideration different levels of management authorities at the local, national, sub-regional, or regional levels as appropriate. The foregoing issues and concerns are among the priorities that would be addressed by IFRDMD with functions that dovetail towards sustainable development of inland fisheries in the Southeast Asian region (**Box 2**), through its initial Program of Work as shown in **Box 3**.

References

FAO and NACA. 2003. Myanmar Aquaculture and Inland Fisheries. RAP Publication 2003/18. Australian Centre for International Agricultural Research; Network of Aquaculture Centres in Asia-Pacific; and Regional Office for Asia and the Pacific, Food and Agriculture Organization of the United Nations, Bangkok, Thailand; 60 p

Kartamihardja, E.S. 2015. The Success of Fish Stock Enhancement and Restocking in Inland Waters of Indonesia. Paper presented during the SEAFDEC Symposium on Strategy for Fisheries Resource Enhancement in the Southeast Asian Region, Pattaya, Thailand, 27-30 July 2015. Southeast Asian Fisheries Development Center, Bangkok, Thailand

Chumnarn Pongsri. 2015. Sustainable Utilization of Water Resources: Fisheries Perspective. Paper presented during the World Water Week, 23-28 August 2015, Stockholm, Sweden

SEAFDEC. 2010. Fishery Statistical Bulletin of Southeast Asia 2008. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2011a. Proceedings of the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 20020: Adaptation to a Changing Environment," Volume I: The Conference Proceedings, 13-17 June 2011, Bangkok, Thailand. Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 211

SEAFDEC, 2011b. Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020. Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 15-16

SEAFDEC. 2011c. Fishery Statistical Bulletin of Southeast Asia 2009. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 149 p

SEAFDEC. 2012. Fishery Statistical Bulletin of Southeast Asia 2010. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 143 p

SEAFDEC. 2013. Fishery Statistical Bulletin of Southeast Asia 2011. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 133 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia 2012. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2015. Fishery Statistical Bulletin of Southeast Asia 2013. Southeast Asian Fisheries Development Center, Bangkok, Thailand; in press

Try, Ing and Hort Sitha, 2011. Promoting Effective Fisheries Co-management through Community Fisheries in Cambodia. ***In***: Fish for the People Vol. 9 No. 2 (2011). Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 73-78

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Fish Stock Enhancement and Restocking of the Inland Waters of Indonesia: Lessons Learned

Endi Setiadi Kartamihardja

The Fisheries Act No. 31 (2004) of Indonesia as amended by Fisheries Act No. 45 (2009) stipulates that the inland waters of Indonesia are under one Fisheries Management Area and could be used for fisheries and aquaculture development. The total area of Indonesia's inland waters is about 276.0 million ha, comprising 223.0 million ha of rivers and floodplains, 1.8 million ha of lakes, 27.0 million ha of man-made lakes or reservoirs and dams, and 24.0 million ha of wetlands and swamp areas. Stock enhancement and culture-based fisheries are among the approaches promoted by the country in these inland waters to optimize their utilization for fish production to ensure food security, and as means of providing additional incomes to fishers and attaining fishers' human well-being. This article describes the lessons learned in the successful implementation of stock enhancement and culture-based fisheries in the inland waters of Indonesia.

Map of Indonesia showing main groups of islands

Generally viewed as a positive fisheries management tool for centuries, stock enhancement and restocking of fish in inland waters have also been practiced in Indonesia for a long time, although the country's stock enhancement activities in the past had been technology-based and focused mainly on producing fish, resulting in limited or no demonstrated successes. Since 1999 however, the country's stock enhancement and restocking practices had been based on scientific evidence that includes establishing the bio-limnological characteristics of water bodies, *i.e.* productivity and ecological niche of the water bodies, structure of fish communities, life cycle and biology of the fish stocks. In addition, fisheries co-management had been promoted focusing on the so-called local wisdom or local knowledge approach. Thus, the fish species used for stock enhancement had been closely reviewed, and the causes of successes or failures compiled and analyzed to determine the best approach for future restocking. Nevertheless, recent successes in the country's fish stock enhancement activities have been realized through the use of species that can reproduce naturally in inland water bodies.

In support to the stock enhancement activities and as means of enhancing the fishery resources, the country also promotes culture-based fisheries in its inland water bodies. Culture-based fisheries had always been considered as one of the means of replenishing natural stocks whose populations have declined due to overfishing, habitat loss and water degradation. Also aimed to increase production in natural environments, culture-based fisheries involve the releasing or transplanting of hatchery-produced seeds and juveniles into water bodies, and allowing the fish to grow on natural foods until marketable size.

Inland Water Resources of Indonesia

The inland waters of Indonesia comprise rivers (*i.e.* 5,590 major rivers; 94,573 km in length) and their tributaries (65,017 km); lakes (*i.e.* 840 major lakes, 736 small lakes); reservoirs (*i.e.* 162 major reservoirs and 1,341 small reservoirs); and vast area of swamplands (Ministry of Public Works–Directorate General of Waters Resources, 2013). Most of the country's lakes (**Table 1**) and reservoirs had been restocked with fish in order to recover depleted species populations and increase fish catch for food security of peoples, especially those in rural areas. The distribution area of the country's inland water bodies is shown in **Fig. 1**.

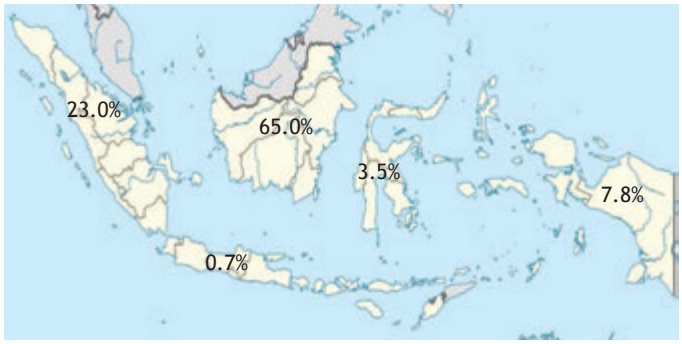


Fig. 1. Distribution of major inland water bodies of Indonesia Sumatra (23.0%); Kalimantan (65.0%); Sulawesi (3.5%); Irian Jaya (7.8%); Java-Bali (0.7%) ***Source:*** *Sarnita (1986)*

Fish Diversity in Inland Water Bodies of Indonesia

Indonesia is also endowed with diverse freshwater fish species, which according to reports could be more than 1,300 species. These species inhabit the Sundaland (about 798 species),

Table 1. Most important lakes of Indonesia (in terms of stock enhancement and restocking)

Province/Lakes	Area (ha)	Depth (m)	Altitude (a msl)
Sumatra			
Laut Tawar	7,000	80	1,100
Toba	112,000	550	950
Maninjau	9,790	180	450
Singkarak	10,780	80	360
Diatas	3,600	36	1,100
Dibawah	1,200	80	800
Ranau	12,590	229	540
Kerinci	6,000	45	900
Kalimantan			
Luar	15,000	6	25
Genali	18,000	6	24
Sembuluh	33,750	10	16
Jempang	15,000	5	10
Semayang	12,000	5	10
Melintang	9,000	5	10
Sulawesi			
Limboto	4,500	4	15
Tondano	6,000	30	500
Poso	32,300	450	1,000
Lindu	3,150	100	9
Tempe	10,000	5	293
Towuti	56,100	590	382
Matano	16,500	650	250
Bali			
Batur	1,590	80	1,000
Irian Jaya			
Sentani	9,360	50	70
Paniai	14,150	20	1,742
Ayamaru	2,200	-	250
Yamur	3,750	-	90
Tage	2,400	-	1,750
Tigi	3,000	-	1,740

Adapted from Sukadi and Kartamihardja (1995); Kartamihardja (2012)

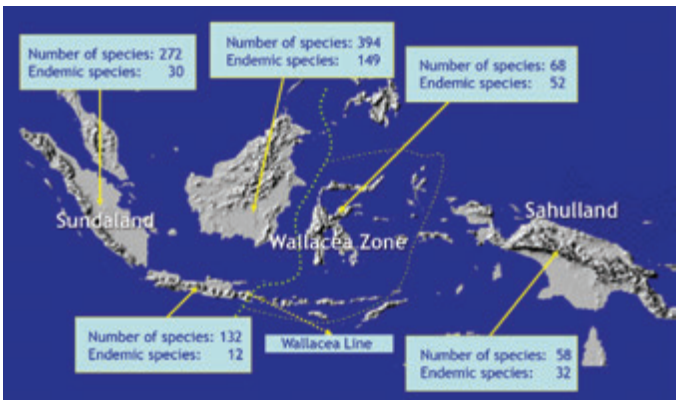
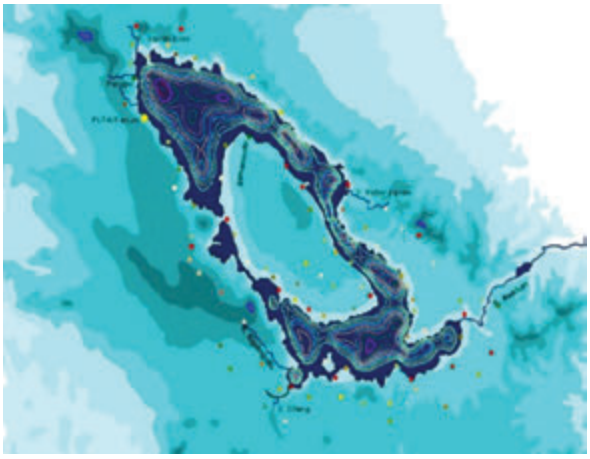


Fig. 2. Freshwater fish diversity of Indonesia
Source: Kartamihardja (2015b)



Above: Toba Lake in Sumatra, Indonesia; *Left:* Sempor Reservoir, Central Java, Indonesia

Wallacea (68 species) and Sahulland (about 58 species) zones of the country (**Fig. 2**). Of the total of about 924 species, 275 species or about 30% are endemic species. Sundaland, also known as Sundaic region, is a biogeographical region of Southeast Asia that was believed to have been exposed during the last ice age.

This zone includes the Malay Peninsula and the large islands of Borneo, Java and Sumatra, and surrounding islands. Wallacea zone includes a group of many Indonesian islands such as Sulawesi as well as Lombok, Sumabawa, Flores, Sumba, Timor, and many smaller islands.

With a total land area of about 347,000 km^2, Wallacea zone lies between Sundaland and Sahulland zones, the latter of which includes the tropical portion of Australia-New Guinea land mass. The most common fish species found in Sundaland, Wallacea and Sahulland zones in Indonesia are shown in **Fig. 3**.

Production from Inland Fisheries

The total fisheries production volume of Indonesia in 2012 which was about 18.8 million metric tons accounted for 47% of the total fisheries production of Southeast Asia, and contributed about 12% to the world's total fisheries production (**Table 2**).

In terms of value, Indonesia contributed about 30% to Southeast Asia's total fisheries production value, while the other nine (9) Southeast Asian countries contributed the

Fig. 3. Inland fish species of Indonesia: *from top to bottom* - fishes in Sundaland, Wallacea, and Sahulland zones, and ornamental fishes common in these zones

remaining 70%. Of the country's total fisheries production volume in 2012, about 29% came from marine capture, 2% from inland capture, and 69% came from aquaculture.

Meanwhile, in terms of value, 37% was contributed by marine capture, 6% by inland capture, and 57% by aquaculture. Taking into account inland fisheries as a whole, comprising inland capture fisheries and freshwater aquaculture, its contribution to the total production of the country in 2012 was

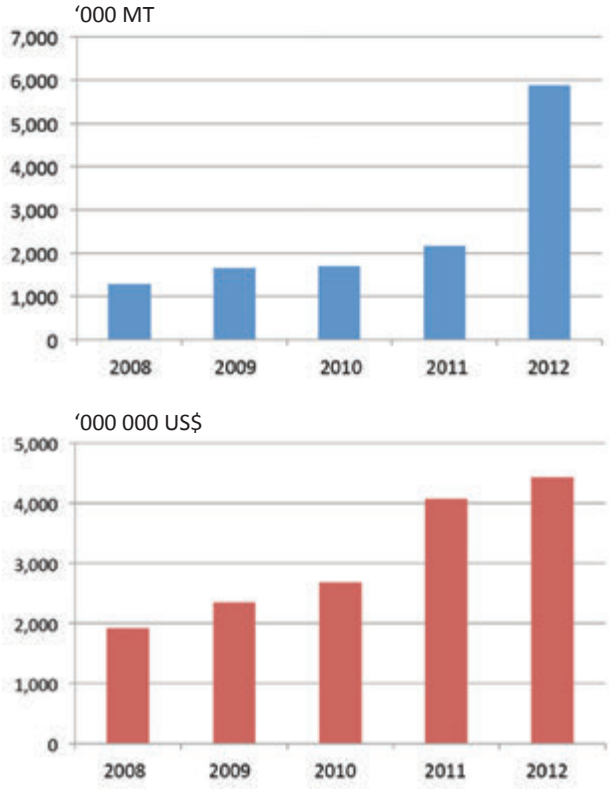


Fig. 4. Trend of inland fisheries production of Indonesia: *above* - production volume; *below* - production value

31% in terms of volume and 33% in terms of value. Moreover, it should be noted that the country's production from inland fisheries in 2008-2012 had been increasing at an average rate of 27% per year in terms of volume and 18% per year in terms of value, the highest increase of which was attained in 2012 (**Fig. 4**).This trend signifies the relevance of inland fisheries to the country's food fish supply, hence, the need for sustainable management of the inland fishery resources justifying the efforts of the Government of Indonesia to carry out stock enhancement and restocking activities in the country's water bodies in order to enhance the contribution of inland fisheries not only to the economy of the country but also to the food security of its people.

Fisheries Potentials of Lakes and Reservoirs in Indonesia

Of the 28 major lakes in Indonesia (**Table 1**), 22 are categorized as eutrophic, 13 are oligotrophic, and 6 are mesotrophic. Eutrophic lakes have excessive nutrients, *i.e.* nitrogen and phosphorus, and are able to support abundant growth of aquatic plants, to the extent that these plants including some algae could dominate the water bodies. Such growth also supplies the fish and biota that inhabit the water bodies, but in some cases, excessive algal bloom could occur resulting in fish kills.

Oligotrophic lakes usually have low primary productivity due to low nutrient contents and low algal production. However, the bottom waters have ample oxygen and capable

Jatiluhur Reservoir, West Java, Indonesia

of supporting fish species that require well-oxygenated water to survive. Mesotrophic lakes usually have certain levels of intermediate productivity due to medium levels of nutrients. These lakes have clear waters with submerged growth of aquatic plants. In addition to natural lakes, there are also man-made lakes or reservoirs that have multi-purpose uses (**Table 3**), such as for generating electricity, flood control, irrigation, and supplying drinking water. Most of these reservoirs have

Table 2. Fisheries production 2008-2012: World *vs*. Southeast Asia *vs*. Indonesia

	2008	2009	2010	2011	2012
Total fisheries production*: World ('000 MT)	**143,100.0**	**145,800.0**	**148,100.0**	**155,700.0**	**157,900.0**
Marine capture fisheries ('000 MT)	79,900.0	76,600.0	77,800.0	82,600.0	79,700.0
Inland capture fisheries ('000 MT)	10,300.0	10,500.0	11,300.0	11,100.0	11,600.0
Aquaculture ('000 MT)	52,900.0	55,700.0	59,000.0	62,000.0	66,600.0
Total fisheries production: Southeast Asia**					
- Volume ('000 metric tons (MT))	**27,207.8**	**28,917.1**	**31,438.4**	**33,487.7**	**39,567.2**
- Value ('000 000 US$)	**28,585.8**	**29,215.3**	**38,744.2**	**43,782.9**	**44,958.9**
Marine capture fisheries					
- Volume ('000 MT)	13,814.4	14,140.4	14,874.5	15,095.5	15,590.7
- Value ('000 000 US$)	12,338.2	10,416.7	15,898.8	21,178.8	20,049.0
Inland capture fisheries					
- Volume ('000 MT)	2,329.5	2,397.3	2,377.3	2,646.1	2,820.0
- Value ('000 000 US$)	2,215.4	2,834.5	2,526.5	2,914.4	3,226.6
Aquaculture*					
- Volume ('000 MT)	11,063.9	12,379.5	14,186.7	15,751.2	21,160.5
- Value ('000 000 US$)	14,032.2	15,964.2	13,377.7	19,689.7	21,683.3
Total fisheries production*: Indonesia**					
- Volume ('000 metric tons (MT))	**9,054.9**	**10,064.1**	**11,662.3**	**13,626.2**	**18,763.9**
- Value ('000 000 US$)	**9,700.8**	**7,493.1**	**14,086.0**	**14,955.0**	**13,292.2**
Marine capture fisheries					
- Volume ('000 MT)	4,701.9	4,789.4	5,039.4	5,328.6	5,401.0
- Value ('000 000 US$)	4,957.3	1,682.0	6,558.1	7,099.9	4,863.3
Inland capture fisheries					
- Volume ('000 MT)	497.7	494.6	345.0	368.6	393.6
- Value ('000 000 US$)	521.0	616.7	546.9	635.8	793.2
Aquaculture					
Freshwater culture					
- Volume ('000 MT)	786.4	1,162.3	1,347.2	1,791.7	5,491.5
- Value ('000 000 US$)	1,398.4	1,735.9	2,134.4	3,434.6	3,642.8
Brackishwater culture					
- Volume ('000 MT)	691.4	1,680.7	1,416.0	1,531.5	1,708.1
- Value ('000 000 US$)	1,840.9	2,156.1	3,409.4	2,657.0	2,643.9
Mariculture					
- Volume ('000 MT)	2,377.4	2,537.1	3,514.7	4,605.8	5,769.7
- Value ('000 000 US$)	983.2	1,297.6	1,437.0	1,127.6	1,349.1
Production from inland fisheries****					
- Volume ('000 metric tons (MT))	**1,284.1**	**1,656.9**	**1,692.2**	**2,160.3**	**5,885.1**
- Value ('000 000 US$)	**1,919.4**	**2,352.6**	**2,681.3**	**4,070.4**	**4,436.0**

* *Source: FAO (2014)*
** *Source: SEAFDEC (2014)*
*** *Sources: SEAFDEC (2010); SEAFDEC (2011); SEAFDEC (2012); SEAFDEC (2013); SEAFDEC (2014)*
**** *Note: inland fisheries comprise inland capture fisheries and freshwater aquaculture*

also been stocked with fish, and thus, serving also as source of nutrients for the local people as well as livelihoods for fishers.

The potentials of major lakes and reservoirs in Indonesia have been assessed, the results of which are shown in **Table 4**. The potential fish yield (FY) and productivity for each of the lakes and reservoirs was estimated based on two aspects, namely: primary production and phytoplankton biomass, and morphoedaphic index (MEI) which is a worldwide model for estimating fish yield. In order to simplify estimations, the lakes and reservoirs were categorized into volcanic lakes, floodplain lakes, multipurpose reservoirs, irrigation reservoirs, and small lakes-reservoirs.

Table 3. Some of the multipurpose reservoirs in Indonesia (as of 1990s)

Province or Group of Islands/ Multipurpose Reservoirs	Area (ha)	Depth (m)		Altitude (m)	Main Function*	Year constructed
		max	ave			
West Java						
Saguling	5,340	90	18	625	E, F, I	1985
Cirata	6,200	106	34	250	E, F, I	1987
Jatiluhur	8,300	95	37	110	E, F, I, W	1965
Curug	650	10	3	25	I, W	1971
Central Java						
Wonogiri	8,800	28	8	140	E, F, I	1981
Wadasintang	1,460	85	30	115	E, F, I	1987
Kedungombo	6,100	50	16	100	E, F, I	1989
Mrica	1,500	36	13	231	E, F, I	1989
Sempor	255	16	8	77	E, I, W	1987
East Java						
Karangkates	1,500	70	23	270	E, F, I	1972
Selorejo	400	46	16	600	E, F, I	1970
Lahor	260	50	14	300	E, F, I	1977
Wilingi	380	28	6	163	E, F, I	1983
Bening	570	10	8	11	F, I	1933
Sengguruh	290	24	7	296	E, I	1987
Bali						
Palasari	100	35	11	1	F, I	1989
Nusa Tenggara						
Batujai	890	14	2	4	F, I, W	1983
South Kalimantan						
Riam Kanan	9,200	50	18	25	E, F, I	1983
Lampung						
Way Rarem	1,400	25	6	60	F, I	1982
Way Jepara	220	42	15	55	F, I	1976

Adapted from Sukadi and Kartamihardja (1995) and Kartamihardja (2012)

* Note: E = Electricity generation, F = Flood control, I = Irrigation, W = Drinking water supply

Small reservoir in Indonesia

Results of the analysis (**Table 4**) indicated that small lakes-reservoirs have the highest potential fisheries yield, making it essential to promote fisheries development and management activities including stock enhancement and restocking in small lakes-reservoirs.

There are about 2,077 small water bodies in Indonesia comprising 736 lakes and 1,341 reservoirs with areas that range from 1.0 to 200.0 ha and water volume of more than 200,000 m^3 (**Table 5**). Management of these water bodies should be enhanced while culture-based fisheries could be adopted. Some of the major reasons for developing culture-based fisheries in the small water bodies are shown in **Box 1**.

Box 1. Reasons for adopting culture-based fisheries in small water bodies

- Highest potential yield
- Distributed in rural areas, and not fully utilized yet
- Easy to manage
- Fish seed stocks could be optimized
- Risk impact of fish stocked could be minimized
- Fish production could be maximized for food security and additional income for rural people
- Fishers' groups could be relatively small and thus, are easy to establish
- Conflicts of interest among users would be minimized

Lessons Learned from Stock Enhancement and Restocking Activities of Indonesia

Some of the successful case studies related to stock enhancement and restocking of Indonesia's inland waters include the following:

Introduction of small fish, bilih (*Mystacoleucus padangensis*) to Toba Lake in Sumatra

Bilih (*Mystacoleucus padangensis*) is an endemic species of Singkarak Lake also in Sumatra. In 2003, about 3,000 heads of *bilih* were introduced in Toba Lake to increase the Lake's

Table 4. Estimated potential fish yields of lakes and reservoirs in Indonesia

Types of water bodies	Area (ha)	FY equation	Correlation coefficient (R^2)	Potential fish yield: FY (kg/ha/year)
Volcanic lakes	10,000.0-110,000.0	$FY = 13945A^{-0.49}$	R^2=0.829	43-189 (111.0±50.1)
Floodplain lakes	2,000.0-20,000.0	$FY = 9E+6A^{-1.15}$	R^2=0.830	118-675 (266.0±188.0)
Multipurpose reservoirs	1,000.0-10,000.0	$FY = 679.6A^{-0.11}$	R^2=0.827	239-320 (273.0±27.4)
Irrigation reservoirs	>200.0-500.0	$FY = 4191A^{-0.42}$	R^2=0.827	288-455 (364.1±51.9)
Small lakes-reservoirs	1.0-200.0	$FY = 3687A^{-0.10}$	R^2=0.714	1,621-3,965 (2,835.0±623.6)

Source: *Kartamihardja (2015a)*

Table 5. Number of small water bodies in Indonesia (1.0-<200.0 ha)

Province/Island	Lakes	Reservoirs	Total
Sumatra	329	217	546
Java	327	342	669
Bali	14	29	43
Nusa Tenggara	27	586	613
Sulawesi and Maluku	37	151	188
Papua	2	16	18
Total	**736**	**1,341**	**2,077**

Source: *Kartamihardja (2015a)*

Bountiful harvest of *bilih* in Toba Lake

fish production, and since *bilih* spawns naturally, the fish was distributed all over the lake and has now dominated the total fish catch of Toba Lake. Moreover, records have shown that since 2005, the catch of *bilih* from Toba Lake had been increasing and reached about 45,000 metric tons in 2012.

Stock enhancement of Siamese catfish in Wonogiri Reservoir, Central Java

In 1991-2001, about 36,450 seeds of the Siamese catfish (*Pangasionodon hypophthalmus*) were introduced in Wonogiri Reservoir in Central Java. Capable of growing fast, the Siamese catfish also spawns naturally, and reports have indicated that catfish seeds have now been distributed in the mouth of Keduwang River, which is reported to be a spawning area of the catfish. From 2001 to 2012, the catch of catfish in the Reservoir had been increasing with a peak of 200 metric tons in 2012.

Siamese catfish seeds harvested from the mouth of Keduwang River that flows from Wonogiri Reservoir

Culture-based fisheries of Siamese catfish in Mahalayu Reservoir, Central Java

Small in size, the Mahalayu Reservoir has an area of about 250 ha with mean depth of 9.0 m. In December 2011, about 400,000 heads of catfish fry (5-7 cm TL) were stocked in this Reservoir. After three months, the fish weighed about 200-250 g/head, and in December 2012, about 12,300 kg of catfish was harvested from the Reservoir, weighing 500-600 g/head. The value of the fry stocked was Indonesian Rupiah (IDR) 80.0 million, while the value of production after one year was IDR 122.8 million (IDR 7,500 ≅ US$ 1.00).

Siamese catfish caught from Mahalayu Reservoir one year after stocking

Culture-based fisheries of giant freshwater prawn in Darma Reservoir

Darma Reservoir has an area of about 400 ha with an average depth of 9.7 m, and is inhabited by 120 fishers. The potential yield of the Reservoir is 121-347 metric tons/year. In 2003, about 26,000 tails of giant freshwater prawns were stocked and after 8 months, the fishers caught a total of 337.65 kg (250-750 g/tail) valued at IDR 13.5 million or US$1,800.00. The optimum stocking density of the Reservoir is 100,000 tails which could be valued at IDR 140 million.

Culture-based fisheries of milkfish in Jatiluhur Reservoir, West Java

A multipurpose reservoir, Jatiluhur has an area of 8,500 ha, mean depth of 37.0 m, and maximum depth of 95 m. It has been established that phytoplankton density in the Reservoir is high as an impact of eutrophication processes from cage culture. In 2008-2009, about 2,000,000 seeds of milkfish (5-7 cm FL) were stocked in the Reservoir. By the end of 2010, milkfish production from the Reservoir was 6,235 kg (600-800 g/head) and the 2012, the total production was 9,235 kg (500-1,500 g/head).

Milkfish seeds stocked in Jatiluhur Reservoir (*left*) and milkfish harvested from the Reservoir after one year (*right*)

Culture-based fisheries of milkfish in Sempor Reservoir, Central Java

Sempor Reservoir has an area of 255 ha with mean depth of 16.0 m and is being used for generating electricity, as well as source of drinking water and irrigation. Being meso-trophic, the Reservoir's high plankton density served as source of natural food for milkfish. About 300,000 heads of milkfish

fry (5-7 cm FL) were stocked in the Reservoir, and after 3-4 months, the fish has grown to 300-500 g/head and in 10-12 months, the fish weighed 0.8-1.2 kg/head.

In summary, the fish yield had increased in all the aforesaid case studies after stock enhancement had been implemented in selected lakes and reservoirs in Indonesia. **Table 6** summarizes the status of productivity and the economic benefits that could be gained from the said stock enhancement activities.

Based on the successes attained in stock enhancement of the country's lakes and reservoirs, the Government of

Box 2. Management measures adopted in stock enhancement of lakes and reservoirs in Indonesia

- Establishment of spawning and nursery protected areas for the Siamese catfish and *bilih* (or other species that spawn naturally)
- Regular stocking of seeds for fish species that do not spawn in inland water bodies naturally
- Regulating the mesh size of nets (gillnet and lift net) for fishing
- Zoning of lakes/reservoirs for fisheries utilization
- Diversification of fish products and processing
- Development of marketing system
- Capacity building for management institutions and fisher's groups
- Implementation of fisheries co-management

Table 6. Productivity of lakes and reservoirs after stock enhancement

Lakes/Reservoirs	Area (ha)	Species stocked	Productivity before stock enhancement (kg/ha/yr)	Productivity after stock enhancement (kg/ha/yr)	Increase in productivity	Economic value* (IDR/ha/yr)
Toba Lake	112,000	bilih	22.0-28.0	340.0-400.0	350.0 (1400%)	5,250,000
Wonogori Reservoir	7,800	catfish	26.0-35.0	59.0-62.0	30.5 (102%)	457,500
Mahalayu Reservoir	275	catfish	60.0-75.0	102.0-129.0	49.5 (73%)	742,500
Darma Reservoir	400	giant freshwater prawn	75.0-123.0	99.0-128.0	14.5 (15%)	217,500
Jatiluhur Reservoir	8,300	milkfish	27.0-32.0	178.0-181.0	150.0 (508%)	2,250,000
Sempor Reservoir	255	milkfish	3.5-4.0	7.9-9.2	5.0 (133%)	na

*Note: Economic values were analyzed 2-5 years after the start of stock enhancement activities

Sources: *Kartamihardja (2015a; 2015b)*

Box 3. Specific lessons learned from stock enhancement of lakes and reservoirs in Indonesia

- Stocking activities through culture-based fisheries were undertaken regularly
- Fish species for restocking were those that spawn naturally
- Fish seeds were stocked at optimum level
- Harvesting of fish stock was regulated
- Marketing system was developed
- Management institutions were strengthened
- Fisheries co-management was promoted
- Monitoring and evaluation were carried out by fishers' groups and local communities

Indonesia has been promoting management measures for the sustainable development of inland fisheries, as shown in **Box 2**. In particular, the lessons learned from the aforementioned successful case studies are shown in **Box 3**.

Conclusion and Recommendations

Indonesian lakes and reservoirs have different limnological characteristics as well as productivity (potential fish yield). Therefore, all fish stock enhancement activities should be supported by scientific evidence. There is also a need to conduct basic research on productivity, niche ecology, structure of fish community, and trophic levels of lakes and reservoir. Moreover, it is also necessary that co-management regime of lake and reservoir fisheries should be developed. The strategies for undertaking stock enhancement in lakes, reservoirs and other inland water bodies based on the experience of Indonesia (**Box 4**) could be adapted in Southeast Asian countries that have similar conditions as those of Indonesia. Furthermore, the Government of Indonesia for its part should facilitate and support stock enhancement and restocking initiatives of fishers by providing them with consistent supply of locally-produced fish seeds. Nevertheless, the introduction of fish species should be done with precautionary approach especially in inland water bodies that are inhabited by endemic fish species, *e.g.* in Sulawesi and Papua of Indonesia.

Box 4. Strategies for undertaking stock enhancement in lakes and reservoirs

- Identification of water bodies suitable for stock enhancement
- Selection of fish species to be stocked (taking into consideration biological, social and economic aspects)
- Fish species to be introduced should be plankton feeders and/or herbivores (fish stocked should mainly utilize the natural food/plankton in water bodies)
- Development of local hatcheries to provide the seeds or fingerlings
- Establishment of regulations on fishing in the stocked areas
- Development of co-management scheme and strengthening coordination among users
- Formulation of technical guidelines for dissemination to fishers

References

Kartamihardja, E.S. 2012. Stock Enhancement in Indonesian Lakes and Reservoirs Fisheries. Indonesian Fisheries Res. J. 18(2): 91-100

Kartamihadja, E.S., 2015a. Potential of culture-based fisheries in Indonesian inland waters. ***In***: Sena S. De Silva, B.A. Ingram and S. Wilkinson (eds.), *Perspectives on culture-based fisheries developments in Asia*, Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand; pp 73-81

Kartamihardja, E.S. 2015b.The Success of Fish Stock Enhancement and Restocking in Inland Waters of Indonesia. Paper presented during the SEAFDEC Symposium on Strategy for Fisheries Resource Enhancement in the Southeast Asian Region, Pattaya, Thailand, 27-30 July 2015. Southeast Asian Fisheries Development Center, Bangkok, Thailand

SEAFDEC. 2010. Fishery Statistical Bulletin of Southeast Asia 2008. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2011. Fishery Statistical Bulletin of Southeast Asia 2009. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 149 p

SEAFDEC. 2012. Fishery Statistical Bulletin of Southeast Asia 2010. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 143 p

SEAFDEC. 2013. Fishery Statistical Bulletin of Southeast Asia 2011. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 133 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia 2012. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

Sarnita, A.S. 1986. Introduction and stocking of fish in lakes and reservoirs in Southeast Asian countries with special reference to Indonesia. Reports and Papers presented at the IPFC expert consultation on Inland Fisheries of the Larger Indo-Pacific Islands. Bangkok Thailand, 4-6 August 1986. FAO Fish. Rep. No. 371 Suppl. FIRI/R371

Sukadi, Fatuchri M. and E. Setiadi Kartamihardja. 1995. Inland Fisheries Management of Lakes and Reservoirs with Multiple Use in Indonesia. ***In***: Petr, T. and M. Morris (eds). Indo-Pacific Fishery Commission: Papers contributed to the Regional Symposium on Sustainable Development of Inland Fisheries under Environmental Constraints; Bangkok, Thailand, 19-21 October 1994; and Country Reports presented at the Sixth Session of IPFC Working Party of Experts on Inland Fisheries, Bangkok, Thailand, 17-21 October 1994. FAO, Rome; pp 101-111

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Promoting Co-management in Inland Fisheries:
Experience of Lao PDR

Sommano Phounsavath

Lao People's Democratic Republic, in short Lao PDR, is a mountainous land-locked country located in the Lower Mekong River Basin in Southeast Asia, and endowed with rich and abundant natural water resources as well as man-made water bodies. These inland water resources have great potentials for the development of capture fisheries and aquaculture if properly managed and developed in a sustainable manner. Of the country's land area of 236,800 km^2, about 87.7% or 207,674 km^2 drains into the Mekong River contributing about 35.0% of the Lower Mekong River's discharge, while another 12.3% in the north-eastern area drains to the north of Viet Nam into rivers that flow to the Gulf of Tonkin in South China Sea. Against the backdrop of such scenario, the Department of Livestock and Fisheries of Lao PDR with support from development partners started in early 1980s the promotion of community-based fisheries management, and later on, fisheries co-management for the different types of water bodies throughout the country, such as rivers, reservoirs, community ponds, and small-scale natural wetlands. The progress of such development is summarized in this article which is based on the paper presented by the author during the Experts Meeting on Cooperation on Fisheries, Aquatic Resources and Wetlands: 20-year Lessons Learnt organized by SEAFDEC in Phnom Penh, Cambodia in November 2014.

The population of Lao PDR was estimated in 2014 at 6.8 million, 75-80% of whom still live in rural lifestyle. In 2005, ADB (2008) estimated that about 33% of the country's total population lived below the poverty line. Nevertheless, the people of Lao PDR, especially those in rural communities, still rely heavily on aquatic resources, *i.e.* fish and other aquatic animals, as their most reliable sources of animal protein. The country's fisheries depend on its water ecosystems consisting mainly of rivers and streams, hydropower and irrigation reservoirs, diversion weirs, small water bodies, floodplains, and wet-season rice fields. The country's water resources for capture fisheries estimated at more than 1.2 million ha (Phonvisay, 2013) are capable of producing fish that could earn the country about US$150.0 million per year. The country's average consumption of inland fish is about 24.5 kg/capita/year while other aquatic animals account for about 4.1 kg/capita/year and marine products around 0.4 kg kg/capita/year. Thus, the country's total consumption of fish is estimated at 29.0 kg/capita/year (Phonvisay, 2013), most of which are domestically produced.

Lao PDR has diverse ecosystem and aquatic species, of which more than 480 freshwater fish species have been identified that include 22 exotics while more species are still being discovered from time to time (Phonvisay, 2013). Other aquatic animals comprise about 37 amphibians, 7 species of crabs and 10 species of shrimps that have been recorded, but these records are believed to cover only 15% of the estimated total. Utilized mainly for human consumption, most of these aquatic species are produced through inland capture fisheries and aquaculture.

Moving from Community-based Fisheries Management to Fisheries Co-management

In early 80s, the Government of Lao PDR decentralized the management of the country's natural resources to local authorities and communities based on the so-called "Community-based Natural Resources Management (CBNRM)" approach. CBNRM was first adopted in the country's forestry sector through the establishment of "community forestry" at the national level, where land and forest were allocated to local communities for them to manage and use as their own. The irrigation sector also adopted a community-based approach for the management of the country's irrigation plans and facilities by establishing

Map of Lao PDR

the "water users' groups" mainly comprising the farmers' groups coming from the local communities. Likewise, the fisheries sector also fostered the same approach through the promotion of community-based fisheries management. About two decades later, the Mekong River Commission (MRC) - Fisheries Programme introduced the concept of "fisheries co-management" in four countries of the Lower Mekong Basin including Lao PDR. Specifically, the project on management of reservoir and river fisheries was carried out in two phases, *i.e.* Management of Reservoir Fisheries in the Lower Mekong Basin (MRF): Phase 1 from 1995 to 2000, and subsequently, the Component on Management of Reservoir and River Fisheries in the Lower Mekong Basin (MRRF): Phase 2 implemented from 2000 to 2010. In the course of the implementation of MRF and MRRF, various constraints were identified that hinder the development of sustainable inland fisheries in the country.

Confirmed through a Participatory Rural Appraisal (PRA) survey, such constraints included: inadequate local organization structure for the management of fisheries at the community level; overfishing and illegal fishing; non-regulated fish trading that led to depletion of the fish stocks; and destruction of critical fish habitats that consequently led to declining daily fish catch. Moreover, fishery regulations were not in place while the local fishery authorities did not have sufficient capacity to manage and control the fishery resources. In order to address such concerns, the central and local fishery authorities of Lao PDR, namely: the Department of Livestock and Fisheries (DLF), Provincial Agriculture and Forestry Office (PAFO), and District Agriculture and Forestry Office (DAFO) facilitated the development of fisheries co-management in target reservoirs and fishing communities through the conduct of case studies, taking into consideration the lessons learned from the MRF and MRRF. These case studies were carried out in a hydropower reservoir (Nam Ngum 1), irrigation reservoirs (Nam Houm, Nam Souang, Huay Siet, and Pak Peung), and in fishing communities located along the Mekong River in Khong District, Champasak Province.

The shift toward a more holistic view of aquatic resources management undertaken by the Government of Lao PDR has until recently been based mainly on the regulatory framework within the natural resources and environment sector, such as the Forestry Law, Environment Protection Law, Water Resources Law, and the Conservation of Wildlife and Aquatic Animals Law. It was only after July 2009 when the country's new Fishery Law was enacted that fisheries management was brought within one cohesive framework. Specifically, the Fishery Law provides a framework for implementing, managing, monitoring and inspecting capture fisheries and aquaculture. It aims to promote aquaculture, conserve and protect fisheries resources for sustainable development, and ensure the availability of fish and other aquatic animals (OAAs) for food security. The law also promotes community-based fisheries management and control measures, such as establishing conservation zones and community ponds and crafting fishing regulations, and providing for the protection of aquatic resources and ecosystems through various measures. Nevertheless, implementation of the new Fishery Law will continue to be a challenge as it would require training, monitoring and research, as well as support to community-based fisheries management. Nonetheless, given the importance of fish and OAAs to the people of Lao PDR as source of food and income, there is a need to improve fisheries management and aquaculture development based on water resource ecosystems and socio-economic conditions of the rural areas. This therefore calls for a holistic approach of incorporating fisheries in an integrated water catchment and basin management as stipulated in the new Fishery Law.

Institutional and Legal Frameworks

In the new Fishery Law No. 03/NA: 2009 of Lao PDR, Article 6 stipulates the Basic Principles of Fisheries. Specifically, Article 6 (4) stipulates that "Establishment and protection of conservation zones for aquatic species and of their habitats, and food sources are to create the best conditions for their growth and proliferation and are aimed at maintaining the ecosystem balance;" while Article 6(5) specifies that "Conservation, protection, development, exploitation of aquatic fauna, the management and inspection of fisheries shall be in conformity with international treaties to which the Lao PDR is a party." Moreover, the Fishery Law also promotes two types of fisheries models: Family and Commercial Fisheries (**Box 1**).

Box 1. Provisions in Fishery Law that promote Family and Commercial Fisheries

Article 14: *Family fisheries include aquaculture, conservation, protection, development, catching and exploitation of aquatic fauna in a specific body of water in conformity with laws and regulations primarily for use in the daily lives of the families.*

Article 15: *Commercial fisheries model includes the aquaculture, propagation, capture and processing of fish and other aquatic fauna for trading and distribution and includes the conservation and protection of aquatic fauna.*

Although people in Lao PDR have always been involved in fishing since ancient times, the fishery sector of Lao PDR is a relatively new sector compared with other sectors within the Ministry of Agriculture and Forestry (MAF). In the early 1990s, a technical division called the "Division for Extension of Fish Culture and Raising of Small Animals" was established under the Department of Livestock and Veterinary (DLV). However, upon recognizing the increasing importance of fisheries and aquaculture for the livelihood of local people, the Government of Lao PDR renamed the DLV in 1996 into the Department of Livestock and Fisheries (DLF) and established under this Department is the "Fisheries Division". After the establishment of the "Nam Xouang

Box 2. Authorities responsible for fisheries development and management in Lao PDR

Ministry of Agriculture and Forestry (MAF)

- **Department of Livestock and Fisheries (DLF)** under the MAF has the following roles and responsibilities with regard to fisheries development and management:
  1. Formulate national strategies, policies and legal frameworks for fisheries for submission to the Government for consideration and future elaboration for inclusion in national programs and projects for country-wide management of fisheries;
  2. Disseminate and provide country-wide training on the policies, regulations and laws related to fisheries activities in order to raise public awareness and gain public support of and respect for the preservation of aquatic fauna resources;
  3. Provide guidance, monitoring and evaluation of the implementation of fisheries activities under DLF supervision throughout the country;
  4. Develop, train and upgrade the personnel involved in the management of fisheries;
  5. Consider commercial fisheries operations in terms of managing the varieties of aquatic fauna and to submit proposals to the Government regarding the specific fish species which require protection;
  6. Create and improve information systems, the recording of the documents and licenses of commercial fishery operations, and the various documents related to the Fisheries Management Committees for specific water bodies;
  7. Coordinate with other sectors and local authorities with respect to activities related to fisheries, including publicity campaigns and active search for domestic and international funding for the conservation, protection, development and the use of aquatic fauna;
  8. Liaise and cooperate with other regional and international organizations on matters relating to fisheries; and
  9. Provide regular summaries and reports on the outcomes of fisheries activities to the Government.

- **Division of Fisheries (DOF)** of the DLF has a central role of fulfilling the overall management of the fisheries in the country and its organizational structure is divided into three sections, namely: Fishery Resources Management, Aquaculture Management, and Fishery Inspection.

- **Provincial Livestock and Fisheries Section (PLFS)** under the Provincial Agriculture and Forestry Office (PAFO) has the following roles and responsibilities:
  1. Disseminate strategic plans, policies, orders and legal frameworks related to fisheries, first as detailed workplans and projects, and then the details of their implementation;
  2. Disseminate and provide training on the policies and legal frameworks of fisheries for the people in order to improve their understanding of, commitment to and participation in the strict implementation;
  3. Provide guidance, and conduct monitoring and evaluation of the work related to fisheries operations of the District Agriculture and Forestry Offices (DAFOs);
  4. Provide comments on the cancellation or suspension of commercial fisheries operations within their areas of authority;
  5. Provide technical guidance and support to the Fisheries Management Committees (FMCs) of specific water bodies, fishermen's groups and individuals engaged in fisheries activities within their areas of responsibility;
  6. Coordinate with other relevant sectors on fisheries operations within their areas of authority;
  7. Create and improve information systems, recording of the operating licenses of commercial fisheries, and various documents related to Fisheries Management Committees (FMCs) of specific water bodies within their areas of responsibility;
  8. Mount publicity campaigns and actively search for domestic and international funding sources for fisheries related work;
  9. Liaise and cooperate with regional and international organizations on fisheries in keeping with the objectives as identified by senior management; and
  10. Provide regular summaries and reports on the outputs and outcomes of the implementation of fisheries activities to the Ministry of Agriculture and Forestry and the capital, provincial administrative authorities.

- **District Livestock and Fisheries Unit (DLFU)** under the District Agriculture and Forestry Office (DAFO) has the following roles and responsibilities
  1. Manage the implementation of the workplans, projects, agreements, orders, declarations and advisories of the Ministry of Agriculture and Forestry and the Provincial Agriculture and Forestry Offices;
  2. Disseminate the policies and legal frameworks related to fisheries activities to the people in order to improve their understanding of, commitment to and participation in their strict implementation;
  3. Provide guidance, encouragement, follow up and facilitation to the Fisheries Management Committees for specific water bodies in the formulation of fisheries regulations within their areas of jurisdiction;
  4. Provide comments on the cancellation or suspension of commercial fisheries operations within their areas of jurisdiction;
  5. Provide technical guidance and support to the Fisheries Management Committees for specific water bodies, fishermen's groups and individuals engaged in fisheries activities within their areas of jurisdiction; and
  6. Provide regular summaries and reports on the outputs and outcomes of the implementation of fisheries activities in the district to the Provincial Agriculture and Forestry Offices and the municipal, district administrative authorities.

Aquaculture Development Center" (NADC) in 2001 with support from Japan International Cooperation Agency (JICA), many government fish stations in almost all 17 provinces and in Vientiane Municipality were established or improved. For the first time, the DLF developed a policy framework for fisheries development in Lao PDR (Phonvisay, 1996) which included four priority areas, namely: (1) aquaculture and floodplain management; (2) reservoir fisheries management;

(3) aquatic resources assessment and management; and (4) post-harvest fishery technologies and regulations.

In 1999 however, MAF restructured the technical departments and separated the fishery sector into three main technical departments to be responsible for fisheries and aquaculture management, research and extension. These are: (1) DLF responsible for fisheries management; (2) National Agriculture and Forestry Research Institute (NAFRI) for research; and (3) National Agriculture and Forestry Extension Service (NAFES) for extension (mainly aquaculture extension) which was renamed later as the Department of Agriculture Extension and Cooperatives (DAEC). Meanwhile, the Living Aquatic Resources Research Center (LARReC) was also established under NAFRI for the main purpose of conducting research on capture fisheries and aquaculture.

The Lao Fishery Law, which was declared in force through a presidential decree in July 2009, specifies the principles, regulations and measures governing the organization, implementation, management, and inspection of works in fisheries; promotion of aquaculture, conservation, protection, development and sustainable exploitation of aquatic fauna, aiming to ensure the provision of fish and other aquatic fauna as food source for all people of Lao PDR; and protection of the environment for the economic development of the nation.

As stipulated in Article 43 of the Fishery Law, the Ministry of Agriculture and Forestry (MAF) with the DLF as its technical fishery department, is the central line agency responsible for fisheries management in coordination with other relevant sectors and local administrative authorities. The authorities responsible for the management of fisheries in Lao PDR are outlined in **Box 2**, while the organization structure of MAF of Lao PDR is shown as **Fig. 1**. In addition, ***Fisheries Management Committees (FMCs)*** have also been established for specific water bodies (*e.g.* rivers, reservoirs, community ponds, wetlands). In Article 43 of the Fishery Law of Lao PDR, FMCs serve as local fisheries management organizations at the community level with corresponding roles and responsibilities, while Articles 50, 51 and 52 stipulate

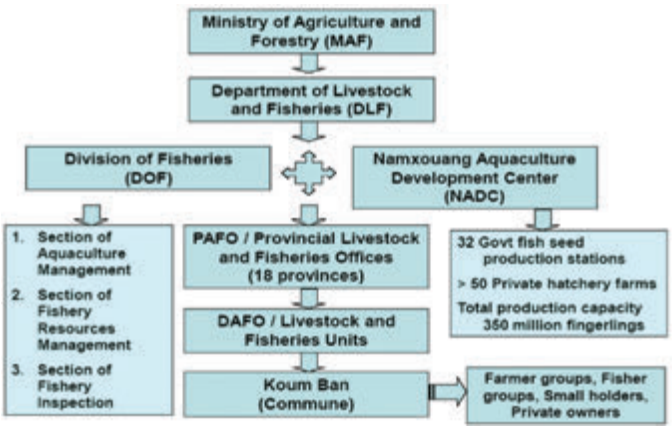


Fig. 1. Organization Structure of the Fishery Sector in Lao PDR

in details the procedures for the establishment, organization structure, rights and duties of FMCs (**Box 3**). Moreover, Article 48 promotes the establishment of ***Fishermen's Associations (FAs)*** and ***Fishermen's Cooperatives (FCs)***. However, the rules and principles governing the management, operations, rights and responsibilities of FAs and FCs still need to be defined in terms of their specific regulations. Furthermore, Article 53 promotes the establishment of ***Village Fisheries Regulations*** (**Box 4**).

Promotion of Fisheries Co-management

The status of implementation of community-based fisheries resources management in Lao PDR could be gleaned from the results of implementation of three case studies. These are: (1) Establishment of Fishing Cooperatives at Nam Ngum 1; (2) Establishment of Fishermen's Association at Nam Theun 2; and (3) Establishment of RFMCs and VFMCs.

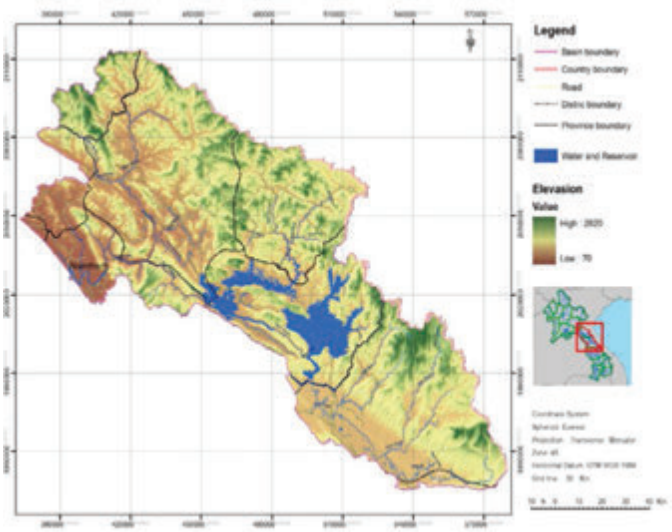
Case Study 1: Establishment of fishing cooperatives at Nam Ngum 1

Constructed during 1968-1971 mainly for generation of hydropower, the Nam Ngum Reservoir (Nam Ngum 1) is located in Vientiane Province with an area of 477 km^2, mean depth of 19 m, and catchment area of 8,640 km^2. Of the 16,660 people living along the Reservoir Basin, 3,450 are local fishers about 50% of whom are full-time fishers (Mattson *et al*., 2000). Fishing cooperatives were organized at this Reservoir from 1979 to 1983 but were discontinued when support from the development projects was phased out, and also due to communities' minimum participation and inadequate experience on cooperative management and administration (Phounsavath, 1998). Later, seven fishing cooperatives were established by government technical staff of the "Nam Ngum Reservoir Management and Development Project" (NRMDP) and local authorities with financial support from fisheries community development projects, *i.e.* the Interim Mekong Committee (1978-1983 and 1988-1992), and MRC (1995-2003). As a national project, NRMDP was officially established by MAF but later renamed as the Nam Ngum Reservoir Fisheries Management Center (NNRFMC) and placed under the administration of PAFO of Vientiane Province. This time around constraints were still encountered including among others, the absence of priority strategies for community development; minimum level of participation from local fishers; lack of legal framework and incentives for organizing the fishers; failure to establish self-sustaining fishing cooperatives; changing regulations and practices of fish market management, fish prices and taxation system by local provincial authorities; and inadequate investment for the basic infrastructures and facilities in local fishing communities.

Nam Ngum River Basin
Source: *Phounsavath (2014)*

In an effort therefore to address such concerns, the PAFO of Vientiane Province developed a five-year strategic plan (2011-2015) for the overall management and development of Nam Ngum 1 Reservoir covering nine (9) action plans. These are: (1) management of fisheries; (2) management of conservation areas for aquatic animals and wildlife; (3) establishment of village network for fisheries management and extension; (4) conservation and reproduction of endangered indigenous fish species; (5) promotion of fish processing products; (6) fish culture extension (culture in cages/pens); (7) reduction of shifting cultivation through alternative livelihood alternatives; (8) protection of bank erosion and the environment: and (9) monitoring/data collection on the ecological changes of the reservoir limnology.

Case Study 2: Establishment of fishermen's association at Nam Theun 2



Nam Theun River Basin
Source: *Sioudom (2013)*

The Nam Theun River Basin located in Khammouane Province has a catchment area of 14,813 km^2 and length of about 353 km with about 142,466 people living along its River Basin. Large numbers of fish species (between 70 to 100 species) have been recorded in the Basin, depending on the season and yearly occurrence and capability of enumerators to identify the species. Sioudom (2013) reported that of the more than 70 fish species, 11 were new to fisheries science. The Nam Theun 1 Reservoir is one of the largest dams in Lao PDR for hydropower generation with a reservoir area of about 280 km^2 and catchment area of 14,072 km^2, and a total energy generating capacity is about 600 mega watts (MW). Moreover, Nam Theun 2 Reservoir, also a hydropower dam has reservoir area of 450 km^2 and catchment area of 3,475 km^2, and total generating energy of 1,075 MW.

The first fishermen's association for the Nam Theun 2 Reservoir was officially organized in July 2009 through an official agreement of the Governor of Nakai District who was also the Vice-chair of the Nam Theun 2 RMC (Ref. No 207 dated 9 July 2009). Consisting of 16 Village Fisher's Groups (VFGs), this fishermen's association is supervised by the Nam Theun 2 Reservoir Management Committee (RMC) which was officially established through a Prime Minister's Decree (Ref. No 309 dated 27 April 2009). The RMC members are representatives from relevant key authorities such as DLFU of DAFO Nakai District, and responsible for supervising the fisheries management and development of Nam Theun 2 Reservoir.

Box 3. Establishment of the Fisheries Management Committees (FMCs)

Principles for Establishment of FMCs

FMCs shall include the participation of fishers, to ensure that effective management of fisheries resources is promoted through the involvement of the following government authorities:

1. District Governor and Municipal Head shall approve the request and appoint the committee as proposed by the village authority;
2. Provincial Governor and Capital Mayor shall approve requests and appointments of the Committee (In the event that the boundaries of the fisheries resource areas are in two districts or municipalities in the province, the action would be based on the proposal from relevant District Governors or Municipal Heads);
3. The Minister of Agriculture and Forestry shall approve and appoint the Committee, in the event that the boundaries of the fisheries resource areas are in two provinces, capitals or more based on the proposal of relevant Provincial Governors or Capital Mayors;
4. The decision of the District Governor, Municipal Head and Provincial Governor, the Capital Mayor shall keep the appointments of Fisheries Management Committee and transmit the information to relevant agriculture and forestry sectors for control and inspection.

Structure of FMCs

The structure of the **Fisheries Management Committees (FMCs)** shall comprise representatives from the various organizations as identified below:

1. Representatives from the village, district or provincial fisheries organizations;
2. Representatives from the fishermen's groups;
3. Representatives from village or district social organizations;
4. Village, District or Municipal Security Officers; and
5. Representatives from other relevant sectors as deemed necessary.

Rights and Duties of FMCs

1. Prepare plans for the management and development of fisheries within their own water resource areas, namely: identified fisheries areas, conservation zones, protected areas, fish spawning grounds, areas for the expansion of fish species, fish release areas, and others;
2. Propose plans and regulations for the management of fisheries including the use of fishing gear and methods, seasons and prohibitions related to the catching or trapping of certain protected aquatic animals, and submit these to the municipal, district administration authorities for their consideration, approval and adoption;
3. Disseminate and publicize the fisheries management plans and regulations through posters and announcements in the mass media;
4. Protect the rights and benefits of the fishermen including settlement of disputes arising from the management of the water resource areas under their control;
5. Guide, follow up, and inspect the implementation of fisheries management regulations in the areas under their control;
6. Seek funding to support fisheries management and development in the water resources areas under their control;
7. Collect annual statistics related to fisheries, including the production, details of fishermen, fish conservation zones, and summaries and reports and submit these to the local authorities and the relevant sectors;
8. Exercise other rights and duties as assigned by the relevant sectors.

Case Study 3: Establishment of RFMCs and VFMCs

In 2000-2010, the MRC-Fisheries Programme supported the implementation of a pilot project to promote fisheries co-management in selected water bodies (reservoirs, rivers) by establishing local "***Fisheries Management Committees***" (FMCs). Four irrigation reservoirs in Vientiane and Bolikhamxay Provinces were selected as pilot areas for the establishment of "***Reservoir Fisheries Management Committees***" (RFMCs) whose members comprise representatives from village authorities (village headmen, village elders, village development committees, village security guards, among others), fishermen and women's groups. This project was jointly implemented by LARReC under NAFRI and DLF (PAFO and DAFO) as well as local district administrative authorities (District Governor's Office). The District Governors officially approve and declare in force the establishment of RFMCs, their roles and responsibilities, as well as fishery regulations for each specific reservoir. The DLFU staff (DAFO) plays a "facilitation role" in the implementation process such as conducting field surveys, planning, implementation, monitoring, and evaluating each reservoir, and provides technical advice and support to the RFMCs that play the "implementation role".

However, planning and decision-making as well as implementation of some management activities (*i.e.* setting up of fishery regulations, enforcement, patrolling, fish re-stocking, monitoring and evaluation, among others) are done through joint arrangements, *e.g.* Nam Houm and Nam Xouang Reservoirs (Vientiane Municipality), Huay Siet and Pak Peung (Bolikhamxay Province). In 2006-2010, "***Village Fisheries Management Committees***" (VFMCs) were established in five fishing villages located in Khong District, Champasak Province also known as the Siphandone Wetland Area. Located in the southern part of the country, this Wetland Area supports abundant fisheries in the Mekong River and its tributaries. The PAFO and DAFO facilitate and support the establishment and functions of the VFMCs.

In 2009, the DLF with support from WWF-Lao PDR developed the "Fisheries Co-management Guidelines" based on practical experiences and lessons learned from the Community Fisheries Project (ComFish Project) implemented in five pilot provinces (Bolikhamxay, Khammouane, Savannakhet, Xekong and Attapeu) and the Project for Aquatic Resources Management and Livelihood implemented in Xekong Province (ARL-Xekong). The guidelines focus on the participatory process for the development of village fishery regulations and formal procedures for approval and enforcement. In 2010, the MRC-Fisheries Programme also supported the development of a manual on fisheries co-management in reservoirs for Lao PDR but this manual has not been finalized yet due to budgetary constraints. This manual was based on the practical experiences and lessons learned from a project on "Reservoir Fisheries Management" implemented from 2000 to 2010 in four pilot reservoirs (Nam Houm, Nam Xouang, Huay Siet and Pak Peung).

Conclusion

Fisheries management in Lao PDR focuses on three aspects, namely: (1) management of people; (2) management of fish; and (3) management of fish habitats. ***Management of people*** entails organizing the local fishers, fishers' groups and other key stakeholders into local fisheries management bodies (*i.e.* FMCs) with clear roles and responsibilities, and officially approved by local authorities. Organizing the local fish traders and fish farmers could also be undertaken, if necessary. Development of specific fishery regulations and enforcement system (*e.g.* patrolling/ monitoring system) is a pre-requisite, while promotion of alternative livelihood is encouraged to improve the well-being of local fishing communities. ***Management of fish*** involves all activities related to management of fish stocks such as catch and stock enhancement. This could include artificial fish seed production, nursing and restocking of fish fingerlings in closed water bodies such as reservoirs or community ponds to increase fish production.

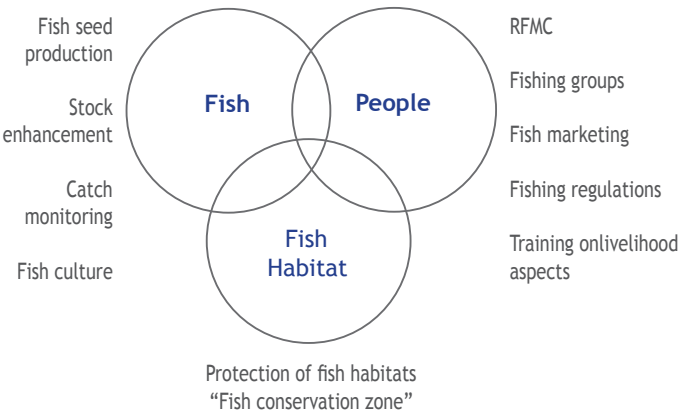
Promotion of aquaculture especially fish culture in cage and pen is encouraged not only to increase fish production but also to create additional household income. ***Management of fish habitats*** implies the implementation of activities that aim to improve critical fish habitats, especially the spawning grounds and dry-season refuges. A successful approach that is being promoted in both natural and man-made water bodies in Lao PDR is the establishment of "Fish Conservation Zones" (FCZs). In addition, the establishment of specific fishery regulations such as closed-season and closed-area are commonly practiced to protect important fish habitats especially at the onset of the spawning season (wet season). Regular monitoring and patrolling of the FCZs are also carried out to protect the natural fish stocks in the various water bodies. From the practical experiences gained, the key ***entry points*** for the development of community-based fisheries management and/or fisheries co-management at the community level for the different types of water bodies in Lao PDR could be classified into three aspects as shown in **Box 5**.

Way Forward

The development of the country's aquatic resources should be mainstreamed in the development plans of the Government, considering that it is a key component in ensuring food security for the rural people, as well as providing them with additional income and employment opportunities. R&D on the development of interlinked strategic frameworks of

Box 4. Article 53 of Fishery Law promoting Village Fisheries Regulations

- At the village level, management of fisheries operations shall be regulated through the issuance of regulations governing fishing in certain designated areas, mainly set aside as conservation, protection and development areas, and the use of fisheries resources as established by the village authority in consultation with the FMCs for a specific water body, villages, neighboring communities, in coordination with the Village Agriculture and Forestry Unit or the district or municipal Agriculture Forestry Offices in the event that the regulations apply to many villages within a single district.
- The village fisheries regulations come into force after endorsement by the District Governor and the Municipal Head



Box 5. Entry points for the development of community-based fisheries management or fisheries co-management

Community ponds: could be both natural or man-made or small- to medium-size reservoir. The culture system could follow "culture-based fisheries" considering some forms of fish stock enhancement and other management measures. The most common management activities could include: establishment of VFMCs, development of village fishery regulations, conduct of training on fish seed production (artificial fish breeding/ nursing in hapa), fish stocking, and so on.

Reservoir fisheries: As artificial man-made water bodies, reservoirs could be for hydropower or irrigation. The management activities could include: establishment of RFMCs, development of fishery regulations, enforcement activities (*i.e.* patrolling), establishment of FCZs (*e.g.* permanent or seasonal closed areas), promotion of fish culture in cages and/or pens, training on fish seed production, fish stocking, fish processing, fish marketing, collection of catch data and/or fish landing data.

River fisheries: Practiced in the Mekong River mainstream and its tributaries, this small-scale traditional and subsistence fisheries, is multiple-species and multiple-gear which is extremely difficult to manage due to the multitude of scattered fishing grounds that are highly dependent on seasonality based on hydrology and climate. The management activities could include: establishment of VFMCs, development of village fishery regulations, establishment of FCZs (*e.g.* permanent or seasonal closed areas), enforcement activities (*i.e.* patrolling), promotion of fish culture in cage, conduct of training on fish seed production, fish stocking, fish processing, fish market, collection of catch data and/or fish landing data, and so on.

resource assessment and management of capture fisheries should be carried out in parallel with the promotion of sustainable inland aquaculture. Such effort would require a well-balanced development of aquaculture, fisheries and the aquatic environments which in turn, requires the conduct of research and surveys of each sub-sector, technical development, and training at all levels, with the involvement of relevant agencies. Since there is still room for improvement of the fisheries management and aquaculture development based on water resource ecosystems and socio-economic conditions of the rural areas, the fisheries sector should be better-incorporated in an integrated water catchment and basin management system. Where appropriate, decentralization of fisheries management and co-management measures could be applied, to ensure the participation by and empowerment of local fishing communities and other primary stakeholders in implementing the management measures.

References

DLF. 2009. Fisheries Co-management Guidelines. Department of Livestock and Fisheries, Vientiane, Lao PDR (in Lao language)

DLF. 2009. Law on Fisheries. Division of Fisheries, Department of Livestock and Fisheries, Vientiane, Lao PDR

DLF. 2011. National Fisheries Strategy from now up to 2020 and Five-year Action Plan 2011-2015. Division of Fisheries, Department of Livestock and Fisheries, Vientiane, Lao PDR

Mattson Niklas, Nilsson Henrik, Phounsavath Sommano, 2000. The Fishery of Nam Ngum Reservoir, Lao PDR. Component Report No 26, Management of Reservoir Fisheries in the Mekong Basin II, Mekong River Commission, Vientiane, Lao PDR

Phonvisay Singkham. 1996. Policy Framework for Fisheries Development in Lao PDR. Department of Livestock and Fisheries, Vientiane, Lao PDR

Phonvisay Singkham. 2013. An Introduction to the Fisheries of Lao PDR. Mekong Development Series No.6, 62 pp. Mekong River Commission, Phnom Penh, Cambodia. ISSN 1680-4023

Phounsavath Sommano. 1998. Community-based Fisheries Management as an Approach to Participatory Management of Reservoir Fisheries – a Case Study of Two Fishing Villages at the Nam Ngum Reservoir, Lao PDR. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science. Asian Institute of Technology, School of Environment, Resources and Development, Bangkok, Thailand

Phounsavath Sommano. 2014. Development of Fisheries Co-management in Lao PDR: Past Experiences and Future Perspectives: Paper presented during the Experts Meeting on Mekong Cooperation on Fisheries, Aquatic Resources and Wetlands: 20-year Lessons Learnt, 12-14 November 2014, Phnom Penh, Cambodia

Sioudom, K. 2013. Basin Profile for the Nam Theun/Nam Kading, Nam Hinboun and Xe Bang Fai, Lao PDR. Project Report: Challenge Program on Water & Food Mekong project MK3 "Optimizing the management of a cascade of reservoirs at the catchment level". ICEM – International Centre for Environmental Management, Hanoi Viet Nam, 2013

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Sustainable Management of Inland Fishery Resources in Myanmar: Issues and Concerns

Nilar Kywe, Thaw Tun Oo and *Aung Than Oo*

Management of inland water fisheries has been promoted in Myanmar for decades as means of developing the country's fisheries in a sustainable manner, preventing the extinction of fishery resources, and safeguarding the health of freshwater fishery resources and habitats. For management purposes, the country's inland fisheries had been divided into: leasable and open fisheries. In leasable fisheries (locally known as Inn leasable fisheries), the fishing rights are granted through a lease agreement with the Department of Fisheries (DoF) of Myanmar subject to stipulations relating to the area, species, fishing implements, fishing period, and methods used. Open fisheries are operated in all other inland areas and waters adopting all kinds of fishing operations, with the right to fish in such areas also licensed by DoF including the fishing gears used. The leasable fisheries at Myaung in Bhamo Township, Kachin State which had been adopting sustainable management, serves as a demonstration site for other leasable fisheries in Myanmar.

Myanmar is one of the largest mainland countries in Southeast Asia with a land area of 656,578 km^2 and population of about 51.5 million based on the 2014 Myanmar Census. The country is endowed with inland water resources composed of riverine and estuarine systems. Its extensive river system comprises the Ayeyarwady (formerly known as Irrawaddy) River which is about 2,170 km long and its tributaries are the Chindwin about 960 km long, Sittaung (560 km), and Thanlwin (1,300 km). Ayeyarwady River which originates from Mainland China, traverses the entire length of the country from north to south, and drains into the Andaman Sea. According to Welcomme (1985), the water discharge of Ayeyarwady River is 13,000 m^3/sec from a catchment area

Map of Myanmar showing the Ayeyarwady (Irrawaddy) River

Table 1. Fisheries production of Myanmar (2008-2012)

	2008	2009	2010	2011	2012
Total Fisheries Production					
Qty (metric tons (MT))	3,147,605	3,491,103	3,901,979	4,149,799	4,417,676
Value ('000 US$)	3,156,405	5,283,701	5,821,638	6,065,596	7,067,139
Inland capture fisheries					
Qty (metric tons (MT))	814,740	899,430	1,002,430	1,163,159	1,246,460
Value ('000 US$)	788,325	1,349,145	1,503,645	1,744,738	1,869,690
Freshwater aquaculture					
Qty (metric tons (MT))	605,552	670,773	772,397	761,697	785,733
Value ('000 US$)	641,278	664,260	724,138	736,975	1,134,881
Mariculture/brackishwater aquaculture					
Qty (metric tons (MT))	48,303	53,390	78,122	55,123	52,693
Value ('000 US$)	141,288	208,905	193,568	203,690	213,465
Marine capture fisheries					
Qty (metric tons (MT))	1,679,010	1,867,510	2,048,590	2,169,820	2,332,790
Value ('000 US$)	1,585,514	3,081,391	3,400,287	3,580,203	3,849,103

Sources: *SEAFDEC (2014), SEAFDEC (2013), SEAFDEC (2012), SEAFDEC (2011), SEAFDEC (2010)*

of about 424,000 km^2, which is located entirely in Myanmar. In addition, the inland water resources of Myanmar also include seasonal floodplains of about 8.5 million ha, other water bodies about 1.3 million ha, freshwater aquaculture ponds about 29,000 ha, and reservoirs of about 115,960 ha. These inland water resources had produced for Myanmar in 2012, about 1.3 million metric tons (MT) of fish from inland capture fisheries valued at about US$1.9 billion and about 786,000 MT from freshwater aquaculture valued at about US$1.2 billion (SEAFDEC, 2014). The country's production from inland capture fisheries which accounted for about 28% of its total fisheries production in 2012 and freshwater aquaculture contributing about 18% (**Table 1**), demonstrates the importance of inland fisheries to the country's economy. Almost entirely associated with livelihoods in rivers and estuarine areas, inland fisheries in Myanmar has been playing an important role in supplying fish to its populace, especially those in rural areas. Currently, the Department of Fisheries (DoF) under the Ministry of Livestock, Fisheries and Rural Development of Myanmar has the key role in the management of the country's fishery resources.

Management of Inland Fisheries in Myanmar

Inland fisheries has been practiced in Myanmar since 1864 during the British Rule of the country and managed in accordance with fisheries rules enforced since 1872. Since then, inland fisheries had been managed in accordance with the fisheries rules. However, considering that the country's fisheries production had been decreasing, the government promoted leasable fisheries and enacted the Fisheries Act in 1905, which identified the boundaries of leasable fisheries, auction system and fishing period in the leasable fisheries.

After a change of the country's administrative system in 1991, the country enacted the Freshwater Fisheries Law. Based on such Law and for management purposes, the country's inland fisheries have been divided into leasable and open fisheries.

Net enclosure constructed around leasable fisheries area

In leasable fisheries, also known locally as Inn leasable fisheries, the fishing rights are granted through a lease agreement with the DoF subject to stipulations relating to the area, species, fishing implements, fishing period, and methods used. Open fisheries are also allowed based on the fishing license or floating tenders issued that specify the fishing grounds and any other methods that could be used in all inland water areas except in leasable fisheries.

Leasable fisheries also serve as conservation areas and production promotion sites based on collaborative arrangements among the lease owners and the DoF. However, the short-term lease period of one-year created some concerns as the lessees also had short-term outlooks for the fisheries and did not think of investing more in the fisheries and were not anxious to conserve the resources. As a matter of fact, this led to over-exploitation of resources as the lessees tended to maximize their catch without having thoughts on the sustainability of the fishery resources. Thus in 1909, the long-term lease system was adopted as means of preventing the extinction of indigenous species and depletion of fisheries habitats, sustaining fish production of leasable fisheries, monitoring and controlling illegal fishing in the lease areas, and promoting responsible fisheries practices in the lease areas.

In 1988-1989, the long-term lease permission program was suspended but was restarted in 1992. Under this resumed program, lease owners granted the long-term permission have to undertake various activities such as repairing the waterways where fish migrates, enhancing the fish stocks in the lease areas, and promoting the conservation of fisheries habitats. Considering that such activities could not be completed in one year, DoF grants the lessees long-term permission from 3 to 9 years. Thus, the lessees do not have to bid again for the auction and pay high fees for their lease areas during the lease period.

In order to promote the production and conservation of indigenous species, DoF has initiated culture-based system and capture-based system in leasable fisheries since 1997. At present, most of the lessees have been conducting these systems since these have provided them beneficial returns. Such practices in leasable fisheries have been promoted by the DoF as ways and means of obtaining sustainable fish production and at the same time promoting conservation measures. Since then, nearly 500 leasable fisheries have been permitted to operate long-term lease arrangements annually. Among the long-term leasable fisheries, Myaung leasable fisheries in Bhamo Township, Kachin State which adopted sustainable management, had served as demonstration site for other leasable fisheries in the country.

As leasable fisheries progressed, some of the lease areas had been observed to be deteriorating due to siltation, agriculture operations, mining, and road and dam construction. The

deteriorated habitats coupled with illegal fishing and overfishing resulted in the depletion of the fishery resources that eventually led to overall decreases in the country's fish production from inland capture fisheries. Thus, the DoF finally established guidelines for preventing further decline of habitats and fish stocks, especially in the lease areas based on long-term lease agreement of three years. Since then, stipulations in the lease agreement include the conditions spelled out in the guidelines (**Box 1**).

Box 1. Guidelines detailing the responsibilities of lease holders (lessees) in the lease areas

- Submit to DoF proposal for long-term operation of lease area including workplan
- Upon issuance of lease agreement, implement the workplan under the supervision of DoF
- Conduct regular repair of waterways where fish migrates, and promote stock enhancement and conservation of fisheries habitats based on culture-based and capture-based systems
- Promote conservation of indigenous fishes by adopting capture-based system
- Enhance fisheries production using culture-based system by stocking fish seeds during the transition, *i.e.* nursing fish seeds in net enclosures in pens or cages or earthen ponds prior to releasing them to lease areas
- Rehabilitate the habitats in order that wild fish would reach the spawning and nursing grounds in the lease areas, *e.g.* deepening of shallow waterways, removing fallen trees and small bushes as well as other aquatic growth, creating spawning and nursery grounds in some areas along the migration route

As for open fisheries, all fishing gears are licensed by DoF. However, for some larger gears such as bagnets set in rivers, the right is licensed through a tender system, also known as floating tender. The DoF also regulates the operations of open fisheries, *i.e.* as these fisheries are not allowed to operate during the closed season from May to June of each year to allow spawning and recruitment of fish stocks.

Model Leasable Fisheries in Myanmar

With the main objective of conserving the inland fisheries habitats and fish stocks, the DoF has been conducting many activities in collaboration with leasable fisheries stakeholders. One of the most successful long-term leasable fisheries is

located in Myaung of Bhamo Township, Kachin State in the northern part of Myanmar. Recognize for its successful management that led to increase in fish production, the Myaung leasable fisheries had been used as model and demonstration site for other leasable fisheries to learn lessons from. Awarded during in auction in 2013-2014, the Myaung lease area consists of river channels connected to the Ayeyarwady River, where the main channel is managed by the lease holder while in the small channels, other fishers are allowed to fish by the lessee.

Based on the proposal submitted to DoF for the operation of Myaung leasable fisheries, the lessee has been allowed to operate in the lease area for a period of three years from 2014 until 2017. The stakeholders of Myaung leasable fisheries established that one of the most important factors that led to their success in managing the lease area is the regular cleaning of the waterways or canals as well as removing vegetations that grow in the waterways, to facilitate the migration of spawners. Furthermore, the activities that have been conducted in the lease area are in accordance with the workplan submitted to DoF (**Box 2**) and other relevant conditions (**Box 3**). The lessee also adopts culture-based and capture-based culture systems in the lease area, and a fishpen is constructed inside the area to rear indigenous fish species and culture some commercial species. The fish outside the fishpen is also nurtured and fed to enable the fish to grow to marketable size. The concerned stakeholders depend on the fish harvested outside the fishpen for their consumption especially during the closed season (June-August). Selective harvesting has also been applied in the Myaung leasable fisheries in order to sustain its fish production.



(*left*) Clearing of debris and other clogging materials from migration routes; (*center*) transferring nursed fish seeds from pens to lease area; (*right*) transferring indigenous fish juveniles to lease area

Box 2. Workplan of Myaung leasable fisheries for 2014-2017

May	• Preparation of fisheries habitat and maintenance of waterways o Digging shallow waterways, removal of fallen trees, small bushes and other aquatic vegetation o Construction of net enclosure (fishpen in the lease area)
June-August	• Wild fish is lured using feeds or baits and collected in the lease area, while seeds of cultured fish are reared in the fishpen
September-October	• Liming of the fishpen area to prevent water pollution
September-March	• Fishing period • Lessee and concerned stakeholders harvest fish outside the net enclosure (fishpen) • Selected breeders and undersized fish are transferred to fishpen for nursing

Source: *Kywe* et al. *(2015)*

Box 3. Other conditions in the workplan of Myaung leasable fisheries

- Daily patrolling of the lease area by fishers' team of the lessee to prevent poaching, fish poisoning, electro-fishing in the lease area especially during the closed season
- Fishing gears allowed in the lease area: drag nets, cast nets and lift nets, and to some extent, set gill nets. Lessee inspects the mesh size of nets used by other fishers in the lease area
- Migration and reproduction of fish should be ensured in the lease area, while good water quality and health of the habitats should also be promoted
- Catch by species, size and weight especially for commercial fishes should be recorded and reported to DoF
- Indigenous fish species and some cultured species incidentally caught in the lease area should be released to natural water bodies

Source: *Kywe* et al. *(2015)*

Legal Framework Relevant to Inland Fisheries Management

The DoF of Myanmar formulated a new Freshwater Fisheries Law in 1991 to ensure that the changing conditions in the country's inland fisheries are taken into account, which the 1905 Burma Fisheries Act had inadequately covered. In addition, having been empowered by the Forest Law of 1992, the Government has declared that all mangrove forests are protected areas, and fishing within three hundred yards of such mangrove areas is strictly prohibited. Meanwhile, the most relevant regulations under the 1991 Freshwater Fisheries Law are shown in **Box 4**.

Issues and Concerns

Various approaches and related activities had been tried by the DoF of Myanmar for the sustainable management of leasable fisheries, *e.g.* giving back 1.0% of revenues to the inland fisheries sub-sector through a stocking program; return of 30.0% of revenues to long-term lease holders in the form of grants for improved management that includes: environmental rehabilitation, restoration and enhancement; clearing of floodplain channels to allow improved access of fish to the feeding and breeding grounds; and rearing of fish in pens within the lease area. Although the impacts of these factors are difficult to monitor and record, production and revenues are however reported to DoF, especially with respect to the trend of production from leasable fisheries. Nonetheless, one of the main concerns of the inland fisheries sub-sector of Myanmar is proper compilation of production and other data for planning and policy-making purposes. For example, data from reservoir fisheries are not compiled by DoF because reservoirs are under the control of the Ministry of Agriculture and Irrigation. Even if fishing in reservoirs is officially not allowed as means of allowing fish stocks to recover, fish is still harvested from reservoirs since these water bodies are restocked regularly. As a consequence from such practice, the catch had not been included in the country's statistical reports until 2000.

The Union of Myanmar is divided into States and Divisions, which are then divided into districts then to townships then lastly to villages. All fisheries license holders are required to report their catches to DoF through designated local township

Box 4. Regulations relevant to fisheries management stipulated in the 1991 Freshwater Fisheries Law

Closed fishing areas: 30 areas reserved for leasable fisheries had been identified for protection and management to ensure survival of juveniles of commercially important fish species, and these are located in Yangon, Pago, Sagaing, Mandalay, and Ayeyarwady Region.

Closed fishing season: for all freshwater fisheries, fishing is not allowed from May to July.

Protection of spawners, breeders and fingerlings of freshwater fishes. Species that should not be caught, exported, killed or kept in captivity without permission from the Director General of DoF, especially during the closed season are identified.

Prohibited trading of spawners, breeders and fingerlings of the giant freshwater prawns *Macrobrachium rosenbergii* and *M. malcolmsonii*: catching, exporting, selling, killing or keeping in captivity of such species especially during the closed season is not allowed without permission from the Director General of DoF. In case of accidental catch, these should be released immediately to natural water bodies.

Prohibited trading of the African catfish *Clarias gariepinus*: import, export, culture, production, sale, propagation or possession of the African catfish (*Clarias gariepinus*) is not permitted.

Prohibited fishing gears: fishing gear that is destructive to the environment and fishery resources are banned, as well as electro-fishing and fishing that uses poisons, chemicals and explosives, and other gears that obstruct the waterways such as those in dams and banks of rivers.

officials. Specifically for leasable fisheries, the lessees keep records of the fisheries, especially the catch records which are collected by designated local officers. In all cases, there is no sampling of the catch although reports are required especially for large gear, while some township officers were reported to have estimated the catch when these are not available from the lessees. After compiling the reports every two weeks, the township officers submit the reports to the central offices of DoF on a monthly basis. The officers are supposed to verify the catch records and other information through ocular inspection and field visits in the lease areas or fishing locations for open fisheries. However, such approach is not usually undertaken since many officers at township level only work part-time on fisheries statistics, as they have other duties in the township that include fisheries extension. In the case of leasable fisheries, the catch is reported in terms of value and quality (*i.e.* high and low quality), but information from open fisheries is reported by volume only and not by any category. Nevertheless, in both fisheries, there is very limited information on species composition.

It is in this aspect that collection and compilation of fisheries information should be improved, and could include: weight and species of fish caught, weight of feeds for fish outside and inside the fishpens, information on stock assessment of cultured species and wild species, and results of analysis of monitoring and evaluation of fish production. Nonetheless, it should also be considered that the Government has been giving more focus on agriculture extension, mining and industrial development. Given the importance of fisheries, especially inland fisheries to food security of the country, the fisheries sector in general and inland fisheries in particular, should also be given equal attention as other sectors. Specifically for leasable fisheries, support from the Government is needed in the reconstruction and/or maintenance of waterways considering the high labor and machinery costs. In addition, since the process of annual auctioning of leasable fisheries had been found to result in over-exploitation, such system should be reviewed and revised accordingly.

Conclusion and Recommendations

For the sustainability of inland fisheries, habitat conservation should be promoted as this is important for the growth and propagation of fish. In leasable fisheries, selective fish harvesting should be enhanced to ensure sustainable fish production and resources conservation while leasable fisheries should be sustained as these have the potentials for resources and habitat conservation compared with open fisheries. Information collection and sharing of knowledge and experiences among stakeholders should be improved. Moreover, sufficient supply of quality seeds of indigenous species should be produced in hatcheries for stock enhancement of the species.

Based on the experience of Myaung leasable fisheries, similar approach should be promoted in other areas of the country for the sustainable production of fish which could supply the nutritional requirements of local people especially during the closed season. Since conservation of indigenous species is already developed, lessees should be encouraged to provide breeders to DoF-operated hatcheries as well as to backyard hatcheries operating near the lease areas. In general, there is a need for the Government to put more emphasis in the conservation of freshwater fishery habitats and resources as well as in the extension of long-term lease awarded to responsible lease holders.

On the part of the DoF of Myanmar, an analysis of the impact of cultured species on the wild species should be conducted based on regular surveys. There is also a need for DoF to conduct R&D on the rehabilitation of critical fisheries habitats and the results of which could be applied in leasable fisheries. Over-all it still remains a great challenge for Myanmar to manage its fisheries, more particularly its inland capture fisheries.

References

Nilar Kywe, Thaw Tun Oo and Aung Than Oo. 2015. Inland Fisheries Habitat Management of Myanmar. Paper presented during the SEAFDEC Symposium on Strategy for Fisheries Resource Enhancement in the Southeast Asian Region, Pattaya, Thailand, 27-30 July 2015. Southeast Asian Fisheries Development Center, Bangkok, Thailand.

SEAFDEC. 2010. Fishery Statistical Bulletin of Southeast Asia 2008. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

SEAFDEC. 2011. Fishery Statistical Bulletin of Southeast Asia 2009. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 149 p

SEAFDEC. 2012. Fishery Statistical Bulletin of Southeast Asia 2010. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 143 p

SEAFDEC. 2013. Fishery Statistical Bulletin of Southeast Asia 2011. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 133 p

SEAFDEC. 2014. Fishery Statistical Bulletin of Southeast Asia 2012. Southeast Asian Fisheries Development Center, Bangkok, Thailand; 135 p

Welcomme, R.L. 1985. River Fisheries. FAO Fish. Tech. Paper 262: 332 p

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Transforming a coral reef cove into mariculture hub: Igang Marine Station of SEAFDEC/AQD

Aerial view of SEAFDEC/AQD Igang Marine Station in Guimaras Province, Philippines in 1980s

The Igang Marine Station (IMS) of SEAFDEC Aquaculture Department (SEAFDEC/AQD) is situated in a coral reef cove in Nueva Valencia, Guimaras Island in central Philippines. Home to broodstocks of milkfish, grouper, sea bass, snappers, and other commodities, IMS is composed of four islets interconnected with clusters of floating cages. In these cages, fishes mature and spawn spontaneously during the normal breeding seasons, demonstrating sustainable mariculture and promoting blue culture technology.

The coral reef cove at Igang in Nueva Valencia, Guimaras that has been transformed into what is now the IMS of SEAFDEC/AQD

IMS was established in 1974 primarily for the conduct of studies on the breeding of tiger shrimp (*Penaeus monodon*) in pens. These studies resulted in major breakthroughs that include the unprecedented completion of the life cycle of *P. monodon* in captivity in 1975, which was followed closely by the rematuration of spent spawners, paving the way for the establishment of *P. monodon* broodstock. In 1983, another milestone was attained at IMS with the completion of the life cycle of milkfish or bangus (*Chanos chanos*) leading to the development of milkfish broodstock and promotion of the Philippine National Bangus Breeding Program. Meanwhile, natural spawning of captive breeders in cages was first observed and recorded at IMS in 1979.

Since then, new nursery and grow-out technologies in floating net cages have been developed and verified for high-value marine species such as grouper (*Epinephelus* spp.), sea bass (*Lates calcarifer*), snapper (*Lutjanus argentimaculatus*), and

pompano (*Trachinotus blochii*), and demonstrated to fish farmers for the promotion of sustainable mariculture.

IMS also maintains stocks of abalone (*Haliotis asinina*) and sandfish (*Holothuria scabra*) for studies on improving the culture of these commodities in cages. The current work of abalone focuses on improving the grow-out culture technology in cages and broodstock propagation for hatchery use. For sandfish, its potential for polyculture with selected marine fishes is being explored.

Mariculture Park demonstration and training facility, IMS

IMS also hosts a small giant clam garden, where about 200 giant clams (*Tridacna* spp.) which were released in 2006 have been looked after for stock enhancement studies. Mass production of *Kappaphycus* spp. plantlets in sea-based nursery system is also being conducted at the IMS.

Also forming part of the IMS complex is a mariculture park demonstration and training facility which serves as a model of sustainable mariculture technology for marginal fishers. The mariculture park also caters to entrepreneurs interested in investing in aquaculture. Recent studies have now put more focus on integrated multi-trophic aquaculture (IMTA), which refers to the farming of different aquaculture species together, allowing the waste of one to be recycled as feed for another species.

Specifically, the milkfish research activities conducted at IMS use soy products as alternatives to fish meal in practical feeds for milkfish grown in floating net cages. The carrying capacity of the waters of IMS is regularly monitored and evaluated, while the physico-chemical parameters of waters beneath the cages are also being measured to ensure that the activities at IMS do not pollute the environment.

To support the research and training activities, IMS has an Administrative Office, staff quarters, and fully-furnished guest houses nestled on top of the islets. IMS is also open for eco-tourism on specified seasons.

For more information, refer to *www.seafdec.org.ph.*

Cover of Fish for the People Volume 13 Number 2: 2015 shows part of what is now the IMS as a mariculture hub demonstrating blue culture technology

CALENDAR OF EVENTS

Date	Venue	Title	Organizer(s)
2016			
29 Jan-5 Feb	Rayong, Thailand	Regional Training Course on Stock Assessment – Part I: The Basic Knowledge of Fisheries Biology	SEAFDEC Secretariat
1-13 February	Samut Prakan, Thailand	Regional Training Workshop on Larval Fish Identification and Fish Early-life History Science (Basic course: Key to Family)	SEAFDEC Secretariat
8-10 February	Colombo, Sri Lanka	6th APFIC Regional Consultative Forum Meeting "Promoting blue growth in fisheries and aquaculture in the Asia-Pacific"	APFIC
8-12 February	Thailand	Expert Meeting on Regional Cooperation for Implementation of Port State Measures (PSM) in the Southeast Asian Region	SEAFDEC Secretariat
12-14 February	Colombo, Sri Lanka	34th Session of the Asia-Pacific Fisheries Commission	APFIC
15-19 February	Binangonan, Philippines	Training Course on Freshwater Prawn Hatchery & Grow-out Operations	SEAFDEC/AQD
22-24 February	Makati City, Philippines	Regional Technical Consultation on EMS/AHPNS and Other Trans-boundary Diseases for Improved Aquatic Animal Health Management in Aquaculture in Southeast Asia	SEAFDEC/AQD & BFAR Philippines
7-11 March	Auckland, New Zealand	5th Global Fisheries Enforcement Training Workshop (GFETW)	International MCS Network
18-26 March	Samut Prakan, Thailand	Regional Training Course on Stock Assessment – Part II: The Stock Assessment	SEAFDEC Secretariat
22-24 March	Kochi, India	Capacity Building Workshop on Regional and National Good practices in Seafood Traceability	INFOFISH
4-8 April	Viet Nam	48th SEAFDEC Council Meeting	SEAFDEC Secretariat
18-22 April	Binangonan, Philippines	Training Course on Carp Hatchery & Grow-out Operations	SEAFDEC/AQD
25 April (Tentative)	Palembang, Indonesia	Opening Ceremony and Inauguration of IFRDMD	SEAFDEC/IFRDMD & MMAF Indonesia
26-28 April (Tentative)	Palembang, Indonesia	1st Workshop on Enhancement of Sustainability of Catadromous Eel Resources in South East Asia	SEAFDEC/IFRDMD
Last week April - 1st week May	Iloilo, Philippines	Training Course on Sandfish (*Holothuria scabra*) Seed Production, Nursery and Management	SEAFDEC/AQD
April (Tentative)	Bangkok, Thailand	RTC on Development of Regional Guidelines for Small-Scale Fisheries in the Southeast Asian Region	SEAFDEC Secretariat
9-13 May	Binangonan, Philippines	Training Course on Freshwater Prawn Hatchery & Grow-out Operations	SEAFDEC/AQD
9-30 May	Iloilo, Philippines	Training Course on Mud Crab Hatchery Operations	SEAFDEC/AQD
23-25 May	Bangkok, Thailand	14th INFOFISH World Tuna Trade Conference and Exhibition	INFOFISH
2nd-4th week May	Iloilo, Philippines	Training Course on Abalone Hatchery & Grow-out Operations	SEAFDEC/AQD
6-10 June	Binangonan, Philippines	Training Course on Tilapia Hatchery & Grow-out Operations	SEAFDEC/AQD
13-22 June	Iloilo, Philippines	Training Course on Mud Crab Nursery & Grow-out Operations	SEAFDEC/AQD
Mid-June - 3rd week July	Iloilo, Philippines	Training Course on Marine Fish Hatchery	SEAFDEC/AQD
June (Tentative)	Iloilo, Philippines	Training Course on Seaweed Farming	SEAFDEC/AQD
June (Tentative)	Singapore	Regional Training Course on Identification of Toxic Harmful Algal Bloom (HAB) Species	SEAFDEC/MFRD
June (Tentative)	Samut Prakan, Thailand	Regional Training Workshop on Larval Fish Identification and Fish Early-life History Science (Advanced course: Key to Species)	SEAFDEC Secretariat
26-28 July (Tentative)	Palembang, Indonesia	1st Workshop to Review Activities and Methodologies for Promotion on Inland Fishery	SEAFDEC/IFRDMD
3 August	Bangkok, Thailand	High-level Consultation on Regional Cooperation in Sustainable Fisheries Development Towards the ASEAN Economic Community	SEAFDEC Secretariat
4-6 August	Bangkok, Thailand	ASEAN Fisheries Conference and ASEAN Seafood Exposition	Thai DOF, SEAFDEC, NACA, INFOFISH
22-26 August	Binangonan, Philippines	Training Course on Tilapia Hatchery & Grow-out Operations	SEAFDEC/AQD
22-26 August	Iloilo, Philippines	Training Course on Catfish Hatchery and Grow-out Operations	SEAFDEC/AQD
12-16 September	Binangonan, Philippines	Training Course on Freshwater Prawn Hatchery & Grow-out Operations	SEAFDEC/AQD

Southeast Asian Fisheries Development Center (SEAFDEC)

What is SEAFDEC?

SEAFDEC is an autonomous intergovernmental body established as a regional treaty organization in 1967 to promote sustainable fisheries development in Southeast Asia.

Mandate

To develop and manage the fisheries potential of the region by rational utilization of the resources for providing food security and safety to the people and alleviating poverty through transfer of new technologies, research and information dissemination activities

Objectives

- To promote rational and sustainable use of fisheries resources in the region
- To enhance the capability of fisheries sector to address emerging international issues and for greater access to international trade
- To alleviate poverty among the fisheries communities in Southeast Asia
- To enhance the contribution of fisheries to food security and livelihood in the region

SEAFDEC Program Thrusts

- Developing and promoting responsible fisheries for poverty alleviation
- Enhancing capacity and competitiveness to facilitate international and intra-regional trade
- Improving management concepts and approaches for sustainable fisheries
- Providing policy and advisory services for planning and executing management of fisheries
- Addressing international fisheries-related issues from a regional perspective


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The second prize drawing winner, *Koam Seyma*, from the national drawing contest in Cambodia

National Drawing Contests were organized in all ASEAN-SEAFDEC Member Countries as part of the preparatory process for the ASEAN-SEAFDEC Conferene on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" held by ASEAN and SEAFDEC in June 2011 in Bangkok, Thailand, in order to create awareness on the importance of fisheries for food security and well-being of people in the region.