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MEKONG FISHERIES NETWORK NEWSLETTER

FISH PASSES AND MIGRATIONS

CAN FISH PASSES MITIGATE THE IMPACTS OF WATER-RELATED DEVELOPMENT ON FISH MIGRATIONS IN THE MEKONG BASIN?

By Terry J. Warren and Niklas S. Mattson

Different life-history stages of fish normally require separate habitats to optimize survival, growth and reproduction. Migration enables the necessary shifts to be made, but the distance travelled is dependent on habitat distribution and life-history stage.

Migrations are usually undertaken for at least three reasons: trophic, dispersal/refuge and reproduction. Migrations may be lateral, taking place between flooded areas and the mainstream, or longitudinal. Some migrations may involve a movement of only a few metres, whilst others may involve vast distances covering hundreds or thousands of kilometres. Traditionally, fish species have been categorized into migratory and non-migratory types, often based on some arbitrary minimum distance the species migrates for reproduction. However, any migration (short or long), for whatever reason, and at any life stage, may be important. Therefore, it seems more logical to regard most if not *all Mekong fish species as migratory*, albeit to different degrees.

Water-related development projects tend to block fish migration corridors, thus preventing the necessary shift between habitats. To alleviate this, fish passage structures have been constructed at some sites in order to restore, or maintain the linearity of the riverine system. In South-East Asia, only a few fish passage facilities currently exist. In Thailand, structures are in place at the Kwan Phayao, Nong Han and Pak Mun Reservoirs. As far as the authors are aware, no fish passage facilities have so far been incorporated into any water-related projects in Cambodia or the Lao PDR. However, a design is under consideration for the Stung Chinit Water Resources Development Project in central Cambodia (Warren, 1999a), and a fish passage option is still under review at the Theun-Hinboun Hydropower Project in the Lao PDR (Warren, 1999b).

The most famous fish pass in Thailand may be found at Pak Mun Reservoir.

Fish pass evolution started with salmons

Fish pass design has had a long history, dating back some 300 years (Clay, 1995). With an acknowledgement of the devastating effects that water-related development can have on migratory fish populations, the search for an

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FISH PASSES

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appropriate design began in earnest some 50 or so years ago. Much of the early pioneering work was carried out in North America, Canada and Europe and was directed at maintaining migratory populations of salmonids. Millions of dollars have been spent on fish pass research and design for what amounts to only a limited number of species. Such research has yet to be directed at the hundreds of important migratory species found in other countries of the world, and in the tropical regions in particular.

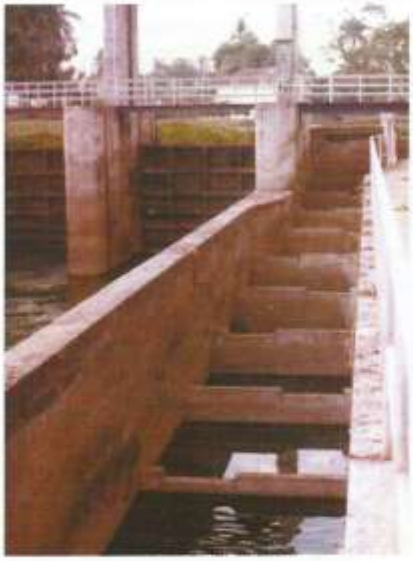
Owing to a scarcity of biological data on tropical riverine species in general, design criteria for fish pass structures in the tropics have mostly been based on educated guesswork, and the applied experiences from work on salmonids. Early designs were the so-called "pool and weir" and "submerged orifice" types (Figures 1 and 2). Both consist of a concrete flume divided into chambers by cross-baffles. With the former type, fish are required to move over the cross-baffles with the current. The latter design requires the fish to move through an opening near the base of each chamber. The main disadvantage of both designs is that they require relatively constant flows to operate effectively, and are rather inefficient at dissipating the kinetic energy of the water flow.

A third type of fish pass is named after its original designer, Denil (Figure 3). The design incorporates a series of vanes on the sides and base of the flume. This has the effect of turning part of the flow back on itself, and is much more efficient at dissipating kinetic energy. However, although it has a proven track record in temperate countries, it likewise cannot accommodate widely fluctuating current flows.

Successful fish pass in Australia

A fourth design, known as the "vertical slot" (Figure 4), is a variation on the "submerged orifice" type. Instead of having a single hole near the chamber base, it incorporates a continuous slot from top to base of each chamber. Unlike the other designs, energy dissipation is reported to be excellent and it can operate efficiently over a much wider range of flows, and up to at least a 5 or 6 m difference in head. It has the added advantage of facilitating the movement of almost all sizes and life-cycle stages of fish at any preferred water depth. In Australia, the original fish pass structures at the Ben Anderson Barrage on the Burnett River, and the Kolan Barrage on the Kolan River in Queensland have recently been redesigned and upgraded to the "vertical slot" design. Both fish pass structures have proven far more effective than the original design, and the Ben Anderson has been declared the most successful fish pass in Australia (Institute of Engineers, 1999).

Unfortunately, for projects built on tropical rivers where fish fauna are rich, and where differences in head may exceed 10 m, the options for fish pass designs appear to be limited at present. Fish locks (or lifts) have been incorporated into various project designs in many countries, and have a good track record of success. They have the main advantage of facilitating the bi-directional movement of a wide range of species and life-cycle stages of those species. They are disadvantageous in that they require regular attendance and maintenance, and are comparatively expensive.



In Thailand, a fish pass is in place at the Kwan Phayao Reservoir (left). The structure built at the Kwan Phayao Reservoir was replicated at the Nong Han Reservoir (right).

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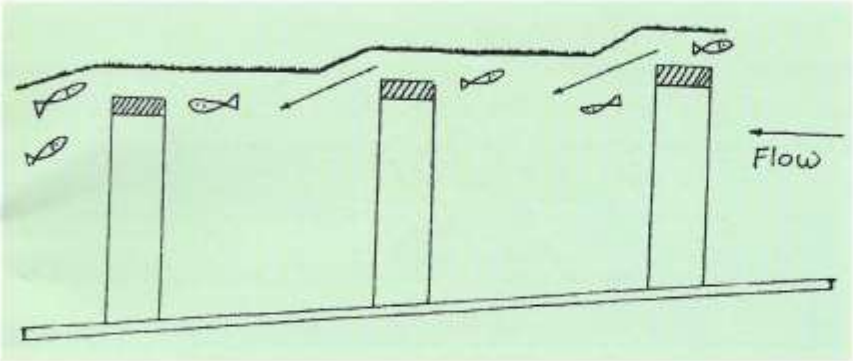

Figure 1: "Pool and weir" fish pass

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Alternative fish pass facilities: Only for small dams

In Europe, the building of nature-like bypass channels is one approach which has received attention in recent years (e.g. Jungwirth *et al.*, 1998). In essence, the idea is to create a channel that resembles a natural river or stream, which allows the fish to pass an obstruction in the river channel. However, this approach is probably not suitable or practical for large-scale high-head dams.

Pak Mun experience in Thailand

The Pak Mun Dam on the Mun River in north-eastern Thailand is located close to Ubonratchathani. It was completed in 1994. The run-of-the-river type dam is the first hydropower dam in South-East Asia where a fish ladder has been incorporated. A recent draft report by the World Commission on Dams (more information is available at http://www.dams.org) concludes that the fish ladder, which is of the combined pool and weir type, is not well designed and is performing poorly. The report also notes that important spawning habitats have been lost due to inundation by the head pond and that fish yields above the dam have been considerably reduced. One hundred or more fish species may have disappeared from the upstream areas since the construction of the dam.

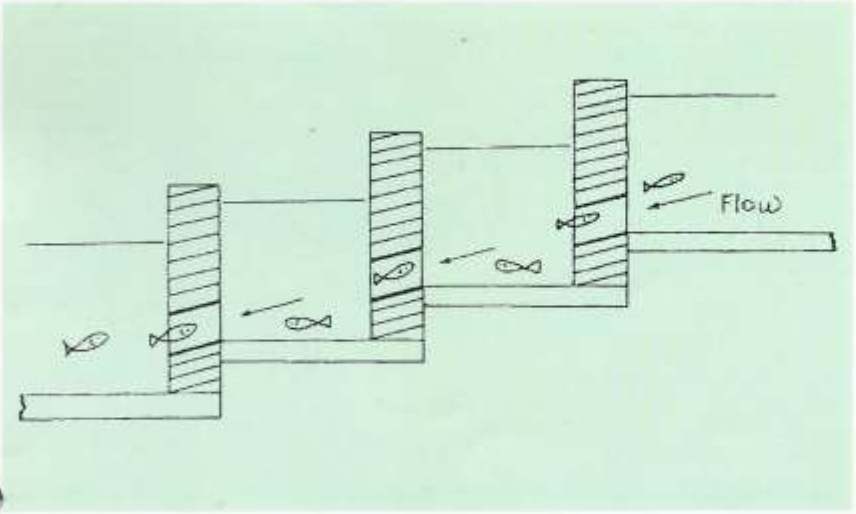

Figure 2: "Submerged oriface" fish pass

Theun-Hinboun in the Lao PDR

The Theun-Hinboun Hydropower Project in central Lao PDR has a 210 MW generating capacity and came "on-line" in early 1998. It is the Lao PDR's most important single project in terms of generating foreign exchange through electrical power sales to Thailand. The barrage is built on the Theun River that supports a rich and diverse range of fish species, many of which are migratory. Earlier EIA reports recommended that a fish pass option be investigated (NORPLAN, 1996). However, a decision was taken not to proceed with an in-depth study of the various possibilities. As predicted, the main wet-season spawning migration in the Theun River was blocked in 1998 (Warren, pers. obs.) and compensation is now under review for those villagers who have suffered damage to their fisheries both upstream and downstream from the dam. Perhaps the greatest "loss" of all surrounds the wasted opportunity to have built an experimental fish pass at Theun-Hinboun. Even several different designs could have been test-run under "real" conditions, and built at a fraction of the total cost of the 260 million dollar project during its construction phase. Perhaps there are valuable lessons to be learned here for the decision-makers involved with future water-related development in any of South-East Asia's river basins.

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What's next?

The effectiveness and performance of any fish pass built on a South-East Asian river cannot be guaranteed, and it is doubtful that a design could maintain the absolute status of a pre-impoundment migratory fish population. In addition, there is a danger that poorly researched or outdated designs may be incorporated at some projects purely to appease environmental critics. To arrive at a design that meets the requirements of perhaps 50 to 100 different species of migratory fish remains a formidable challenge. To delay further research work, or to ignore the problem altogether, may prove ultimately to be very costly.

Fish pass designs for tropical river systems still have some way to go in order to achieve the desired results. However, "necessity" always has been, and always will remain "the mother of invention." The following recommendations may mitigate the impacts of water-related development on fish migrations in the Mekong Basin.

- Research into the life histories and migratory behaviour of important Mekong fish species should be prioritised. This has begun under the supervision of the MRC Fisheries Programme by the *Assessment of Mekong Fisheries Component*.
- All new water-related development projects must be held responsible for investigating fish pass options before the project is approved, and should form part of any EIA. Such investigations must consider the bi-directional requirements of the fish in order to complete their life cycles, as well as preserve the destination habitats.
- Research should be conducted to determine which type(s) of fish passes are most suitable for Mekong fish species.
- Long-term monitoring of the fisheries in regulated rivers, including fish pass performance, must be properly reported and preferably in international peer-reviewed journals. Publication in obscure internal reports is unacceptable.
- The impact of any newly built structure on fish migration must be viewed in terms of its cumulative effect and is unlikely to be independent of earlier built obstructions. A holistic approach is required taking into account the whole river basin.

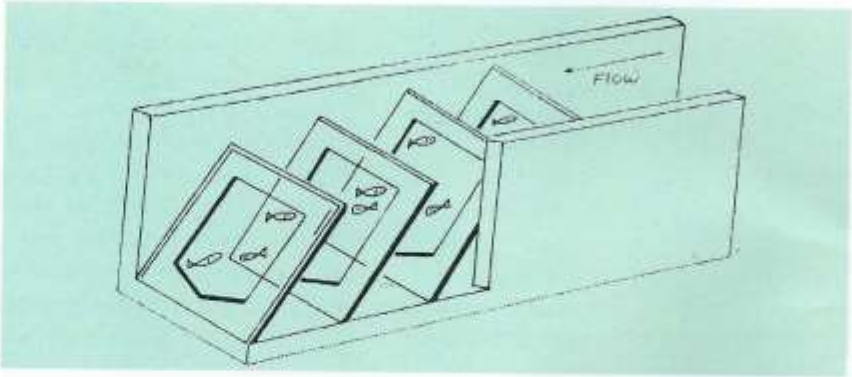

Figure 3: "Denile" fish pass

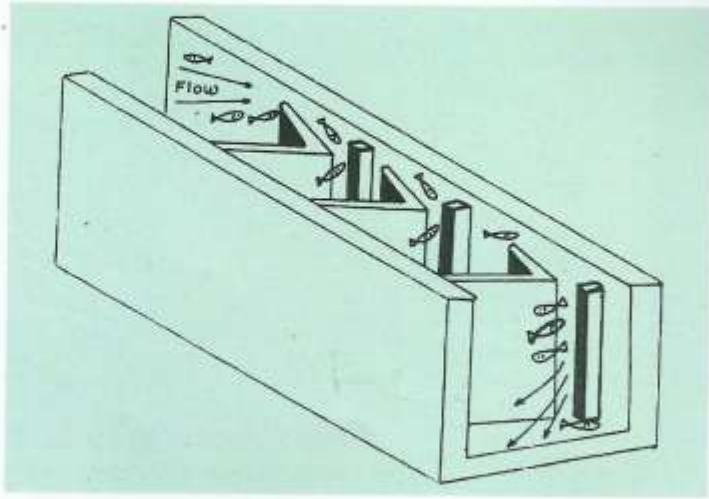

Figure 4: "Vertical slot" fish pass

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AUSTRALIAN RESERVOIRS: TOXIC WATER, NO PROBLEM!

By bubbling air into the bottom of the reservoirs, Australians have solved the problem of anoxic bottom water and toxic water release from reservoirs. This "Champagne System" may further open up for increased fish production from the otherwise dead bottom layers of water. *Catch and Culture* visited Queensland in Australia, where the technology has proven successful.

by Jorgen G. Jensen

Fish Kills and Skin Problems from Reservoir Water

Problems in reservoir management are plentiful. Reservoirs with a depth of more than 10-15 metres will usually form an anoxic bottom layer, i.e. a zone with little or no oxygen, where no fish or crustaceans can live. The stratification is caused by a temperature difference between the warmer surface water and the colder bottom water. Dead biological material sinking to the bottom will deteriorate and often develop hydrogen sulphide, which is a highly toxic gas. Consequently, only the upper surface layer is inhabited by fish, and most often by small pelagic species, which, although nutritious, have a low market value.

Sometimes in the cold season the surface water may chill down and, helped by strong winds, the reservoir may "turn". That is, the surface water, now heavier than the water at the bottom, will sink down to the bottom and the bottom water will come to the surface, leading to considerable fish kills. If cage culture of fish is practised in the reservoir, it may all be destroyed during such events.

Problems are noticed downstream as well. If the water intake to the turbines is placed in this anoxic "hypolimnion", the water downstream from the dam will be anoxic, strong smelling and with the potential for causing fish kills and skin problems for people using the water. This problem has been described in relation to the Nam Ngum Reservoir by Roel Schouten in *Catch and Culture* (Vol. 4, No. 2, December 1998, pp. 1-5).

Tim Wrigley in front of the bubbling North Pine Reservoir.

A "Destratifier" Is the Answer

North Pine Reservoir in Queensland, Australia, delivers the drinking water to the state capital, Brisbane. It was plagued by the development of blue-green algae (*Cylindrospermopsis cariborskii*) during the hot season, which made the water toxic. An anoxic hypolimnion allowed for the release of high quantities of phosphate, manganese and iron, which together with low light intensity created good living conditions for this organism.

Two pipes were installed at the bottom of the reservoir, and air was blown into the deepest part of the reservoir during the warm season. "Within 10 weeks of operation the reservoir was isothermal and the anoxic layer eliminated," recounts Tim Wrigley, the Project Manager from Sinclair Knight Merz, the company which was in charge of installing the new technology. Isolated patches of warmer surface water of 1-2 metres depth may still be found during the warm season, but they seem to have no detectable negative effect. The algae problem has been reduced considerably and the reservoir is again in use supplying drinking water to Brisbane.

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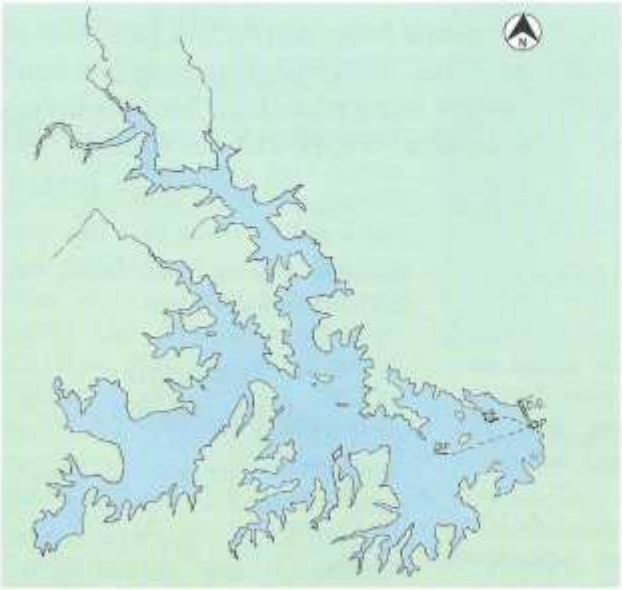

The approx. 21 sq. km North Pine Reservoir with air pipes and diffusers indicated. DS = Dam Site; DF = Diffusers; P = Pump House

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How It Works and What It Costs

The North Pine Reservoir covers an area of 21.63 sq. km when full and has a maximum depth of 35.1 metres. The reservoir stratifies at the 10-metre depth already, and 40% of the water volume was anoxic in the warm season.

The detailed design of the system was preceded by careful hydrological modelling of the reservoir. As a result, the two pipes were installed at the bottom, leading from the compressor house at the dam approx. two km out to two selected deep areas. Here they were connected to two 550-600 metre long perforated tubes or "diffusers". Two air compressors, one per diffuser, each of 75 kW would then supply 440 litre/sec of air to the diffusers, in order to reach this remarkable result. The temperature of the water at selected sites in the middle of the reservoir, being an indicator of the degree of stratification, is checked at one metre intervals from the surface to the bottom, and the results are sent by telemetry to the computers of the company, where the efficiency of the system can be checked in the office in Brisbane.

The whole wonder has cost approx. AUS$ 800,000 (USD 420,000), or only some 0.2 – 0.4% of the cost of the dam construction, including approx. AUS$ 80,000 (USD 42,000) for the compressors and development costs. Operational costs amount to AUS$ 21,000 per year. The system is surprisingly simple and effective, and, ensures Tim Wrigley, the maintenance costs are negligible.

Can We Use It in the Mekong?

In the Mekong Basin, with its many hydropower reservoirs, the use of the system may solve the problem of fish death in the reservoirs and downstream from the dam as well as other problems imposed upon the fishing communities at dam construction. This may in itself be a justification for testing the system. However, it may also prove to recover its own costs, or even to be a good business in itself, by making it possible to use the now useless bottom area of the reservoirs as a habitat for bottom feeding fish or maybe even for high value shrimps.

In a reservoir the size of North Pine Reservoir, the direct operational costs will be recovered already at a catch increase of 28 tonnes or 13 kg/ha (less if shrimps are included), which may be rather easily obtained. Including the capital cost (approx. 10%) and depreciation of the equipment over 10 years, the annual costs of the system may rise to USD 71,000 requiring an increase in fish production of 43 kg/ha in order to cover the costs.

Increased fish production in the reservoir itself is, however, not the only benefit of the system. The elimination of accidental losses in cage culture and of fish kills downstream are other factors, which may increase the economic feasibility of the system. Established at the time of dam construction, the costs will be negligible. A cost reduction may be gained from reduced development costs compared to the first time, and lower labour costs in the Mekong Region, and by using low cost electricity at the hydropower dams.

Cost cutting or not, careful hydrological modelling of the reservoir cannot be avoided. All reservoirs are different, and the specifications of the system must be adapted accordingly. And all attempts have not been successful in Australia either. In the Chaffey

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ASSESSING MEKONG AQUATIC HABITATS FROM SPACE - Why the high-tech approach?

By Thomas Boivin, David Coates, David Levy and Niek van Zalinge

In order to sustain Mekong fisheries, it is essential that managers have access to up-to-date information and cost-effective tools for monitoring the impacts of human activities on aquatic resources. Remote sensing data can make a substantial contribution. This article describes the results of a recently completed project called, *Using RADARSAT for Improving Fisheries Management and Food Security in the Mekong River Watershed, South-East Asia.*

Linking Aquatic Habitats, Fish Production and Food Security

Fish yields in rivers such as the Mekong are functionally related to the spatial extent of aquatic habitats, the duration and timing of flooding and other environmental conditions. Therefore, declines in aquatic habitat availability, or ecosystem health, as a result of habitat destruction or modification, pollution and water-management activities, will lead to a significant reduction in fish production and the possibility of a collapse of the fishery. Any unintended decline in inland capture fisheries production, apart from its economic impact, is a direct threat to food security (see David Coates, "Inland Fisheries and Food Security," *Catch and Culture*, Vol. 1, No. 1, August 1996, pp. 2-3). Hence, protection and management of aquatic habitats is critical to sustainable development and food security in the Mekong Basin. In addition, similar reasoning leads to the conclusion that the rehabilitation of already damaged areas can result in significant positive impacts on fisheries. River fisheries managers are increasingly becoming aware that fisheries management requires habitat management. More importantly, they are becoming more actively involved with this.

In order to protect and manage these habitats, we need to know where they are, their extent and current status. We also need a cost-effective way of monitoring changes in their status over time. Given the massive size of the Mekong Basin, and the large extent of the flood plains in particular, remote sensing (that is, obtaining the data by looking from a distance) is perhaps the only viable tool. Common remote sensing methods comprise satellite imagery and aerial photography.

Information needs

To better understand the flood plain dynamics in the Lower Mekong Basin, accurate data are needed to:

- Delineate the boundaries and extent of critical flood plain and other wetland habitats;
- Determine the duration of flooding in these habitats and the extent of change during the annual flooding season (within year variation);
- Assess variation in flood extent between years; and
- Determine the relationship between changes in fish habitat and impacts upon fisheries production.

In response to these needs, a project was designed to investigate the utility of remote sensing information (particularly RADARSAT-1 imagery) for assisting fisheries and aquatic habitat management in the Lower Mekong Basin. Funding constraints limited the study to Cambodia, particularly the Tonle Sap. Here, ongoing field activities of the MRC Fisheries Programme could supply crucial ground-truthing information and data on fisheries activities, including habitat exploitation patterns (mainly at Kampong Tralach and Kampong Chhnang along the Tonle Sap River). This article describes the flood plain capture fisheries, although similar data have implications for aquaculture development and reservoir management. RADARSAT scenes were acquired between May 1999 and January 2000 to provide a synoptic overview of the Great Lake and Tonle Sap River flood plain.

What is RADARSAT Imagery?

Canada's RADARSAT is an advanced Earth observation satellite equipped with Synthetic Aperture Radar (SAR). This is a powerful instrument that can transmit and receive microwave signals to "see"

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ASSESSING MEKONG AQUATIC HABITATS FROM SPACE

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through clouds, haze, smoke and darkness, and thereby obtain high quality images of the Earth in all kinds of weather at any time. The technology offers significant advantages in the weather conditions commonly encountered in South-East Asia, that preclude observation by aircraft or optimal satellites (e.g., SPOT and Landsat). RADARSAT has already proved its operational capability to provide timely information on the extent of flooding in the Mekong Basin, and in other parts of Asia. It has been found to be useful at both the regional level, for basinwide monitoring, as well as for more detailed assessments of individual watersheds. The project was the first to systematically investigate the application of RADARSAT technology for the quantification of aquatic habitats in support of fisheries management in the Lower Mekong Basin.

This is the first attempt to systematically investigate the application of RADARSAT technology for the quantification of aquatic habitats in support of fisheries management in the Lower Mekong Basin.

Methods

Land use maps specific to the areas were produced from existing aerial photographs and topographic maps. These served as baseline information for a Geographic Information System (GIS) developed together with the MRCS Technical Support Division (TSD). A total of 22 RADARSAT images taken during the dry and wet seasons (1999-2000) were acquired. The resulting images were assigned colour-codes to reflect the differences in radar intensity on the different data acquisition dates. These were then used to map the spatial extent of the wetland habitats of key importance to fisheries and their variation in location and extent over time. Then, by combining the radar data with the GIS land use information, the amount of flooded habitat in different land use categories was calculated. Field (ground-truthing) visits were made at different times of the flooding cycle to describe and record fish habitats, and to verify features identified on the RADARSAT and other imagery. Training and technology transfer of RADARSAT data processing techniques to the TSD was an integral part of the project from the outset.

Aquatic Habitat Assessment in the Great Lake and Tonle Sap River

The large-scale images obtained can be used, for example, to calculate flooded areas for the Great Lake/Tonle Sap as seen in the Table below. The values correspond with the published literature on flooded areas for this region, although the exact extents vary according to specific flood conditions (that is, depending on the day the images are taken). The fourfold increase in inundated area in the season in question translates into a corresponding increase in available fish habitat. During intense floods, the flooded area may expand up to six times its dry season size. However, the significant variations require data collection over a longer and more detailed time series to describe the dynamic nature of Mekong aquatic habitats.

The fine-scale imagery obtained, and associated GIS, are currently being used by fisheries researchers to assess the fisheries in detail (see Figure 1 on the next page). Some larger-scale fishing gears (e.g., lot fences, arrow traps, etc.) are also clearly visible from other images (not shown here due to publication limitations).

RADARSAT Data Used for Fisheries

RADARSAT imagery is useful to identify a range of fisheries and wetland habitats including:

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Date of RADARSAT Image Acquisition	Total Extent of Open Water (ha)	Difference from Low Water Condition (ha)
May/June 1999 (early flooding season)	351,653	(0)
October 1999 (peak of flooding)	1,282,603	930,950
January/February 2000 (receding flood)	475,977	124,324

ASSESSING MEKONG AQUATIC HABITATS FROM SPACE

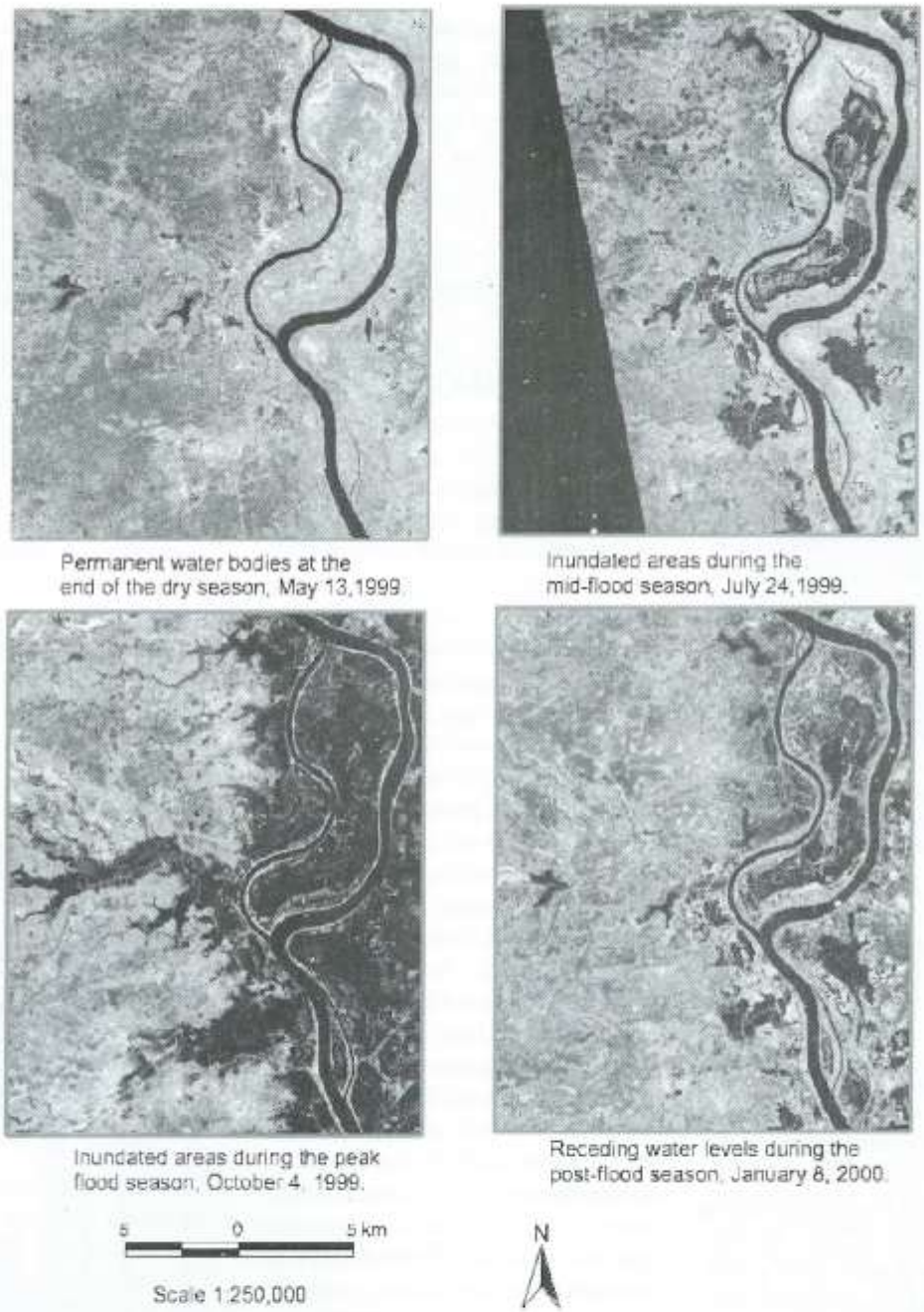

Figure 1: ***Fine mode RADARSAT imagery (8 m resolution) was used to document the aquatic habitat in the ongoing MRC Fisheries Programme studies in Cambodia. These four images are of the same location near the Tonle Sap River (the Kampong Tralach, Fishing Lot 18, a site that is located to the west of the lower end of the "island" in the river. The island itself is practically fully submerged in the flood – see bottom left image). The change in the flooded extent, and resulting fish habitat, between the dry and wet seasons may be clearly seen by the dark radar signature of the water (view images from top left clockwise round to top left again to see one flood cycle). Amongst other uses, these images enable scientists to quantify the area and type of habitats that produce the fish in catches being simultaneously recorded on the ground. Also, the dry season image (top left) clearly shows the location and extent of dry season refuges for fish (dark areas dotted about the landscape).***

ASSESSING MEKONG AQUATIC HABITATS FROM SPACE

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- Extent and duration of seasonal flooding;
- Permanent water bodies (rivers, tributaries, lakes, dry season refuges);
- Seasonal water bodies (flood plain habitats);
- Flood plain margins, upland runoff and patterns of inundation in major water bodies;
- Land use (rice agriculture areas and aquaculture developments);
- Larger fishing structures and fishing activities (e.g., arrowhead traps, Dai fishing activities, etc.);
- Aquaculture ponds;
- Local dykes and dams;
- Areas of flooded fixed vegetation, including patches of flooded rice paddies; and
- Floating or rooted beds of aquatic vegetation.

This is useful information in the struggle for a better understanding of the resources to be managed. RADARSAT has proved particularly powerful at sensing aquatic habitats and is of most use when applied within a broader GIS framework (as is being developed at the TSD). Serious discrepancies in the current land-use classification system, which exhibits biases towards dry season and agricultural uses of land were also noted. The current land classification system can perpetuate these biases in policy and planning that do not take full account of the aquatic phase of land-use. These can only be rectified by including details of the dynamic nature of many habitats that is so obvious from the RADARSAT/flooding data. This kind of information is essential if we are to look at the potential impacts of water management on fisheries. Importantly, similar information is also required by many other sectors. One outcome of the work was to help fisheries, environment and GIS specialists to work together better on a common problem, but from different perspectives.

How RADARSAT can monitor Aquatic Habitats

Fisheries production depends on aquatic habitats. Therefore, any monitoring of trends in the fishery must include monitoring of the environment upon which the fishery depends. Traditionally, water in large rivers is monitored, if at all, primarily on the basis of river heights and mainstream flows. But development activities lead to the gradual, sometimes rapid, disconnection of flood plain habitats from the mainstream (through direct flood control measures or other activities than can indirectly affect flooding). In addition, habitat changes can occur independently of hydrologic changes (e.g., the conversion of flood forest to rice fields around the Tonle Sap). Therefore, within stream measurements have limited use for monitoring the majority of aquatic habitats. The only viable monitoring option, certainly at the basinwide or sub-catchment scale, is through remote sensing. It is within this context that RADARSAT, and related technologies, offer great promise.

The specific applications of RADARSAT and related technologies, owing to the expense involved, should remain in the realm of technical specialists. Any significant investment in this kind of technology should be based on multi-user considerations. In this context, costs need not be excessive. The role of fisheries specialists should be to develop "fisheries" inputs into the overall development of remote sensing/ GIS technology. From the fisheries perspective, work continues on refining RADARSAT and other interpretations of aquatic habitats. Involvement in these areas is expanding into the Lao PDR, Thailand and Viet Nam. The flooding and fisheries data are also currently being linked to potential changes in water utilisation, including the modelling activities conducted with ICLARM and in relation to the MRC Water Utilisation Programme (WUP). RADARSAT derived data are already being incorporated into the long-term remote sensing activities of the TSD through this and other RADARSAT initiatives. Currently, the project team are assessing the utility of the next generation technology (RADARSAT 2) through a project initiated by the MRCS Environment Division.

Project Team

The Hatfield Group of Companies, including Hatfield Consultants Ltd. of Vancouver, British Columbia, Canada (www.hatfieldgroup.com), and PT Hatfindo Prima of Bogor, Indonesia, undertook the project described above, assisted by RADARSAT International, Richmond, British Columbia, Canada, and AERDE Environmental Research, Halifax, Nova Scotia, Canada.

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BATS AND FERTILISER

Going batty or free fertiliser? – A new way to perceive appropriate technology

by Don Griffiths, Sem Viryak and Hilary Rifkin

Mr. Suth Sen from Kandal Village, Trapeang Krasang Commune, Bati District, Cambodia, is 49 years of age. When first contacted by the Danida funded MRC Fisheries Programme Component, Rural Extension for Aquaculture Development (READ) in 1999, he had 1.28 hectares of land, including one hectare of rice paddy, a 280 m^2 pond, six chickens and two pigs. His land supports eight family members as no household member has off-farm employment.

Since 1999, following READ training on fish seed nursing, Mr. Sen has worked in collaboration with the Component and is now a local supplier of fish seed to other pond owners. Mr. Sen has impressed READ Component staff with his efforts to date. Mr. Sen has invested profits from last year and expanded his nursery operation from one pond, to six nursery and grow-out ponds thereby greatly increasing his fish seed nursery production capacity. In addition, Mr. Sen has also branched out into rice-fish culture. He stocked tilapia fry in a refuge pond adjacent to his rice field. 15 days after the rice seedlings were transplanted, he released the tilapia to forage in the rice field, which he had modified by digging a peripheral refuge trench. With rice and fish his income from the same plot of land will significantly increase and he'll save on pesticide costs.

1. Sugar palm leaves, cut and tied back.

Call the Bats in with Bananas

Early in May this year, READ staff were slightly sceptical when Mr. Sen told them that he had cut half way through the fronds of four of his sugar palm trees (*Borassus flabellifer*), bent the fronds back and tied them into position, almost like hanging hair, as a substrate to attract bats to nest. (Plate 1 at left shows the sugar palm leaves, cut and tied back).

In addition, Mr. Sen tied a plastic sheet around each tree trunk to prevent predators climbing from the ground and attacking the nesting bat colonies that Mr. Sen was confident would establish themselves.

On their next visit, READ staff were amazed to discover that Mr. Sen was collecting between 5 – 10 kg daily of fresh pungent bat manure (guano) from under one of the trees. (Plate 2 above shows the bat droppings at the base of the tree and the plastic sheet that prevents climbing predators). The quantity of bat manure deposited daily depends on the number of bats in the colony and this typically ranges from 30,000 to 50,000 bats. Bats stay at one site for 10 to 15 days, but move on when the nesting area becomes dirty and lice infestation rises above a certain threshold level. When this happens Mr. Sen baits his other nest substrate trees with bananas to entice the bats to roost. After the bats depart one tree Mr. Sen cleans out the old bat nests and will bait it again later to attract the bats back. He learned this technique from a neighbouring farmer.

2. Bat droppings at the base of the tree and the plastic sheet that prevents climbing predators.

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Fish Fry Thrive on Bat Manure

Fresh bat manure quality depends primarily on whether the nesting bats are fruit or insect eaters. The manure of both bats is extremely rich in nutrients. Insect eating bat manure is highly rich in nitrogen (10-3-1, N-P-K, on a dry weight basis), while that of fruit eating bats is highly phosphate-rich (2-26-0) and contains trace elements (Cervantes, 1998). Table 1 indicates that bat manure from fruit-eating bats contains twice as much nitrogen and 85 times more phosphorus than poultry manure on a dry weight basis. Poultry manure is the best on-farm animal nutrient source ahead of pigs, cattle and buffalo in descending order (Little, 1987). Mr. Sen uses half of the nutrient rich bat manure for his rice field, 30% to fertilise the homestead vegetable plot that his wife manages and 20% to promote natural phytoplankton feed in his nursery ponds for the fish fry. Using the bat manure also allows Mr. Sen to make better use of the finite amount of fertiliser produced by the two pigs, the cow, eight ducks and five chickens he now owns.

Bat manure sells for US$1.25 kg^{-1} (Riel 4,810 kg^{-1}) in central markets of Phnom Penh. Sold at market the bat manure Mr. Sen collects would have considerable cash value. 5 kg of bat manure provides the equivalent amount of nutrients as US $2.04 (Riel 7,880) worth of urea and triple super phosphate fertiliser.

Providing a nesting substrate to encourage colonies of fertiliser producing bats is innovative, environmentally friendly and economically sound. Moreover, this episode demonstrates the potential benefits of a thorough examination of local indigenous knowledge and shows how much extension staff can learn from traditional farming practices.

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	Total nutrient content Approximate percentage on a dry weight basis		
Fertiliser	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Urea	48	0	0
Triple super phosphate	0	20	0
Bat manure (fruit)	2	26	0
Bat manure (insect)	10	2	2
Compost	0.1 – 0.3	<0.1	0.1 – 0.3
Green manure	0.2 – 0.5	<0.1	0.2 – 0.4
Pig manure	0.7	<0.1	0.5
Poultry manure	1.0	0.3	0.3
Sewage sludge	2 – 6	1 – 2	0.1 – 0.4
Wood ashes	0	0.1	2 – 6

Table 1. The total nutrient content of some organic fertilisers [modified from the Florida Cooperative Extension Service (1973), Brubaker, K. (1985) and Cervantes (1998)].
(Note: TSP is Riel 1,200 kg and Urea is Riel 800 kg.)

ECOLOGICALLY SUSTAINABLE AQUACULTURE MANGROVE PARK

"Rung Sat"** is a special name given to the mangrove forest in Can Gio district, 40 km from downtown Ho Chi Minh City, designated in January 2000 for inclusion in the World Network of Biosphere Reserves by Unesco (Man and the Biosphere Programme). One **"Rung Sat" Experiment is described by Ms Thieu Thi Tao from personal experience.

In our 350 acres of "Rung Sat" Ecologically Sustainable Aquaculture Mangrove Park (EAMP), we carry out a polycultural method, taking into account the balance between three ecological levels (ground, water and air).

New Aquaculture Model

In an area where dozens of industrial shrimp farms have collapsed despite hundreds of thousands of US dollars invested in several thousands of acres and expertise from local and foreign scientists, the idea of running yet another shrimp farm would be considered as silly. Therefore, it's no surprise that our project didn't receive any material support. But we made up our minds to help create a **model of aquaculture** for the benefit of the local people who have suffered too much in the long war and are starving in their "gold forest and silver sea".

We obtained bank loans by mortgaging a private house and land in downtown Ho Chi Minh City at a monthly interest of 1.75% in 1996 (lowered to 0.85% in 2000). We have paid over six hundred million VND interest for a loan of one billion five hundred million VND (= one hundred thousand US dollars).

Eco-aquaculture System

Our farming system is neither intensive, nor extensive, because our water area depends on the tidal level. Besides the high surrounding dykes, we have flat moors that are flooded by the high tide. Prawns find their natural feed here. The stocking density varies according to the flooded area and the plankton abundance, i.e. on the season. If we only consider the canal area, the stocking density sometimes comes up to 20 larvae per square metres.

Our polyculture AquaSilviculture Integrated Farming is called **Ecologically Sustainable Aquaculture** (ESA), or Eco-aquaculture. When Biodiversity Conservation is well done, creatures from the wild come back.

We can mention shrimps and prawns in our **EAMP aquatic habitat,** namely *Peneaus merguiensis* (banana prawn), *P. indicus* (white prawn), *P. monodon* (giant tiger prawn), *Metapeneaus ensis* (greasy backed prawn), *Macrobrachium rosenbergii* (giant freshwater prawn), etc., among which the favourite stocking species is *Peneaus monodon*.

Fish species here include *L. calcarifer* (giant sea-perch, sea bass), *Mugilidae* (mullet), *Epinephelus* (grouper), *Oreochromis niloticus* (tilapia) which is stocked selectively to clean the bottom together with shellfish and oyster, namely *Anadara granosa* (blood cockles).

On the water's edge, we have Crabs such as *S. serrata, P. pelagicus* and *grapsidae*. We only stock mud crabs (*Scylla serrata*) to be harvested. Amphibians are also coming back such as *Rana tigrina* (frog), *Bufo melanostictus* (toad), *Varanus salvator* (varan) and even *Crocodilus porosus* (mangrove crocodile) showed up once in the Chang Hang tributary.

Picture shows workers dredging up the pond bed. Note that the pond is full of water. As mentioned in the article, the pond bottom is never dried up. See the vegetation on the water's edge, especially a young coconut tree transplanted to the dyke.

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RATIONALLY EXPLOITING NATURAL RESOURCES

(Continued from page 13)

On the ground habitat, *Sus scrofa* (boar and wild pig), *Pytho reticulatus* (python), *Lutra lutra* (otter) *Macaca fascicularis* (monkey), have increased by the hundreds, and goats and chickens feed in the wild.

In the air habitat, we have *Apis mellifera* (bee), *Columba palumbus* (dove and pigeon) and especially mangrove birds that came back to rest long ago, have recently laid their eggs and chosen EAMP as their hatchery grounds. This phenomenon means that our ecosystems are attaining a balance.

Here, the botanical diversity is safeguarded with mangrove trees such as *Rhizophora, Ceriops, Bruguiera, Avicennia, Sonneratia, Excoeratia, Lumnitzera, Phoenix paludosa, Nypa fruticans*, and mangrove bushes and creepers such as *Acrostichum aureum, Acanthus ilicifolius, Derris trifoliata*, and *Cayratia trifolia*. We are taking special care of two typical species of Can Gio mangrove which can't be found elsewhere in Viet Nam: the big tree species called *Intsia bijuga* and a mangrove creeper (*Azima sarmentosa*).

Giant tiger prawn weighed and measured: >100 g and >24 cm. This animal was caught two weeks before the rest of the stock were poisoned.

We don't need to dry our pond bottom, neither do we have to practise liming to reduce acidity of the water and soil because all our water borders are covered with native vegetation.

Based on the natural food chain process, we manage the feed and feeding accordingly to the season. On average, this is 2% of the body weight per day, i.e. only one third to half the amount of commercial feed used in intensive farming for the same stocking density. In polyculture and integrated farming, waste is used as a resource and the internal cycling of nutrients is increased.

Manpower Strategy

Unlike industrial shrimp farming relying on mechanical or electronic equipment, our eco-aquaculture enrolls local manpower. We offer free housing with modest home appliances so that each household occupies a guardhouse on a sluice-gate and manages the immediate surroundings.

We have given jobs to some 20 households including over 70 people. This means that over 10% of the relief-seeking households in the village has been eradicated, not to mention the number of relatives being helped by our workers because their monthly earnings are around one million VN Dong.

We never miss our daily meeting with workers to exchange views on:

- Stakeholders events
- Upgrading expertise, techniques and experience in eco-aquaculture
- Consciousness of environmental protection and the significant role of the mangrove ecosystem and biodiversity
- Respecting the law on one side and on the other, firmly and bravely fighting against lawbreakers

The responsibility among family members means: no pilfering, no speaking abusive or insulting words, no gambling and no strong drink. Hard working parents give a good example to their children who go to school.

Impact of pollution and climate change

Once an environmentally friendly shrimp farming method is implemented, the problem is to deal with natural calamities and human sabotage due to inattentiveness, irresponsibility, petty material advantages, envy and blind greed.

Since mid-1996, we began stocking Tiger shrimps and mangrove crabs. Our clean products are in great demand at local restaurants as well as for export. We sell EAMP products on-the-spot to traders at a high market price.

Whenever we encountered a severe flood or deluge like this year, our shrimps and crabs fled to the wild so we lost money. But since

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ECO - AQUACULTURE

► *(Continued from page 14)*

they enriched the natural ecosystem, we still felt useful. However, when our shrimps died suddenly without any symptom of disease and we realised that they were deliberately poisoned, we were disappointed with human behaviour. Nevertheless, we won't give up. We'll sell our mortgaged property to pay off our bank debts and find a smaller shelter. We're determined to carry on our work to the bitter end.

But it's an enormous challenge for us. How to deal with acid rain when the Hiep Phuoc power station nearby keeps throwing out dark smoke from charcoal combustion? How to deal with accidental oil spills? When Can Gio district is irrigated with waterways where even big ships come in from the high sea? How to deal with industrial and urban wastes discharged downstream without any treatment?

Ms Thieu Thi Tao presenting a paper on Eco-aquaculture in the mangrove of Can Gio at an international workshop held by the International Resources Institute at Subic Bay, the Philippines.

The transfer of science and technology to the community cannot ignore the social regime. It's up to the Public Administration whether the work will succeed or fail.

UNUSUAL DISCOVERY

Completely new freshwater animal discovered, and they are all female

Danish scientists have found a completely new kind of freshwater animal down a cold well in Greenland and are keeping a colony of them in a refrigerator, the Arctic magazine *Polarfronten* reported on the Internet recently.

The 0.1 millimetre long freshwater organism does not fit into any of the previously known animal families - making it only the fourth such creature to be discovered on Earth in the past 100 years. Studies of the animal named *"Limnognathia maerski"* show that it shares some characteristics with certain seawater life-forms. Scientists from Copenhagen University and Aarhus University in Denmark have established a new phylum (or family) for the tiny animal, whose most remarkable feature is a set of very complicated jaws.

It now has its own branch, Micrognathozoa, on the tree of the world's known animals, which are divided into slightly more than 30 families. *Limnognathia maerski,* which reproduces through parthenogenesis (reproduction from gametes, or sexual cells capable of fusing with another without fertilisation). It uses its jaws to scrape the bacteria and algae it feeds on from underwater moss growing in icy wells which freeze over during the long Arctic winter.

The animal was found in samples taken in 1994 from a well in Isunngua on Disco island in northwestern Greenland. A colony of the tiny creatures, all female, are currently living in a refrigerator at Copenhagen University.

(Reported by Reuters via the Nation, 18 October 2000).

AUSTRALIAN RESERVOIR

► *(Continued from page 6)*

Dam Project in the Murray Darling Basin, a similar system failed in a 542 ha. reservoir, but the air inflation was lower, only 100 litre/sec. However, it underlines the fact that nothing comes by itself. For the Mekong Basin it would be very interesting to test the system under controlled conditions and see if a series of tedious problems and loss of income for the fishers in relation to reservoirs may be solved.

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ASSESSING HABITATS

(Continued from page 10)

The MRC Fisheries Programme as well as the Environment and Technical Support Divisions, and the Department of Fisheries, Cambodia, were involved in the design and implementation of the project. The funding came largely from the Canadian Space Agency.

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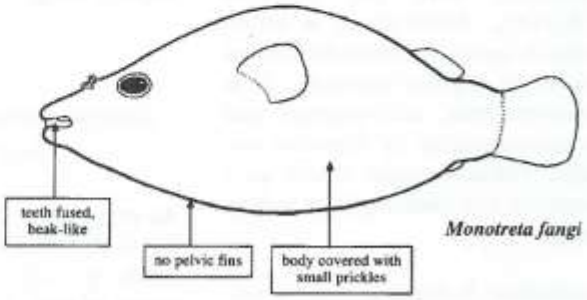
PUFFERFISH

The recent death of several people eating Pufferfish around the Tonle Sap in Cambodia has led to renewed interest in this highly toxic species that dwells in salt and fresh waters. Dr Mai Dinh Yen of Hanoi National University offers some information below.

Pufferfish are among the four sub-orders of the order Tetraodontiformes. The four sub-orders are: Tetraodontoidei (Pufferfish), Balistoidei (Triggerfish), Ostracionoidei (Cowfish) and Moloidei (Sunfish). The Tetraodontiformes are a group of Percomorpha fish with a high degree of specialisation: a single gill opening on each side, no pelvic fins, small gill openings, scales modified to look like prickles, without spines on the fins, and teeth fused.

All fish species of the Tetraodontiformes live in the tropical and subtropical seas particularly close to coral reefs. Only a few dozen Pufferfish are found exclusively in fresh water.



From W.J. Rainboth, 1996. Fishes of the Cambodian Mekong. Rome, FAO.

Sixteen species of Pufferfish live in the Mekong River Basin. They belong to **five genera** as follows:
Genus Lagocephalus with (1) body elongated, (2) two nostril openings on either side of the front. Two species are *Lagocephalus oblongus*, and *L. sceleratus*. They only occur in Viet Nam (V).
Genus Carinotetraodon with (1) 11-13 dorsal fin rays, (2) 10-12 anal fin rays, (3) nasal tube short and rounded with a terminal opening. One species is *Carinotetraodon lorteti* (V and Cambodia (C)).
Genus Chelonodon with (1) 9-16 dorsal fin rays, (2) 8-15 anal fin rays, (3) nasal tube with long anterior and posterior flaps. Three species are *Chelonodon biocellalus* (V, C), *C. fluviatilis* (V, C and Laos (L)), and *C. nigroviridis* (C).
Genus Chonerhinos with (1) 25-28 dorsal fin rays, (2) 21-22 anal fin rays (3) nostril with a simple cavity surrounded by a high rim. Two species are *Chonerhinos nefastus* (L, C and Thailand (T)), and *C. moderatus* (L).
Genus Monotrera with (1) 12-14 dorsal fin rays, (2) 10-12 anal fin rays, (3) nostril with tubular nasal tentacle that is divided into two lips. Eight species are *Monotrera cambodgiensis* (C, T), *M. fangi* (L, T, C), *M. leiurus* (L, C, V, T), *M. suvatti* (T), *M. baileyi* (L, T), *M. palembangensis* (V, L), *M. cutcutia* (L, V), and *M. barbatus* (L).

The name of Pufferfish are: in Viet Nam, Ca Noc; in Cambodia, Trey Krepot (Kampot); in Laos, Pa Pao; in Thailand, Pla Pak Pao; and in French, Poissons Ballons.

The distinguishing characteristics of Puffers Tetraodontidae are: the body is inflatable and the skin has small prickles that may be confined to the belly. There are four fused teeth in the jaws. The caudal fin is truncated and rounded.

Pufferfish are considered as small and medium sized fish. Their body length is approx. 5-20 cm. In the Mekong River Basin, Pufferfish usually live in slowly flowing or stagnant waters. They are found in estuaries as well as lower and middle courses of the mainstream and tributaries where they feed on mollusks and crustaceans as well as other invertebrates and some vascular plants. Occasionally they feed on fish scales and fins.

Pufferfish are sexually dimorphic and spawn in the littoral zones. They are known to be quarrelsome and aggressive fish.

They are called "puffer" because of their ability when attacked to inflate themselves with water or air to assume grotesque proportions. The coat of their stomach is thin, elastic and smooth. Therefore, Pufferfish have the ability to swell when the stomach is full of water or air. The fish can then float and be carried away according to the water current.

Pufferfish are not fished commercially but may be captured incidentally with other species by seines,

(Continued on next page)

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PUFFERFISH continued

set nets, cast nets or traps. Their viscera, such as heart, liver, kidney, stomach, blood, skin and ventral muscular tissues, are poisonous. The toxic substance is Tetraodontoxin.

Tetraodontoxin is an aminopehydroquinazolin with the formula $C_{11}H_{17}N_3O_8$. Although it is easily diluted in water, it cannot be diluted in common organic solutions. It is thermo-resistant, acid-tolerant and non-decomposable by digestive enzymes. Tetraodontoxin reacts as a neurotoxic and haemolytic in human beings.

Nonetheless, Pufferfish may be edible if all the above toxic organs have been carefully removed and the fish boiled at a high temperature. They are a favourite dish of risk-takers in Japan, where a high price is paid for this type of Russian roulette.

Some species of Pufferfish are treated as aquarium fish where they delight onlookers at a safe distance.

PUFFERFISH IN SIEM REAP

In a related incident, the World Health Organisation has reported that it is almost certainly poisonous pufferfish, and not pesticides or toxic fruit, that killed seven people and sickened nearly 70 others in the Siem Reap area of Cambodia in late June 2000. Reports of illness and death first surfaced along the Ou Cheak River, about 40 km downstream from Anlong Veng district. Within minutes after eating the fish, some fell ill with headaches, dizziness, nausea, vomiting, diarrhea, extreme fatigue and exhaustion.

The trouble spread to the Kralanh and Puok districts where people were poisoned by fish believed to have migrated downstream from Anlong Veng.

LETHAL FISH IF IMPROPERLY PREPARED

Samples tested in Australia and Japan

As reported in the *Cambodia Daily* by Jody McPhillips (21 August 2000, p. 12), although the first round of tests found traces of pesticides in the fish, further testing revealed that the levels were so low as to be insignificant. Twelve samples of various kinds of fish from the Ou Cheak River in Siem Reap Province were subjected to more sophisticated laboratory tests in Japan and Australia.

The Australian lab, which specialises in pesticide testing, subjected each of the twelve samples to tests for 39 different pesticides, performing a total of 468 tests. Only six of those tests came up positive for pesticides, and that was for amounts so low as to be harmless to humans.

Twelve samples were also sent to a Japanese lab at Tohoku University in Sendai that specialises in fish. That lab found that most varieties of fish submitted, including catfish and shrimp, were harmless. But the samples also included pufferfish that is poisonous if prepared improperly. The Japanese lab determined that the pufferfish samples were definitely toxic.

Villagers do not heed Dire Warnings

Health officials in Cambodia do not have an explanation as to why so many people may have eaten fish known to be poisonous and why the rate of poisonings would be higher in 2000 than past years. The Ministry of Health had sent clear warnings to the areas before. One wonders whether some of the ancient local knowledge has been lost due to the political upheavals of the 1970s and the lack of systematic education during the time of the Khmer Rouge. Many people in rural areas still lack educational facilities and are illiterate.

The Japanese lab clearly identified Saxitoxine (STXs) in high enough concentrations to cause human fatality. There were also high concentrations of neosaxitoxin (neoSTX) and decarbamoylsaxitoxin (de STX). Anti-saxitoxin ELISA kits can be useful to monitor the toxin in various fish and other aquatic animals to prevent them from ingesting a lethal dosage. The lethal dose of saxitoxin by oral intake is estimated to be 2 mg STX or less (or 10,000 mouse units = the amount to kill a mouse of 20 g body weight in 20 minutes).

It appears that if non-puffers and shrimps and crab contain low amounts of the toxins, adult humans will only become ill with the symptoms described above, but not die.

(Additional data obtained through the courtesy of the Food and Agriculture Organisation's representative in Cambodia).

For further information contact the MRC Fisheries Programme, MRC Secretariat, P.O. Box 1112, Phnom Penh, Cambodia, Tel: (855-23) 720-979; Fax: (855-23) 720-972; http://www.mrcmekong.org