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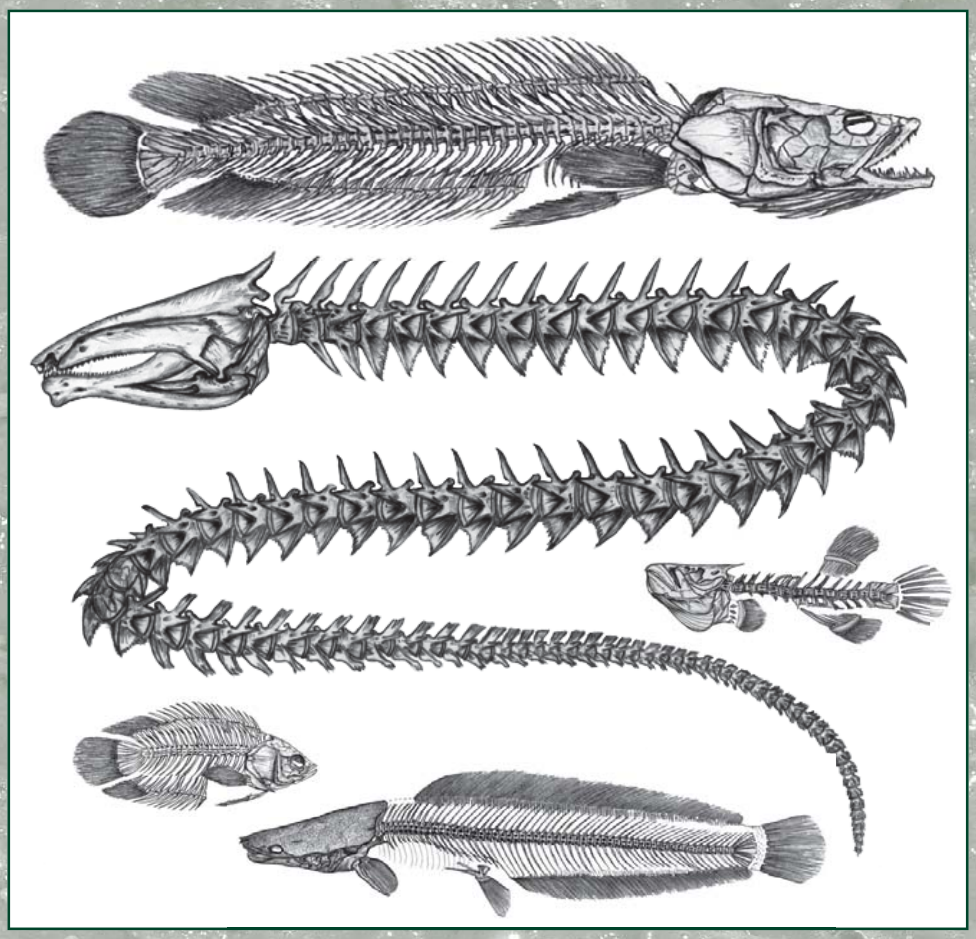

INSIDE

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Contributions to *Catch and Culture* should be sent to peterstarr@mac.com and copied to mrcs@mrcmekong.org
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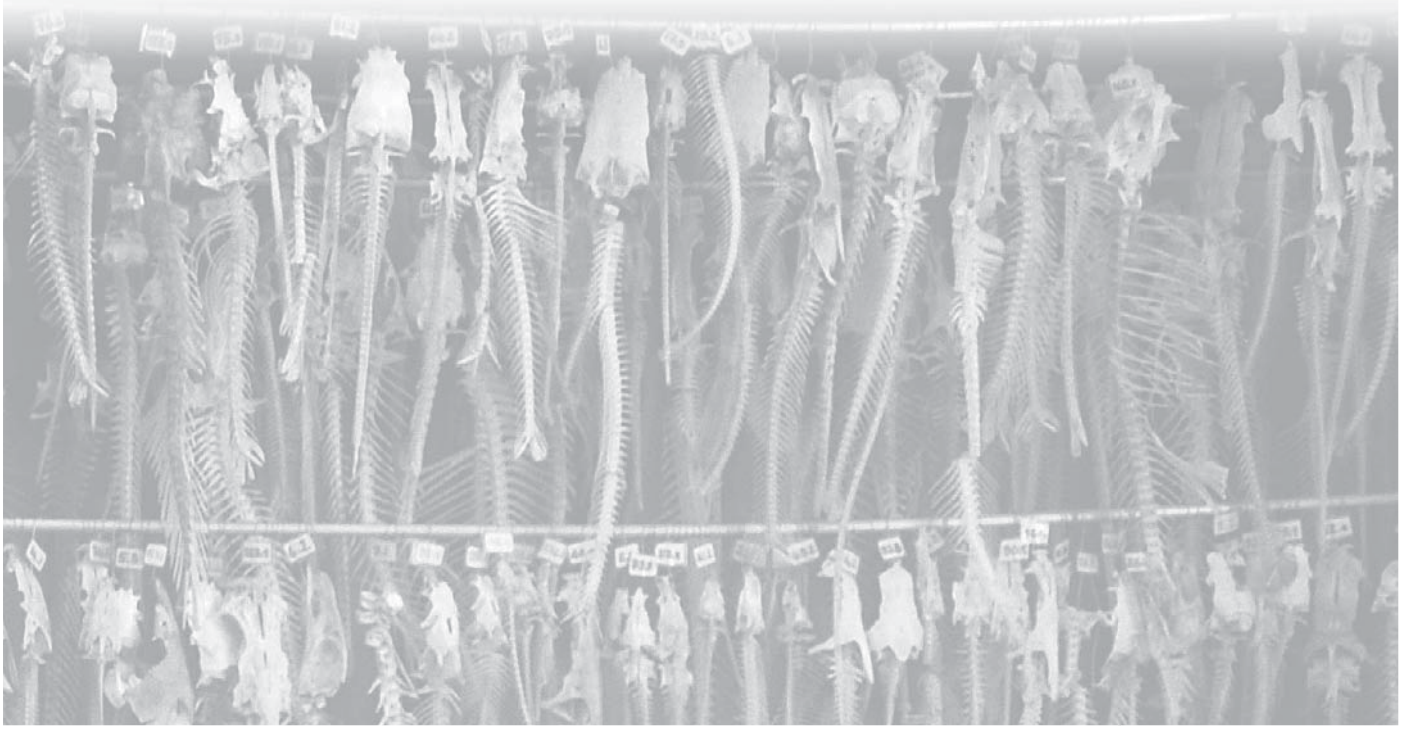
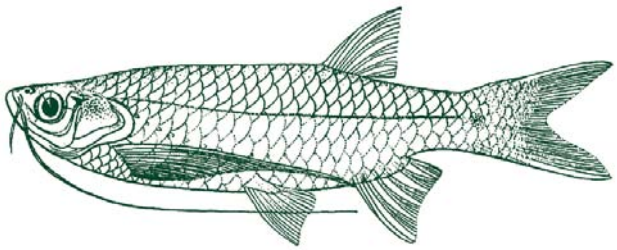
Editor: Peter Starr

Design: Chhut Chheana

Cover illustration: Voeun Vuthy



Contents



Basin Development Plan and **Fisheries**

By Kent G. Hortle *

The Mekong basin supports extensive fisheries which provide livelihoods and food security for millions of people. Infrastructure development in much of the basin is limited, compared with many other large river basins, and now water resources development in the Mekong is accelerating. In particular, many hydroelectric dams and irrigation projects are proposed or under construction. Regional governments generally support developing water resources to increase economic growth, help to alleviate poverty, improve livelihoods, and work towards meeting the UN Millennium Development Goals. At the same time, the possible negative effects on fisheries and other natural resources need to be understood and given adequate weight in development planning.

The MRC is mandated to prepare a Basin Development Plan under the Basin Development Programme, which is currently in its second phase (BDP2). The plan aims to support the countries to implement integrated water resource management (IWRM) to achieve a balance between economic, environmental and social outcomes. During 2009 and 2010, the BDP supported development and assessments of basin-wide development scenarios. These are based on groupings of projects which could significantly modify hydrology, including dams for hydroelectricity, irrigation and water supply, as well as flood mitigation projects. The projects were nominated by the countries as those considered important in their national development planning. As a result, the assessment is not intended to be a bottom-up balanced consideration of all possible development

Figure 1. **The eight main scenarios considered in the BDP assessments**

Scenario Description	Baseline 2000 BS	Upper Mekong dams	Definite future	LMB 20-year plan without m/s dams	LMB 20-year plan without lower m/s dams	LMB 20-year plan without Cambodian m/s dams	LMB 20-year plan without Thai m/s dams	LMB 20-year full-development plan with m/s dams
Year		2015	2015	2030	2030	2030	2030	2030
Infrastructure Code		2015-UMD	2015-DF	2030-20Y w/o MD	2030-20Y w/o LMD	2030-20Y w/o CMD	2030-20Y w/o TMD	2030-20Y
Full China upper Mekong cascade								
25 additional tributary hydro dams								
Additional tributary dams, for irrigation & water supply								
Mekong mainstream dams - upper Lao (6) upstream of Vientiane								
Mekong mainstream dams - Thailand (2)								
Mekong mainstream dams - Lower Lao at Khone Falls (2)								
Mainstream dams - Cambodia (2)								

pathways; rather it reflects the reality of national planning. The eight main scenarios considered are summarised in Figure 1. The baseline was set as Year 2000, with the 'definite future' in 2015 including all projects which are already being implemented, most of which are on tributaries in Lao PDR. After 20 years (i.e. by 2030) up to 12 mainstream dams and many dams on tributaries were considered in the 'full development plan'. Other scenarios considered fewer dams on the mainstream.

Grouping projects allows a very broad assessment of benefits and costs, including the impacts on the other non-consumptive water uses, especially fisheries, biodiversity and navigation. The scenario assessments facilitated national and regional discussions on the acceptable balance between water resources development and environmental and social impacts. As a result of these assessments, the LMB countries acknowledge that there remains considerable potential for development of Mekong water resources. In particular, the countries recognise three major water resources development opportunities, each involving its own type and level of uncertainties and risks, which require more information and understanding and joint learning for informed investment decisions to be made:

● the opportunity to abstract more water for irrigation or intra-basin diversion without affecting the baseline dry season flow. This however requires stronger cooperation with China to secure the additional dry season water, and strong implementation of the agreed MRC Procedures that will regularly monitor water use and how this will affect baseline flows.

● the opportunity for more intensive tributary hydropower development with requirements for a greater focus on trans-boundary impacts and the sustainability of individual projects; and

● the opportunity for some mainstream hydropower development, particularly the six projects proposed upstream of Vientiane, provided that the current uncertainties and risks are fully addressed and trans-boundary approval is obtained through the MRC's Procedures for Notification, Prior Consultation and Agreement.

As a result of the scenario assessments, and in particular the fisheries assessment discussed below, the countries understand that the uncertainties and risks associated with some water resources developments, such as the proposed mainstream dam projects downstream of Vientiane, are too significant to consider in this phase of the basin planning process as development opportunities. The extensive consultation process followed during the assessments allowed fisheries issues to be brought to the forefront and has significantly raised the awareness of the importance of inland fisheries among those responsible for other sectors. The IWRM-based development strategy for the LMB currently in draft is being further reviewed prior to finalisation and endorsement by the MRC's Joint Council.

Fisheries assessment of the BDP scenarios

The BDP Fisheries Assessment was carried out in early 2010 based on general information on each scenario and some simple assumptions about likely impacts. The full report is available on the MRC website and is briefly summarized here.

The report assessed the general impacts of the BDP scenarios on fisheries yield in the LMB. It indicated likely order-of-magnitude impacts on yield of fisheries in each country and basin-wide to highlight the major fisheries issues arising from the scenarios. Other issues (such as biodiversity, socioeconomics) were only considered to a limited extent in the fisheries assessment, but were the subject of separate reports. The fisheries report first provides an estimate of the baseline (year 2000) size of the fishery (total yield of fish plus other aquatic animals - OAAs) in the LMB in each country, based on an existing consumption review. Aquaculture 'production' is then estimated, and subtracted from the consumption estimate to provide an estimate of the yield of the capture fishery in 2000. The extent of aquatic habitats in the Lower Mekong Basin (LMB) was assessed based on GIS data, and information on yield per unit area was used to estimate yield from each habitat class in each country. A broad range of yields was first estimated, and then the total yield was 'forced' to match the consumption estimate by assuming certain levels of yield from each habitat class in each country. The size of the fishery is somewhat uncertain, because there may be biases in data and because yield varies from year-to-year. However, the approach allows the definition of a starting point and a clear allocation of the proportions which originate from each habitat class in each country

to provide the basis for a balanced assessment and for adjustments based on other information or further analyses.

Impacts on fisheries production (and hence yield) were assumed to increase and accumulate up to the level of full development in an upstream-downstream progression as more dams are added. The impacts were assessed against the year 2000 baseline fisheries yield in each of three broad habitat classes as follows:

● **River-floodplain habitats** were assumed to support about 45% of the LMB's capture fisheries yield. Dams are likely to cause biodiversity losses, which would be very significant under full development as a result of major modifications to LMB river systems. The extent of biodiversity loss remains an important subject for further analysis and consideration. The assessment assumes a loss of fisheries productivity as a result of reductions in production of sensitive species, as well as losses due to reductions in flooded areas. There is no consideration of possible mitigation, management or other factors that might offset these losses, so the assessment in this respect is conservative. With full development, the predicted basin-wide loss of catches from river-floodplain habitats is 56% (or 585 thousand tonnes per year) of the baseline yield of 1,035 kt/year, with most (60%) of these losses in Cambodia. Mitigating or managing the impacts of dams on fisheries is and will continue to be a major challenge in the LMB

● **Rain-fed habitats** were assumed to support about 45% of the LMB's capture fisheries yield, based on their very large extent, but assumed lower yield per unit area. Fisheries in rain-fed habitats are populated by black fish and other locally resident fish and OAAs, and they are largely 'disconnected' from immigration from river-floodplain habitats, because of barriers and shallow water depths. There will be little direct impact of dams on these habitats, but irrigation development may cause both positive and negative effects. Positive effects were assessed in the best case as being directly related to additional irrigation, which can support fisheries production and also provide dry-season refuges. Negative effects in the worst-case arise from conversion to intensive rice-farming with shallow and fluctuating water depths and high pesticide use. The possible increase in yield from expansion of rice-fields into existing forest was not assessed so in this and some other respects the assessment is conservative. For rain-fed fisheries, with full development, the range of impacts on the baseline yield of 1,044 kt/year varies from a best-case gain of 21% (226 kt/year) to a worst-case loss of 38% (-395 kt/year) an overall difference of about 621 kt/yr, similar to the hypothesised loss from river-floodplain fisheries. This simple comparison suggests that rain-fed fisheries should receive a good deal more attention in development planning, particularly of irrigation schemes.

● **Reservoir fisheries:** existing reservoirs and some other large water-bodies were estimated to support about 10% of the LMB's capture fishery yield. Additional yield from new reservoirs was assessed using conservative assumptions on yield per unit area. Deep reservoirs with fluctuating levels and pulsed discharges (such as those formed by mainstream dams) are likely to be relatively unproductive, whereas small, shallow, eutrophic and stocked irrigation reservoirs with a regular wet-dry season pattern of filling and draw-down are likely to be relatively productive. The increase in fisheries from reservoirs is estimated at 16-64 kt/year, an increase of 7-28% over the baseline of 226 kt/year; this will be locally important but will do little to offset river-floodplain losses at a basin-wide scale.

Overall, the full development scenario by 2030 causes nett losses of capture fisheries ranging from 295 kt/year (best-case) to 964 kt/year (worst-case), or about 13-42% of the LMB baseline catches of 2.3 Mt/year. By any measure the overall capture fishery losses would be significant; for example they are equivalent to the entire fish/OAA consumption of 6.5–21.2 million people, or 12-38% of the LMB population of 56.3 million people in 2000 at the mean consumption rate of 45.5 kg/person/year.

Consumption demand for fish and OAAs was estimated for 2015 and 2030 based on population growth and assuming constant per-capita consumption. Future aquaculture production was assessed based on conservative projections from national figures from recent years. All production in Lao PDR and Cambodia was assumed to be internally consumed, about 10% of Thai LMB production to be exported, and about 35% of Viet Nam delta production

The three broad habitat classes in the lower Mekong basin that support fisheries: rain-fed rice-fields and associated small water-bodies (top left, near Siem Reap), reservoirs and other large water-bodies (a typical irrigation reservoir in northeast Thailand, top right) and river-floodplain habitats (the Mekong floodplain upstream of Phnom Penh).

PHOTOS: KENT G. HORTLE AND JOE GARRISON

was assumed to be internally consumed. The delta dominates aquaculture production and exports now, and is likely to continue its dominance. In general, the scenarios improve the economics of aquaculture through increasing the availability of water spatially and in the dry season as well as by improving infrastructure and electricity supply, so further growth would be supported. However there are also some negative effects that would require management; these include increasing contamination by pesticides and other chemicals as well as loss of wild brood-stock and trash fish.

To assess the overall impact of the scenarios on fisheries, the future consumption demand was subtracted from the future supply (catches plus aquaculture yield) to produce graphs for each country and for the LMB to provide an indication of the overall situation under each scenario. From a basin-wide perspective, there would be an excess of internally consumed aquaculture production in the best case, and a slight deficit in the mid-case. In the worst-case, internally consumed aquaculture would not compensate for losses, leading to a basin-wide deficit of 436 kt/year by 2030. This does not take account of the large exports from the Viet Nam delta, which would provide a large excess at a basin-wide level under any scenario or assumptions. From this basin-wide perspective, the possible losses might not appear to be too serious, but there are major differences in costs and benefits of the developments between and within the LMB countries. These can be broadly summarised

under the various assumptions made and under full-development to 2030 as follows.

● **Lao PDR:** there would be significant losses from river-floodplain fisheries, which in the best case would be more than offset by increases in rain-fed and reservoir fisheries. Additional aquaculture provides a further safety margin so that in the worst case at a national level there is a small predicted loss. However, within the country the losses would directly impact those who depend upon capture fisheries, for example along the Mekong and large tributaries. Possible benefits would accrue to others, e.g. lowland rice farmers or commercial fishers in reservoirs.

● **Thailand:** there would be relatively limited impacts on river-floodplain fisheries, but potentially very large positive or negative impacts on rain-fed habitats where irrigation would be expanded. The overall situation could vary from a large excess to a large deficit in the supply needed to meet consumption demand, despite some benefit from increasing aquaculture. Most fisheries yield derives from subsistence capture fisheries (some stocked), but most fisheries policy focuses on aquaculture. The major issue to be addressed is how to develop 'fish-friendly' irrigation systems which will support increased subsistence capture fisheries yield to meet demand.

● **Cambodia:** Cambodia has much to lose from intensive development, with very significant effects on the yield from its productive river-floodplain capture fisheries. The most damaging dams are likely to be those on the mainstream in Cambodia itself as they directly impact migration routes and spawning grounds of many of the fishery species in the river-floodplain catches. Any possible compensation in rain-fed habitats and by aquaculture is likely to be relatively minor leading to very large nett losses even under the best-case assumptions by 2030, and would not directly compensate those most-affected, the many landless and poor people who depend directly upon capture fisheries.

● **Viet Nam delta:** there would be a steady decline in capture fisheries yield with significant net losses and little difference between best and worst-cases. However, aquaculture would under any assumptions more than compensate for losses and would supply a considerable excess for internal consumption, but this excess may not be available or affordable to compensate for losses elsewhere in the basin. The success of aquaculture in the Mekong delta depends upon its dense canal system and flat and low-lying landscape, and many other factors, which will limit the extent to which it can be replicated elsewhere.

● **Viet Nam highlands:** there is at present and would continue to be a deficit of fisheries products under any scenario. Currently there are significant imports from other places including the delta and even under the best case (with significant increases in yield from new reservoirs) there would be a continuing need for internal imports.

The uncertainty in predictions as noted in the assessment could be reduced through synthesis of empirical information regarding dam impacts in the LMB in three key areas:

1. reviews of project monitoring data from LMB dam projects,

2. survey impacts of existing dams in the LMB, for example in northeast Thailand, and

3. repeating pre-dam fishery surveys.

The results of the assessment will be used in development of Strategic Guidance for Fisheries, which will become part of the IWRM strategy and will help to mainstream Fisheries in basin-wide and national planning.

* *Mr Hortle is the Chief Technical Advisor of the MRC Fisheries Programme*

Future **innovations** needed to help basin **meet challenges** of **dam development**

Some of the world's leading fisheries scientists call for an accelerated search for innovative solutions that avoid the major social and economic impacts expected from mainstream dam development in the Lower Mekong Basin. Such investments are required urgently, they argue, and need to be accompanied by investments that build capacity to adapt to the prospect of declining fisheries and other ecosystem services.

Two years ago, the Mekong River Commission convened a group of the world's leading fisheries experts to review the impact of proposed mainstream dams on fish migration. Led by Patrick Dugan, deputy director of the World Fish Center, the international group of scientists found that mainstream dams in the middle and lower reachers of the Lower Mekong Basin could affect more than 70 percent of the basin's catch (see *Catch and Culture*, Vol 14, No 3). Dr Dugan and other scientists who took part in the meeting of experts in Vientiane in 2008 now reckon that major investments in innovative technology and alternative livelihood strategies are required to reduce and cope with losses that are caused by mainstream dam construction. In a paper* published by the Royal Swedish Academy of Sciences in June, the authors find "no evidence to suggest that the current drive towards dams in the mainstem of the Mekong will stop." If all dams go ahead, "a large part of the river's fish production, and the economic, nutritional and social benefits of this ecosystem service will be lost in the coming decades."

The paper considers two broad scenarios for the future well-being of people who depend on these resources. In the first, institutions and communities are unable to adapt. Significant loss of fisheries and other benefits result in "large-scale loss of livelihoods and nutritional and social disruption for millions of people in the basin, especially in the low income communities of Cambodia, Laos and Viet Nam." The authors note that this raises the prospect of increased social conflict and rural-to-urban migration by people seeking jobs with the additional risk of increased movements of people beyond the Lower Mekong Basin. In the second scenario, institutions and communities adapt successfully. Hydroelectric power drives economic diversification and electricity exports, generating income for other investments such as developing enterprises and creating jobs for those who can no longer earn an income from fishing. The authors acknowledge that these are "plausible arguments" with Asia's economic growth in recent decades providing reason for optimism. On the other hand, however, "substantial international experience of dam development suggests that the probability of successful adaptation by fishing communities in the face of ecosystem degradation is low." Without first investing in diversifying and strengthening livelihoods so the poor are better able to cope with changes arising from dam development, the probability of successful adaptation is especially low. Given the limited capacity of national institutions to pursue integrated approaches to basin development and the marginal participation of poor stakeholders in political decision making, 'this will be especially difficult."

Formidable challenge

Yet future innovations may help society meet challenges now thought to be insurmountable. The paper asserts that "investments to identify, develop and apply such innovations are now required urgently." These will need to tailor the planning, design and operation of dams to sustain river fisheries and other ecosystem services. But this has so far proved elusive in all other major rivers with hydropower development similar to those proposed for the Mekong, and doing so in the Mekong presents a "formidable challenge." The search for innovative solutions that avoid major social and economic impacts "therefore needs to accelerate while being accompanied by investments that build capacity to adapt to the prospect of declining fisheries and other ecosystem services." Such adaptation will need to consider new livelihood strategies for people living along the Mekong and its tributaries. "Only by pursuing this dual approach will it be possible to minimise the negative impacts of future basin development on the poor who depend on the basin's natural ecosystems," the authors conclude.

* Dugan PJ, Barlow CB, Agostinho AA, Baran E, Cada GF, Chen D, Cowx IG, Ferguson JW, Jutagate T, Mallen-Cooper M, Marmulla G, Nestler J, Petrere M, Welcomme RL, Winemiller KO (2010) Fish migration, dams, and loss of ecosystem services in the Mekong Basin, AMBIO, 39(4):344-348.

Integrating data from fisheries **monitoring** programmes in the Lower **Mekong Basin**

Cambodian, Lao, Thai and Vietnamese scientists have started to integrate data from four separate fisheries monitoring programmes with the aim of quantifying basin-wide changes over time. Monitoring undertaken so far has covered fish catches with different types of fishing gear in various habitats and the abundance of fish larvae drifting downstream from spawning areas.

The Mekong River Commission Fisheries Programme has been supporting four separate fisheries monitoring programmes in the Lower Mekong Basin in recent years. In addition to monitoring the status and trends of fisheries, these programmes provide an important reference point or baseline for monitoring any impacts of fisheries management and development activities including dam construction. Two of the programmes date back to 1994. These involve a commercial bagnet fishery on the Tonle Sap River in northern Phnom Penh and Kandal province in Cambodia and a semi-commercial trap fishery at Khone Falls in the southern Lao province of Champassak. In addition, comprehensive monitoring of fish larvae density has been carried out on the Mekong and Bassac rivers in Viet Nam since 1999 and the Mekong and Tonle Sap rivers in Cambodia since 2004. The fourth programme, involving subsistence fisheries, has been monitoring fish abundance and diversity at 23 sites in all four countries of the lower basin since 2007.

In July, fisheries biologists from Cambodia, Lao PDR, Thailand and Viet Nam met in Sihanoukville for four days to report on the status and latest results of the four monitoring programmes and to conduct an integrated analysis of the the data for the first time.

Participants at the Regional Workshop for the Integrated Analysis of Data from MRC Fisheries Monitoring Programmes

PHOTO: LEM CHAMNAP

Table 1 **Fishing sites using gill nets monitored since 2007**

Country	Province	District	Village	River
Cambodia	Stung Treng	Siem Pang	Pres Bang*	Sekong
Cambodia	Stung Treng	Talarborivat	Ou Run*	Mekong
Cambodia	Ratanakiri	Voeunsai	Banfang*	Sesan
Cambodia	Ratanakiri	Lum Phat	Day Lo*	Srepok
Cambodia	Kratie	Sambor	Koh Khne*	Mekong
Lao PDR	Luang Prabang	Luang Prabang	Ban Pha O*	Mekong
Lao PDR	Vientiane	Hatxayfong	Ban Thamuang*	Mekong
Lao PDR	Bolikhamxay	Paksan	Ban Xinh Xay*	Mekong
Thailand	Nakhon Phanom	Tad Phanom	Ban Nam Kum	Mekong
Thailand	Mukdahan	Wan Yai	Song-khon	Mekong
Thailand	Mukdahan	Muang	Nalair	Mekong
Thailand	Loei	Chiang Khan	Chiang Khan	Mekong
Thailand	Loei	Chiang Khan	Noy	Mekong
Thailand	Nakhon Phanom	Tha Utain	Chaiyaburi	Mekong
Thailand	Ubon Ratchathani	Khemarat	Ladcharoen	Mekong
Viet Nam	An Giang	An Phu	Ap 2	Mekong

Organised by the Inland Fisheries Research and Development Institute (IFReDI) of the Cambodian Fisheries Administration, the regional workshop was co-chaired by Dr So Nam, the IFReDI director, and Dr Ashley Halls, the former coordinator of Fisheries Ecology, Valuation and Mitigation (FEVM) component of the Fisheries Programme who is now a consultant to the programme. In an opening address, Mrs Kaing Khim, deputy director general of the Cambodian Fisheries Administration, said the workshop reflected a strong MRC focus on research and monitoring to support fisheries management and development in the region with the aim of generating “tangible and valuable outputs” for the Fisheries Programme.

As a first step towards integrating the analysis of monitoring data to indicate regional fishing trends in the Mekong River over time, the workshop in July identified gill nets as the most common type of gear used in artisanal fisheries in all four countries. Among the 23 small-scale fishing sites being monitored by the MRC Fisheries Programme since 2007, gillnets are used at 16 sites. Seven of these sites are located in Thailand, five in Cambodia, three in Lao PDR and one in Viet Nam (see Table 1). Both the Cambodian and Lao sites were also monitored between 2003 and 2005. With the exception of three tributary sites in northeast Cambodia, all are located along the mainstream of the Mekong.

To identify which species could be monitored on a regional basis, the total catch data for all types of fishing gear used in MRC monitoring programmes at all sites were broken down by country. Of more than 500 fishes identified in the monitoring—including the commercial dai fishery in Cambodia and the semi-commercial lee trap fishery in Lao PDR—it was found that about 140 species were common to all four

Putrea Solyda (Cambodia)

Photo: Lem Chamnap

Vannasay Soukhaseum (Lao PDR)

Photo: Lem Chamnap

Tiwarat Talengkietleela (Thailand)

Photo: Lem Chamnap

Vo Vi An (Viet Nam)

Photo: Lem Chamnap

Table 2 **Most common species**

Ranked alphabetically according to highest catch weights in fisheries monitored in all four countries

Species	Family
Goonch *(Bagarius bagarius)*	Sisorid catfishes (Sisoridae)
Red tailed tinfoil *(Barbonymus altus)*	Carps (Cyprinidae)
Silver barb *(Barbonymus gonionotus)*	Carps (Cyprinidae)
*Belodontichthys trucatus**	Carps (Cyprinidae)
Tiger botia *(Botia helodes)*	Sheatfishes (Siluridae)
Clown featherback *(Chitala ornata)*	Featherbacks (Notopteridae)
Violet giant barb *(Cosmochilus harmandi)*	Carps (Cyprinidae)
Mekong giant barb *(Cyclocheilichthys furcatus)*	Carps (Cyprinidae)
Common carp *(Cyprinus carpio)*	Carps (Cyprinidae)
*Hemibagrus wickioides**	Bagrid catfishes (Bagridae)
Lesser silver mud carp *(Henicorhynchus lobatus)*	Carps (Cyprinidae)
Siamese mud carp *(Henicorhynchus siamensis)*	Carps (Cyprinidae)
Black shark minnow *(Labeo chrysophekadion)*	Carps (Cyprinidae)
Silver sheatfish *(Micronema apogon)*	Sheatfishes (Siluridae)
Reddish sheatfish *(Micronema bleekeri)*	Sheatfishes (Siluridae)
Bocourt's catfish *(Pangasius bocourti)*	Shark catfishes (Pangasiidae)
Sharp nosed catfish *(Pangasius conchophilus)*	Shark catfishes (Pangasiidae)
Long-barbel catfish *(Pangasius macronema)*	Shark catfishes (Pangasiidae)
Red finned catfish *(Pangasius pleurotaenia)*	Shark catfishes (Pangasiidae)
*Puntioplites falcifer**	Carps (Cyprinidae)

* Common name in English unavailable

countries. In terms of catch weight, about half of these species each accounted for more than 10 kg of the total catch in each country.

'Improving our understanding of the spatial and temporal dynamics of the fish resources of the basin is fundamental'

Only 20 species accounted for more than 100 kg or more than 3 percent of the total catch in each country. Half of these were carps and a fifth were shark catfishes. The rest were sheatfishes, a sisorid catfish, a featherback and a bagrid catfish (see Table 2). About a third of these species are threatened by mainstream dam development (see *Catch and Culture*, Vol 15, No 3). To enable more integrated monitoring of fisheries along the Mekong mainstream and the Sesan-Sekong-Srepok tributary system, further work is being carried out to rank species according to relative abundance.

In a report on the workshop, Dr Halls concluded that "improving our understanding of the spatial and temporal dynamics of the fish resources of the basin is fundamental for effective resource management, basin development planning, and fisheries impact assessments. Maintaining the existing, and now well refined, fisheries resource monitoring programmes should therefore remain a priority."

Chea Tharith (Cambodia)

PHOTO: LEM CHAMNAP

Nguyen Nguyen Du (Viet Nam)

PHOTO: LEM CHAMNAP

A full report of the workshop can be obtained from the editor of *Catch and Culture*.

Late prehistoric site in Cambodia **yields** thousands of **fish bones** from 18 families

By Voeun Vuthy *

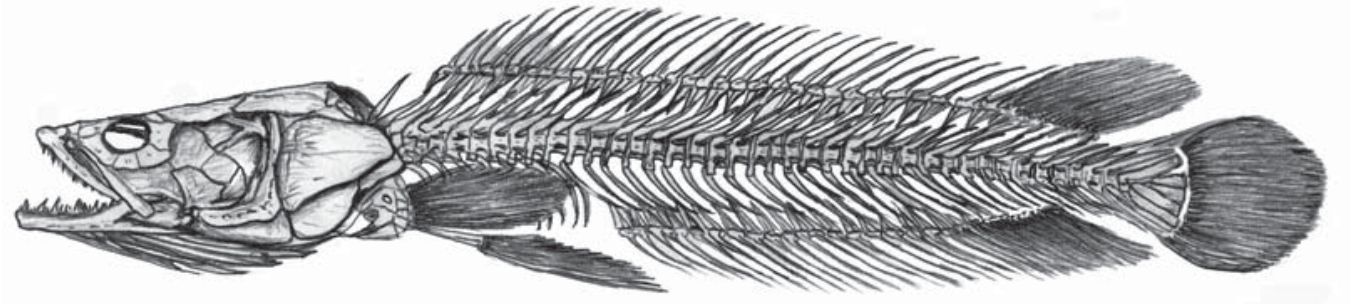
Recent research by the Cambodian government indicates that people living near the Tonle Sap Lake more than 2,000 years ago were already engaged in fish processing. Earlier research from a site nearby suggests that more recent inhabitants may have included highly-skilled fishermen. Some of the specimens from both sites are scheduled to go on permanent display in November at a museum next to the Angkor Temples in Siem Reap.

Zooarchaeology is the study of animal remains such as bones, teeth and shells that have been unearthed from archaeological sites. Since animal remains may represent food refuse or domesticated animals, they can inform us about many aspects of the lives of ancient people including diet and nutrition, food processing, subsistence strategies and belief systems. More generally, they help reconstruct the palaeofauna and ecosystem of a period by providing a vivid picture of the environment that humans inhabited at the time. Zooarchaeological analysis usually consists of studying assemblages of individual remains based on a long and time-consuming inventory of bones including identification of species, genus and family as well as age and size.

Excavation at Koh Tameas in 2005

Photo: Voeun Vuthy

Over the past decade, the Ecole Française d'Extrême Orient (EFEO) and the Authority for the Protection and Management of Angkor and the Region of Siem Reap (Apsara Authority) have excavated many sites in Siem Reap. Two of these sites, Prei Khmeng and Koh Tameas, are located about about five kilometres from the Tonle Sap Lake during the wet season, with the distance increasing to about 15 kilometres during the



Snakehead (Channidae)

Illustration: Voeun Vuthy

dry season. In addition to human remains, charcoal, pottery, beads, bronze, iron, stone, bricks, shells and other artefacts, the two sites have yielded thousands of bone samples of fish and other animals.

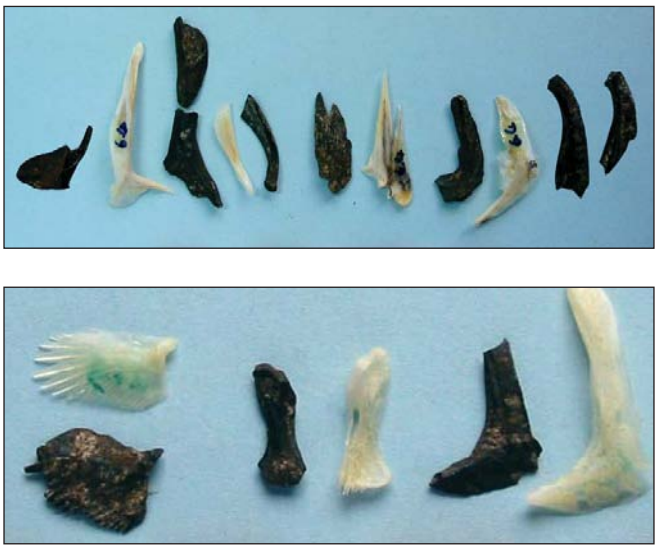
Prei Khmeng

Prei Khmeng is pre-Angkorian, dating back to between 100-700 AD, and is located on a small mound near the Western Baray, a huge reservoir built during the Angkor period over a 16-year period between 1050 and 1066 AD. EFEO and the Apsara Authority excavated the site in 2000, 2001 and 2003. Researchers at the Faculty of Archaeology at Cambodia's Royal University of Fine Arts then analysed 586 fish bone fragments, identifying 310 specimens belonging to 11 families (see table above).

Fish bones identified from Prei Khmeng

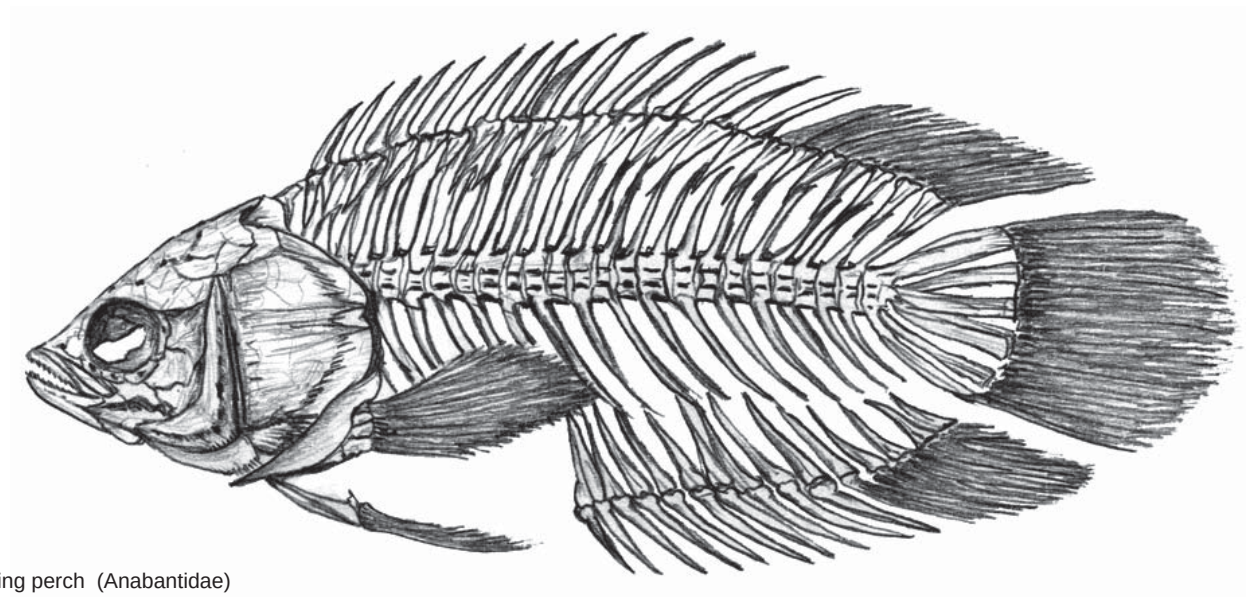
From 586 fragments analysed by the Rural University of Fine Arts

Family	Fragments	%
Snakeheads (Channidae)	190	60
Shark catfishes (Pangasiidae)	35	10
Bagrid catfishes (Bagridae)	25	9
Climbing perches (Anabantidae)	24	8
Carps and barbs (Cyprinidae)	16	5
Air-breathing catfishes (Clariidae)	11	2
Needlefishes (Belonidae)	3	2
Featherbacks (Notopteridae)	2	1
Sheatfishes (Siluridae)	2	1
Croakers (Sciaenidae)	1	1
Spiny eels (Mastacembelidae)	1	1
Total	310	100

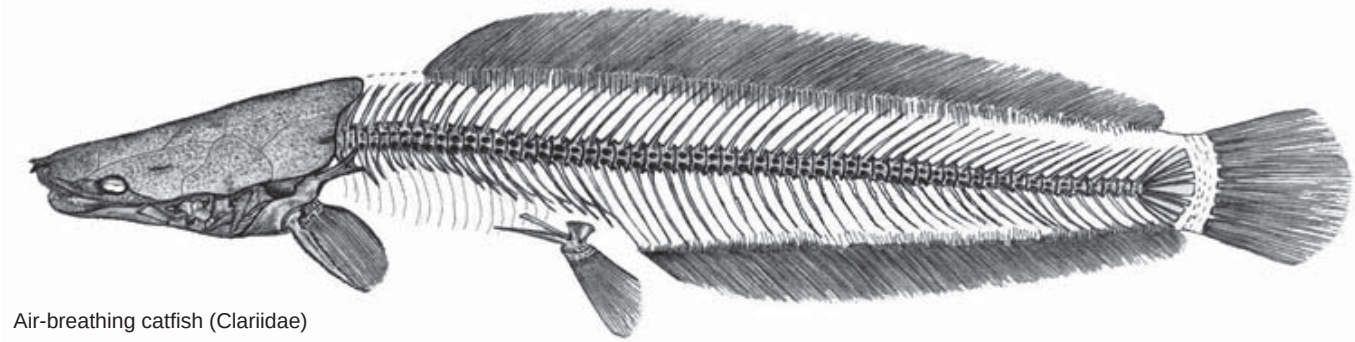


Among bone fragments that could be identified, those from snakeheads (top) were the most common at both sites. Fragments of climbing perch bones (bottom) were also common.
Photo: Voeun Vuthy

Judging from the bone fragments, most of the fishes identified at Prei Khmeng were black fishes which occur in shallow, standing or sluggish waters such as rice-fields and associated habitats where fish can be caught all year. Less than half of the fishes came from further away in deep streams or the Tonle Sap



Climbing perch (Anabantidae)
Illustration: Voeun Vuthy



Air-breathing catfish (Clariidae)
Illustration: Voeun Vuthy

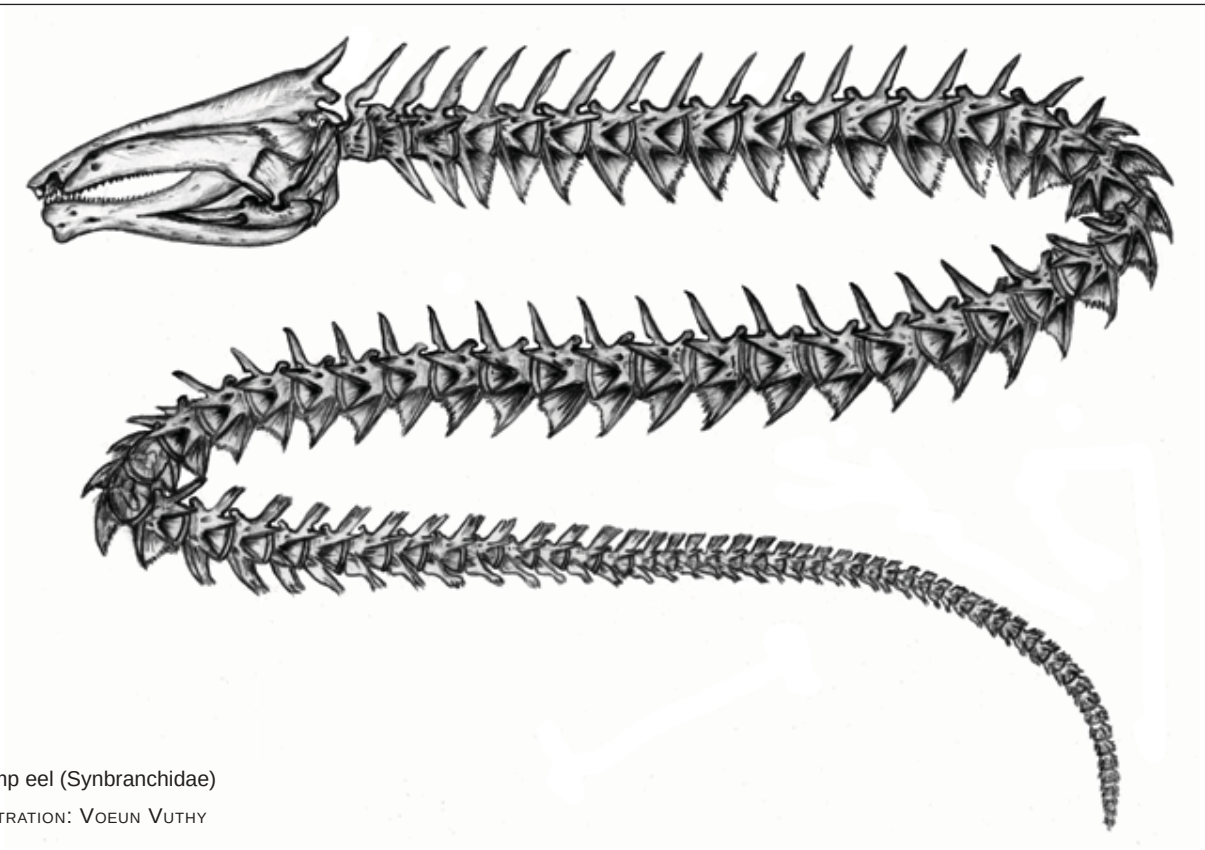
Lake. These include the giant snakehead (*Channa micropeltes*), the giant carp (*Catlocarpio siamensis*), the Mekong giant catfish (*Pangasianodon gigas*) and the great white sheatfish (*Wallago attu*). Some are very large individuals, indicating much lower fishing pressure than today. Catching such large fish would require specialised equipment and skills. Alternatively, people may have collected fish that were trapped in shallow waters. These might have been easily speared or killed by other simple means.

Prei Khmeng is surrounded by low-lying floodplains, which have not changed much since pre-Angkorian times. These floodplains offered extensive fishing grounds for the Prei Khmeng people. There was no need to go far away to catch fish. Depending on the season, the people of Prei Khmeng probably exploited the Tonle Sap themselves, or traded with people living closer to the lake much as they do today.

Koh Tameas

The second site from which fish bones have been analysed is a burial mound that was excavated after it emerged from the bed of the Western Baray during the exceptionally dry year of 2004. While the site dates back 3,865 years, the fish bones are about 2,100 years old and Koh Tameas provides the first overview of the diet of a population living near the Tonle Sap Lake during this late prehistoric period. But the zooarchaeological study is even more ground-breaking in terms of the environmental archaeology. The large quantity of samples collected (10,119 assemblages) provide an ideal diversity of fauna for studying such an early period. Comparisons with Prei Khmeng show how practices changed between the two periods. For instance, half of the fishes identified from Koh Tameas came from the Tonle Sap Lake, including snakeheads (Channidae) and sheatfishes (Siluridae). But the proportion is lower at Prei Khmeng, suggesting that people in the more recent period tended to favour shallow, standing and sluggish waters such as rivers and paddy fields, a practice related to a more stable agrarian way of life. There was also the amazing discovery of some otolith fragments of the Irrawaddy dolphin (*Orcaella brevirostris)*, suggesting that this

Long and time consuming
Photo: Voeun Vuthy



Swamp eel (Synbranchidae)
Illustration: Voeun Vuthy

Identifying fish bones and calculating the minimum number of individuals

The identification of fish bones is usually carried out by directly comparing the morphology of the bones with the fish skeletons of known species and size in reference collections. It is often not possible to identify fish bone materials beyond the level of family and only sometimes to genus and occasionally to species. The level of identification of fish bone fragments varies according not only to the state of preservation, but also to the morphology of the family, genus or species. This is because many fish families that occur in Cambodia comprise many members which have very similar bone morphology, notably carps and barbs (Cyprinidae), snakeheads (Channidae) and sheatfishes (Siluridae).

When an identification is made, the approximate length of the fish is estimated, either through direct comparison or through measurement of the bones. The reconstruction of the length of the fish together with its minimum number of individuals is a good indicator for the economic value that the different fish taxa played in human communities. Calculating the minimum number of individuals is generally based on skull elements and commonly carried out taking the greater of the left or right values for a particular element within each context with no correction for pairs. The minimum number of individuals can be an excellent indicator of the relative frequencies of various fish species represented in a sample.

The second site from which fish bones have been analysed is Koh Tameas, a burial mound that was excavated after it emerged from the bed of the Western Baray during the exceptionally dry year of 2004. While the site dates back 3,865 years, the fish bones are about 2,100 years old and Koh Tameas provides the first overview of the diet of a population living near the Tonle Sap Lake during this late prehistoric period. But the zooarchaeological study is even more ground-breaking in terms of the environmental archaeology. The large quantity of samples collected (10,119 assemblages) provide an ideal diversity of fauna for studying such an early period.

species—now critically endangered in the Mekong—was present in the Tonle Sap Lake around 3,000 years ago.

Wide range of ecosystems

From Koh Tameas, the animal bones reveal the broad spectrum of a foraging economy which exploited a wide range of ecosystems—forests, grasslands, marshlands, rivers, inundated fields and the Tonle Sap Lake. Many mammal taxa could be determined, notably wild and domesticated pigs as well as cattle, water buffalo, serow and various species of deer. Among mammals that are now rare were Asiatic jackals, fishing cats, leopard cats and one tiger. Reptiles and amphibians were also found including crocodiles, frogs and five different species of tortoise and turtle. Birds included wild chickens, ducks, spot-billed pelicans and spotted doves. Remains of Asian elephants and rodents were also unearthed.

Among the 2,909 fish bones analysed by the Archaeology and Prehistory Department of the Cambodian Ministry of Culture and Fine Arts, 1,336 have been identified from at least 16 different families (see box on this page). Unlike the remains of pigs and chickens, they were not found in any obvious clusters. But by looking at various cooked dishes prepared as offerings in ancient tombs, it is possible to figure out prehistoric diets. We now know that meals prepared by people living near the Tonle Sap Lake during this period included fish soup as well as salted, marinated, roasted and smoked fish.

Fish bones identified from Koh Tameas

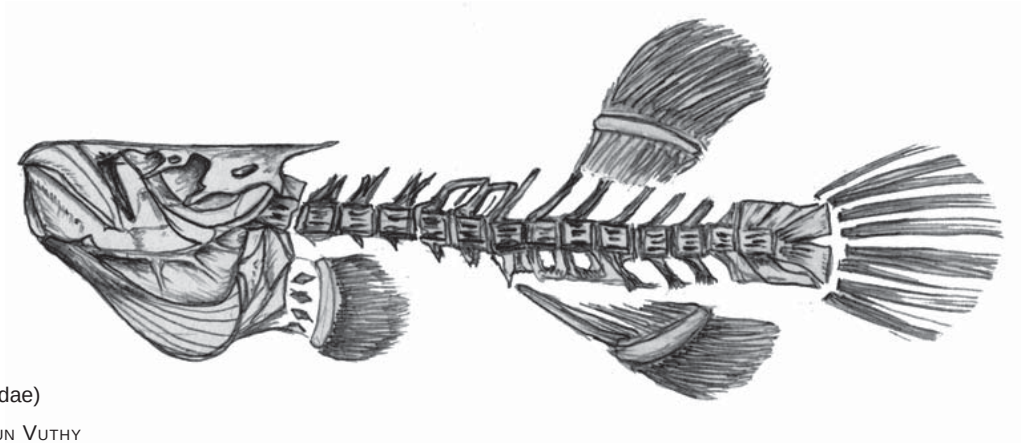
From 2,909 fragments analysed by the Ministry of Culture and Fine Arts

Family	Fragments	%
Snakeheads (Channidae)	582	44
Climbing perches (Anabantidae)	289	21
Air-breathing catfishes (Clariidae)	127	9
Bagrid catfishes (Bagridae)	127	9
Carps and barbs (Cyprinidae)	105	8
Needlefishes (Belonidae)	75	5
Sheatfishes (Siluridae)	23	2
Swamp eels (Synbranchidae)	12	1
Shark catfishes (Pangasiidae)	10	1
Featherbacks (Notopteridae)	4	<1
Soles (Soleidae)	3	<1
Asian leaf fishes (Nandidae)	2	<1
Threadfins (Polynemidae)	2	<1
Croakers (Sciaenidae)	2	<1
Spiny eels (Mastacembelidae)	2	<1
Puffers (Tetraodontidae)	1	<1
Total	1,336	100

** Mr Voeun Vuthy is deputy director of the Archeology and Prehistory Department of Cambodia's Ministry of Culture and Fine Arts. The article is based on his research papers for EFEO on the fish remains from Prei Khmeng and Koh Tameas and a presentation he gave to the National Museum in Phnom Penh earlier this year.*

Further reading:

Voeun, V. (2006) Osteological guide of fishes from the Mekong system in Cambodia, Fishbone Collection, Phnom Penh, Cambodia.



Puffer (Tetraodontidae)

Illustration: Voeun Vuthy

Fish bone display in Siem Reap

Some of the fish bones from Koh Tameas, Prei Khmeng and other sites formed part of a six-month exhibition at the Cambodian National Museum in Phnom Penh earlier this year. The displays from the Angkor Ancestors Exhibition have since been shipped to the Preah Norodom Sihanouk Angkor Museum in Siem Reap, where a permanent Angkor Ancestors Exhibition is scheduled to open at the museum in November. The Apsara Authority is preparing the exhibition with the assistance of EFEO staff including Cambodian archaeologists Ly Vanna and Kong Virek as well as French architect Christophe Pottier, the former director of EFEO in Siem Reap who has recently relocated to the University of Sydney where the Greater Angkor Project is based (see *Catch and Culture*, Vol 11, No 2) . Dr Ly Vanna and Dr Pottier are curators of the exhibition with the installation overseen by Adeline Beuken, a French conservator and restorer of artworks and archaeological materials who has been working in Cambodia since April.

Preah Norodom Sihanouk Angkor Museum is located in Boueng Don Pa village in Slakram commune of Siem Reap district. The museum is open between 0800 and 1700 from Tuesday to Sunday (closed Mondays). Last admissions are at 1630. Entrance fees are $3 for foreigners and KHR 1,000 for Cambodians.

Mr Voeun Vuthy with French conservator and restorer Ms Adeline Beuken in the laboratory of the Department of Archaeology and Prehistory at the Ministry of Culture and Fine Arts in August

Photo: Lem Chamnap

Delta company **markets feed** developed with **research institute**

By Peter Starr *

A company from Bac Lieu province has started marketing V2 Feed, a new prawn feed developed in cooperation with the Research Institute for Aquaculture No. 2

In a highly competitive landscape dominated by foreign feed producers, Bac Lieu Feedmill Joint Stock Company (Bafeco) stands out as the only wholly Vietnamese-owned company supplying feed for shrimp in the Mekong Delta. Established in 1998, Bafeco operates a Dutch-built plant in Bac Lieu province that produces feed for black tiger shrimp (*Penaeus monodon*) which are farmed in Bac Lieu and Soc Trang provinces.

In late 2009, Bafeco started technical cooperation with the Research Institute for Aquaculture No 2 (RIA2) in Ho Chi Minh City, which has its own feed mill at the National Breeding Centre for Southern Freshwater Aquaculture in Cai Be in Tien Giang province. The RIA2 mill aims to improve the quality of shrimp feed for efficient and sustainable shrimp aquaculture. The mill was financed by a $500,000 grant from Hungary's Research Institute for Fisheries, Aquaculture and Irrigation (HAKI) and has been producing feed for catfish, tilapia and a couple of marine species since 2007. The feed produced is largely for research purposes, although some is also shared with farmers. "We are carrying out an experimental production project of improving feed production technology for *tra* catfish, black tiger shrimp and fresh water prawns," says Nguyen Van Nguyen, the deputy director of the Centre for Fishery Post Harvest who oversees

Workers at the RIA2 aquatic feed mill in Cai Be

Photo: Lem Samean

Bafeco general director Cao Van Quat (left) visiting Dong Thap in July with other company officials

PHOTO: LEM SAMEAN

the feedmill. "We cannot compete in terms of price but we can compete in terms of quality." According to Mr Nguyen, most of the ingredients such as fish and soybean meal as well as meat bone meal are imported from countries such as Argentina, Brazil, Chile, Hungary, Mexico, Peru and the United States. Rice bran and cassava powder are sourced locally, although cassava is also imported from Cambodia and Lao PDR. Among other ingredients, amino acids in the form of DL Methionine and L- Lysine are supplied by Nutreco NV of the Netherlands under its Trouw Nutrition brand (see box below). The feedmill's output is nevertheless modest at 500 kg per hour when the single production line manned by four people is operating.

Dutch giant moves into Vietnamese shrimp feed market

In July, Dutch animal nutrition and aquatic feed giant Nutreco NV announced the acquisition of 100 percent of Tomboy Aquafeed Joint Stock Company, the fourth largest supplier of fish and shrimp feed in Viet Nam, for an undisclosed sum. With revenues of about EUR 18 million in 2009, Tomboy has two plants near Ho Chi Minh City and in Long An province, and employs about 300 staff. Annual revenues amounted to EUR 18 million in 2009. Nutreco says the acquisition, under its Skretting aquatic feed division, is part of a strategy to expand its global market positions in feed specialties and fish feed in growth markets. "Skretting has a global leading position for the production of high-quality fish feed in a sustainable manner," Nutreco vice president Knut Nesse said. "We want to capitalise on this position and our know-how by approaching new markets with regards to geography and species. This acquisition perfectly fits in our growth strategy to further develop positions in strategic markets with feed for new species such as shrimp. It offers Skretting an entrance in Viet Nam and an interesting platform for future growth." Other foreign feed companies operating in the Mekong Delta included Cargill of the United States, Charoen Pokphand (CP) Group of Thailand and Uni-President Enterprises Corp of Taiwan.

Viet Nam now world's fourth-biggest importer of Peruvian fishmeal

Viet Nam was the world's fourth bigger importer of Peruvian fishmeal in 2008 and 2009, surpassing Taiwan in both years, according to the FAO publication *Globefish*. Viet Nam took about 5 percent of the world's importation of fish meal from Peru in 2009. China remained the major consumer, taking about half of the total Peruvian fishmeal exports, followed by Germany and Japan (see table below).

Peruvian fishmeal exports (2004 to 2009)

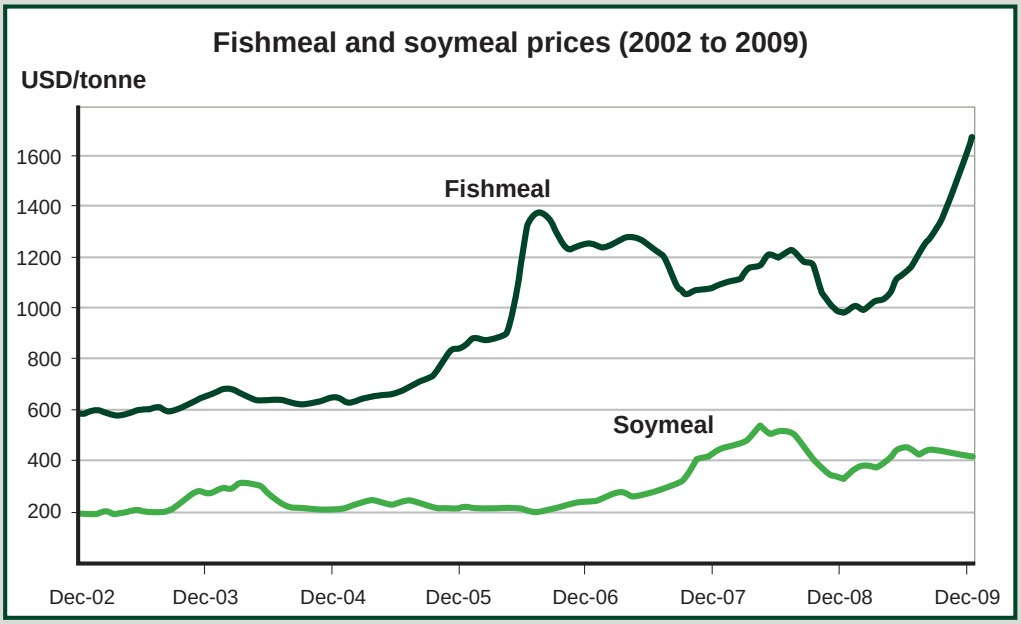
000 tonnes

	2004	2005	2006	2007	2008	2009
China	813.0	1049.4	535.2	555.2	831.9	753.9
Germany	153.1	235.9	208.9	166.0	191.9	269.1
Japan	197.0	170.2	174.0	149.7	148.1	117.1
Taiwan PC	83.0	84.0	57.1	39.3	46.8	61.4
Viet Nam	na	na	na	na	63.1	62.5
UK	na	na	na	na	22.7	54.4
Others	508.9	461.9	338.4	349.1	259.5	335.7
Total	**1755.0**	**2001.4**	**1313.6**	**1259.3**	**1564.0**	**1537.2**

SOURCE: FAO

Globefish described Viet Nam's emergence as a major fishmeal importer as a "relatively new development" that reflected strong demand from its growing shrimp feed industry. The FAO publication said that damage to the Chilean fishmeal industry arising from an earthquake and tsunami in February was putting upward pressure on Peruvian prices, resulting in a record high of $1,900 a tonne in Chinese ports in March.

With production of 1.39 million tonnes*, Peru was the world's biggest fishmeal producer last year followed by Chile with 668,000 tonnes, according to International Fishmeal and Fishoil Organisation figures cited by *Globefish*. Other big producers were Iceland (251,000 tonnes), Denmark (151,000 tonnes) and Norway (148,000 tonnes) Apart from the earthquake damage in Chile, *Globefish* predicted that a stronger than-expected El Niño climate pattern in 2010 was likely to put additional upward pressure on prices since catches of Peruvian anchovies (*Engraulis ringens*), the main raw material for fishmeal production, were usually very low in such years.



SOURCE: FAO

* Production and export figures may be inconsistent because of the use of different data sources and time lags.

Uni-President develops climbing perch feed with RIA2

Taiwan's leading food company Uni-President Enterprises Corp has joined forces with Viet Nam's Research Institute for Aquaculture No. 2 (RIA2) to evaluate pelleted feed types for climbing perch (*Anabas testudineus*), a species native to the Mekong which is increasingly popular among farmers in the delta. To evaluate the feed before mass production by Uni-President (Vietnam) Co Ltd, RIA2 is conducting an experiment at the National Breeding Centre for Southern Freshwater Aquaculture In Cai Be in Tien Giang province for up to six months. Trinh Quoc Trong, deputy director of the centre, says the first type of feed will be tested with 7-day old fry in a 15 cubic-metre concrete tank. Another type of feed will be tested in six 15 square-metre hapas (net enclosures) suspended in a 1,000 square-metre pond. Each hapa is being stocked with 26-day old sub-fingerlings at a density of 50 fish per square metre. Three hapas will be used to test Uni-President grow-out feed, while the other three will be used for the control feed. Fish will be grown in the hapas until they reach a marketable size. Mr Trong says the fish are being sampled for growth performance at intervals of 45, 150 and 180 days. After harvesting, the fish will be weighed and also measured if necessary. Total production of each hapa will also be recorded and data analysed for variations between the two types of feed. As part of its long-term goal of becoming the world's biggest food company, Uni-President has identified Viet Nam as a production base for exporting both aquatic feed and instant noodles.

Since it started collaborating with RIA2 in 2009 to ensure the quality of its products, Bafeco has started to produce feed for black tiger shrimp and giant freshwater prawns (*Macrobrachium rosenbergii*). In July this year, Bafeco general director Cao Van Quat and other company officials started marketing the new feed to distributors in Tam Nong district in Dong Thap, the Mekong Delta province bordering Prey Veng in Cambodia. With annual production estimated at 3,000 tonnes worth about $18 million, Dong Thap province is the largest producer of giant freshwater prawns in Viet Nam. Tam Nong district has the province's highest concentration of freshwater prawn farms.

A feed distributor (left) from Tam Nong district in Dong Thap province meeting with Bafeco company officials in July

Photo: Lem Samean

Compressed prawn feed is available in five sizes at average VND 20,000 ($1.10) per kilogram and is co-branded V2 Feed after the abbreviation RIA2 uses for the Vietnamese name of the research institute. In 2009, RIA2 began supplying commercial hatcheries in Dong Thap with post-larval prawns with the aim of meeting about 25 percent of the demand from giant prawn farmers in the Mekong Delta (see *Catch and Culture*, Vol 15, No 3).

**Mr Starr is the editor of* Catch and Culture

Feed production development in **Lao PDR**

By László Váradi *

Under a public-private partnership funded by a Hungarian government loan, the Lao government is implementing a project to build high-quality fish feedmills in Vientiane and Luang Prabang. Partners include research institutes from both countries as well as a leading Hungarian feed producer and the Vietnamese research institute where Hungary financed the construction of a similar mill.

Hungary's Research Institute for Fisheries, Aquaculture and Irrigation (HAKI) and the Lao National Agriculture and Forestry Research Institute (NAFRI) have been collaborating for many years under the framework of the Food and Agriculture Organization (FAO) of the United Nations. Under an FAO project, a pilot-scale feedmill was built in 1976. Activities of the feedmill included training people from developing countries, including Lao PDR and Viet Nam, and developing feed formula using ingredients available in Southeast Asia such as rice bran and cassava.

Members of the European Union are required to provide aid to developing countries. When Hungary became a member, Lao PDR was considered an appropriate target taking into account its Least Developed Country (LDC) status and a long tradition of collaboration in agricultural development between the two countries. When the Hungarian government decided to provide a tied loan to Lao PDR in 2009, the development of seed and feed supplies was identified as priority activities for aquaculture and agriculture.

Hungarian engineers assisting with the assembly of the extruder at the new Nongteng feedmill in Vientiane

Photo: HAKI

Thus, the development of industrial feed manufacturing for fish, poultry and pigs is a major component of the Hungarian project. The total project budget for the 18-year zero interest loan is $8.6 million of which about 60 percent is the feed component. Under the framework of the project, three feedmills are being built with production capacities of one to two tonnes per hour (see table below). The first feedmill in Vientiane was scheduled to open in the second half of August.

Three new feed mills

Location		Capacity	
		Fish	Pig/poultry
1	Nongteng (Vientiane)	1 t/h	2 t/h
2	Naluang (Luang Prabang)	1 t/h	—
3	Namtouan (Luang Prabang)	—	2 t/h

Since the feed component is the major element of the tied aid project, the main Hungarian contractor is Vitafort, one of the leading feed producers in Hungary (under the terms of the tied loan, at least 50 percent of goods and services must come from Hungary). The local partner of Vitafort is NAFRI under the Lao Ministry of Agriculture and Forestry which is responsible for implementing the project. The feedmills have been designed by Hungarian engineers who took into account the results and experiences in operating a similar feedmill in Cai Be in Viet Nam which was built under a Hungarian Development Assistance Cooperation Programme (see previous article). Most of the special equipment (pre mixer, automatic scale, hammer mill, paddle mixer, pellet press line with cooler, extruder line with dryer, and cooler, steam boiler with water treatment system) is supplied by Hungary. The feedmills in Nongteng and Naluang also include extruder lines to produce floating feed for fish. Operation of the equipment in the modern mills is computer-controlled.

Nongteng feedmill under construction

Photo: HAKI

Hungarian-Lao-Vietnamese collaboration

The light-structure buildings and steel support frames for the equipment are being built by two Vietnamese companies that are also assembling the production line and installing the electrical system. Earth and concrete works are being executed by Lao companies. Construction works are continuously supervised by Hungarian experts who are also assisting in trial operations of the mills.

Under the project, the loan is provided by the Hungarian government to the Lao government with long-term operation of the facilities based on a public-private partnership involving private entrepreneurs both from Lao PDR and Hungary. R&D institutions will also assist the efficient operation of the feed factories through the elaboration of feed formula and feeding technologies and also through advising farmers and providing training for them. Research Institute for Aquaculture No. 2 (RIA2) in Ho Chi Minh City, which oversees the Cai Be mill (see previous article), is also involved in the development work. RIA2 expert Dr Le Duc Trung assists the Hungarian engineers with his “tropical knowledge” and the Lao workers are trained at Cai Be.

The development of the feed production sector is a milestone in the agricultural development of Lao PDR, where animal feed supply has been based mainly on imports even though most feed ingredients are available locally. One of the goals of the agricultural strategy of Lao PDR is to develop the production of high-quality food from locally-made feed. Developing the feed production sector in Lao PDR contributes not only to the economic development of the country

Products from the RIA2 feedmill in Viet Nam, where Lao staff were trained in August

PHOTO: LEM SAMEAN

but also provides employment and contributes to improving the knowledge base and culture related to modern agriculture.

** Dr Váradi is director-general of the Research Institute for Fisheries, Aquaculture and Irrigation (HAKI) at Szarvas in southeastern Hungary. HAKI is the leading aquaculture research institute in Central and Eastern Europe, having been upgraded to an international aquaculture development centre under an FAO/UNDP project between 1975 and 1980. Since then, it has been regularly involved in aquaculture development programmes in Asia, mainly in Lao PDR and Viet Nam. The Hungarian research institute also serves as the coordinating body for the Network of Aquaculture Centres in Central and Eastern Europe (NACEE) founded by aquaculture institutes from Belarus, the Czech Republic, Hungary, Russia and Ukraine in 2003. The NACEE network now spans 15 countries including Bosnia Herzegovina, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Moldova, Montenegro, Poland and Romania.*

In terms of **effluent discharge,** farmed **catfish** seem to **compare favourably** with **other** cultured **species**

An international study analyses fish feeds used by catfish farms to estimate how much nitrogen and phosphorous they discharge into the Mekong Delta. Despite the rapid expansion of catfish farming in recent years, the environmental impact is found to be relatively minor.

Dealing with effluent discharge is one of the biggest long-term challenges for the catfish farming sector in the Mekong Delta (see *Catch and Culture*, Vol 15, No 2). But how much effluent is being discharged every year and how does farmed catfish compare with other cultured species in terms of its environmental impact? A recent international study* has estimated the amount of nitrogen and phosphorous in effluent waters by analysing the feeds used in the farming of Sutchi river catfish (*Pangasianodon hypophthalmus*), the most widely farmed species in the delta.

'The median phosphorous discharge level is considerably lower for commercial feeds than for home-made feeds'

Part of a project funded through the Collaboration for Agriculture and Rural Development (CARD) programme of the Australian Agency for International Development (see box), the study randomly chose 12 samples of commercial feed pellets. These came from six relatively large manufacturers each producing more than 200 tonnes of feed a year. The study also looked at four samples of farm-made feeds that use local ingredients such as dried fish powder, rice bran and soybean meal, although the study noted only about 3 percent of farmers use such feeds today. Almost half of these feeds are produced on site with the rest being bought from other farms.

Better management practices

The CARD project is designed to develop better management practices for catfish farmers in the Mekong Delta to enhance overall economic and environmental sustainability. Improved on-site management of catfish effluent by farmers to reduce broader off-site environmental impacts within the delta forms the basis of new draft practices under trial by farmers in the delta. Results of these trials and final recommendations for better management practices will be presented to stakeholders at a national workshop in Long Xuyen in November.

The results of the analysis, published by the Royal Swedish Academy of Sciences in July, show that the median nitrogen discharge levels are similar for commercial and farm-made feeds at around 46 or 47 kg per tonne. But at around 14 kg per tonne, the median phosphorous discharge level is considerably lower for commercial feeds than for home-made feeds which is more than 18 kilograms per tonne. Based on the median levels for commercial feed, catfish farming in the Mekong Delta would have discharged more than 31,000 tonnes of nitrogen and almost 10,000 tonnes of phosphorous in 2007 when catfish production came to almost 700 tonnes. When production rose to almost 1.1 million tonnes in 2008, the sector would have discharged more than 50,000 tonnes of nitrogen and almost 16,000 tonnes of phosphorous. However, the amount of effluent from the catfish sector may be "substantially lower" since not all nitrogen and phosphorous is discharged directly into the Mekong

Special Insert

Catch and Culture

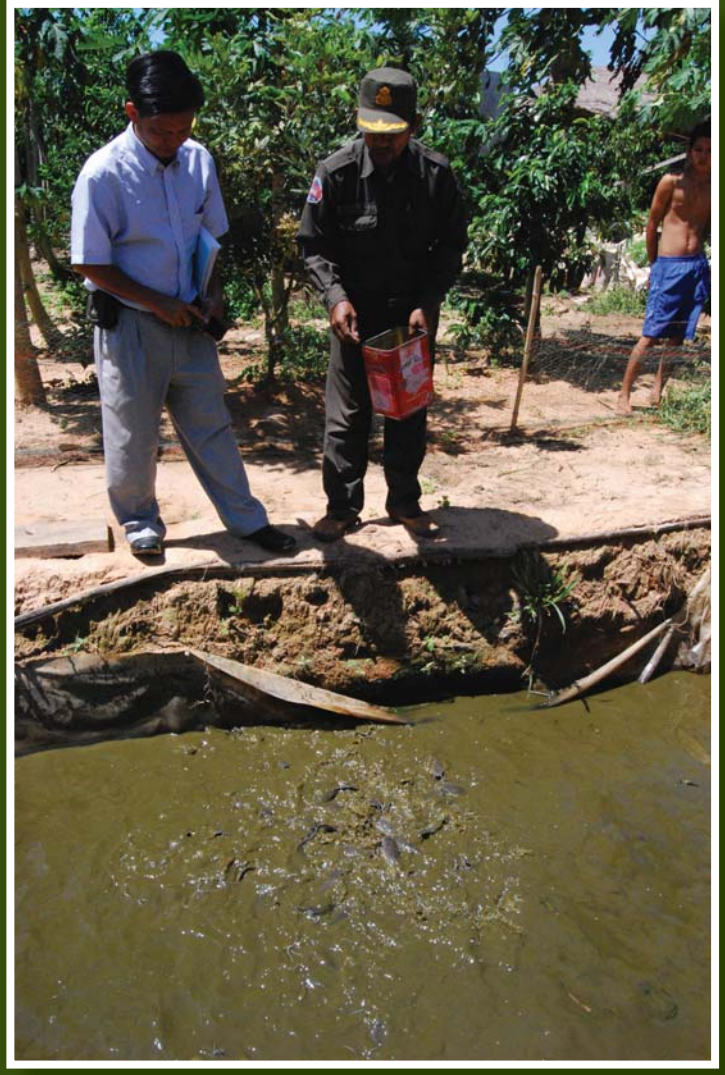
Promoting Aquaculture for Disabled Veterans

In April this year, Cambodian Prime Minister Hun Sen ordered the Ministry of Agriculture Forestry and Fisheries to promote small-scale aquaculture as a family business, especially in areas that lack fish. One such area is the Taken Koh Sla Military Handicapped Development Zone in Kompong Speu province. Located on a plateau half way between Phnom Penh and Sihanoukville, the 700 hectare zone was established in 2007 at the initiative of the prime minister who also chairs the Cambodian Veterans Association. Today, it has 400 families which have each been allocated brick houses and 1.5 hectares of land. To help supplement their modest military pensions, Cambodia's Fisheries Administration has been promoting small-scale culture of air-breathing catfishes from the *Clarias* genus of walking catfishes, known as *trey andaing* in Khmer. But as Samdech Hun Sen noted during a visit in March, "we have a major problem here for water as this is a place not for rice cultivation but legume and fruit tree cultivation." To improve water supplies, he ordered the Ministry of Industry, Mines and Energy to take action in cooperation with military engineers. The zone currently has only three natural ponds and a small rain-fed reservoir for drinking water. A stream running though the area was virtually dry at the height of the wet season in August.

Photos: Lem Chamnap and Cambodia New Vision

Lieutenant-Colonel Khem Sary (left), who narrowly escaped death after being shot through the chest in Pursat province in 1982, has been raising walking catfishes since before the zone was established. He now has six small ponds of 8m² and 12m² which he dug himself and lined with plastic sheeting supplied by the government. The ponds, which are only 1m deep, are stocked with hybrids of bighead walking catfish and African catfish (*Clarias gariepinus* male x *Clarias macrocephalus* female) supplied by the fisheries cantonment office in Sihanoukville province. The war veteran also buys fingerlings from a private hatchery in Takeo province which he sells to other farmers. These sometimes include individuals that are pure African catfish, a species introduced into Viet Nam from the Central African Republic in 1974 which is now established in the wild throughout the Lower Mekong Basin. Consumers prefer the hybrid which doesn't grow as fast the alien species but has more flesh. Both are highly tolerant of poor water quality and thus highly suited to the dry conditions of Takeo Koh Sla.

Photos: Lem Chamnap



In addition to the lack of water, feed is the second big constraint to aquaculture at Taken Koh Sla. While farmers used to feed their fish with termites, this resource has been depleted. Lt-Col Khem Sary now uses commercial feed, spending about KHR 700,000 ($160) for each three-month production cycle. Stocked with 400 fingerlings, the smaller ponds typically yield about 50 kg each after three months, excluding fish that are consumed by the soldier, his wife and two children. The larger ponds are stocked with 600 fingerlings, yielding about 80 kg. Commercial feeds may be expensive, but they significantly effect growth. Chum Chin (below), whose husband sustained a head injury during the war, has 12 small ponds at Taken Koh Sla. She uses rice and kitchen scraps as feed but says each pond yields less than 10 kg after three months. The wholesale price of walking catfish at a nearby market is about KHR 6,000 riel ($1.45) a kilogram.

Photos: Lem Chamnap

With the aim of supplying fingerlings to other farmers, Lt-Col Khem Sary has recently built a hatchery with assistance from the Fisheries Administration. It wasn't functioning yet in August as the new tank was still dry. While he has access to the nearby reservoir, his gasoline pump is not powerful enough so he is saving to buy a larger diesel pump of 25 horsepower for around $500. In the meantime, he has bought two calves for $200 each to start culturing earthworms from manure to reduce feed costs. The idea is to use ground dried worms as hatchling feed when the hatchery starts operating. In an address to military veterans in June, Samdech Hun Sen noted that Cambodia had more than 90,000 veterans with some 260,000 dependants. Government expenditure on veterans comes to KHR 6.4 billion ($1.5 million) a month, which averages out at less than $17 for each family.

Photos: Lem Chamnap

River. Some farms, for example, discharge water via sludge ponds from which nutrient-rich sludge is subsequently used to fertilise adjacent agricultural production. Wastewater is also often discharged directly onto rice fields or gardens.

Scope for improving feed

The discharge estimates are based on a feed conversion ratio (FCR) of 1.69 for commercial pellets, considered the average for the catfish farming sector (and meaning that 1.69 kg of feed is required to produce 1 kg of fish). The study notes that commercial feed ratios in the delta appear to be generally higher, and therefore less efficient, than ratios for other well-established fin fish farming systems. They are also highly variable, from 1 to 3, indicating that refining feed formulations and improving feeding practices—to reduce wastage, for example—may lower the FCR in catfish farming and thereby reduce nutrient loadings in effluent water. The study also took into account the existing feeding practices in the sector, for example the different protein content of the feeds used at different stages of the growth cycle, as well as the feeding intensities.

'Catfish fed on commercial feed discharged significantly less nitrogen than six other species reared in cages or ponds that were fed on both commercial and other feeds'

Regardless of the type of feed used, one of the major findings of the study is that catfish farming in the Mekong Delta "compares favourably" with the culture of other species in terms of nitrogen and phosphorous discharge.

For nitrogen, Sutchi river catfish fed on commercial feed discharged significantly less than six other species reared in cages or ponds that were fed on both commercial and other feeds. With nitrogen discharges ranging from 33 to 70 kg per tonne, the Mekong species also compared well with common carp (*Cyprinus carpio*), with a range of 31 to 86 kg a tonne, and rainbow trout (*Oncorhynchus mykiss*), with discharges ranging from 47 to 71 kg per tonne.

For phosphorous discharges, fewer comparisons with other species were available. Discharges ranged from about 10 to 20 kg per tonne for Sutchi river catfish fed with commercial feed. This was the below the ranges for silver perch (*Bidyanus bidyanus*) as well as channel catfish (*Ictalurus punctatus*) and blunt snout bream (*Megalobrama amblycephala*). Among other species, phosphorous discharges ranged from almost 7 to 24 kg per tonne in the case of rainbow trout and from about 9 to 26 kg per tonne in the case of common carp.

The authors suggest that the favourable comparisons may be due to the relatively high feed efficiency of Sutchi river catfish, and the generally lower protein and higher carbohydrate content of catfish diets compared with other species. The study also highlights earlier research showing that the nitrogen content of Sutchi river catfish is only 1.8 percent of wet weight compared with 2.2 to 3.4 percent in other species. Phosphorous content is also lower at 0.21 percent compared with 0.39 to 1.20 percent in other species.

Mitigating climate change?

The study concludes that the catfish farming sector in the Mekong Delta is "currently responsible for relatively minor environmental impacts" in terms of nitrogen and phosphorous discharge within the catchment as a whole. In addition to its enormous socio-economic importance to the region, the industry may also help mitigate climate change. With the Mekong having the 10th highest flushing rate of all rivers in the world, the study notes it's conceivable that nutrients discharged are carried out into the South China Sea rapidly, enriching the immediate waters. Studies on the Amazon show that nutrient discharges from rivers can enhance carbon sequestration (essentially a process of removing carbon from the atmosphere and depositing it in a "reservoir") through enhanced diazotrophy—the accelerated growth of diatoms and subsequent sinking of these organisms with a carbon skeleton to the sea bottom. So in the long run, the authors conclude, catfish farming in the Mekong Delta could likewise help to sequester "significant quantities" of carbon.

* De Silva SS, Ingram BA, Nguyen PT, Bui MT, Gooley GT, Turchini GM (2010) Estimation of nitrogen and phosphorous in effluent from the striped catfish farming sector in the Mekong Delta, Viet Nam, AMBIO 39(7): 504-514.

Export **ambitions** in aquarium trade lead to **new** Vietnamese **research** into **koi**

By Peter Starr *

In recent years, koi have become popular in the Vietnamese aquarium fish trade. With the aim of boosting exports, the government is now setting its sights on the global market for these high-value varieties of common carp.

As part of Vietnamese government research into reproduction and grow-out techniques for exports of high-value aquarium fishes, Research Institute No. 2 (RIA2) in Ho Chi Minh City has been conducting genetic experiments on ornamental varieties of common carp (*Cyprinus carpio*) since 2008. Originally developed in China and now widely known as koi, the Japanese name for the fish, the carp are bred for their colours, patterns and shape. Koi are widely sought by collectors worldwide and often command premium prices (see *Catch and Culture*, Vol 16, No 1). Under the RIA2 project, the desired colour traits are red, black and white fish, pure red or white fish and either red fish with white markings or white fish with red markings. The project, which is being carried out at the National Breeding Centre for Southern Freshwater Aquaculture in Cai Be in Tien Giang province in the Mekong Delta, began with the purchase of 26 broodstock of about 1 kg, including 16 fish from Singapore which together cost $8,000. The other koi were acquired from Ho Chi Minh City for less than $20 each. By the end of 2010, the project aims to have produced 10,000 individuals at least 8 cm long as well as 100 broodstock.

Like a virgin

The experiments conducted by RIA2 involve gynogenesis, a form of asexual reproduction found in

Ornamental carp on display at the Viet Nam Fisheries Festival in Can Tho In April

Photo: Trinh Quoc Trong

reptiles, amphibians and teleost fishes (most ray-finned species) in which offspring inherit maternal genes only. The term is derived from the Greek words for "female" and "creation". Induced gynogenesis in fishes dates back to the mid-20th century. Research initially focussed on shocking fish eggs with chilled water to suppress meiosis, a type of cell division that results in two cells each with half the number of chromosomes of the parent cell, to produce embryos with two complete sets of chromosomes which are known as diploids. The technique, known as meiotic gynogenesis, has been refined over the past 30 years following ground-breaking work by George Streisinger, the late Hungarian-born geneticist at the University of Oregon. Experimenting with zebra fish (*Brachydanio rerio*), he pioneered mitotic gynogenesis whereby diploids are produced by inhibiting mitosis, the type of cell division that results in two cells each with the same number of chromosomes of the parent cell (rather than half as occurs with meiotic divisions). Such mitotic diploids are also known as "doubled haploids", indicating a double set of unpaired chromosomes, and have been a major focus of gynogenetic research in fisheries since Streisinger's research was published (see box next page).

Female koi grow faster than males and are preferred by consumers so gynogenesis is a useful technique for breeding ornamental carp since offspring are usually all-female. The parameters for the technique used by Vietnamese researchers have been developed taking into account several comments from Boris Komelsky of Kentucky State University, who researched gynogenesis in common carp in Viet Nam two decades ago while working at the Tropical Centre of the Soviet Academy of Sciences. The process itself takes less than an hour and is remarkably simple. At first, sperm from male koi are removed with a syringe and put on ice. To reduce the density, the sperm are then diluted with a saline solution and irradiated with an ultra-violet lamp which destroys the paternal DNA. Eggs from females are then fertilised with the irradiated sperm, which triggers the development of the eggs. The fertilised eggs are then placed in a bath of warm water, which inhibits mitosis through heat shock, before being transferred to an incubator.

Refining the parameters

The team conducting the experiments includes RIA2 deputy director Nguyen Van Sang as project leader, Trinh Quoc Trong, the deputy director of the Cai Be breeding centre, and technician Trinh Quang Son.

Collecting the sperm

Photo: Trinh Quoc Trong

Ultra-violet lamps used to irradiate the sperm

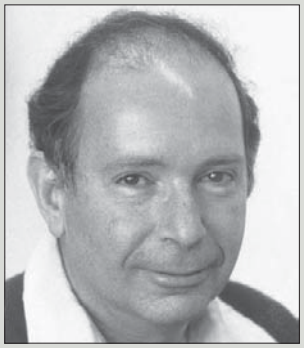
Photo: Trinh Quoc Trong

Stripping the eggs

Photo: Trinh Quoc Trong

Shock and awe

In 1981, the scientific journal *Nature* published a ground-breaking paper by George Streisinger on cloning zebra fish (*Danio rerio*) from pure strains of the popular aquarium species that he obtained from Hong Kong and India. The publication by the University of Oregon geneticist triggered widespread research into the production of doubled haploid fish through gynogenesis and later androgenesis, where offspring inherit the paternal genes only. To mark the 25th anniversary of the publication, Hans Komen of Wageningen University in the Netherlands and Gary Thorgaard of Washington State University carried out a review* of this research in 2006 that was subsequently published by *Aquaculture* in 2007.



Dr Streisinger

Photo: University of Oregon

Their paper contained a summary of the fish species for which gynogenetic or androgenetic doubled haploids had been produced since 1981. Among the two dozen species reviewed, most were carps (Cyprinidae) or salmonids (Salmonidae) including several alien species that are now established in the Lower Mekong Basin such as the common carp (*Cyprinus carpio*) and the grass carp (*Ctenopharyngodon idellus*). Among other freshwater families, doubled haploid fishes produced included the Siamese fighting fish (*Betta splendens*), which is native to the Mekong, as well as African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromus niloticus*), another two species that have been introduced to the basin.

Of the 40 research papers cited, 25 involved gynogenesis and 15 androgenesis. In the first step of the process, ultra-violet irradiation was the most common method of destroying the DNA of the sperm in gynogenesis although gamma irradiation was also used in some cases. Experiments involving androgenesis used both forms of irradiation as well as x-rays to destroy the DNA of the egg. In the second step, after fertilisation takes place, genome duplication was achieved by either shocking the fertilised eggs with hot water or subjecting them to pressure shocks.

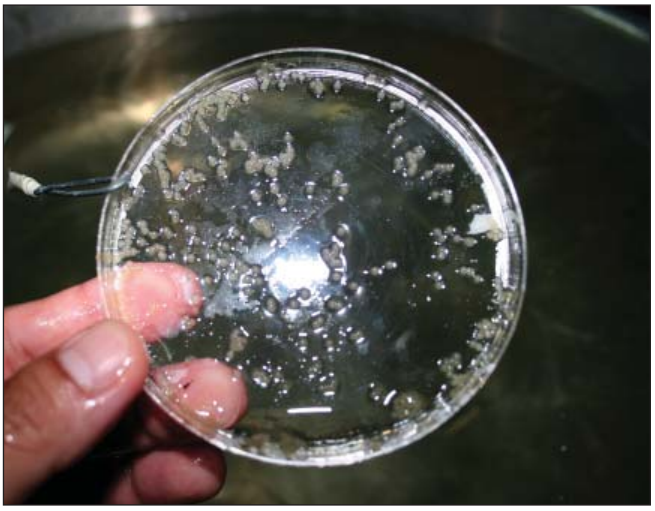
Among the papers reviewed, only one dealt with ornamental carp. In this case, the koi sperm were irradiated with ultra-violet light and the fertilised eggs shocked with hot water at 40 degrees for periods of two to three minutes. Yields of hatched fry were eight percent. Among the four experiments using regular common carp, two involved gynogenesis and two androgenesis. Gynogenetic research by Komen himself, whose findings were published in 1991, yielded hatched fry of almost 16 percent using ultra-violet irradiation of sperm with hot-water shocks of 40 degrees lasting two minutes. Of the two other gynogenesis experiments with common carp, one using gamma radiation yielded almost 11 percent with a 40 degree shock lasting one and a half minutes. The other, which used ultra-violet irradiation, achieved a hatched fry yield of almost 20 percent with a heat shock of the same temperature lasting two minutes.

According to Komen and Thorgaard, increasing the extremely low yields of doubled haploids in a variety of fish species was the biggest challenge after 25 years of research. “Heat and pressure shocks are easy to apply, but have wide ranging, undesirable side-effects on embryo development. Clearly, more research and innovative approaches are needed,” they concluded. As for Dr Streisinger’s contribution to science, “perhaps the biggest lesson is the importance of time, patience and continuity for maintaining clonal lines if this approach is to see more widespread use.” Streisinger himself got to see little of the substantial amount of research his paper triggered. Three years after it was published, the molecular biologist died while scuba diving off the coast of Oregon. He was 56.

* Komen, H and Thorgaard, G (2007) Androgenesis, gynogenesis and the production of clones in fishes: a review. Aquaculture 269: 150-173.

Further reading:

http://www.neuro.uoregon.edu/k12/george_streisinger.html



Eggs fertilised by irradiated sperm

PHOTO: TRINH QUOC TRONG

According to Mr Trong, the project had produced 8,000 koi as of July, or 80 percent of the year-end target, using both gynogenetic and regular breeding techniques. For those produced through gynogenesis, "our fertilisation and hatchery rates are still very low so we have a lot of work to do," Mr Trong said. On the other hand, survival rates of gynogenetic fish are typically higher than those produced through regular breeding of ornamental carp, where as little as 0.1 percent of offspring inherit the colour, pattern and shape traits being sought by koi breeders. For now, the project is refining the parameters of the experiments conducted so far. According to Mr Trong, the most important is the dilution rate of the sodium chloride solution which allows the sperm to be irradiated more evenly. This has been narrowed to 1:20, 1:40 and 1:80. Next comes the intensity of the ultra-violet irradiation, also known as radiant incidence. In the experiments carried out in Cai Be, researchers have used a wave length of 254 nanometres on the lamp, the wave length most commonly used in gynogenesis. The parameters for radiant incidence, which are adjusted by a radiometer, were 250, 500 and 750 microwatts per square centimetre as of July with irradiation lasting from 8 to 10 to 15 minutes. The next most important parameter is the time between insemination and the warm water bath, which has been narrowed to 1.5 and 2.0 minutes. While the water temperature is constant at 40.2 degrees, the duration of the shock now varies from 1.5 to 2.0 to 2.5 minutes.

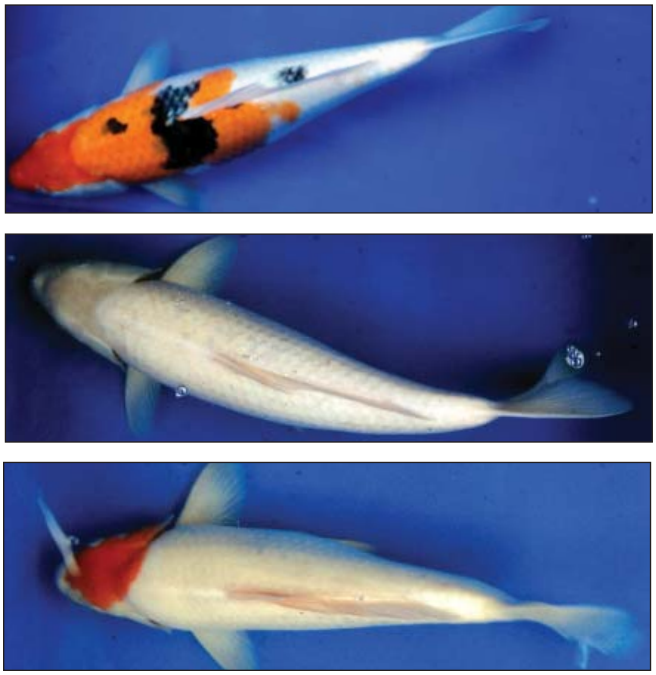
Incubators used for hatching ornamental carp at the National Breeding Centre for Southern Freshwater Aquaculture in Cai Be

PHOTO: LEM SAMEAN

RIA2 technician Trinh Quang Son holding a dish with ornamental carp eggs that have been fertilised with irradiated sperm

PHOTO: LEM SAMEAN

While the colour of the offspring is known within two days, Mr Trong says it takes from five to six months to know the sex of the fish. Dutch geneticist Hans Komen has noted that sex reversal, which is known to have occurred in at least one case involving a cross between wild and domesticated strains of common carp, may be caused by a mutation. In this particular case, which was documented by Komen in 1992, there were equal numbers of males and females. Cloned carp with this mutation have since been found to be suffering from adrenal hyperplasia, a condition that masculinises external female genitalia in humans. In gynogenetic research carried out by RIA2 more than a decade ago into silver barb (*Barbonymus gonionotus*), a popular food fish native to the Mekong region, 93 percent of the fish produced were female and the remaining 7 percent either male or unidentified. Scientists attributed the presence of males to inadequate security that allowed wild silver barbs to enter the ponds while water was being changed.



Three of the desired colour traits are red black and white (top), pure white (middle) and white with red markings (bottom)

PHOTO: TRINH QUANG SON

Sixth meeting of Mekong **giant catfish** working group held in Thailand

By Naruepon Sukumasavin *

The Mekong Giant Catfish Working Group consists of scientists from various organisations working in the Mekong River Basin. It meets to coordinate research activities, synthesise information and develop the conservation strategy for the species. The working group meets roughly once a year to update the information and offer recommendations for research and policy development to support the management of the giant catfish, especially on the maximum catch number according to a population quantitative assessment model. Recommendations are disseminated to relevant agencies for consideration in the implementation of national policy. They are also disseminated to the Technical Advisory Body (TAB) for Fisheries Management of the MRC Fisheries Programme. The sixth working group meeting was held on April 29 in Chiang Khong, Thailand.

ISSUES DISCUSSED

Institutional and financial needs to set up a formal monitoring system to document incidental catches of the Mekong giant catfish (*Pangasianodon gigas*) in Thailand, Lao PDR and Cambodia. It has been recognised that the system for reporting incidental catches can be strengthened by clarifying the role of technical agencies at district, provincial and national levels. It should also be determined if incidental catch monitoring can be improved by including further efforts in other locations. The technical and financial support for this should be determined to support national agencies. Improved collection and reporting of incidental catches will support the use of the population model and understanding of the recovery of the wild population.

Female Mekong giant catfish caught by Chiang Khong fishermen
PHOTO: CHIANG RAI FISHERIES STATION

Considerable confusion between authorities and fishermen in Chiang Rai and Bokeo in 2009. This was the result of poor understanding and communication of the process to approve fishing for giant catfish in both countries. The Thai authorities authorised special licenses to catch a maximum of two giant catfish by fishers from Chiang Khong. The Lao authorities in Bokeo, however, did not authorise any fishing for the giant catfish due to the critically-endangered status of the species which is protected under Lao law. The authorities in Bokeo requested the Thai authorities to intervene and stop all fishing. Shortly after this request was made, the Thai authorities cancelled the licenses for Chiang Khong fishermen to catch giant catfish (although one female was captured during this period). This cancellation caused considerable confusion among authorities and fishermen in Chiang Rai and Chiang Khong about the correct procedure for issuing approval to fish for the giant catfish during the spawning period of the dry season. The process to approve any quotas or moratorium on fishing must be clarified between the two countries at the national, provincial and district level.

Female giant catfish being landed in Chiang Kong earlier this year
PHOTO: CHIANG RAI FISHERIES STATION

The role of each organisation (national agencies, WWF, MRC, TAB) in the management of the species. This served to alleviate previous confusion at the provincial level about the composition of the working group and the purpose of the recommendations to policy makers.

Data from Cambodia of the Dai # 2 operator in the Tonle Sap River shows that 70% of the known catch of Mekong giant catfish in Cambodia is from this single operator. Furthermore, the data shows that 80% of the bycatch occurs in November. It was discussed whether the operation of this dai should be adjusted to reduce the amount of by catch by closing this operation until December. It was also strongly recommended by the working group that any bycatch in Cambodia must have fin clip samples taken for aging the fish and studying the genetics.The presentation of Cambodian work concluded that due to poor handling of bycatch, more than 50% of tagged Mekong giant catfish died shortly after being released back into the river. Greater effort has been made to improve handling of the fish during tag and release to decrease this mortality rate and aid in the recovery of the population and monitoring of tagged fish. Cambodian researchers have been involved in tagging and releasing bycatch for about 10 years. A total of 84 individuals have been tagged but no fish have been recaptured to date. A new method of tagging the fish is now being used to improve research methods to monitor these tagged fish.

Genetic study: 2 populations or a single population above and below Khone Falls? There remains debate whether there are two populations separated by the Khone Falls. Genetic information suggests a single population with the hypothesis that mature fish are migrating to spawning grounds in the Chiang Khong–Houayxai area, and fry and fingerling are drifting downstream to Cambodia.

There needs to be greater effort on morphology research. This would help to understand current distribution, migration and drift during various stages of development (larvae, fry, fingerling, juvenile, adult). There is also a need for increased capacity of fisheries agencies to identify the morphological characteristics of the species. A morphological key (in English and/or national language) would help fisheries researchers to develop this capacity.

Spawning site identification research, place and time. WWF and the Thai Department of Fisheries are collaborating on ichthyoplankton research to find egg, larvae or fry in the Chiang Khong–Houayxai area. In 2010, this will be the third year running that this type of research has been conducted. No samples have been collected to date. The working group provided advice to the research team on possible adjustments to be made to the sampling location and time in order to improve the methodology for collecting samples. This research aims to positively identify spawning habitat locations in the Mekong River.

RESOLUTIONS

The working group coordinator will be the focal point for collecting catch numbers, in order to avoid the missing information. The information should be clarified by the national line agencies in each country.

According to the model and the catches reported by Cambodia, the working group recommends that the catching quota for Chiang Khong–Houayxai should be less than 5 fish. However, the two provinces have agreed not to catch any fish this year.

The rationale to set provincial limits on fishing has not come from scientific recommendations based upon the population assessment model produced by the working group. The group should work to disseminate the information in the model to their organisations.

The working group realises that the meeting is a good time to update the model with all new information provided by the members to make it a more useful tool for making policy recommendations on allowable catch. The model is also undergoing a peer review process led by the principle author Kai Lorenzen, which would serve to verify the application of this model in setting catch limits on Mekong giant catfish across the Mekong Basin.

The meeting agrees that more basin-wide research should be done for monitoring catch (incidental or targeted catch) and possible spawning sites, not only between Chiang Khong and Houayxai. This research should also include the genetic and morphological studies to produce tools for identifying the species at different stages of growth and development (i.e. taxonomic keys for identifying larvae and fingerlings). It is recommended that the coordinator and representatives from the 4 line agencies work together to produce a proposal and submit to MRC Fisheries Programme and other donors. Much of this information on taxonomic keys for fingerlings already exists but would need to be translated from Thai into English or Khmer.

To closely monitor the change of the population, the working group recommends that greater effort must be made to monitor the basin-wide catch of the Mekong giant catfish. This data is important for improving the population assessment model. Not only is it important that this catch data be documented, but the communication of this data within and between fisheries agencies must be improved. Currently, there remains uncertainty over the correct procedure for reporting catches by fisheries technicians at the district, provincial and national levels. This leads to uncertainty in our understanding of the actual number captured each year, and whether the total catch for the entire basin is less than the 10 fish recommended by the population assessment model.

Research on identification of spawning ground. The targeted sampling site should possibly be Ban Pak Ing with more effort on frequency and sampling time.

The working group agrees to explore the management approaches to deal with the issue of the very high incidental catch at Dai # 2, particularly in November. When incidental catches do occur (for example, in the dai traps of Cambodia or the li traps in Siphandone), fisheries staff must collect and record catch information such as length, weight and sex, and collect genetic material for analysis. This type of monitoring programme requires regional support to assist national agencies to improve monitoring efforts. Support includes discussion with technical staff about the objectives of this monitoring programme, roles and responsibilities in reporting any catch, and proper techniques for collecting genetic material.

** Dr Naruepon is director of the Information Technology Centre of the Thai Department of Fisheries and also the coordinator of the Mekong Giant Catfish Working Group.*

Fishermen with their catch

Photo: Chiang Rai Fisheries Station

A **restaurant** with **rods**, a **garden** of **dreams**

Weekend getaways with recreational fishing are drawing big crowds of young city dwellers in Viet Nam and Cambodia.

HO CHI MINH CITY, VIET NAM: Nguyen Hai Tuan says he got the idea for a restaurant where diners could fish for their own meals when he was working in the forestry sector in the Central Highlands of Viet Nam and the Mekong Delta. “I used to go everywhere and see restaurants with cabins over the water. But the customers could only eat and not fish themselves,” he recalls. Today, Mr Tuan presides over a 500-seat restaurant with 40 cabins over a large fish pond where customers have the option of catching their own lunch or dinner. Established by his family 15 years ago, Thu Nga 1 Restaurant and Fish Pond is located on a canal about 200 metres from the Saigon River in Binh Thanh District of Ho Chi Minh City, just a few kilometres upstream from the centre of town. Surrounded by coconut palms, the once-rural area is a popular getaway resort for locals on weekends, although road access is somewhat difficult by car.

Former rice fields

“It was difficult when we set up as there were rice fields here then,” Mr Tuan says. “We could not use trucks so we had to do all the excavation by hand.” Today, the focal point of the 0.5 hectare site is a fish pond of about 5,000 cubic metres and 1.8 metres deep stocked with several native Mekong species, notably gouramies, catfishes and snakeheads. The most common are giant gouramies (*Osphronemus goramy*), kissing gouramies (*Helostoma temminkii*), Sutchi river catfish (*Pangasianodon hypophthalmus*), walking catfish (*Clarias batrachus*) and striped snakeheads (*Channa striata*). The pond is also stocked with Nile tilapia (*Oreochromis niloticus*), an introduced species now widely farmed in the Lower Mekong Basin. Stocking sizes are usually between 1-2 kg and fish are obtained from farms in the Mekong Delta province of Tien Giang or Dong Nai province northeast of Ho Chi Minh City.

Mr Tuan

Photo: Lem Chamnap

Unlike some recreational fishing facilities, Thu Nga 1 does not charge customers by the amount of time spent fishing. If they feel the urge, restaurant customers simply request a rod with a hook and bait for a modest fee of VND 5,000 ($0.25) and pay nothing more unless they catch a fish. When a fish is caught, staff weigh it and charge the customer at a rate of VND 60,000 ($3) a kilo. The customer then chooses whether to have the fish cooked at the restaurant for VND 40,000 ($2) or to take it to cook at home. “Some people catch fish too big to take home,” Mr Tuan says, noting that the pond contains Sutchi river catfish weighing as much as 10 kg. In such cases, the customer still has to pay for the fish caught in which case it’s usually cooked on site for the 24 staff members to share.

Vietnamese relaxing at the Thu Nga 1 Restaurant and Fish Pond on a Saturday afternoon

Photo: Lem Chamnap

Popular with young people

Mr Tuan says he has about 10 competitors in the area, although most are just renting the land and don't own it outright like his family company. "We're not the biggest but we're the most popular with customers," the manager says, noting that the family also owns a popular regular restaurant in Ho Chi Minh City. Mr Tuan says Sunday is usually the best day for business, and that the periods just before and after the Lunar New Year in January or February are the most popular time of year. When *Catch and Culture* first visited on a Saturday lunchtime in April, the parking lot appeared full with hundreds of motorcycles but only two cars. Mr Tuan says Thu Nga 1 is especially popular with young Vietnamese. "Foreigners sometimes come but they're usually long-term residents rather than tourists," Mr Tuan says. "Japanese, Koreans and Chinese come and spend a lot of money. But Europeans and Americans are very tight and sometimes we get backpackers arriving by bicycle who buy only one drink. " When *Catch and Culture* returned in June with a senior European delegate from the World Economic

Recreational fishing is also popular among women

Photo: Lem Chamnap

Forum conference that was then taking place in Ho Chi Minh City, we tried to dispel the bad image by ordering a very large giant gourami and lots of other dishes. But we didn't catch any fish.

Thuy Nga 1 is located at 558/12 Binh Quoi Street, P 28, Binh Thanh District, Ho Chi Minh City, about 15 minutes from the centre of town depending on traffic. Tel: 3898-6239 and 3556-2351. Mobile: 0918-171-061.

* * *

KIEN SVAY DISTRICT, CAMBODIA: When his father acquired the three-hectare block of land near Phnom Penh a decade ago, the lake that occupied most of the site was already stocked with catopas (*Pristolepis fasciata*) and striped snakeheads. (*Channa striata*). Sok David recalls that the subsequent massive earthworks, including the construction of dykes and levees and the planting of trees, involved thousands of truckloads of soil. Today, Soun Soben Resort just outside of Phnom Penh is divided into three ponds up to 11 metres deep. The ponds are connected by shaded walkways and bridges, interspersed with concrete nagas, garudas and other mythical beings. Peacocks, turkeys and even a deer roam freely around

Mr Sok David

Photo: Lem Chamnap

Landing a Sutchi river catfish at the Soun Soben Resort

Photo: Lem Chamnap

Part of the hidden harvest

Along with subsistence fisheries, recreational fisheries feature prominently in *The Hidden Harvests*, a joint study by the World Bank, the Food and Agriculture Organization (FAO) of the United Nations and the World Fish Center released in June. The study includes specific recommendations to national fisheries authorities such as reinforcing collaboration with tourism authorities and angler associations to evaluate and manage recreational fisheries. It also urges national statistics offices and fisheries agencies—in association with the development community—to improve data collection and reporting of fisheries-related economic activities, including specific attention to subsistence recreational fisheries.

"The food value of recreational fisheries should not be ignored—it extends into subsistence fisheries," the study says. "However, by their nature recreational fisheries overlap with both subsistence and commercial fisheries. They may compete with both and can exert significant pressure on the fishery resources giving rise to conflicts and policy issues. It means that all three activities must be responsibly managed and that the governance regime and allocation processes balance the competing needs of the interest groups and society." The study also notes that recreational fisheries provide governance arrangements with applications beyond these fisheries. These include indigenous people's rights over recreational fisheries, separation of angling and land rights, community leasing of water bodies, stock enhancement, licensing and levies, catch reporting, management cost recovery approaches and payments for ecosystem services.

The study estimates that angling provides recreation and food to about 220 million people and and contributes about $190 billion to the global economy. That compares with an estimated $274 billion for both marine and freshwater capture fisheries including post-harvest activities. In addition to its contribution to the global economy, the study finds "significant" employment generated by recreational fishing. In addition to their market valuation, society attributes additional non-market values to recreational fisheries. "While recreational fisheries tend to have a relatively greater importance in developed countries, rising incomes in developing countries provide opportunities to develop and sustain these fisheries and build on the links to tourism and other aquatic recreational activities." Indeed, the study notes that China has an estimated 90 million people whose hobby is fishing, an activity which is also promoted under the country's National Healthy Exercise Plan.

Further reading:
International Bank for Reconstruction and Development/World Bank (2010) The Hidden Harvests: the global contribution of capture fisheries, World Bank, Washington.

the resort. "My father always loved animals," says Mr Sok David, an American-educated Cambodian who is now director of the resort in Prek Eng commune in Kien Svay district of Kandal province, about 15 kilometres southeast of central Phnom Penh.

Native species

The ponds are stocked with more than a dozen species, mostly native Mekong fishes. Some of these are commonly used for stocking by fish farmers in Cambodia, notably the Sutchi river catfish *(Pangasianodon hypophthalmus)*, the bighead walking catfish (*Clarias macrocephalus*) and the silver barb (*Barbonymus gonionotus*). Other cyprinids include the small-scale river carp (*Cirrhinus microlepis*), Hoeven's carp (*Leptobarbus hoevenii*) and the beardless barb (*Cyclocheilichthys apogon*). The ponds are also stocked with moonlight gouramies, *(Trichogaster microlepis)* great white sheatfish (*Wallago attu*) and clown featherbacks (*Chitala ornata*). Apart from red tilapia hybrids, the main alien species are silver carp (*Hypophthalmicthys molitrix*) and bighead carp (*Hypophthalmicthys nobilis*).

Most of the fish are bought from the Vietnamese fish farms, nurseries and hatcheries which proliferate along the Tonle Sap River on the highway heading north out of Phnom Penh. The fish are fed twice a day on

The resort is a popular weekend getaway for Korean fishermen

Photo: Lem Chamnap

a simple diet of rice bran and bread. The ponds still contain the two original species from the lake although Mr Sok David concedes that the highly carnivorous snakeheads are problematic, as he found out recently when he stocked 3,000 juvenile red tilapias. “There’s only about a hundred left. They were wiped out by the snakeheads.”

Soun Soben, which means “dream garden” in Khmer, charges a flat fee of $3 an hour for fishing, regardless of whether people bring their own rods or use those provided by the resort. The fee covers whatever visitors catch, Mr Sok David says, noting that a competing recreational fishing ground near Phnom Penh charges the same amount for each kilogram caught. But he also expresses growing frustration with some of the more proficient anglers who use highly effective bait and take away huge catches. At the same time, the director reckons that only about 10 percent of customers have the patience to fish from the 70 bungalows dotted around the ponds. “The rest just sit around watching the other people fish,” he says.

Up to 4,500 people a day

In addition to a restaurant featuring snail and chicken specialities, Soun Soben has meeting facilities and also caters for parties and weddings. Most visitors are city dwellers, although some are also from Kien Svay which is increasingly resembling the outskirts of the capital these days with new housing developments changing what was once an exclusively rural area. “We can get up to 4,500 people a day like we did on New Year’s Day. But on a regular Sunday, it’s between about 300 and 500,” Mr Sok David says. Among foreigners, Koreans and Chinese are dominant, although there are also small numbers of Australians, Americans and French. The resort has about 30 employees. On busy days, however, the staff are complemented by local villagers. Is the business particularly profitable? “We break even,” the director says.

Soun Soben Resort is located at 321 Tiger Road, Prek Eng Commune, Kien Svay District, Kandal Province, about 15 minutes from the Monivong Bridge depending on traffic. Tel: 015: 233-344

Cambodian **fish yield** estimate rises in 2009

Deputy Prime Minister Bin Chhin (left) with Agriculture, Forestry and Fisheries Minister Chan Sarun (middle) and Fisheries Agency Director-General Nao Thuok (right) at the National Fish Day ceremony in Kampot province on July 1

PHOTO: LEM CHAMNAP

Cambodia's yield from freshwater capture fisheries came to an estimated 390,000 tonnes* last year, up from 365,000 tonnes in 2008. Speaking at the National Fish Day ceremony at Malech Reservoir in Kampot province on July 1, Agriculture, Forestry and Fisheries Minister Chan Sarun said aquaculture production rose to about 50,000 tonnes, up from 40,000 tonnes a year earlier. The yield from marine capture fisheries was estimated at 75,000 tonnes, boosting overall fisheries production to 515,000 tonnes, up from 471,000 tonnes.

Dr Chan Sarun said Cambodia now had more than 55,000 households farming fish and other aquatic animals such as frogs, crabs and shrimp as well as 225 hatcheries producing about 100 million fry a year. To promote the livelihoods of Cambodian soldiers, the minister noted that the Fisheries Administration was also supporting fish farming among military border units and at a centre for disabled war veterans (see special insert in this issue).

In terms of freshwater species, Dr Chan Sarun said catches of small cyprinids continued to decline in 2009. But yields were higher for bigger species in the shark catfish (Pangasiidae) and snakehead (Channidae) families as well as for Mekong giant barbs (*Cyclocheilichthys furcatus*), sailfin shark carp (*Labeo chrysophekadion*), great white sheatfish (*Wallago attu*) and clown featherbacks (*Chitala ornata*). In the absence of Prime Minister Hun Sen, who was recovering from influenza, this year's ceremony was presided over by Deputy Prime Minister Bin Chhin.

* Official estimates of fish catches are typically much lower than those based on field household surveys. See Coates D (2002) Inland capture fishery statistics of southeast Asia: current status and information needs. RAP Publication 2002/11: 1-114.

With **Phnom Penh** move, **fisheries programme** will return to **natural** home

MRC Chief Executive Officer Jeremy Bird (left), Cambodia National Mekong Committee Secretary-General Pich Dun (second from left), Water Resources and Meteorology Minister Lim Kean Hor (centre left), Environment Minister Mok Mareth (centre right) and Cambodia National Mekong Committee Vice Chairman Sin Niny (right) at the opening of the new Phnom Penh office on August 26

PHOTO: LEM SAMEAN

To avoid costly and disruptive rotations of the MRC secretariat every five years, the Lao and Cambodian capitals are now jointly hosting its various functions with the Fisheries Programme scheduled to move to Phnom Penh by the end of the year.

The Mekong River Commission inaugurated its second secretariat office in Phnom Penh on August 26, eight months after the four member governments decided to decentralise the organisation into two permanent locations rather than rotate the headquarters every five years.

Under the new arrangement, Phnom Penh is now home to two of the secretariat's divisions, those responsible for technical support and operations which include fisheries. In addition to the Regional Flood Management and Mitigation Centre established in 2008, the office also has representative staff of three sections responsible for finance and administration, international cooperation and communications and human resources. The secretariat's other two divisions, responsible for environment and planning, remain in Vientiane along with the chief executive officer and the three section heads.

The opening ceremony, which coincided with the twice-year meeting of senior officials from the MRC Joint Committee in Phnom Penh, was presided over by Cambodian Water Resources and Meteorology Minister Lim Kean Hor, the Cambodian member of the MRC Council, and Environment Minister Mok Mareth,

who serves as the country's alternate member.

In an address to government officials and other stakeholders who attended the opening, H.E. Lim Kean Hor said both countries and cities would benefit from the new co-hosting arrangement, describing Cambodian and Lao needs as being "proportionately more" than the commission's other two members, Thailand and Viet Nam. He also highlighted "strong geographical linkages" in some of the MRC's work, noting that Cambodia and the Mekong Delta in Viet Nam were historically likely to face more regular flooding than the northern part of the Lower Mekong Basin. "Similarly, the proportion of people that rely on the vast Mekong fishery for their main source of protein is higher in the southern part of the basin than further north," the minister said.

MRC Chief Executive Officer Jeremy Bird expressed similar remarks. "Fisheries in Cambodia and the Tonle Sap are very significant for the basin so their natural home is in Phnom Penh with many other sector programmes," he said. In addition to the Flood Management and Mitigation Programme, these include the Navigation Programme, the Agriculture and Irrigation Programme and the Information and Knowledge Management Programme. While member countries took time to agree to the specifics of the new arrangement, Mr Bird noted that this had been the case with other regional institutions including in Europe, where the European Parliament is co-hosted by Strasbourg and Brussels with its secretariat located in Luxembourg and Brussels.

Following its establishment in 1995, the MRC secretariat moved from Bangkok to Phnom Penh in 1998 and then to Vientiane in 2004 under a five-year rotation agreement until a permanent home could be found. In 2007, the agreement was revised in favour of a co-hosting arrangement to reduce the costs and disruption of relocating more than 150 staff every five years. The new secretariat office is located on the Bassac River in a building originally constructed with Japanese assistance for the regional flood centre. The Fisheries Programme plans to move into the expanded building in December. The new office is close to the former headquarters of the secretariat, which now houses the Tonle Sap Basin Authority established in 2007 (see *Catch and Culture*, Vol 14, No 3).

Senior officials endorse MRC Fisheries Programme from 2011 to 2015

Senior officials from Cambodia, Lao PDR, Thailand and Viet Nam have endorsed in principle the programme document for the Third Phase of the MRC Fisheries Programme from 2011 to 2015. The endorsement, made during a meeting of the MRC Joint Committee in Phnom Penh in August, followed a 16-month formulation period in which more than 350 stakeholders were consulted (see *Catch and Culture,* Vol 16, No 1). The new phase is budgeted at $12.5 million including $10.8 million in international contributions. As of August, Danish International Development Assistance (Danida) had pledged $5 million while Swedish International Cooperation Agency (Sida) had pledged $2 million. National contributions from the four member countries have increased from 10 percent to 18 percent. In a presentation to the meeting in Phnom Penh, Fisheries Programme Coordinator Xaypladeth Choulamany said that the new phase would be more focussed on monitoring and facilitation rather than collecting information and more orientated towards MRC core functions rather than sectoral development. And while the structure of the earlier phases was "compartmentalised into distinct thematic components", the third phase will have a "true programme approach structured around outcomes with multiple interactions and relationships, strong cross fertilisation and synergies across technical specialities," Mr Xaypladeth said. The new phase will also involve increased coordination with National Mekong Committees and implementation by fisheries agencies in the four countries. In addition to issues specific to fisheries, the programme will also address cross-cutting issues such as climate, poverty, gender, sustainability rights and public health. The twin objectives of the third phase are sustainable fisheries management and development and improved rural livelihoods. Four outcomes have been identified—promoting integrated water resource management, monitoring trends and impacts and filling in information gaps, fostering regional dialogue and developing capacity. The 2011-15 phase envisages 23 activities resulting in 11 outputs. The work plan will be front loaded and reduced to core functions in the latter third of the five-year period. Further details including institutional arrangements and work plan priorities are scheduled to formulated during the inception phase from January to June, 2011. The MRC Joint Committee, which meets twice a year, comprises four senior officials responsible for implementing policies and decisions.

Australian **genetic study** reappraises **evolution** of Asian **snakeheads**

When did the snakehead family of fishes diverge into an Asian genus and an African one? And where? A new study using both molecular data from multiple genes and comprehensive fossil evidence tries to find out.

The natural distribution of the snakehead fish family (Channidae) is today limited to Asia (the genus *Channa*) and Africa (*Parachanna*). The range of *Channa,* which includes several economically-valuable species in the Lower Mekong Basin, extends from Iran to Indonesia and Northeast Asia including China and Siberia. *Parachanna*, with only three species, is restricted to central western Africa. But when did the common ancestors of Asian and African snakeheads diverge, where did they originate and how did the Asian genus evolve in different parts of Asia?

With more comprehensive fossil records now available, researchers at Queensland University of Technology in Australia have been getting a clearer picture of the evolutionary development of Asian snakeheads. Previous studies have been based on molecular data from single genes (mitochondrial DNA) or fossils alone. These indicate that the family originated in Africa and may have diverged and given rise to different lineages more than 100 million years ago, possibly in relation to continental breakup, or as recently as only 4 million years ago.

Not Out of Africa

A new study* by Eleanor Adamson and two colleagues at the university's science faculty uses both molecular data from multiple genes and fossil calibration. It suggests that the snakehead family split about 40 to 50 million years ago. Since then, the study suggests, the evolution of Asian snakeheads seems to have been heavily influenced by multiple broad-scale "dispersal events" across India and Southeast Asia. It also suggests that dispersal westward from Africa was limited during the Miocene epoch from about 5 to 23 million years ago, meaning that an "Out-of-Asia Into-Africa" hypothesis best explains the current distribution of the snakehead family.

The study also observed deep divergence within striped snakehead (*Channa striata*) about 7 million years ago at around the same time as the East Asian monsoon developed. Found in many freshwater habits, the striped snakehead can move easily across ground and is probably the most common snakehead found in southern Asia today. The authors conclude that the wetter monsoon climate probably enabled the species to disperse and assume its modern distribution.

New species in Cambodia?

Involving collaboration with the Mekong River Commission, the study involved collecting samples from 19 sites across Asia, mostly in Cambodia, Lao PDR, Thailand and Viet Nam but also in western Indonesia, northern Malaysia and southern India. While an unknown snakehead species sampled from northern Cambodia resembled the great snakehead (*Channa marulia*) found in India, the authors suggested it might be a "new" species that has not yet been described to science. They also suggested that the Indian species *Channa diplogramma* warranted taxonomic recognition as being distinct from the Indonesian snakehead (*Channa micropeltes*). These two fishes last shared a common ancestor about 5 million years ago.

While not considered in the study, the authors briefly mentioned the possible relationship between modern Asian and African snakeheads and those that inhabited Europe more than 13 million years ago. They suggested that these may represent a third group now extinct that could have originated in a second expansion westward from Asia, either before or after the *Parachanna* genus departed for Africa at least 40 million years ago.

* Adamson, EAS (2010) A reappraisal of the evolution of Asian snakehead fishes (Pisces, Channidae) using molecular data from multiple genes and fossil collaboration. Molecular and Phylogenetic Evolution 56(2):707-17.

Navigating changing **waters**

SOURCE: USGS

The United States Geological Survey releases a video warning that dams along the Mekong mainstream or lower tributaries could damage the food security of a region more dependent on inland fisheries than anywhere else in the world. The video also highlights the need to maintain natural sediment levels and prevent over-use of ground water to help the Mekong Delta avoid the higher rates of relative sea-level rise found in the Mississippi Delta in the United States and the Chao Phraya Delta in Thailand.

In July last year, United States Secretary of State Hillary Clinton met with the foreign ministers of Cambodia, Lao PDR, Thailand and Viet Nam on the sidelines of the annual ASEAN Ministerial Meeting in Phuket. During the meeting, which was followed by a second meeting to discuss Mekong-related issues in Hanoi in July this year, the ministers viewed a video on challenges facing the Lower Mekong Basin prepared by the United States Geological Survey (USGS).

An updated version of the video, *Forecast Mekong: Navigating Changing Waters*, has since been uploaded to the USGS website (http://deltas.usgs.gov/). The video is partly based on a fisheries baseline study for the MRC's recently-completed strategic environmental assessment of proposed hydropower dams. According to the USGS, the video is a "form of science diplomacy requested by the US Department of State to educate policymakers and citizens in Southeast Asia about the vital importance of the Mekong River and delta in maintaining food security and livelihoods in the region." The video also seeks to "make policymakers aware of

the potential impacts of climate change on people and the environment of the Mekong Delta."

Threats to fisheries

Fisheries are prominently featured in the nine-minute video. It describes the river as "critical to the food security and livelihoods of millions of people" who are among the biggest consumers of freshwater fish in the world. At the same time, sediment is the "lifeblood" of delta ecosystems, providing nutrients for agriculture and fisheries and sustaining coastal wetlands. Sediment starvation caused by dams, navigation and flood control structures compounds problems of subsidence, the sinking of the ground surface that increase vulnerability of deltas to sea-level rise. Capturing sediment before it reaches the delta can have unintended consequences including high rates of land loss, coastal erosion and sinking cities that are more vulnerable to flooding. In the Mississippi Delta, which suffered net land losses of almost 1,200 square kilometres since 1956, the USGS notes that sediment delivery to the coast decreased 50 percent in in 20th century, particularly after the construction of levees and major dams. "With these essential minerals and nutrients no longer reaching the coast, the Mississippi Delta is experiencing a staggering rate of land loss, coastal erosion and subsidence."

In comparison, the Mekong still caries large amounts of nutrient-rich sediment downstream, nourishing the highly-productive Tonle Sap Lake, described as "the heart of the world's largest inland fishery", and the fertile Mekong Delta. By reducing flow and trapping sediment, the USGS notes that upstream dams on the Mekong could damage the productivity of the lake. Regulating the flow of the Mekong can be seen as a benefit of building dams. "But changing natural water flow patterns could be devastating for fisheries," the agency warns, noting that the annual expansion and contraction of the Tonle Sap Lake is what makes its fisheries so abundant. At the same time, submerged vegetation of the floodplains provides young fish with food and shelter from predators. In addition to the degradation of fish habitats caused by the likely changes to the volume and timing of flows, "dams on the Mekong mainstem or lower tributaries can block the passage of migrating fish and could damage the food security of a region more dependent on its inland fisheries than anywhere else in the world."

The USGS notes that hydropower dams in the United States have affected important commercial fisheries such as salmon. "A series of large dams can transform a flowing river into a series of lakes that block or limit the passage of salmon and other migratory fish. Overfishing, habitat loss and water diversion for agricultural use can further contribute to salmon declines." While dams have brought inexpensive power to the northwestern United States, "the cost has been a steep reduction in salmon and other migratory fish populations. Similar impacts could be seen on commercial fisheries in the Mekong in the future. Although modifications to hydropower dams have improved the survival of fish moving through the cascade of dams many salmon populations are still endangered and the United States now spends over $160 million per year on salmon recovery."

Avoiding high rates of sea-level rise

With regards to climate change, the USGS video notes that human activities in coastal deltas can exacerbate subsidence which further accelerates local rate of sea-level rise. The Chao Phraya Delta in Thailand, for example suffers from a "serious subsidence problem" caused by a combination of groundwater withdrawal and a severe reduction in the amount of sediment replenishing coastal wetlands. In the Mekong Delta, sea-level rise projections indicate that millions of people could be displaced by increased coastal flooding and that vast areas of ricefields could be inundated with saltwater.

"Maintaining the Mekong River's natural sediment levels and preventing the over-use of ground water will help the Mekong Delta avoid the higher rates of relative sea-level rise found in the Mississippi and Chao Phraya deltas," the USGS says. The agency is already developing tools to monitor ecosystems and forecast the consequences of climate change in partnership with governments and universities in the region. "We are addressing challenges to transfer these vulnerable ecosysytems of the Mekong Delta to more resilient ones," it says. "Through comparative studies and ecological forecasting, we are beginning to harmonise natural landscape functions with human socio-economic drivers to guide the management of healthy ecosystems and a sustainable delta. We must embrace the future of delta resources now so that they will be resilient for many years to come."

Investment principles for developing sustainable **aquaculture** to feed the **poor**

Prompted by a British documentary on how overfishing is creating a global crisis, senior scientists at the World Fish Center outline five principles to guide investment in sustainable aquaculture solutions that meet the needs of the poor in developing countries.

The World Fish Center has added its voice to the growing chorus calling for action to address the crisis in global fisheries. In a paper* published by the Swedish Academy of Sciences earlier this year, the agency's director general and three colleagues highlight the need to look not only at large-scale fisheries but also at small-scale fisheries. The paper is in response to *The End of the Line*, a recent British documentary which the authors describe as a "rich, well-argued and sobering picture of how people, the oceans' top predator, have brought many of the world's fisheries to collapse."

However, the authors argue, the film only touches upon some important issues, notably the consequence of overfishing on the world's poor. While educating affluent consumers and managing the world's large-scale fisheries and trading systems sustainably is important, "this needs to be accompanied by efforts to maintain the world's small-scale fisheries that provide food and income for the vast majority of producers and consumers in the world."

'The film's three prescriptions to help solve the crisis are at best only partial'

The authors argue that the film's three prescriptions to help solve the crisis are at best only partial. These include using the power of consumer choice to demand that fish are caught more sustainably and lobbying politicians to cut the size of fishing fleets and impose fish quotas based on sound science. The third is campaigning for marine protected areas where commercial fishing is banned. To tackle the crisis comprehensively, the authors propose two more prescriptions. First, development agencies should be lobbied to use aid to secure the productivity of fish stocks on which the world's poor depend. Second, they should also be urged to invest in sustainable aquaculture solutions that meet the food needs of the poor in developing countries.

'Development agencies should be lobbied to use aid to secure the productivity of fish stocks on which the world's poor depend ... they should also be urged to invest in sustainable aquaculture '

To guide such investment, the paper outlines five principles to support:

- operation and development of small-scale fisheries,
- livelihood diversification,
- technology development in small-scale fisheries,
- increased adaptive capacity and resilience, and
- small and medium-scale aquaculture enterprises.

The authors argue that modest investments based on these principles can deliver major benefits, pointing to analyses of the needs of seven countries in sub-Saharan Africa. These indicate that a $30 million investment in policy improvement, management and marketing chains in small-scale fisheries can produce 350,000 tonnes more fish per year for low-income countries, improve fish supplies and food security for 35 million people by 2020 and a further 90 million

Repairing nets in Prek Kmeng, a fishing village about 25 km downstream from Phnom Penh. Compared with affluent consumers, the consequences of overfishing will be far more profound on poor people in developing countries who depend on small-scale fisheries for food and income.

PHOTO: LEM CHAMNAP

by 2015. Combined with improvements in policy and access to markets, the same investment in technology development, transfer and capacity building for aquaculture can produce 3 million tonnes of fish by 2020 and generate up to $2 billion a year.

The paper notes that 70 percent of the world's fish catch comes from developing countries, of which more than half comes from small-scale fisheries. These fisheries also are collapsing—a major problem for the 22-24 million full or part-time fishers in developing countries who depend upon them and the 68-70 million who work in post-harvest activities. "With 90-95 percent of the catch destined for local domestic markets, the fish supply crisis here will also have far more profound consequences than the omission of bluefin tuna from the sushi bars of Tokyo or Paris, or North Sea cod from supermarket shelves in London or Oslo."

* Hall SJ., Dugan P, Allison EH, Andrew NL (2010) The end of the line: who is most at risk from the crisis in global fisheries? AMBIO 39:78—80.

Protest outside a London restaurant serving blue-fin tuna in 2009. According to scientists from the World Fish Center, prescriptions such as educating affluent consumers to help solve the global fisheries crisis are at best only partial.

PHOTO: END OF THE LINE WEBSITE

To what extent do **subsidies** to the **fisheries** sector violate **WTO rules?**

A WTO working paper finds that government-subsidised research and port construction falls within the realm of "general infrastructure" and should therefore not be actionable under international trade law.

The World Trade Organization (WTO) estimates that governments around the world provide billions—possibly tens of billions—of dollars in subsidies to fisheries every year. For almost a decade, efforts have been underway to clarify and improve WTO rules on such subsidies, especially those that contribute to overcapacity and overfishing. The challenge now facing trade negotiators, the WTO says, is to strengthen rules while respecting important policy concerns of members, particularly developing and least-developed countries. But how are subsidies defined? Under Article 1 of the Uruguay Round Agreement on Subsidies and Countervailing Measures in 1994, part of a package of accords that led to the WTO's establishment, subsidies fall into two categories. The first type of subsidy covers government or public contributions that lead to direct or potentially direct transfers of funds or liabilities (like loan guarantees), foregone government revenues (like tax credits), government provisions of goods and services other than "general infrastructure" or government purchases of goods. Subsidies are also deemed to exist if governments either make payments to funding mechanisms or direct the private sector to carry out such functions. The second type of subsidy covers any income or price support that increase exports or reduces imports as stipulated by the General Agreement on Tariffs and Trade (GATT) of 1947, the framework that governed global trade before the WTO was set up in 1995.

Debatable

According to a recent WTO working paper* by economists Franke Asche of the University of Stavanger in Norway and Martin Smith of Duke University in the United States, many fisheries subsidies appear to meet the definition of Article 1. These include fuel and boat-building subsidies as well as preferential tax treatment. But what about government port and wharf construction or the free provision of fisheries research and regulatory infrastructure (or for that matter, a free fisheries research and development newsletter like *Catch and Culture*)? While these types of support less obviously meet the definition of Article 1, the authors acknowledge that it "could be debated" that they do indeed fall outside of the area of general infrastructure. But would they fall into the category of "actional subsidies" under Article 5 of the agreement? Although there are some exemptions for agriculture, such subsidies are generally those that have "adverse effects" such as injuring the domestic industry or causing serious prejudice to another WTO member. According to the authors, "whether any subsidies to fisheries contribute to an 'adverse effect' as in Article

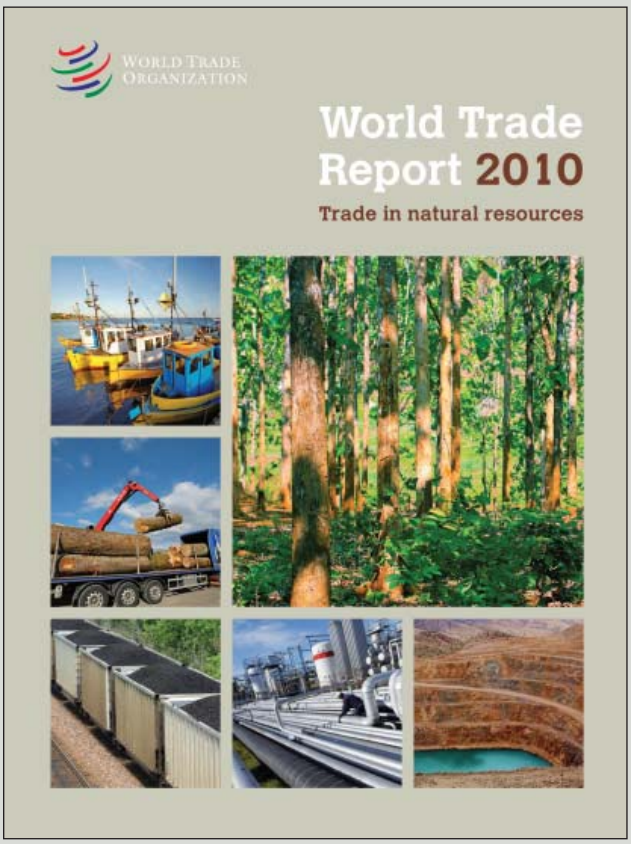
Political mandate

At the WTO ministerial conference in Hong Kong in 2005, trade ministers noted that there was "broad agreement that the Group should strengthen disciplines on subsidies in the fisheries sector, including through the prohibition of certain forms of fisheries subsidies that contribute to overcapacity and over-fishing." Ministers called on WTO participants to undertake further detailed work to "establish the nature and extent of those disciplines, including transparency and enforceability." At the same time, "appropriate and effective special and differential treatment for developing and least-developed Members should be an integral part of the fisheries subsidies negotiations, taking into account the importance of this sector to development priorities, poverty reduction, and livelihood and food security concerns."

WTO chief says subsidies can be useful but can also make matters worse

Mr Lamy launching the World Trade Report in Shanghai in July

Photo: WTO



The WTO Working Paper on Trade in Fisheries was commissioned as a background analysis paper for the World Trade Report for 2010 which is devoted entirely to natural resources. Launched by WTO Director-General Pascal Lamy in Shanghai in late July, the 250 page report examines the characteristics of trade in natural resources, the policy choices available to governments and the role of international cooperation. Among the range of policies affecting trade in natural resources, "subsidies and export policies appear to be the most challenging," Mr Lamy says in the foreword. But while subsidies can be useful to address market failures and change incentive structures that favour superior outcomes, "they can also make matters worse. Everything depends on what subsidies governments are deploying, and whether they are responding to public welfare concerns or pressures from narrow interest groups." To counter rising tariffs in importing countries and manage external environmental factors, governments may use export taxes and restrictions for various reasons including economic diversification and domestic price stabilisation. "But at the same time, export taxes and restrictions may also raise world prices and shift economic 'rents' arising from scarcity. Beggar-thy-neighbour policies of this nature reduce economic welfare, increase trade tensions and provoke retaliation," Mr Lamy warns.

The World Trade Report notes that various studies have suggested that subsidies to fisheries are in the order of tens of billions of dollars each year and make up a "substantial portion" of the value of the fish catch. Between 1996 and 2006, it was found that government financial transfers to fisheries by members of the Organisation of Economic Cooperation and Development (OECD), the Paris-based club of rich countries, averaged $6.1 billion a year, peaking at $7 billion in 2006. In that year, the United States was the biggest fisheries subsidiser, accounting for 30 percent of OECD transfers, followed by Japan which made up 28 percent of the total. While data for developing countries is more difficult to obtain, the World Trade Report quoted a study showing they accounted for 32 percent of all fisheries subsidies in 2003. Among Lower Mekong Basin countries, fisheries subsidies came to $697 million in Viet Nam, $553 million in Thailand and $7 million in Cambodia which together exceeded fisheries subsidies in India alone which amounted to almost $1.1 billion. Among developing countries, China ranked first with fisheries subsidies of almost $4.2 billion in 2003.

Further reading:

World Trade Organization (2010) World Trade Report 2010: Trade in natural resources, World Trade Organization, Geneva.

5 likely depends critically on the existing management regime and the bioeconomic circumstances of the relevant fishery." In some cases, where subsidies actually reduce the amount of fish harvested, neither importers from a subsidising country nor exporters to a subsidising country appear to have grounds for a WTO complaint. In other cases, they argue, subsidies to an optimised fishery exporter could produce an adverse effect for the domestic industry in the importing country, thereby constituting an actional subsidy.

The authors note that the the complexities of global trade in fish and other aquatic animals have been well highlighted by the United States when it took anti-dumping action against imported shrimp from Brazil, China, Ecuador, India, Thailand and Viet Nam in 2003 (see *Catch and Culture*, Vol 11, No 1). An important basis for the claim was that international organisations like the World Bank subsidised the development of aquaculture in these countries and conferred an unfair competitive advantage on a growing export industry. "Quantitatively assessing this claim is difficult," the authors wrote, pointing to the dramatic differences in the production methods of foreign shrimp farmers and American shrimpers which make it difficult to compare imports with domestically-caught wild shrimp. For consumers, however, the products are similar which means farmed shrimp imports compete directly with the wild shrimp caught in American waters.

'The anti-dumping case brought by the United States raised some interesting equity issues'

According to the WTO working paper, the anti-dumping case brought by the United States raised some interesting equity issues. For example, what might happen if an international development organisation encourages a country to develop a particular industry? If that country succeeds in developing a successful export industry, it may subsequently be punished with an anti-dumping duty legitimised by another international organisation, namely the WTO.

At the same time, environmental non-governmental organisations and possibly some development organisations may provide technical support and financial incentives to farm fish more sustainably in the future. Will that be seen as a subsidy and grounds for anti-dumping duties allowed by the WTO? As the authors note somewhat wryly, "one could stretch the logic further and suggest that lack of international coordination in such cases could lead to inefficient investment in infrastructure."

'What might happen if an international development organisation encourages a country to develop a particular industry? If that country succeeds in developing a successful export industry, it may subsequently be punished with an anti-dumping duty ...'

With regard to subsidies, the authors conclude that their elimination will alleviate some pressure on fish stocks and help to mitigate overfishing. "However, we believe that the elimination of subsidies is not likely to eliminate overfishing problems as long as fisheries remain open access or are regulated by a weak management system. Moreover, we believe that many subsidies discussed in this literature could be considered general infrastructure (e.g. fisheries research and port construction), and fisheries subsidies to open access countries generally do not appear to violate existing WTO rules." For the time being at least, it looks like those behind government fisheries research institutes and port construction programmes in the Lower Mekong Basin can relax.

* Asche F, and Smith MD (2010) Trade and Fisheries: Key Issues for the World Trade Organization, Staff Working Paper ERSD-2010-03, World Trade Organization, Geneva.

Office of the Secretariat in Phnom Penh (OSP)
576 National Road #2, Chak Angre Krom,
PO Box 623, Phnom Penh, Cambodia
Tel: (855-23) 425 353 Fax: (855-23) 425 363

Office of the Secretariat in Vientiane (OSV),
Office of the Chief Executive Officer
184 Fa Ngoum Road,
PO Box 6101, Vientiane, Lao PDR
Tel: (856-21) 263 263 Fax: (856-21) 263 264