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    MRC completes first comprehensive analysis of Tonle Sap dai fishery
A newly-published report recommends improving Lao fisheries management and aquaculture development while better incorporating the sector in integrated water catchment and basin management.

In Lao PDR, fisheries are exploited extensively by rural communities who fish near their own land and consume most of the catch locally. Traditional systems for managing access and fishing effort are widespread and fisheries are an integral part of the livelihood of entire communities. It is estimated that national fishery production could be more than 200,000 tonnes per year, valued at approximately USD 150 million, in which fish accounts for about 80 percent of the total production with about 20 percent from OAAs.

Inland fisheries catch statistics are much-disputed in Lao PDR. In 2007, the Department of Livestock and Fisheries estimated the total fish production at about 144,000 tonnes in the country, of which capture fisheries (excluding OAAs) accounted for approximately 62 percent, with 38 percent coming from aquaculture. More reliable information on catches and on aquaculture is needed, especially for OAA catches and productivity in wet-season rice-fields and small water bodies. A regular monitoring system should be directed toward more field-based monitoring, and would be improved if the system covered the importance of secondary values from fisheries as well as the influence of biodiversity and environmental factors in various types of habitats.

The development of aquatic resources should be recognised by the Government in its development planning, as it is a key component in improving food security for many rural people, as well as providing them with additional income and employment opportunities. Two interlinked strategic frameworks of resource assessment and...
the management of capture fisheries should be developed, in concert with the promotion of the sustainability of aquaculture. Such research and development requires well-balanced development between aquaculture, fisheries and aquatic environments and this, in turn, requires research and surveys of each sub-sector, technical development, training at all levels and the involvement of higher education.

The shift toward a more holistic view of aquatic resources management by the Government has until recently been based mainly on the regulatory framework within the natural resources and environment sector, such as the Forestry Law, the Environment Protection Law, the Water Resources Law, and the Aquatic and Wild Animals Law. A new fishery law was enacted in Lao PDR in July 2009, bringing fisheries management within one cohesive framework. It 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 for food security. The law provides for community fisheries management and control measures, such as establishing conservation zones and community ponds and making fishing regulations. It also provides for protection of aquatic resources and ecosystems through various measures. Implementation will continue to be a challenge, requiring education,
Challenges for the Lao fisheries sector

In rural areas of Lao PDR, inland capture, mostly subsistence and semi-subsistence fisheries, is complex in nature and involves a wide variety of activities undertaken by people from a wide spectrum of socio-economic backgrounds. This type of capture fishery is difficult to manage through control of exploitation, except in the areas where fishing activities are more centralised, such as in large reservoirs. As fish need a suitable habitat and water quality, and a certain type of hydrological regime which allows their migration from one habitat to another within a certain period of time each year, any activities or developments which cause habitat degradation, water pollution or that restrict migration may cause some impact on fisheries. These include urban developments, industrialisation, deforestation, agricultural intensification, and dam construction. Other impacts on fisheries and aquatic biodiversity may arise from overfishing, illegal fishing and the introduction of exotic species.

Hydropower dam development projects which affect fisheries include Nam Ngum, Theun Hinboun, Nam Theun 2, Houy Ho, Nam Mang, Nam Leuk and the succession of dams that are being built on the Nam Ngum, Nam Theun, and Xe Kaman. Development of hydropower and large irrigation reservoirs has positive and negative effects on the fisheries as well as on the environment. For example, migration of riverine fish is obstructed by dams, but the impact may be mitigated by proper planning, construction techniques and flow control regimes as well as provision of fish passage facilities. The construction of large reservoirs can also present significant opportunities for new fisheries. Dams also cause many other impacts downstream by modifying flows and water quality, which require various measures to mitigate negative effects.

Fortunately, the hydropower reservoir developments and large projects in Lao PDR have to be implemented through the Environmental Protection Law (02/99/NA), the Decree of the Environmental Protection Law (102/PM) and the Regulation on Environmental Assessment (1770/STEA). Uniform environmental assessment requirements and procedures should improve the integration of environmental conservation in all socio-economic development projects. For example, the Nam Theun 2 Project was required to comply with various management measures, including integrated catchment basin management, property and fisheries access rights, an extension programme for stocking and harvesting techniques, private or public sector investments on hatcheries and stocking programme, and the decentralisation of fisheries management to ensure participation by fishers and primary stakeholders in implementing management measures.

Based on the MRC Management of Reservoir Fisheries Project experiences, monitoring of catches and management measures have been neglected in many important irrigation reservoirs such as Nam Tien, Nam Tin, Nam Tam, Nam Khou, Houy Sakhouang, Houy Suy, Houy Chiew, Houy Nhot Bak, Houy Khiew, Houy Toklok, and Houy Lampanh.

In Lao PDR in 2007, there were 10,993 temporary irrigation weirs, 213 gabion dams, 1,160 permanent diversion weirs which qualified as ‘small diversion dams of various sizes across streams’ and there were also 108 gates and dykes. There were also many pumping schemes, which covered 248,143 ha of paddy fields. However, the impact on fisheries from these irrigation developments is still unclear. It is necessary to undertake an assessment of impacts and mitigation measures concerning these structures and, more importantly, there is a great need for monitoring fisheries productivity and aquatic diversity in streams and in rice-field ecosystems throughout Lao PDR.

A reassessment and monitoring of impacts also needs to be undertaken in areas where fisheries are being affected by pollution from activities such as slash and burn shifting cultivation, mining, agricultural intensification using pesticides, road construction, industrial waste water discharge and fish cage culture in rivers and reservoirs.
monitoring and research, as well as support to community-based fisheries management. Given the importance of fish and OAAs to people as food and income, there is a need for improvement of fisheries management and aquaculture development based on water resource ecosystems and socio-economic conditions of various rural areas. The fisheries sector should be better-incorporated in integrated water catchment and basin management. Where appropriate, decentralisation of fisheries management and co-management measures should be applied, to ensure participation by and empowerment of local fishing communities and other primary stakeholders in implementing management measures.

Further reading

Phonvisay Singkham (2013) An introduction to the Fisheries of Lao PDR. Mekong Development Series No. 6. Mekong River Commission.

Species diversity

More than 481 fish species have been identified in Lao PDR, including 22 exotic species, and more species are being discovered regularly. Among other aquatic animals, about 37 amphibians, 7 species of crabs and 10 species of shrimps have been recorded, but these records cover only about 15 percent of the estimated total.

Consuming fish and other aquatic animals

The people of Lao PDR, especially in the rural communities which account for more than 75 percent of the population, still depend upon the country’s fish and other aquatic animals as their most reliable sources of animal protein intake. The estimate of actual fish consumption per capita (kg/capita/year) of inland fish is 24.5 kg, while other aquatic animals account for about 4.1 kg and marine products around 0.4 kg, to make a total of 29 kg of fish and aquatic products consumed per capita per year.

Fish landing site in Khong District, Champassak Province
Cambodia launches pilot study to assess Tonle Sap mollusc fishery

BY NGOR PENG BUN, CHHUYON KIMCHHEA AND PRAK LEANG HOUR *

The Fisheries Administration of Cambodia has begun a one-year study of a mollusc fishery in the largest lake in Southeast Asia. Launched in February and financed by the Mekong River Commission Fisheries Programme, the pilot study aims to assess the status of the fishery in Kampong Chhnang province, one of the five main provinces around the Tonle Sap Lake. Cambodian researchers expect to describe the types of fishing gear used and identify key species of which at least three will be measured for length and weight. The study also aims to record the yield and value of the fishery, identify key distribution channels and assess the impacts of local mollusc production.

Fish and other aquatic animals (OAAs) are consumed regularly by almost all people in the Lower Mekong Basin. They provide a major source of employment and income as well as protein and essential elements (including calcium, iron and zinc) and vitamins — particularly Vitamin A (Hortle, 2007). In Cambodia, Hortle estimated that average consumption of fish and OAAs was 52.4 kg/person/year, of which 42.2 kg were from freshwater fish, 1 kg from marine fish and 9.2 kg from OAAs, mainly shrimps, crabs, molluscs, insects, snakes and frogs.

Based on available fish consumption data, Hortle also estimated that the OAA yield in Cambodia was around 105,467 tonnes/year. RUPP (2010 cited in Persson et al., 2010) reported that snails, crabs, eels, frogs, toads and other species from rice paddies and canals accounted for 60-70 percent of the food from common pool resources consumed by the poorest households in Cambodia.

Molluscs are among the important OAAs

Coconut snails (Mekongia swainsoni) and crow snails (Filopaludina martensi cambodjensis) on sale in the provincial capital of Kampong Chhnang

PHOTO: NGOR PENG BUN
contributing to food security, especially for the rural poor in Cambodia (Persson et al., 2010).

‘The razor clams look very fine. They get clams, mud clams and pond snails just by scooping them out of the Freshwater Sea’
— Chinese envoy Zhou Daguan

In the Mekong Basin, including the Tonle Sap, molluscs are extremely high in diversity (Rainboth, 1996). During his visit to Cambodia in the late 13th century, Chinese envoy Zhou Daguan observed that fish and other aquatic animals including frogs, tortoises, turtles, lizards, large crocodiles and molluscs were abundant on and around the Tonle Sap Lake (reprinted Zhou, 2002). "The razor clams look very fine. They get clams, mud clams and pond snails just by scooping them out of the Freshwater Sea," Zhou wrote, referring to the lake.

Davis (1979 cited in MRC, 2003) indicated some 120 species, of which at least 111 are endemic to the Mekong River, the greatest known biodiversity in the world. Nguyen and Nguyen (1991 cited in Lamberts, 2001) identified 29 molluscs in the zoobenthos of “the Mekong, the Tonle Sap channel and the floodplains”, making up 85 percent of the zoobenthos by weight. Halwart (2006) identified at least one mollusc species (Pila sp.) from Cambodian ricefields used as food, feed, bait and for trade.

Hortle et al. (2008) surveyed nine 25-hectare sites in Battambang province between July 2003 and February 2004 to quantify the yield and value of ricefield fisheries (fish and OAAs) in areas typical of the rain-fed, lowland, wet-season rice fields surrounding the floodplain of the Tonle Sap. The survey revealed that crabs, frogs, shrimps, water snails and snakes contributed 23 percent to the catch volume of 26,730 kg and 11 percent of the catch value of KHR 91,650,857 (USD 22,900). Big and small water snails made up around 10 percent of the catch.

According to MRC (2003), at least six species of bivalves and four kinds of snails are commonly consumed in Lao PDR and other riparian countries including Cambodia. According to MRC (2003), at least six species of bivalves and four kinds of snails are commonly consumed in Lao PDR and other riparian countries including Cambodia. Snails are said to be collected around the edges of lakes or ricefields. In Cambodia, bivalves, locally known as leah, are caught at the end of the rainy season as floodwaters recede. In one study in Kampong Cham province (cited in MRC, 2003), the annual total catch for 130 families was 138 tonnes, with

Freshwater molluscs in Cambodia
Six species on sale in markets in Kampong Chhnang province and Phnom Penh

| Family                 | Species                              | Khmer                  | English                      |
|------------------------|--------------------------------------|------------------------|------------------------------|
| Ampullariidae (apple snails) | Pila polita                        | ខ្យងគូថស្រួច           | Sharp-tail snail (kouth srouich) or conic snail |
| Ampullariidae (apple snails) | Pila ampullacea                    | ខ្យងគូថទាល             | Blunt-tail snail (kouth teal)    |
| Ampullariidae (apple snails) | Pila scutata                       | ខ្យងស្រ               | Ricefield snail (kchong srae) or pila snail |
| Viviparidae (river snails)       | Filopaludina martensi cambodjensis | ជាទុកឈឺ              | Crow snail (kchao kaek)         |
| Viviparidae (river snails)       | Mekongia swainsoni                  | ជាកំពត              | Coconut snail (kchao dong)      |
| Corbiculidae (basket clams)       | Corbicula moreletiana               | លៀស                   | Asian clam (kchao kaek)         |
Golden apple snail: ‘an inappropriate introduction with disastrous consequences’

Scientists working in the Lower Mekong Basin have recorded at least two species of freshwater snails from the *Pomacea* genus of apple snails. Both are native to South America and are now a pest to rice farmers in the region. According to Swiss ichthyologist Maurice Kottelat, the golden apple snail (*Pomacea articulata*) was introduced into all countries of the Lower Mekong Basin for aquaculture and ornamental use from 1988 onwards (see *MRC Technical Paper No 9*). Its introduction into Thailand was from Taiwan. Another species known as *Pomacea gigas* was introduced into Thailand from an unknown country and has become established in the wild. The golden apple snail is now widespread in very high densities in the Mekong Delta where it attacks rice crops but also provides food for humans and feed for ducks and pigs (see *Catch and Culture*, Vol 19, No 1).

'Duck farmers who have used the crushed snails as feed have suffered mortalities among their flocks'

The authors of the MRC technical paper published in 2003 noted that the alien species competed with snails such as native species from the *Pila* genus which are “relatively benign” since they only attack plants that are already moribund. The invasive species, however, accumulate toxic materials in their shells. "Duck farmers who have used the crushed snails as feed have suffered mortalities among their flocks," the paper said, describing the case of these species as “an example of disastrous consequences that can follow from an inappropriate introduction.”

The introduction into East Asia can be traced back half a century. According to Kenji Ito of the Department of Entomology and Nematology at Japan’s National Agricultural Research Center, the golden apple snail was imported into Japan as an aquarium pet by a company in Kyushu in 1964. By the early 1980s, it was being farmed as a "fashionable" food for human consumption. But Japanese consumers didn't like the taste and stocks were often discarded as the commercial value fell. By 2002, wild populations were reported in 27 prefectures of Japan. Ito’s paper, also published in 2003, noted that the snail was now a "serious rice pest" in most of East Asia.

The *Journal of Ethnobiology and Ethnomedicine* reported in 2007 that the golden apple snail was among wild food resources generally collected by women and children in Kalasin province in northeast Thailand. According to the report, they were being collected by hand or with handnets from canals, swamps, ponds and ricefields during the rainy season. Collectors used spades during the dry season when the snails live under dried mud. The snails were being served parboiled, after being removed from their shells, cleaned in salted water, rinse and mixed with roasted rice, dried chili, lime juice and fish sauce.

Further reading

Welcomme, R. and Chavalit Vidthayanom (2003). *The impacts of introductions and stocking of exotic species in the Mekong Basin and policies for their control*. MRC Technical Paper No. 9. Mekong River Commission, Phnom Penh.
each family earning between USD 90 and 180.

During a field trip to Kampong Chhnang province in 2013, staff from the MRC Fisheries Programme and the Cambodian Fisheries Administration found at least seven species of molluscs commonly reported by traders. Six species from three families — Ampullariidae (apple snails), Viviparidae (river snails) and Corbiculidae (basket clams) — are usually on sale in local markets including those in Phnom Penh. Tonnes of these molluscs were being harvested every day, not only for local consumption but also for export. The field trip also found that invasive golden apple snails (*Pomacea* sp.) were widespread in the Tonle Sap Lake (see box on opposite page).

Many research papers and reports have recognised molluscs and other OAAs as important food sources, especially for the poor. However, data and information about species diversity, abundance, yields and values are not available. The current status of mollusc production in Cambodia, particularly from the Tonle Sap, is unknown. The types of fishing gear used to harvest molluscs have not been well documented. Nor have the peak occurrences of different species, their habitats or factors affecting stocks.

**Mollusc market in Kampong Chhnang**

A report by the Cambodian Fisheries Administration in 2013 noted that the volume of production of snails and clams in Kampong Chhnang province were not well recorded and that the fishery was not being managed. At the same time, the transport and distribution of molluscs to other provinces and export markets were not regulated even though daily purchases by a single trader can range between 2 and 5 tonnes a day. The report noted that snails and clams were an important source of protein for local people, especially those who collect the molluscs. Harvests peak in the wet season for large snails and in the dry season for small snails and clams.
Clam scrapers and push baskets

The Inland Fisheries Research and Development Institute of the Cambodian Fisheries Administration (IFReDI) has described in detail three types of fishing gear that target freshwater clams in Cambodia. The descriptions are contained in *Fishing Gears of the Cambodian Mekong*, a book jointly published in 2003 by the then Fisheries Department and the Mekong River Commission Fisheries Programme.

IFReDI describes two types of clam scrapers — a dredge known as *kantrong kao leah* (កន្ត្រងការូស៊ី) and a hand-held variation called *anchormg kao leah* (អញ្ចរការូស៊ី). With the first type, fishermen aboard motorised boats would drag baskets along the sandy or slightly muddy bottoms of water bodies including the Tonle Sap Lake. In Kampong Chhnang province, they were made from long wooden poles attached to iron frames with thin bars about 10 mm apart. These were used to catch clams in the late dry season and early wet season when water levels are generally low. In addition to the dredge operator, the crew typically included a boat handler and cleaners, usually women, to sort the clams (see illustration above).

On the other hand, the hand scraper could be used by individuals but was reported only in rivers in the neighbouring province of Pursat. These comprised bamboo poles attached to semi-circular open baskets made of chicken wire. At the time, these clam scrapers cost between KHR 25,000 and 35,000 (USD 6.25 and 8.75).

The third type of gear was a skimming push basket known locally as *chok leah* (ចូកលៀស). This was a triangular wicker basket with two fixed rods crossing each other. It was being used in lakes and rivers in the late dry season at depths of up to 1.5 metres (see illustration below). Since the push basket collected stones and other sediments, it was generally used by two people — the operator, usually a man, and a second person to separate and clean the catch. Groups of push-basket operators would sometimes pool their catches in one boat and share cleaning personnel, usually women. This type of fishing gear was reported only in the Stung Sen, a major tributary of the Tonle Sap on the other side of the lake from Pursat in Kompong Thom province, and in recession ponds in the floodplains. At the time, these baskets cost about KHR 25,000 (USD 6.25).

**Further reading**

Deap, L., P. Degen and N. van Zalinge (2003). *Fishing Gears of the Cambodian Mekong*. Inland Fisheries Research and Development Institute of Cambodia (IFReDI), Phnom Penh.
For this reason, Cambodia has prioritised this important issue in its national activity plan supported by the MRC Fisheries Programme. Kampong Chhnang province has been chosen for the pilot phase of research. The province is well known for its molluscs and most rural fishing households in Kampong Chhnang are said to be involved in their collection to support their daily livelihoods. Molluscs from this and other provinces around the Tonle Sap are believed to be distributed to Phnom Penh, other Cambodian provinces and export markets abroad. The study will therefore indicate species diversity, habitats and occurrences as well as the yield and value of a fishery that supports both rural dwellers and the national economy through export earnings.

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Mollusc prices in Cambodia
Big snails, small snails and clams in Kampong Chhnang province in 2013

| Type of mollusc | Landing prices 1 | Wholesale prices 2 |
|-----------------|------------------|--------------------|
|                 | Dry season       | Wet season         | Dry season       | Wet season         |
|                 | KHR  USD         | KHR  USD           | KHR  USD         | KHR  USD           |
| Big snails or kchong (ქូស) | 1,500 - 2,000 0.38 - 0.50 | 600 - 800 0.15 - 0.20 | 2,500 - 3,000 0.63 - 0.75 | 1,000 - 1,200 0.25 - 0.30 |
| Small snails or kchao (ខ្ចៅ) | 700 - 900 0.18 - 0.23 | 300 - 500 0.08 - 0.13 | 1,000 - 1,200 0.25 - 0.30 | 700 - 900 0.18 - 0.23 |
| Clams or leah (លៀស) | 300 - 500 0.08 - 0.13 | 150 - 200 0.04 - 0.05 | 500 - 700 0.13 - 0.18 | 200 - 300 0.05 - 0.08 |

1 for traders buying from collectors  2 for traders selling to customers

From left to right, conic or sharp-tail snail (Pila polita), blunt-tail snail (Pila ampullacea), ricefield or pila snail (Pila scutata), crow snail (Filopaludina martensi cambodjensis) and coconut snail (Mekongia swainsoni)

Photo: Ngor Peng Bun
MRC publishes **atlas of deep pools** in Lower Mekong River and tributaries

Deep pools are common features of the Mekong mainstream and its tributaries. More than 450 deep pools have so far been identified, their morphology described and their locations mapped in the recently published MRC Technical Paper No 31, *Atlas of deep pools in the Lower Mekong River and some of its tributaries*. The atlas uses surveys based on local ecological knowledge (LEK) and a geomorphic statistical analysis (GSA) of the Hydrographic Atlas of the Lower Mekong River.

Deep pools occur along the entire length of the lower Mekong River, in both alluvial and bedrock reaches, at a median spacing of 3.7 km, and ranging from 0.6 to 34 km. Three distinct clusters of pools correspond with steeper reaches of the river. The distribution and formation of deep pools are driven by topographical factors, gradient, geology, and hydrological processes. Most deep pools are 15 - 20 m deep and have areas of 10 - 15 ha. The deepest pools are 80 - 90 m deep. The LEK surveys on tributaries and the mainstream showed that pool depth tends to increase with pool area, whereas the GSA showed no significant correlation between depth and area of pools. This difference probably reflects differences in methods and coverage: the LEK surveys predominantly

![Map of Mekong River and tributaries showing deep pools.](image)
considered bedrock reaches, while the GSA included both bedrock and alluvial reaches.

According to the LEK surveys, pools in tributaries are shallower than those in the mainstream. The GSA found that pool depth is most strongly controlled by channel substrate; hence there are clusters of very deep pools wherever the river is bedrock-dominated. The deepest pools are found: i) between Huay Xai and about 20 km upstream of Vientiane; ii) between Mukdahan and Pakse, where the deepest pools are found; and iii) between Stung Treng and Kratie.

'Pool length, area and volume all tend to increase with distance downstream'

The lack of a distinct increasing trend in pool depth with distance downstream on the mainstream is most likely due to the presence of alternating alluvial and bedrock reaches. However, pool length, area and volume all tend to increase with distance downstream, which suggests that discharge (which increases with increasing catchment area) plays a key role in determining overall pool size.

Whilst information concerning their ecological functioning remains sparse, deep pools are believed to be fundamental for sustaining the fisheries of the LMB, providing critical spawning and refuge habitats for nearly 200 species of fish including the Mekong giant catfish *Pangasianodon gigas* and other critically-endangered species. The distribution of deep pools in the basin is thought to have been an important factor determining the evolution of the three geographically distinct migration systems in the Mekong.

Hydro-accoustic and depletion methods have been used to estimate fish abundance and biomass in deep pools in the Mekong mainstream. Whilst the depletion method is more time-consuming than the hydro-accoustic method, it can be applied without specialist knowledge or technology and provides information at the species level. Reported estimates of fish biomass density from hydro-accoustic surveys (15,600 – 328,000 kg ha⁻¹)

Species diversity higher downstream

Fishers exploit deep pools with up to 15 different gear types, but most commonly gillnets, because of their cost, availability and efficiency. In Viet Nam, trawl nets are most commonly used, but cast nets, hook and line and traps are also common.

Fishing intensity in deep pools increases downstream from Lao PDR (less than 0.1 fishers ha⁻¹) to Viet Nam (approximately 0.7 fishers ha⁻¹). This variation may be indicative of differences in population density and livelihood opportunities, since available evidence indicates that fish biomass density does not vary by the same magnitude.

In Cambodia, where median density estimates for a small sample of deep pools are approximately 0.5 fishers ha⁻¹, fishers report increasing fishing effort and declining catch rates.

Catch rates from deep pools exhibit considerable monthly variation, with peak catches in December and April, corresponding to refuge and spawning migrations respectively. Catch rates have been reported to be three to twelve times higher for gillnets set at the bottom of pools compared to the surface, but fishers must balance these higher catch rates with a high probability of gear loss or damage when nets are set at depth. Evidence that larger fish are also caught at the bottom is lacking.

Surveys reveal that 192 species of fish have been caught from deep pools. Species diversity is significantly higher in Cambodia and Viet Nam compared to Lao PDR. This may reflect differences in habitat diversity or accessibility to locations upstream of the Khone Falls. Species diversity is also higher in mainstream pools compared with tributaries. Species assemblages differ significantly among Lao PDR, Cambodia and Viet Nam, and these differences were best explained by variation in pool latitude and depth. In Cambodia, the composition of fish assemblages in mainstream and tributary pools also appears to differ significantly.
Deep pools are two to three times greater than those from depletion surveys (48 – 1,151 kg ha\(^{-1}\)). Factors (e.g. depth, area, etc.) affecting deep pool habitat quality indicated by species diversity, fish biomass density or mean fish weight, remain uncertain.

'The construction of mainstream hydropower dams in the Mekong River is probably the greatest threat to the ecological functioning of deep pools'

The construction of mainstream hydropower dams in the Mekong River is probably the greatest threat to the ecological functioning of deep pools. Dams could deny fish access to deep pools and alter flows and sediment transport. In reservoirs, pools will tend to fill with sediment, whereas downstream of dams alluvial material may be scoured from pools, deepening them. Changes to depth, velocity and turbulence will ultimately affect the quality and quantity of this critical habitat. For example, the proposed Ban Koum and Lat Sua dams would be likely to reduce flow velocities and turbulence, and partially fill those pools in the reach of the mainstream which has the deepest pools (Mukdahan – Pakse). Dams planned at Stung Treng and Sambor are likely to have a similar effect on deep pools that are located upstream in the vicinity of the Lao-Cambodian border. Dam impacts on tributary deep pool habitat and associated fisheries have already been reported in the Sesan River following the construction of the Yali Falls dam in central Viet Nam. Fish seeking refuge in deep pools during the dry season are also threatened by destructive fishing gear, particularly explosives and poisons illegal, bombing and poisoning continue, particularly in remote areas where enforcement is difficult.
Establishing reserves comprising deep pools in river channels has been identified as a potentially effective management measure to sustain fisheries resources in river systems. Deep pools have been designated Fish Conservation Zones (FCZs) reserves or sanctuaries in many parts of the basin. Fishing restrictions vary from a total ban on fishing within the pool to seasonal restrictions or prohibitions of certain gear. Formal and informal rules are often enforced through local institutions able to apply sanctions for noncompliance. Communities often receive external support with enforcement, monitoring and evaluation activities. There appears to be a common perception among fisher communities that FCZs based around deep pools are effective management tools, but quantitative (CPUE-based) assessments of their benefits have been inconclusive.

Since it is believed that fish congregate in deep pools during the dry season, surveys of pools during this period could provide an effective means of monitoring trends in fish stocks in the basin, including their biomass and diversity. Such monitoring could be performed by local villages over short periods of time using short-duration, depletion-type surveys. Mapping the results of such surveys could help to identify the distribution of fish biomass and diversity, which could be used to formulate trans-boundary management plans. Combining this information with other environmental information may also improve understanding of the factors affecting deep pool habitat quality and functioning.

Further reading

Halls, A.S., I. Conlan, W. Wisesjindawat, K. Phouthavongs, S. Viravong, S. Chan & V.A.Vu (2013) Atlas of deep pools in the Lower Mekong River and some of its tributaries. MRC Technical Paper No. 31. Mekong River Commission, Phnom Penh.
Guide developed for larvae and juveniles of common fish species

The Mekong River Basin supports one of the world’s largest inland capture fisheries, a resource that provides food and livelihoods for millions of people. Maintaining the productivity of the system requires a good understanding of fishes’ life cycles, their migratory habits, as well as their dependence on different habitats at different stages in their lives. The newly published MRC Technical Paper No. 38, *A guide to larvae and juveniles of some common fish species from the Mekong River Basin*, provides descriptions and illustrations for larval and juvenile stages of 64 indigenous and one exotic species.

Accurate identification of fish species at all stages from larva to adult is necessary to support the ichthyological studies which provide basic information for management. Several guides have been recently published for the identification of the adult or sub-adult stages of fishes of the Mekong Basin (e.g. Kottelat, 2001; Rainboth, 1996 and Vidthayanon, 2008). By contrast, there is little or no published information to assist in identification of larvae or juveniles, as is the case generally for fishes of inland tropical waters. Existing regional guides to larvae and juveniles (e.g. Leis and Carson-Ewart, 2000) cover mainly marine species, so they are useful only for identifying some of the coastal fishes that penetrate inland waters, or for identifying to family level some freshwater representatives of marine fish families. There are about 850 fish species recorded from the Mekong basin, and about two thirds of these (including most of the common species) are from purely...
freshwater families (Hortle, 2009), so there is a very large gap in the information that can be used to identify larvae and juveniles of Mekong basin fishes.

The Mekong River Commission has actively sponsored basin-wide fisheries research since the mid-1990s, including local ecological knowledge surveys, logbook monitoring of fisher catches, household surveys, catch assessment surveys, sampling of larvae and juveniles and research on aquaculture of indigenous species. The results have been widely publicised and as a result the importance of fisheries in the Mekong basin is now well-recognised. At the same time, many counterpart staff from the fisheries agencies of the Lower Mekong Basin countries have been trained, including in identification of fish larvae and juveniles. MRC Technical Paper No. 38, A Guide to Larvae and Juveniles of Some Common Fish Species from the Mekong River Basin, includes in a systematic form much of the diagnostic information used during the MRC-sponsored studies of larvae and juveniles.

The publication covers 64 species known from the basin, as well as one introduced species. It is intended to be the first in a series of publications on the larvae and juveniles of Mekong basin fishes. The guide is expected to be widely used in the Mekong basin for ichthyological research, which is expected to become increasingly important as the basin becomes more developed. In particular, information is needed to manage the impacts caused by dams that block fish migration pathways and modify rivers.

The study of fish larvae and juveniles is also necessary in development of aquaculture and in many other applied research fields. The Mekong is a regional hotspot for biodiversity, and several of the fish featured in the guide are listed on the IUCN Red List of threatened species; these are the giant barb, Catlocarpio siamensis (listed as critically endangered in 2006 but not currently listed), Jullien’s barb, Probarbus jullieni (endangered) and the golden mystus, Mystus bocourti (vulnerable). Unfortunately, as a result of lack of basic research, the conservation status of most of the species covered in the manual and many more Mekong species cannot be evaluated at present, highlighting the need for manuals of this type to support basic research.

**Fish reproduction and development**

Fish have a wide array of reproductive behaviours, but they can be broadly classed as...
Guarders are so-called because the eggs and/or young are guarded by one or both of the parents. They produce relatively few eggs which are larger than those of non-guarders. In the Mekong system, guarders include featherbacks (Notopteridae), snakeheads (Channidae) and gouramies (Betta spp. and Osphronemus spp.).

Bearer are fish that carry eggs on or in their bodies during development. In the Mekong system bearers include Ariid catfishes, in which the male parent broods the eggs in his mouth until after hatching, and rice-fishes (Oryzias spp.), in which the fertilised eggs are carried internally or externally (between the pelvic fins) by the female before being laid on vegetation at an advanced stage of development.

Each species description in this manual includes notes on the basic breeding ecology of each species, which can be updated from FishBase (www.fishbase.org). When considered with environmental data (on flow rates and habitats), as well as estimates of the likely age of specimens, field workers may be able to draw some conclusions about the likely time and place of spawning of the fishes. For example, pelagic eggs are likely to drift downstream immediately after spawning, whereas benthic adhesive eggs are more likely to remain where they are spawned until they hatch.

Although some inferences may be drawn based on the sampling location and stage of development of the early life stages of fishes, little is known about the distribution of fish larval drift within river channels in this region, so it should not be assumed that larvae drift passively with the current. Rather, as they develop they may move vertically or laterally in the water column, resting at times on the bed or edges. Much research still needs to be pursued in this area.

**Development of fish**

Fish pass through several stages and change greatly in size and appearance as they develop from egg to adult. There are many variations in schemes used to classify the early life stages of fish. The simple scheme referred to in this

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(1) non-guarders, (2) guarders or (3) bearers, as summarised in Moyle and Cech (2004). The majority of Mekong species are non-guarders, i.e. after their eggs are spawned they are not protected by the parents. Within this group, Mekong fishes may be classed as pelagic or benthic (demersal) spawners.

Some of the common lowland river fishes spawn pelagic eggs, which can drift with rising waters. Pelagic eggs are buoyant or semi-buoyant as they contain oil globules and have high water content. Pelagic eggs are very small (about 0.5–1.2 mm diameter when spawned) and typically hatch within 1–2 days. The newly hatched larvae continue to drift with the current as they develop. Most species spawn early in the flood season when the eggs and larvae may drift with the rising waters to colonise floodplains where food is abundant. However, there are risks; pelagic spawned eggs may be eaten by predators while they are drifting or may be dispersed into unfavourable environments.

Many Mekong species, including most catfishes and cyprinids, are benthic spawners, i.e. the eggs are deposited on the substrate or on submerged plants, including on tree trunks or bushes, as well as on snags or rocks, thereby reducing the predation and dispersal risk incurred by pelagic spawners. Demersal eggs are usually adhesive, so they tend to stick to the surface where they are laid. They may be laid in long strings or wrapped around objects, or may drop into crevices in the substrate. Fish eggs absorb water and swell after they are laid, so benthic eggs (after swelling) tend to become wedged into place. However, fine sediment may adhere to eggs to produce aggregates, which are more likely to be become suspended and drift with the current. Benthic eggs tend to be larger (typically 1-3 mm diameter when spawned) than pelagic eggs. After hatching, the larvae may remain benthic and stay near the spawning locale, or they may become pelagic and drift with the current. Many mainstream fish are benthic spawners, and benthic spawning is also common among floodplain spawners and in some tributary fishes that are relatively non-migratory (e.g. Tor spp.).

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**Development of fish**

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manual follows the nomenclature developed by several earlier workers (Hubbs, 1943; Balon, 1975; Russell, 1976 and Kendal et al., 1984). It should be noted that some species do not develop through the stages precisely as described below. For example, longtoms (Xenentodon spp.), half-beaks (Hemiramphus spp.) and rice-fishes (Oryzias spp.) develop for an extended period within the egg, so that when they hatch they are already at a post-larval stage. Note that the term ‘fry’ is widely used to refer to advanced larvae or juveniles.

1. Egg, embryonic phase or incubation period
This phase covers the period from fertilisation to hatching of the egg. During incubation, the embryo cannot feed, but is nourished by the egg yolk and other food stores. The embryo’s cells divide and differentiate to produce body somites (forerunners of muscle blocks), a beating heart and circulatory system and various other organs or their precursors. Hatching involves the breaking of the chorionic membrane or ‘egg shell’, usually by thrashing movements of the embryo’s tail and body, to release the larva.

2. The larval phase
This phase covers the period from hatching up to the time the fish is a juvenile. The larval phase can be divided into three stages.

- Yolk-sac stage: after hatching the larva has a yolk sac, which is visibly attached to the anterio-ventral part of its body. During this phase the fish is nourished by yolk while the main body parts and sensory systems develop; these include the mouth, gut, anus, eyes and primordial fins or anlages.

- Pre-larval stage: this stage begins when the eye is fully pigmented and the mouth and anus are open and the fish begins to feed on external prey. In pre-larvae, the vertebral column terminates in a urostyle, a long unsegmented rod-shaped bone, which represents a number of fused vertebrae. During this stage, the urostyle begins to flex upwards and the caudal fin rays begin to develop.

- Post-larval stage: during this stage, the urostyle completes upward flexion, the caudal, dorsal and anal fins develop, and the small fish begins to resemble a juvenile. This stage ends when the larva has undergone metamorphosis (some species) or when its pelvic fins have developed.

3. Juvenile phase or stage
A juvenile fish is one in which all organs (except the gonads) are functioning. The fish gradually assumes the full adult shape as it grows. Certain parts of the fish may increase in number as the fish grows, for example, the number of scales or gill rakers.

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Illustration: Apichart Termvidchakorn

Illustration: Apichart Termvidchakorn
4. Adult phase
An adult fish is one that has all organs functioning, including mature or maturing gonads.

Terminology
The main features used in describing fish larvae and juveniles are discussed below, with reference to developmental phases as appropriate.

Myomeres
Myomeres are blocks of skeletal muscle. Myomere counts are expressed as those anterior to and posterior to (pre- and post-) the anus. Myomere counts in older specimens are often equivalent to vertebral counts.

Gut
All fish have a rudimentary straight gut (alimentary canal) as pre-larvae, when most fish feed on easily digestible microscopic zooplankton. The gut folds or coils as the digestive tract develops and as the diet changes, with the timing and shape differing between species. The anus tends to move closer to the head as a fish develops and its position is a useful diagnostic feature.

Gas bladder
By the pre-larval stage, most species develop a visible gas bladder, whose shape, size and position may be useful characteristics for identification. The larvae of Clupeiformes and Gobiidae always have visible swim-bladders. As a fish develops it becomes more opaque, so that as a juvenile or adult its gas bladder is usually not visible. A few fishes (e.g. glass perchlets Ambassis spp.) are transparent as adults, but once fixed in formalaldehyde internal features are not visible.

Head spination
Some fish larvae have on their head and operculum spines which are important as armour against predators. Spination is useful diagnostically for most marine fishes that have pelagic larvae. Spines are present on the pre-larvae of all Perciformes (perch-like fishes). In this manual, spines are important diagnostically for Lobotidae (head spines) and for Cobitidae (spines below the eye).

Eyes
All of the fish larvae in the guide have round eyes except for some Clupeoid larvae which have oval eyes. Most early pre-larvae (i.e. immediately post-hatching) have no pigment in their eyes; the pigment appears later, typically after one day. In some families, (Belonidae and Adrianichthyidae) development is to an advanced stage in the egg, so that when the fish hatches it is a post-larva in which the eyes are already developed and densely pigmented.

Fin formation
The size and position of fins and the number of spines and rays are diagnostically important. The median fins (dorsal, caudal and anal) begin to form from a finfold which is present in the pre-larva; dorsal and anal fins first begin to differentiate as anlages, which are the bud-shaped initial clustering of embryonic cells from which a body part or an organ develops. The paired fins (pectoral and pelvic) develop later than the median fins. The pectoral fins become visible in pre-larvae and begin to develop their spines and rays at the late post-larval stage. Pelvic fins usually develop last. Where fin spines are present they develop before fin rays.

Meristics
Meristics refers to counts of features and the most important are shown for each fish as follows:

- DFC - Dorsal fin ray count
- AFC - Anal fin ray count
- P1FC - Pectoral fin ray count
- P2FC - Pelvic fin ray count

Note: for each fin, the number of spines is denoted by Roman numerals and the number of rays by normal numbers. For example, a fin with one spine and six rays is denoted as I, 6.

MC - Myomere count

Morphometrics
Morphometrics refers to measurements that relate to the shape of the fish, which changes as it grows. Body lengths are expressed in this guide in mm (millimetres) as total length or as standard length.
The approximate total length is noted next to each developmental stage, together with its typical age in days. Standard length is used for morphometric tables because total length cannot be accurately measured if fins are damaged. Important measurements are as follows:

Sn-DF - Snout to dorsal fin origin
Sn-AF - Snout to anal fin origin
Sn-P2F - Snout to pelvic fin origin

Pigmentation
The extent, position and shape of pigmentation are important diagnostically. Many fish have internal pigments as post-larvae, with external pigmentation developing later. Colours are lost during fixation so only melanophores (pigment-producing cells) and black pigmentation (melanin) are shown on the drawings.

Further reading
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Illustrations: Walter Rainboth
Integrated analysis of data from MRC fisheries monitoring programmes

The Mekong River Commission began monitoring inland fisheries in the region two decades ago. It recently completed the first integrated analysis of four major monitoring programmes.

Monitoring the status and trends of fisheries resources in the Lower Mekong Basin (LMB) is required to provide a baseline from which to monitor any impacts of fisheries management and basin development activities including dam construction.

Four major monitoring programmes have been supported by the Mekong River Commission to help monitor the status and trends in the fisheries in the basin:

1. The Dai Fishery Monitoring Programme, Tonle Sap, Cambodia (1994–2010);
2. The Lee Trap Monitoring Programme at the Khone Falls, southern Lao PDR (1994–2010);
3. The Fish Abundance and Diversity Monitoring Programme at up to 40 sites across the LMB (2003–2010); and
4. The Fish Larvae Density Monitoring Programme, Cambodia and Viet Nam (1999–2010).

'Only a limited amount of work has been done to construct time series of the data collected that are much needed to interpret long-term trends in fish resources and for providing baselines for impact monitoring purposes.'

Analyses of much of the data generated by these programmes had been undertaken, some of which had been published. However, only a limited amount of work has been done to construct time series of the data collected that are much needed to interpret long-term trends in fish resources and for providing baselines for impact monitoring purposes.

The integrated analysis presents time series of indices of fish diversity, fish (and their larvae) abundance, biomass and size for the multispecies assemblage and for important species estimated from data collected at more than 50 locations in the LMB by these four monitoring programmes. Intra-annual variation and long-term trends in these indices were examined.

Correlations and functional dependencies in
the indices through space and time were also examined and tested in an attempt to elucidate the extent of fish migrations and identify spawning locations in the basin, and to improve understanding of the life-cycles and dynamics of fish stocks in the basin.

'The assertion that the diversity and biomass of the multispecies assemblage have declined significantly in the basin ... remains contentious'

Significant long-term (1997–2010) trends in the indices were not detected for the multispecies assemblage that seasonally utilises the Tonle Sap-Great Lake Tonle Sap system, nor were changes in its species composition that might be attributable to increasing fishing pressure in response to a growing population. Even populations of some species that are included on the IUCN Red List of endangered species and caught in the Tonle Sap system have shown no apparent decline in relative biomass.

Similarly, no significant trend in the biomass of fish migrating upstream at the Khone Falls in southern Lao PDR was detected between 1997 and 2009. Furthermore, no consistent trends in the indices of relative abundance, biomass or species richness were observed among 10 fisher catch monitoring locations that have been monitored between 2003 and 2010.

However, relative fish biomass at many monitoring locations in the basin and reproductive success appears to have been relatively low since 2005–06 compared to earlier years. Significant declines in the relative biomass index for several species were also apparent at some locations, notably at Pres Bang on the Sekong River.
The assertion that the diversity and biomass of the multispecies assemblage have declined significantly in the basin therefore remains contentious. Much will hinge on whether recent estimates of relative fish biomass in the system will recover to previous levels.

Most of the species selected for detailed assessment exhibit life cycles and migrations that are largely consistent with the general life cycle model described by previous workers. Migrations of several selected cyprinid and pangasiid catfish species appear to extend long distances upstream, at least as far as the uppermost monitoring site at Luang Prabang. However, the migrations of other cyprinids and pangasiid and bagrid catfish species appeared to be much more limited.

Fish migrations from the Tonle Sap system appear to be strongly linked to the lunar cycle as well as the amount of water remaining on the floodplain. A lunar response of fish migrations was not detected further upstream at the lee trap fishery in southern Lao PDR. Instead water level appears to be an important factor affecting the migrations of non-pangasiid species. The pangasiid catfish species analysed for data monitoring appeared to be caught in larger quantities at lower flows.

'Stung Treng province, Cambodia and the three tributaries in the Sesan basin are relatively important spawning locations for small cyprinids'

Statistical attempts to identify spawning locations in the LMB were largely unsuccessful but the
results of less formal analyses suggest that among others, Stung Treng province, Cambodia and the three tributaries in the Sesan basin are relatively important spawning locations for small cyprinids. The Srepok River also appears to provide important habitats for medium and large species of cyprinid and the Sesan and Sekong rivers also appeared to provide important habitats for pangasiid catfish. These locations are consistent with results of analyses of age distributions of larvae sampled at Phnom Penh. Thus, greater consideration might be given to conserving tributary habitat during basin development planning in the future but more research is also needed to fully understand the role of tributaries in the LMB in the lifecycles of important species.

The abundance and biomass of the multispecies assemblage that seasonally utilises the Tonle Sap system responds significantly to the transport of larvae from upstream spawning locations and the extent and duration of flooding indicated by the flood index (FI). It appears that record catch rates recorded for the dai fishery in 2004–05 and 2005–06, and apparent elsewhere in the basin in 2005 were in response to very high rates of recruitment during 2004 and 2005, rather than growth effects. These high levels of recruitment could not be linked to management efforts to conserve or rebuild spawning stock biomass by confiscating illegal gear in the Tonle Sap system. Rather, it appears that a combination of spawning success, larvae survival and rates of transport were important.

Water levels rose rapidly in 2005, second only to the rates observed in 2002. This may have stimulated upstream spawning migrations and benefited larvae survival and transport. However, reasons for the very high rates of recruitment estimated for *Henicorhynchus* species in 2004 remain perplexing. A closer examination of hydrological and water quality parameters across the geographic range of these species and particularly during the spawning season at likely spawning locations, including the Sesan basin, appears warranted.

Many of the analyses described in the document were hampered by the low precision of index estimates. Therefore, consideration might be given to reviewing the size of samples taken by each monitoring programme to detect acceptable minimum detectable differences in index estimates. Other recommendations to improve the four monitoring programmes and their databases are described.

**Further reading**

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Sturgeon cage culture guidelines for lakes and reservoirs in Viet Nam

By Nguyen Hai Son and Nguyen Quang Thai *

As part of Vietnamese government efforts to promote fish farming in highland areas, the Research Institute for Aquaculture No 1 in northern Viet Nam has developed methods and guidelines for raising sturgeon in cages.

Cage culture can be simply defined as an aquaculture production system where fish are held in floating cages. This form of activity on lakes and reservoirs is considered one of the most important trends in many countries seeking to take full advantage of water surfaces to improve aquaculture activities. Cage culture also has several advantages over other methods of culture because it uses existing water bodies and simple technology while requiring comparatively low capital investment.

Sturgeons are a group of high-value species on the world market, and are particularly renowned for their eggs. In Viet Nam, sturgeons were introduced to the Northern Mountains in 2005 in an effort to use availability of cold-water resources, especially in lakes and reservoirs (see Catch and Culture, Vol 19, No 1). Sturgeon is now widely cultured in Viet Nam and the country is today among the world's top 10 producers with the Central Highlands in the Lower Mekong Basin emerging as the main production area.
The farming of sturgeon in Viet Nam is diverse, ranging from tank and pond culture to cage culture. Sturgeon farmed in Viet Nam grow 1.5 to 2.0 times faster than in temperate countries. They also have lower feed conversion ratios and labour costs. Yields over the past five years have improved significantly from an initial 7-10 kg/m³ to 20-30 kg/m³ and even 50 kg/m³.

‘Results are considered effective for sustaining the environment and developing aquaculture in Viet Nam as well as other Asian countries’

Over the past three years, the Research Institute for Aquaculture No 1 (RIA1) in Tu Son district in Bac Ninh province near Hanoi has developed methods and guidelines for sturgeon cage culture in lakes and reservoirs. The results are considered effective for sustaining the environment and developing aquaculture in Viet Nam as well as other Asian countries. The aim of this article is to share with readers these basic methods and guidelines.

**Selecting the species, designing the cage**
Research has indicated that the most appropriate sturgeon species for cage culture are Siberian sturgeon (*Acipenser baerii*), beluga sturgeon (*Huso Huso*), Russian sturgeon (*Acipenser gueldenstaedtii*) and sterlet sturgeon (*Acipenser ruthenus*). The most common cage culture species in Viet Nam is Siberian sturgeon.

Both floating and standing surface cages can be used for sturgeon culture. However, floating cages are considered more suitable. Flotation frames can be made with plastic tanks, polyvinyl chloride (PVC) piping or high-density polyethylene (HDPE)...
Highland aquaculture

In lakes and reservoirs, plastic tanks and HDPE have been recommended.

Nutting should come from lightweight and inexpensive materials such as plastic or nylon nets. Mesh sizes for sturgeon cage culture should be 2 cm, although 3 cm is preferred for grow-out systems. These mesh sizes seem to provide adequate open space for good water circulation through the cage to renew oxygen and remove waste.

Mesh size has to be small enough to prevent fish escaping from the cage. A 1 cm mesh will retain 10 gram sturgeon fingerlings while a 3 cm mesh requires fingerlings weighing at least 30 grams. Larger mesh sizes will allow wild fish to enter the cage and compete with sturgeon for feed.

'As cage size increases beyond 170 cubic meters, costs per unit volume decrease' For high stocking densities, cage sizes between 120 and 170 cubic meters are recommended. As cage size increases beyond 170 cubic meters, costs per unit volume decrease. But production per unit volume also falls due to the reduced rate of water exchange which requires lower stocking density.

In terms of cage shape, a square or circular cage is more suitable than other shapes since water exchange is greater than for other cages with the same volume and mesh size.

Cages should be covered to prevent fish losses and reduce noise that may induce stress, resulting in lower fish production. However, covers are often not applied to large cages if the netting is 40 to 50 cm above the water surface (see above right).

Feeding trays are usually used in cages to minimise feed. These square or cylindrical trays can be made of metal covered with netting (mesh size 0.5 cm). The trays are suspended underwater at a depth of 80-100 cm or more. They should cover only a portion of the cage.

Selecting the site
Any lake or reservoir with year-round water temperatures ranging from 14-26°C is suitable for sturgeon cage culture. Cages should be placed where water currents are greatest. They should also be exposed to the wind, with calm areas avoided. However, more frequent water exchanges may cause physical stress from turbulence. Water current rates from 2 to 8 m/min are acceptable and 5 m/min is excellent. Cages may be sited individually or linked in groups. At least 50 cm should separate each cage to optimise water quality. The cage floor should be at least 2-3 m above the bottom of the lake or reservoir. Greater depths will promote rapid growth and reduce disease.
Managing production

The growth rate of sturgeon depends on water parameters such as dissolved oxygen (DO), pH and, most importantly, temperature. The preferred water temperature range for optimum growth is 16-22°C. Growth reduces significantly at temperatures of more than 24°C and death may occur at more than 27°C. The minimum DO concentration should be at least 3.0 mg/l.

The optimum fingerling size for stocking in grow-out cages depends on the culture period and market demand for size. The shorter the culture period, the larger the fingerlings must be at stocking. Fingerlings of 30 to 40 grams are generally used to produce fish of 1.5 kg or more in cages after one year. If the culture period is longer, it may be possible to rear smaller fingerlings of 20 to 30 grams.

The recommended stocking rate of sturgeon fingerlings depends on the volume of the cage, harvest size, production level and length of culture. The size of a cage therefore determines the stocking density and carrying capacity. Sturgeon production in cages of 72 m³ to 128 m³ is typically 20-25 kg/m³. With higher stocking, production per cubic meter in larger cages is significantly lower (15 kg/m³ or less). Basically, stocking fingerlings can be calculated by this formula:

\[
\text{Stocking density (ind/m}^3) = \frac{\text{Target yield (kg/m}^3)}{\text{Size of harvest (kg/ind)}}
\]

High stocking rates can be used in small cages of 72 to 128 cubic meters. Optimum stocking rates per cubic meter range from 18-20 individuals to produce fish averaging 1.5 kg after one year or 10-15 individuals to produce fish averaging 1.7 kg. Since water exchange is less frequent in large cages, the stocking rate must be reduced accordingly. A staggered production system could be used to facilitate marketing by ensuring regular harvests. The exact strategy will depend on the number of cages available and the total production potential of the body of water.

Generally, total production in cages increases in line with the stocking rate. However, there is a density at which sturgeon become too crowded and water quality within the cage deteriorates, causing a decline in growth rates. In small cages of 72 cubic meters, a reduction in growth usually begins at production levels of around 40 kg per cubic meter. In 100 cubic meter cages, production should be limited to 15 kg per cubic meter. The number of cages that can be deployed in a lake or reservoir — and therefore total fish production — is primarily a function of the maximum allowable feeding rate for all cages in that body of water. The total feed input is related to the number and size of fish in the cages and is limited by the surface area of the lake or reservoir.

Among species other than the Siberian sturgeon, beluga sturgeon has the fastest growth rate, reaching 1.9 to 3.2 kg after one year, 4.7 to 6.9 kg after two years and 7.0 to 10.2 kg after three years. However, this species takes as long as 10 to 15 years to reach sexual maturity. One of the other species, Russian sturgeon, reaches 1.2 to 2.2 kg after one year, 2.4 to 3.8 kg after two years and 4.0 to 6.5 kg after three years.

Photos: Nguyen Quang Thai

Suitable size of fingerlings for cage culture
Providing good quality feed

After stocking, the most important aspect of sturgeon cage culture is providing good quality feed in correct amounts. The diet should be nutritionally complete, containing vitamins and minerals. Protein content should be 45% to 50% for 25 to 50 gram sturgeon and 40% to 45% for larger fish. Since sturgeons are cold-water fishes that require more fat in their diet than tropical species, the fat content of feed should be 8% for small fish and 5% for larger fish.

'Fish should be fed at least once a day, although feeding twice every day is better'

Floating feeds are not recommended for sturgeon cage culture. Sinking pellets that dissolve quickly are not good. Fish should be fed at least once a day, although feeding twice every day is better since sturgeon cannot consume their daily feed requirement for maximum growth in a single meal of short duration. Fish of less than 25 grams should be fed at least three times a day.

The correct amount of feed must be weighed daily. Feeding-rate tables are required to make periodic increments in the daily ration. Fish should be sampled every four weeks to determine their average weight and correct feeding rate for calculating adjustments in the daily ration.

Adjustments can be made by estimating fish growth based on an assumed feed conversion ratio (feed weight divided by weight gain). For example, with an FCR of 1.3, the fish would gain 10 grams for every 13 grams of feed. The correct feeding rate, expressed as percent of body weight, is multiplied by the estimated weight to determine the daily ration.

Feeding-rate tables serve as guides for estimating the optimum daily ration. But they are not always accurate under conditions such as fluctuating temperatures or dissolved oxygen. Demand feeders that let fish feed themselves can be used to eliminate the work (feed weighing, fish sampling, calculations) and uncertainty of feeding-rate schedules.

With high-quality feeds, good growing conditions and effective feeding practices, feed conversion ratios as low as 1.3 with a growth rate of 7.46 g/
day have been obtained. Generally, however, feed conversion ratios will range from 1.4 to 1.5.

**Sampling, harvesting and keeping records**
During sampling or harvesting, part of the net cage is lifted out of the water and fish are caught with a hand net. Fish may then be counted, weighed and returned to the cage for further growth if the size is small.

A sturgeon cage farm should be managed efficiently to maintain and increase productivity and profitability. Farm records should contain details of cage preparation, fingerlings and stocking, feed management, water quality parameters, fish health and harvest. Farmers should also keep all input and output data so production costs, sales, and net income can be easily calculated to evaluate the overall economic performance.

Records of cage environment and fish health should be kept to minimise any problems as early as possible in the production cycle. Record keeping also helps farmers learn from past mistakes, thus reducing the risk and costs of production in subsequent crops.

"Mr Son, an officer at the Mekong River Commission Fisheries Programme, and Mr Thai, a researcher at Research Institute for Aquaculture No 1, developed the methods and guidelines for raising sturgeon in cages in Viet Nam"
Fishes of the Upper Mekong drainage in Yunnan province in China

A recent update of fishes in the Mekong Basin showed that the Upper Mekong in Yunnan province in China accounted for about 12 percent of the country’s freshwater fish species (see Catch and Culture, Vol 19, No 3). The research by Professor Chen Xiao-Yong, of the State Key Laboratory of Genetic Resources and Evolution of the Kunming Institute of Zoology, indicates that almost half of the species are endemic to the Mekong, the highest rate among the six major drainages in the province.

'Almost half of the species are endemic to the Mekong'

Overall, there were 43 families and 629 valid fish species recorded in Yunnan of which 594 were native species, 35 alien species, 255 species endemic to the province and 152 species occurring only in Yunnan in China. These account for almost 40 percent of the freshwater fishes recorded in China.

Among the six major drainages, the Upper Mekong River — including tributaries such as the Nanla River and the Luosuo River as well as Erhai Lake — had the highest number of species after the Pearl River. The following list of fishes from the Upper Mekong, known as the Lancang River (Lancangjiang) in Chinese, is based on Professor Chen's checklist of 183 fishes of the province, published in August last year by Zoological Research, a bimonthly publication produced by the Kunming Institute of Zoology, the Chinese Academy of Sciences and the China Zoological Society. Professor Chen revised the list earlier this year to include another three species. About half the species are also found in the Lower Mekong Basin.

Further reading
Chen, X. Y. (2013) Checklist of Fishes of Yunnan, Zoological Research, 34 (4): 281-243

| Scientific name | Chinese | English | Distribution |
|-----------------|---------|---------|--------------|
| Family Dasyatidae – Stingrays (魟科) | | | |
| Dasyatis laosensis | 老挝魟 | Mekong stingray | Lower Lancang River – Yes |
| Family Anguillidae – Freshwater eels (鳗鲡科) | | | |
| Anguilla bicolor | 二色鳗 | Indian short fin eel | Lower Lancang River – |
| Family Gyrinocheilidae – Algae eaters (双孔鱼科) | | | |
| Gyrinocheilus aymonieri | 双孔鱼 | Siamese algae eater | Lower Lancang River – Yes |
| Family Botiidae – Botiid Loaches (沙鳅科) | | | |
| Sinibotia longiventralis | 疣腹华沙鳅 | — | Lancang River – Yes |
| Syncrossus beauforti | 斑鳍连穗沙鳅 | Chameleon loach | Lower Lancang River – Yes |
| Ambastaia nigrolineata | 黑线安巴沙鳅 | — | Lancang River – Yes |
| Family Cobitidae – Loaches (鳅科) | | | |
| Acantopsis dialuzona | 马头鳅 | — | Lower Lancang River – |
| Lepidocethalichthys berdmorei | 伯氏拟鳅头鳅 | Burmese loach | Nanla River – Yes |
| Lepidocethalichthys hasselti | 赫氏拟鳅头鳅 | — | Lancang River – Yes |
| Acanthopoides gracilis | 拟长鳅 | — | Lower Lancang River – |
| Misgurnus anguillicaudatus | 泥鳅 | Pond loach | Erhai Lake – |
| Paramisgurnus dabryanus | 大鳞副泥鳅 | — | Wayao River – |
| Family Balitoridae – River Loaches (爬鳅科) | | | |
| Vanmanenia semilunata | 湄公河原缨口鳅 | — | Nanla River – Yes |
| Vanmanenia sp. | 湄公河待定种 | — | Lancang River – |
| Balitora lancangjiangensis | 湄沧江爬鳅 | — | Middle-Lower Lancang River – Yes |
| Hemimyzon elongatus | 长体间吸鳅 | — | Lancang River – |
| Hemimyzon pengi | 彭氏间吸鳅 | — | Lancang River – Yes |
| Hemimyzon tchangi | 张氏间吸鳅 | — | Lancang River – |
| Balitoropsis vulgaris | 原爬鳅 | — | Lancang River – |
| Balitoropsis yunnanensis | 云南原爬鳅 | — | Lancang River – Yes |
| Family Nemacheilidae – Stream Loaches (条鳅科) | | | |
| Yunnanilus pleurotaenia | 侧纹云南鳅 | — | Erhai Lake – |

Scientific name Chinese English Distribution
Family Dasyatidae – Stingrays（魟科）
Dasyatis laosensis 老挝魟 Mekong stingray Lower Lancang River Yes
Family Anguillidae – Freshwater eels（鳗鲡科）
Anguilla bicolor 二色鳗 Indian short fin eel Lower Lancang River —
Family Gyrinocheilidae – Algae eaters（双孔鱼科）
Gyrinocheilus aymonieri 双孔鱼 Siamese algae eater Lower Lancang River Yes
Family Botiidae – Botiid Loaches（沙鳅科）
Sinibotia longiventralis 疣腹华沙鳅 — Lancang River Yes
Syncrossus beauforti 斑鳍连穗沙鳅 Chameleon loach Lower Lancang River Yes
Ambastaia nigrolineata 黑线安巴沙鳅 — Lancang River Yes
Family Cobitidae – Loaches（鳅科）
Acantopsis dialuzona 马头鳅 — Lower Lancang River —
Lepidocethalichthys berdmorei 伯氏拟鳅头鳅 Burmese loach Nanla River Yes
Lepidocethalichthys hasselti 赫氏拟鳅头鳅 — Lancang River Yes
Acanthopoides gracilis 拟长鳅 — Lower Lancang River —
Misgurnus anguillicaudatus 泥鳅 Pond loach Erhai Lake —
Paramisgurnus dabryanus 大鳞副泥鳅 — Wayao River —
Family Balitoridae – River Loaches（爬鳅科）
Vanmanenia semilunata 湄公河原缨口鳅 — Nanla River Yes
Vanmanenia sp. 湄公河待定种 — Lancang River —
Balitora lancangjiangensis 湄沧江爬鳅 — Middle-Lower Lancang River Yes
Hemimyzon elongatus 长体间吸鳅 — Lancang River —
Hemimyzon pengi 彭氏间吸鳅 — Lancang River Yes
Hemimyzon tchangi 张氏间吸鳅 — Lancang River —
Balitoropsis vulgaris 原爬鳅 — Lancang River —
Balitoropsis yunnanensis 云南原爬鳅 — Lancang River Yes
Family Nemacheilidae – Stream Loaches（条鳅科）
Yunnanilus pleurotaenia 侧纹云南鳅 — Erhai Lake —
| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Homatula acuticepsphala               | 尖头荷马条鳅                    | —                               | Upper Mekong in Yunnan    |
| Homatula anguiloides                 | 锯嘴荷马条鳅                    | —                               | Lancang River             |
| Homatula erhaiensis                  | 洱海荷马条鳅                    | —                               | Erhai Lake                |
| Homatula pycnolepis                  | 多鳞荷马条鳅                    | —                               | Lancang River             |
| Homatula wulliangensis               | 无量荷马条鳅                    | —                               | Lancang River             |
| Pteronemacheilus meridionalis        | 南方翅条鳅                      | —                               | Luosuo River              |
| Physoschistura raoi                  | 拉奥游鳔条鳅                     | —                               | Lower Lancang River       |
| Physoschistura shuangjiangensis      | 双江游鳔条鳅                     | —                               | Shuangjiang               |
| Schistura amplizona                 | 宽纹南鳅                         | —                               | Nanla River               |
| Schistura bannaensis                 | 皈依南鳅                         | —                               | Nanla River               |
| Schistura breviceps                  | 喙头南鳅                         | —                               | Lower Lancang River       |
| Schistura bucculenta                 | 鼓颊南鳅                         | —                               | Lower Lancang River       |
| Schistura cryptoangiastica           | 隐斑南鳅                         | —                               | Lower Lancang River       |
| Schistura fasciolata                 | 横纹南鳅                         | —                               | Lancang River             |
| Schistura kentungensis               | 温南南鳅                         | —                               | Lancang River             |
| Schistura latifasciata               | 宽纹南鳅                         | —                               | Middle-Lower Lancang River|
| Schistura macrocephalus              | 大头南鳅                         | —                               | Nanla River               |
| Schistura pertica                    | 横纹南鳅                         | —                               | Lower Lancang River Nam Ou|
| Schistura pociuli                    | 留帝南鳅                         | —                               | Lancang River             |
| Schistura porthos                    | 无端南鳅                         | —                               | Lower Lancang River       |
| Schistura schultzi                   | 多鳞南鳅                         | —                               | Lower Lancang River       |
| Schistura sexnubes                   | 六斑南鳅                         | —                               | Lancang River             |
| Schistura watoni                     | 民族南鳅                         | —                               | Lancang River             |
| Sectoria heterognathos              | 异颌棱唇条鳅                     | —                               | Nanla River               |
| Triplophysa brevicauda               | 湿尾高原鳅                       | —                               | Lower Lancang River       |
| Triplophysa jianchuanensis           | 锦川高原鳅                       | —                               | Jianchuan stone loach     |
| Triplophysa stenurus                 | 细纹高源鳅                       | —                               | Lancang River             |

**Family Cyprinidae – Minnows or Carps**

**Sub-Family Danioninae**

| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Rasbora atridorsalis                 | 黑背波鱼                        | —                               | Lower Lancang River       |
| Rasbora dusonensis                   | 黄尾波鱼                        | —                               | Lower Lancang River       |
| Rasbora septentrionalis              | 北方波鱼                        | —                               | Lower Lancang River       |
| Danio apopyris                       | 小鱼丹                          | —                               | Nanla River               |
| Danio chrysotaeniatus                | 金线鱼丹                         | —                               | Lower Lancang River       |
| Gymnodanio strigatus                 | 条纹裸鱼丹                       | —                               | Lancang River             |
| Raia mas guttatus                    | 长嘴鳗                           | —                               | Burmese trout             |
| Barilius caudiocellatus              | 环尾低线鱲                       | —                               | Lancang River             |
| Barilius koratensis                 | 泰国低线鱲                       | —                               | Lower Lancang River       |
| Barilius pulchellus                  | 丽色低线鱲                       | —                               | Lancang River             |
| Opsarichthys bidens                  | 马口鱼                           | —                               | Lancang River             |

**Sub-Family Acheilognathinae (鳅科)**

| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Rhodeus ocellatus                    | 高体鳑鲏                         | Rosy bitterling                  | Lancang River             |
| Acheilognathus barbatulus            | 红须鱠                           | —                               | Lancang River             |

**Sub-Family Cultrinae (鲌亚科)**

| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Paralaubuca barroni                  | 罗甸鳢                           | —                               | Lower Lancang River       |
| Metzia lineata                       | 单纹梅氏鱲                       | —                               | Lancang River             |
| Hemiculterella macrolepis            | 大鳞鳅                           | —                               | Lower Lancang River       |
| Macrochinchthys macrochirius         | 大鳞鳅                           | —                               | Lower Lancang River       |
| Megalobrama ambycephala              | 团头鲂                           | —                               | Wuchang bream Erhai Lake  |

**Sub-Family Gobiobotinae (鳅鮀亚科)**

| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Gobiobotia yuanjiangensis            | 无江鳅                           | —                               | Lancang River             |

**Sub-Family Leuciscinae (雅罗鱼亚科)**

| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Hemibarbus maculatus                 | 花鱼骨                           | Spotted steed                    | Lancang River             |
| Hemibarbus medius                    | 同鱼骨                           | —                               | Lancang River             |
| Pseudorasbora parva                  | 麦德鱼                           | Stone moroko                     | Lancang River             |
| Abbotina rivularis                   | 梅花鱼                           | Chinese false gudgeon            | Lancang River             |

**Sub-Family Gobiobotinae (鳅鮀亚科)**

| Scientific name                      | Chinese                        | English                          | Distribution              |
|--------------------------------------|--------------------------------|----------------------------------|---------------------------|
| Tor laterivittatus                   | 小带结鱼                         | —                               | Middle-Lower Lancang River|
| Tor polylepis                        | 多鳞结鱼                         | —                               | Lower Lancang River       |
### Fish biodiversity

| Scientific name | Chinese | English | Distribution |
|-----------------|---------|---------|--------------|
| Tor sinensis    | 中国结鱼 | —       | Middle-Lower Lancang River — Yes |
| Tor tambra      | 野结鱼 | —       | Lower Lancang River — Yes |
| Tor tambroides  | 似野结鱼 | Thai mahseer | Lower Lancang River — Yes |
| Folifer brevifilis | 脚结鱼 | —       | Lower Lancang River — Yes |
| Hampsala macrolepidota  | 裂峡鲃 | Hampala barb | Lower Lancang River — Yes |
| Puntius semisiscatilus  | 条纹小鲃 | Chinese barb | Lower Lancang River — Yes |
| Onychostoma fusiforme  | 阔嘴白甲鱼 | —       | Lower Lancang River — Yes |
| Onychostoma gerlachi  | 南方白甲鱼 | —       | Lower Lancang River — Yes |
| Scaphidiichthys acanthopterus  | 少鳞舟齿鱼 | —       | Lower Lancang River — Yes |
| Discherodontus parvus  | 小盘齿鲃 | —       | Lower Lancang River — Yes |
| Cyclocheilichthys repasson  | 短须圆唇鱼 | —       | Lower Lancang River — Yes |
| Cosmochilus cardinalis  | 红鳍方口鲃 | —       | Lower Lancang River — Yes |
| Cosmochilus nanlaensis  | 南腊方口鲃 | —       | Lower Lancang River — Yes |
| Puntioplites falcifer  | 镰鲃鲤 | —       | Lower Lancang River — Yes |
| Puntioplites waandersi  | 爪哇鲃鲤 | —       | Lower Lancang River — Yes |
| Poropuntius carinatus  | 棱吻孔鲃 | —       | Lower Lancang River — Yes |
| Poropuntius coggini  | 颊吻孔鲃 | —       | Lower Lancang River — Yes |
| Poropuntius exiguus  | 油吻孔鲃 | —       | Lower Lancang River — Yes |
| Poropuntius kremphi  | 河吻孔鲃 | —       | Lower Lancang River — Yes |
| Barbomyx giononotus  | 犬吻光背鱼 | Silver barb | Lower Lancang River — Yes |
| Sikuka flavicaudata  | 黄尾短吻鱼 | —       | Lower Lancang River — Yes |
| Sikuka gudgeri  | 相吻鱼 | —       | Lower Lancang River — Yes |
| Sikuka longibarbata  | 长须短吻鱼 | —       | Lower Lancang River — Yes |
| Mystacoleucus lepturus  | 细尾长臀鲃 | —       | Lower Lancang River — Yes |
| Mystacoleucus marginatus  | 长臀鲃 | —       | Lower Lancang River — Yes |
| Hypsibarbus vernayi  | 大鳞高须鱼 | —       | Lower Lancang River — Yes |
| Lucioctinus striolatus  | 细纹似鳡 | —       | Lower Lancang River — Yes |
| Percocypris retrodorsis  | 后背鲈鲤 | —       | Lower Lancang River — Yes |
| Sub-Family Laboconinae (野鲮亚科) | —       | —       | — |
| Bangana brevirostris  | 短吻孟加拉鲮 | —       | Lower Lancang River — Yes |
| Bangana lippa  | 脂孟加拉鲮 | —       | Lower Lancang River — Yes |
| Bangana yunnanensis  | 云南孟加拉鲮 | —       | Lower Lancang River — Yes |
| Bangana zhui  | 朱氏孟加拉鲮 | —       | Lower Lancang River — Yes |
| Labeo pierrei  | 皮氏野鲮 | —       | Lower Lancang River — Yes |
| Crosscoelichthys reticulatus  | 舌唇鱼 | —       | Lower Lancang River — Yes |
| Henicorhynchus lineatus  | 单吻鱼 | —       | Lower Lancang River — Yes |
| Lobocheilus melanotaenia  | 云南孟加拉鲮 | —       | Lower Lancang River — Yes |
| Labiobarbus leptocheila  | 长背鲃 | —       | Lower Lancang River — Yes |
| Cirrhus molitoria  | 鳜 | Mud carp | Lower Lancang River — Yes |
| Garra fasciacauda  | 斑纹ʞ头鱼 | —       | Lower Lancang River — Yes |
| Garra cambodiensis  | 斑纹𝗕_caption | —       | Lower Lancang River — Yes |
| Garra imberbi  | 缺须吻鱼 | —       | Lower Lancang River — Yes |
| Garra mirofronits  | 奇额吻鱼 | —       | Lower Lancang River — Yes |
| Mekongina lancangensis  | 澜沧湄公鱼 | —       | Lower Lancang River — Yes |
| Schizothorax dolichonema  | 长丝裂腹鱼 | —       | Lower Lancang River — Yes |
| Schizothorax lantsangensis  | 澜沧裂腹鱼 | —       | Lower Lancang River — Yes |
| Schizothorax lissolobiaitis  | 舌吻裂腹鱼 | —       | Lower Lancang River — Yes |
| Schizothorax nudiventris  | 裸腹裂腹鱼 | —       | Lower Lancang River — Yes |
| Schizothorax taliensis  | 大理裂腹鱼 | —       | Lower Lancang River — Yes |
| Schizothorax yunnanensis yunnanensis  | 云南裂腹鱼 | —       | Lower Lancang River — Yes |
| Ptychobarbus kaznakovi  | 裸腹叶须鱼 | —       | Lower Lancang River — Yes |
| Gymnocypris firmispinatus  | 岸鲤 | —       | Lower Lancang River — Yes |
| Sub-Family Cyprininae (鲤亚科) | —       | —       | — |
| Cyprinus barbatus  | 鱼 | —       | Lower Lancang River — Yes |
| Cyprinus carpio  | 鱼 | Common carp | Lower Lancang River — Yes |
| Cyprinus chilia  | 榄鲤 | —       | Lower Lancang River — Yes |
| Cyprinus daliensis  | 大理鲤 | —       | Lower Lancang River — Yes |
| Cyprinus longipectoralis  | 鲤 | —       | Lower Lancang River — Yes |
| Cyprinus megalophthalmus  | 大眼鲤 | —       | Lower Lancang River — Yes |
| Carassius auratus  | 鱼 | Goldfish | Lower Lancang River — Yes |
| Family Prochilodontidae – Flannel-mouth characforms (鲮脂鲤科) | —       | —       | — |
| Prochilodus lineatus  | 襞纹キンシ | —       | Lower Lancang River — Yes |
| Family Loricariidae – Armored catfishes (甲鲇科) | —       | —       | — |
| Hypostomus plecostomus  | 下口鲶 | Suckermouth catfish | Xishuangbanna — |
### Scientific name | Chinese | English | Distribution
---|---|---|---
**Family Claridae – Airbreathing catfishes** (胡子鲇科)
Clarias batrachus | 蝌胡子鲇 | Philippine catfish | Lancang River in Yunnan
Clarias fuscus | 胡子鲇 | Hong Kong catfish | Lancang River

**Family Bagridae – Bagrid catfishes** (鲿科)
Hemibagrus wyckioides | 丝尾鲿 | — | Lower Lancang River

**Family Siluridae – Sheatfishes** (鲇科)
Clarias batrachus | 蝌胡子鲇 | — | Lower Lancang River
Clarias fuscus | 胡子鲇 | — | Lower Lancang River

**Family Schilbidae – Schilbid catfishes** (锡伯鲇科)
Hemibagrus wyckioides | 丝尾鲿 | — | Lower Lancang River

**Family Pangasiidae – Shark catfishes** (鱼芒科)
Pangasius djambal | 贾巴鱼芒 | — | Luosuo River
Pangasius micronemus | 短须鱼芒 | — | Luosuo River
Pangasius sanitwongsei | 长丝鱼芒 | — | Luosuo River

**Family Sisoridae – Sisorid catfishes** (鮡科)
Bagarius bagarius | 魦 | — | Upper Lancang River
Bagarius yarrelli | 巨魾 | — | Lancang River
Glyptothorax deqingensis | 德钦纹胸鮡 | — | Upper Lancang River
Glyptothorax fuscus | 纺锤纹胸鮡 | — | Lancang River
Glyptothorax longinema | 长须纹胸鮡 | — | Lancang River
Glyptothorax macromaculatus | 大斑纹胸鮡 | — | Lancang River
Glyptothorax myzostoma | 兰坪纹胸鮡 | — | Lancang River
Glyptothorax prolixdorsalis | 长背纹胸鮡 | — | Lancang River

**Family Akysidae – Stream catfishes** (粒鲇科)
Akysis brachybarbatus | 短须粒鲇 | — | Lower Lancang River
Akysis sinensis | 中华粒鲇 | — | Lower Lancang River

**Family Salangidae – Icefishes or noodlefishes** (银鱼科)
Neosalanx taihuensis | 太湖新银鱼 | — | Erhai Lake

**Family Adrianichthyidae – Ricefishes** (怪颌鳉科)
Oryzias minutillus | 小青鳉 | — | Erhai Lake

**Family Poeciliidae – Poeciliids** (胎鳉科)
Gambusia affinis | 食蚊鱼 | — | Widely distributed

**Family Synbranchidae – Swam eels** (合鳃鱼科)
Monopterus albus | 黄鳝 | — | Widely distributed

**Family Mastacembelidae – Polystomidae** (刺鳅科)
Mastacembelus armatus | — | — |

**Family Cichlidae – Cichlids** (丽鱼科)
Oreochromis mossambica | 莫桑比克罗非鱼 | Mozambique tilapia | Lancang River
Oreochromis niloticus | 尼罗罗非鱼 | Nile tilapia | Lancang River

**Family Gobiidae – Gobies** (鰕虎鱼科)
Rhinogobius maculicervix | 颈斑吻鰕虎鱼 | — | Lower Lancang River

**Family Anabantidae – Climbing gouramies** (攀鲈科)
Trichogaster trichopterus | 线足鲈 | — | Three-spot gourami

**Family Tetraodontidae – Puffers** (鲀科)
Monotrete turgidus | 漠公河单孔鲀 | — | Nalna River

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*Fish biodiversity*

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MRC completes first comprehensive analysis of Tonle Sap *dai* fishery

The *dai* fishery lands about 14 percent of the annual catch from the Tonle Sap system. Monitoring trends in migratory fish populations that use the system is an important means to evaluate management and potential impacts from development activities in the Lower Mekong Basin.

The Tonle Sap-Great Lake System is an integral part of the history, culture, ecology and economics of the Mekong region. Species of blackfish and whitefish are the target of industrial, artisanal and subsistence fisheries operating in the system.

Strong competition exists among the fisheries to land in excess of 200,000 tonnes of fish each year equivalent to approximately 10% of the total weight of fish consumed in the entire Lower Mekong Basin (LMB) each year.

The *dai* fishery on the Tonle Sap River, established almost 140 years ago, is an important component of the industrial fishery, landing approximately 14% of the annual catch taken from the Tonle Sap system. It targets the refuge migrations of a multi-species assemblage of fish as they migrate from the Great Lake to the Mekong main

The locations of catch monitoring for the Fish Abundance and Diversity Monitoring Programme under the Assessment of Mekong Capture Fisheries Component of the MRC Fisheries Programme (2003-2005)

*Photo: Joe Garrison*
The stationary trawl or loh dai fishery was introduced into Cambodia by the French colonial authorities between 1873 and 1889 for harvesting small-size fish primarily for fish oil production. The fish oil was used to replace engine oil during World War I. The importance of the fishery for fish oil production has diminished and most of the landed catch is now for human consumption. The dai fishery is located in the lower section of the Tonle Sap spanning more than 30 km across the municipality of Phnom Penh and Kandal Province. Dai nets are arranged in up to 15 separate rows of between one and seven nets anchored perpendicularly to the channel, with the net mouths facing upstream. The most upstream Row (15) is located approximately 35 km from Phnom Penh. Individual dais within a row are allocated an identification letter from ‘A’ to ‘H’. In 2001, dai row #1 with 3 dai units, situated nearby Chhroy Changvar Bridge (presently known as the Cambodian-Japanese Friendship Bridge), was decommissioned as a result of a fishery policy reform in 2000.
**Labiobarbus lineatus**
*(trey khawng veng)*
Omnivorous species found basin-wide in rivers and streams. Undertakes seasonal migrations onto floodplains to spawn.

**Henicorhynchus siamensis**
*(trey riel tob)*
Abundant herbivorous species occurring basin-wide in large and small rivers. It is highly migratory and spawns at the beginning of the flood. The species is extremely important in the *dai* fisheries and is also caught with other gear. Most of the fish is processed to *prahok*.

**Paralaubuca barroni**
*(trey slak russey)*
Feeds on zooplankton. Found in slow flowing or standing water in the Middle Mekong Basin. Processed to *prahok*.

**Labeo chrysophekadion**
*(trey kaek)*
Predominantly herbivorous occurring in flowing and standing water including reservoirs throughout the Mekong Basin. It spawns mainly in the early flood season in a variety of habitats. Commercially important marketed fresh or dried and salted.

**Puntioplites proctozysron**
*(trey chrakeng)*
Omnivorous species occurring in slowly moving and standing water including reservoirs. Moves laterally into the flooded forest during the high water season. Spawning occurs during the flood.

**Pangasius pleurotaenia**
*(trey chhwiet)*
An omnivorous catfish with a basin wide occurrence although apparently more abundant in the Lower Mekong. It is believed to undertake significant spawning migrations during the beginning of the flood season. After spawning in the mainstream, eggs and larvae drift to the nursery areas. The drifting larvae are caught with special gear and cultured. A very important food fish in the Lower Mekong and also used in the aquarium trade.

**Thynnichthys thyynoides**
*(trey linh)*
Pelagic feeding in a variety of habitats basin-wide including the mainstream. It migrates in the mainstream during the dry season. Enters floodplains during the high water season and spawns in the flooded littoral zone possibly throughout the flood season. Caught with a variety of small to large scale gear; Sold fresh and processed.
channel via the river with the receding floodwaters each year. In addition to its significant socio-economic value both locally and nationally, the dai fishery provides a valuable source of data and information to monitor trends in migratory fish populations which seasonally utilise the system and beyond.

MRC Technical Paper No 32, the Stationary Trawl (Dai) Fishery of the Tonle Sap-Great Lake System, Cambodia, represents the first attempt to compile and analyse the available data and information about the Cambodian dai fishery in a single document. It therefore serves as an important reference document for present and future workers involved in the management, monitoring and administration of the fishery. It also contains new insights into the ecology and dynamics of target fish populations important for their management.

The fishery exhibits considerable spatial and temporal variation in catch rate indicators of fish biomass and abundance. This reflects (pulsed) migratory behaviour associated with the lunar cycle, the hydrological cycle (drawdown effects), depletion effects as fish migrate through the fishery, and inter-annual hydrological effects on fish growth and biomass. Above average levels of recruitment were probably responsible for the very high catches observed during 2004–05 and 2005–06. Factors responsible for these high levels of recruitment remain uncertain. There is evidence that the timing of migrations is species and size-dependent with larger species and larger individuals of the same species migrating earlier than smaller fish. These responses are consistent with earlier studies on the system and in other tropical river systems.

| Most common species          | % |
|------------------------------|---|
| Henicorhynchus lobatus       | 27|
| Lobocheilus cryptopogon     | 21|
| Paralaubuca barroni         | 12|
| Labiobarbus lineatus        | 12|
| Henicorhynchus siamensis    | 11|
| Labiobarbus siamensis       |  4|
| Labeo chrysophekadion       |  2|
| Pangasius pleurotaenia      |  2|
| Puntioplites procozystron   |  2|
| Thynnichthys thynnoides     |  1|
| Other species               |  6|

Big stationary bagnet

ILLUSTRATION: ARJAN JANSIUS
Whilst the *dai* fishery is the focus of most fisheries monitoring and evaluation efforts in Cambodia, it is not the only, nor most significant, component of the entire Tonle Sap fishery. Other components with which it interacts and competes, particularly the other lot, artisanal and subsistence fisheries, are also significant and therefore must be given greater consideration in the future.

In spite of the present restricted focus, the monitoring efforts directed at the *dai* fishery have generated the only continuous long-term data set for an inland fishery in Cambodia. Analyses of indicators estimated from this data set have been informative for policy and management evaluation, revealing little or no compelling evidence of changes in the abundance, biomass, size or diversity of migratory fish populations that seasonally utilise the Tonle Sap system and beyond often over distances of more than 600 km. Furthermore, time series of these indicators have equipped managers with an important baseline against which to monitor any impacts of management and basin development activities.

A key finding of this research is that inter-annual variation in the biomass of the multispecies assemblage targeted by the fishery (and hence landings) can be largely explained by flood duration and extent effects on fish growth. Fish growth, indicated by mean fish weight, increases exponentially with the flood extent and duration presumably reflecting changes in feeding opportunities or competition. This response has been modelled, allowing predictions to be made of how the relative biomass of the multispecies assemblage targeted by the fishery (and hence catches) are likely to vary under different flooding conditions, whether natural or modified as a consequence of climate change and/or water management projects in the basin. Owing to the highly migratory nature of the target fish species, these predicted hydrological responses may be observed over large distances, affecting fisheries and piscivorous fish populations beyond the immediate vicinity of the system. The unexplained variation in the model may well reflect variation in recruitment to the system each year in addition to variation in fishing effort (mortality) applied by the other important fisheries within the system or over the migratory range of the target species, reinforcing the need for two more comprehensive monitoring programmes. These results also urge caution when monitoring mean fish size as a proxy for rates of exploitation in the Tonle Sap system and other highly fluctuating environments.

By applying depletion model theory, this research has provided the first estimates of the proportion of fish removed over the range of the fishery, *dai* gear catchability (efficiency), and *dai* fishing mortality rates subject to a number of assumptions. These results are an important first step towards understanding, and thereby controlling, if necessary, the relative sources of fishing effort (mortality) over the migratory range of populations of important species of fish.

Additional studies and monitoring programmes will be necessary to determine the validity of the assumptions underlying these estimates and to quantify the spatial distribution of the remaining sources of fishing mortality in the Tonle Sap system and beyond. Recommendations are made for these studies and programmes, as well as to improve the existing *dai* fishery monitoring programme.

**Further reading**

Halls, A.S.; Paxton, B.R.; Hall, N.; Peng Bun, N.; Lieng, S.; Pengby, N.; and So, N (2013). *The Stationary Trawl (Dai) Fishery of the Tonle Sap-Great Lake, Cambodia*. MRC Technical Paper No. 32, Mekong River Commission, Phnom Penh.
Capture fisheries

The catch being emptied directly into traders' boats
Lateral view of the head of *Physoschistura chulabhornae*, a new species of stream loach found in the northern Thai province of Chiang Mai. The fish is the second new species of stream loach from northern Thailand described since 2012 by Apinun Suvarnaraks of the Faculty of Fisheries Technology and Aquatic Resources at Maejo University in Chiang Mai. This photograph by Dr. Apinun shows the suborbital flap of the male next to the eye.

PHOTO: APINUN SUVARNARAKSHA