



Mekong River Commission

**Deep pools as dry season fish habitats in the
Mekong River Basin**

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Background of the Working Group on Mekong Giant Fish Species

The Technical Advisory Body on Fisheries Management (TAB) of the Mekong River Commission (MRC) was established in June 2000. The TAB gives advice to the MRC Fisheries Programme on technical issues relating to basin-wide fisheries management. During the first meeting, five main issues were identified. Among these was the following:

Deep Pools in the Mekong River

Deep pools in the Mekong River, particularly north and south of the Khone Falls, are supposed to be very important for the conservation of a number of Mekong fish species. They are, in many cases, protected by local or national regulations to prevent fishing, but effective enforcement is difficult. The Cambodia Delegation reported not less than 100 such pools on the Cambodian side of the border, and the Lao Delegation knew of not less than 70 pools on the Lao side of the border. However, the significance of these habitats is not well known, and should be clarified. Co-management might be the solution to management and protection from problems.

It was agreed that the MRC Fisheries Programme (Cambodian Capture Fisheries Component, Assessment of Mekong Fisheries Component) should take action to study the function of deep pools in the Mekong River. The MRC Secretariat Fisheries Unit may explore the opportunities for finding international funds to support the development of co-management systems.

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Summary

The Mekong River is a typical floodplain river, dominated by the monsoon climate of Southeast Asia. It is a dynamic river system, alternating between a flood season from May to October and a dry season from November to April. The monsoon flood-pulse “drives” the system, creating vast areas of seasonally inundated floodplains adjacent to the river channels every year. Floodplains are extremely productive feeding habitats for most important fishes, whereas the river channels mainly serve as refuge habitats during the dry season.

As with most other relatively pristine and unregulated rivers, the Mekong River is a diverse river with alternating environmental characteristics along its path. Some stretches have little variation in depth, whereas other stretches contain rocks and boulders and vary between shallow rapids and deep pools. The deep pools play a crucial role in the Mekong River ecosystem because they are important habitats for many fishes during the dry season. When the dry season sets in, water levels in the Mekong recede and the seasonal fish habitats on the floodplain disappear. As a result, fishes retreat to deeper sections of the river and congregate there until the next flood sets in. Therefore, although fishes are mainly produced in floodplain habitats, deep pools are equally important for maintaining the integrity and productivity of the system. This report focuses on deep pools and their role in fisheries ecology of the Mekong River basin.

Certain stretches of the Mekong mainstream contain a large number of deep pools. The most important stretch is in northern Cambodia, from Kratie to Stung Treng. Along this stretch, 58 deep pools have been identified, where a large number of fish species congregate during the dry season. Some of the pools are also the habitat of the river dolphins, *Orcaella brevirostris*.

The area around the Khone Falls, on the border between Cambodia and the Lao Peoples' Democratic Republic (Lao PDR), also contains numerous deep pools. Some of these pools have been designated as ‘fish conservation zones’ (FCZ) by the local villagers over the past decade. This was done based on local recognition of their importance as fish habitats, particularly during the dry season. The establishment of FCZs is believed to have had a positive impact on the fisheries in the area around them.

On a basin-wide scale, additional stretches have been identified which contain a relatively high number of deep pools. Apart from the area from Kratie to Stung Treng mentioned above (which is the most important deep pool area in the basin), the stretches from Savannakhet to Khone Falls, and from Xayaboury to Louang Prabang are important. Some sections of the basin have been identified as having relatively few deep pools. These the areas from Vientiane/Nong Khai to Paksan/Bung Khan and, most importantly, from Kratie all the way downstream to the Mekong Delta.

Deep pools also exist in some of the major tributaries of the Mekong. In some tributaries, where dams have been constructed (e.g. the Sesan and Theun Rivers), some deep pool habitats have been affected by siltation as a result of changed hydrological conditions. In some areas, the pool habitats, and the fishes they sustain, have virtually disappeared.

The spatial separation between dry-season refuges and flood-season feeding and spawning habitats forces most mainstream Mekong fishes to migrate. These movements can be separated into three different migration patterns. (1) Within the lower part of the basin, fishes move between dry-season refuges in deep pools along Kratie/Stung Treng stretch of the river, and floodplain habitats in southern Cambodia (including the Tonle Sap River and the Great Lake) and the Mekong Delta in Viet Nam. (2) Further upstream, fishes move between deep pools in the Mekong mainstream and floodplain areas along major Mekong tributaries, such as the Mun/Chi and Songkhram Rivers in Thailand, and the Xe Bang Fai and Hinboun Rivers in Lao PDR. (3) Finally, in the upper section of the basin, approximately from the mouth of Loei River, the Mekong turns into a typical mountain river, crossing through steep river valleys with limited floodplain habitats. In this section, fishes mainly move from deep pool habitats along the Xayaboury-Louang Prabang stretch to upstream spawning habitats. Conspicuous examples of this movement is that of the Mekong giant catfish, *Pangasianodon gigas*, and its slightly smaller "cousin", *Pangasius sanitwongsei*.

In relation to future work on deep pools, the following points should be taken into account:

1. Deep pools should be viewed as integrated parts of the overall ecosystem, rather than isolated fish habitats (i.e. an ecosystem approach should be promoted).
2. Since deep pools shelter a large proportion of the Mekong fishes during the dry season, they may provide good opportunities for future monitoring purposes.
3. The issue of deep pool habitats should be integrated into future Environmental Impact Assessment procedures.
4. Prior to any future research activities on deep pools, objectives and priorities should be discussed and set.
5. Existing knowledge about the occurrence and location of deep pools should be consolidated with existing hydrographic data from the basin.

Introduction

1

Fisheries ecology of the Mekong River Basin is intimately linked to, and influenced by, the morphological and hydrological characteristics of the basin. One of the main driving forces for fisheries-ecological processes is the physical separation of important wet and dry season habitats. The vast floodplains associated with the lower Mekong are crucial feeding and rearing habitats for the majority of fish species that are important in fisheries. However, as the flood recedes at the end of the monsoon season, it is equally crucial that fishes can seek refuge in appropriate dry season habitats. In general, dry season habitats are associated with the main river channels and with permanent water bodies on the floodplain (lakes and swamps).

Within the main river channels, certain sections are better suited as dry season habitats than others. In particular, deeper sections of the river are used by a large number of species during this period of the year. These deep sections are often referred to as deep pools (or deep holes), a term that is increasingly being used in the context of fisheries ecology of the Mekong Basin.

The Technical Advisory Body (TAB) of the Fisheries Programme of the Mekong River Commission (MRC) recognised the importance of deep pools as dry season habitats in the Mekong River and recommended that a review be carried out on the current knowledge of deep pools.

This report reviews the current knowledge and information available in relation to the importance of deep pools as dry season refuges in the Mekong Basin. Implications for management are discussed.

1.1 What is a deep pool?

As mentioned above, the significance of deep pools relates mainly to their ecological function as dry season refuges for fishes (although some species spend their whole life in these habitats). Such dry season refuges occur both within the main river channels and in permanent water bodies on the floodplain. For the purposes of this report, the term ‘deep pool’ refers to the riverine habitat, although it is emphasised that floodplain refuge habitats are equally important and must not be ignored.

In relation to river fisheries, the term ‘pool’ has been most often associated with the ‘riffle and pool’ system, a system of alternating shallow rapids followed by deeper pools in the upper, mountainous stretches of river systems. This part of the river is characterised by fast and turbulent flow over a riverbed consisting of rocks, stones and gravel (Welcomme 1985). Different types of pools have been identified based on physical and hydrological characteristics (Welcomme 1985). In the lower parts of rivers, which are characterised by slow water flow and a sandy or muddy bottom, Welcomme (1985) distinguished between ‘shallows’ and ‘deeps’. In general, these terms have also been defined based on morphological and hydrological factors.

For the purposes of this report, we define the term 'deep pool' based on its fisheries-ecological importance rather than on its morphological/hydrological characteristics. Inventories of deep pools should therefore be based on their ecological significance as the primary criterion. Physical characteristics (e.g. morphology, hydrology) are also important as secondary criteria, since they may impact ecological functions of deep pools and thus determine, for example, which species inhabits which types of pools. In other words, once a deep pool area has been identified as an important dry season habitat for certain fishes, morphological (e.g. hydrographic) and hydrological data can be of crucial importance in describing and classifying the habitat in ecological terms.

Based on the above considerations, for the purposes of this report, a deep pool is simply 'a confined, relatively deep area within a river channel, which acts as a dry season refuge for a number of important fish species. For some species, deep pools may also act as spawning habitats.'

On a final note for this section, it should be emphasised that the human need to classify and define always produces the risk of segregating and disconnecting. This may be counter-productive, particularly in the context of river ecology, because although different habitats may be defined within the system, these are deeply integrated parts, which cannot be separated from the system within which they function. So, when we define deep pools, we must at the same time recognise that the most important part of the definition concerns the integrated role which deep pools play within the overall eco-system of the river basin.

1.2 Deep pools – general information

The importance of dry season refuge habitats for fishes in floodplain rivers has long been recognised (Welcomme 1985; Bayley and Petrere 1989, Hoggarth *et al.* 1999). Welcomme (1985) described how most fishes move from floodplain habitats back to the main river channels during the dry season and settle in different habitats along its length, distributing according to depth, bottom-type and vegetation cover. The movement may cover short or long distances, depending on the availability of appropriate dry season habitats within the river channel.

Fishes inhabiting pool habitats during the dry season segregate according to their ecological habits. Welcomme (1985) distinguished three main fish communities in pool habitats based on ecological habits:

- 1) **a pelagic community**, consisting of mainly small species of streamlined, silvery fishes with upward facing mouths,
- 2) **a mid-water community** of larger silvery fishes, streamlined with terminal mouths, and
- 3) **a bottom-living community** of drab coloured fishes with dorsally-humped profiles and ventrally-positioned mouths.

Despite their significance, very little information exists concerning the ecological functioning of deep pools in major rivers, other than the Mekong. In Bangladesh, the establishment of dry season reserves, including deep pools within river channels, have been identified as an important management measure to sustain floodplain fisheries (Hoggarth *et al.* 1999).

Anecdotal information from fishers in the Parana River suggests that major catfish of that river congregate in deep pools in certain places within the river (Welcomme 2001, personal communication). Similar anecdotal information exists for the Amazon and Orinoco rivers. In the Niger River, fishers claim that Nile perch and catfish stay in deep pools of the river channels, especially during low water. Again, this information was never documented in formal literature (Welcomme 2001, personal communication).

2.1. Deep pool areas within the Mekong Mainstream

In recent years, some information relating to deep pools in the Mekong River has accumulated. Two areas have been the main focus of this information: 1) the Mekong mainstream in Kratie and Stung Treng Provinces, northern Cambodia and 2) the Khone Falls, in Champassack Province, in southern Lao Peoples' Democratic Republic (Lao PDR).

2.1.1. Kratie - Stung Treng

Hill and Hill (1994) listed 28 named deep pools as important dry season habitats for fishes in Kratie province, northern Cambodia (presumably identified based on interviews with local fishers in the area). They further stated that, “deep holes in the mainstream of the Mekong would appear to be the primary rearing and dry season holding habitat for large catfish and carp” (page 74).

This list of deep pools has subsequently been extended to 58 pools, 39 of which are situated in Kratie Province and 19 in Stung Treng Province (Vannaren and Kin 2000; see Annex, Table 1).

These pool habitats are critical for sustaining not only fisheries within the two provinces, but for the whole of Cambodia and the Mekong Delta in Viet Nam. Many species spawn in association with these pools, and larvae and juveniles move downstream to the floodplain areas in southern Cambodia and Viet Nam.

Some of the species mentioned as examples of important fishes using deep pool habitats are *Boesemania microlepis*, *Mystus wyckioides*, *Chitala ornata*, *Micronema apogon*, *Pangasianodon hypophthalmus*, *Cirrhinus microlepis*, *Probarbus jullieni*, *Catlocarpio siamensis*, and even the famous giant catfish *Pangasianodon gigas*.

Vannaren and Kin (2000) recommend, among other things, that further studies be carried out related to deep pools, and that co-management practices should be implemented for these important dry season habitats.

2.1.2. Khone Falls

The Khone Falls area in southern Lao PDR has been the subject of several ecological and fisheries studies during the past decade, and thus is one of the most well-described sites within the Mekong in terms of fisheries ecology.

Roberts and Baird (1995) listed seven named pools around the Khone Falls area, and identified them as important fish habitats, based on interviews with local expert fishers:

- ✍ **Boong Pba Gooawng:** important feeding ground for the Irrawaddy dolphin, *Orcaella brevirostris*, a spawning ground for *Boesemania microlepis* and also reported to be a spawning ground for *Catlocarpio siamensis*.
- ✍ **Boong Pba Jook:** spawning ground for *Hypsibarbus sp.* and *Boesemania microlepis*. Dolphins stay there in November-December.
- ✍ **Boong Hin Sang**
- ✍ **Boong Ken**
- ✍ **Boong Pba Leum:** thought to be a spawning ground for *Pangasius sanitwongsei* (the species reportedly surface in this pool during June-July).
- ✍ Deep pools below **Tam Ee Daeng** and **Gawng Nyai:** important habitat for the catfishes *Micronema apogon* and *Bagarius yarrelli*.
- ✍ **Hin Dta Moon:** *Pangasius macronema* is targeted in this pool (which is near the mouth of the Hoo Sahong, the main migration channel for *P. macronema*).

It is apparent from this list that different pools are inhabited by different species. Some pools are even named after certain species, such as **Boong pba gooawng** (“*Boesemania microlepis* Pool”) or **Boong pba leum** (“*Pangasius sanitwongsei* Pool”). Presumably, such differentiation is caused by differences in physical and ecological characteristics between pools. For future classification of these habitats, it will be important to identify the key ecological and physical indicators which determine the functioning of these habitats, and therefore, in turn, the fish species that inhabit them.

Near the Khone Falls, in Khong District, Champassack Province in southern Lao PDR, a co-management programme related to Fish Conservation Zones (FCZs) was set up in 59 villages between 1993 and 1997 (Baird *et al.* 1998). These fish conservation zones were largely associated with deep pools within the Mekong mainstream that, according to local villagers on Khong Island, are important as dry-season refuges for fishes (Baird *et al.* 1998). The fish species most commonly reported as beneficiaries of the FCZs were: *Morulius chrysophekadion*, *Morulius barbatula*, *Chitala blanchi*, *Chitala ornata*, *Micronema micronema*, *Micronema apogon*, *Belodontichthys dinema*, *Hemisilurus mekongensis*, *Boesemania microlepis*, *Labeo erythropterus*, *Cosmochilus harmandi*, *Hypsibarbus malcolmi*, *Probarbus jullieni* (or *spp.*), *Gyrinocheilus pennocki*, *Amphostistius laosensis* (or *spp.*), *Bagarius yarrelli* (or *spp.*), *Pangasius conchophilus*, *Pangasius pleurotaenia*, *Mystus nemurus* and *Mystus wyckioides*. These species are predominantly sedentary species. However, migratory species are also believed to benefit from the FCZs (Baird *et al.* 1998).

Baird *et al.* (1998) also listed some tentative parameters as indicators to classify important habitats within the Mekong. These were: depth, current speed, substrate type, slope, proximity to wetland forest and, finally, occurrence of objects inside the habitat (e.g. logs and rocks). According to local villagers in the area, water depth is the most important habitat parameter to consider. Baird and Flaherty (1999) further elaborated on habitat parameters and concluded that “habitat parameters and other unique environmental factors are likely to be the main determinants of the number of fish species reported to have increased in individual FCZs.”

The effectiveness of the FCZs are currently being evaluated under the auspices of the Living Aquatic Resources Research Centre of Lao PDR (LARReC). A preliminary assessment, based on interviews with villagers involved in the FCZ programme, has been completed (Chomchanta *et al.* 2000). Most of the villagers support the FCZ concept, and one of the main reasons given for the perceived increase in fish populations was that the FCZs act as a dry-season deep water habitat for many species (Chomchanta *et al.* 2000, page 13). Altogether, 24 species (or genera) of fish were reported as having increased in numbers as a result of the FCZs. These include both relatively sedentary species (such as *Boesemanina microlepis*, *Chitala blanchi* and *Chitala ornata*), and migratory species (such as *Pangasius conchophilus*, *Pangasius macronema*, *Probarbus jullieni* and *Cirrhinus microlepis*).

One species, which apparently spends most of its life cycle associated with deep pools in the main river channels, is *B. microlepis*. This species was also listed as one of the main beneficiaries of the FCZs around Khone Falls (above) and has been the subject of detailed studies in this area. Seven deep pools were identified as important spawning habitats for *B. microlepis* (Baird *et al.* 1999). Although it is a relatively sedentary species, *B. microlepis* may depend on the regular return of migratory species, which may constitute part of its diet at certain times of year. Local fishers consider it to be a “hunter” (Baird *et al.* 1999; Poulsen and Valbo-Jørgensen 2000).

The cyprinid *Hypsibarbus malcolmi* also spawns in certain deep pools during the dry season period (Baird and Phylavanh 1999) and one pool near the Khone Falls was reported to be a spawning site for both these species.

2.1.3. Northern Lao PDR

Although existing work related to community-based aquatic resource management is centred around the Khone Falls, management systems also exist in other parts of the basin. During a fisheries survey of Luang Prabang Province in northern Lao PDR, 37 percent of the surveyed villages reported that they have a conservation zone near the village. These conservation zones were mainly associated with deep pools within the river, which were believed to be important breeding grounds for fish (Sjørøsløv 2000).

2.1.4. Basin-wide

One of the main sources of information about the ecology of deep pool dry-season habitats is people living nearby. Many of these local fishers are out on the water fishing every day and have acquired a detailed knowledge of the local environment. During recent surveys along the Mekong mainstream that were carried out by the Mekong River Commission's Fisheries Programme[?], local knowledge was collected from the whole stretch of the lower Mekong River. Although deep pools were not specifically raised as an issue during these interviews, more than 200 records from the survey refer to deep pools as being important habitats for certain fishes (Table 2, Figure 1).

Species with different ecological habits make use of deep pool habitats during the dry season (Table 2). Many highly-migratory species are included in the list such as most members of the Pangasiidae family and cyprinids such as *Probarbus sp.*, *Catlocarpio siamensis*, *Cirrhinus microlepis* and *Cyclocheilichthys enoplos*, as well as relatively sedentary species such as *Chitala ornata*, *wallago attu*, *Mastacembelus armatus* and *Bagarius yarelli*.

[?] Assessment of Mekong Fisheries Component

The station where deep pools were reported most often was at Sandan Village, in Sambor in Kratie Province in Cambodia. Here, 22 species were reported to use deep pools as dry season habitats. These species included many migratory species such as ten members of the Pangasiidae family, *Probarbus jullieni* and *Probarbus labeamajor*, *Henicorhynchus sp.*, *Cirrhinus microlepis*, *Cyclocheilichthys enoplos*, *Paralaubuca typys*, *Morulius chrysophekadion* and *Botia modesta*. Sedentary species reported at this station included *Chitala ornata*, *Boesemania microlepis* and *Bagarius yarelli*.

At Khong Island near the Khone Falls, one station reported 12 different species using deep pools. At Phonthong district, also in Champassak Province, Lao PDR, and at Ban Done Kao in Luang Prabang Province, Lao PDR, 10 species were reported. Table 3 in the Annex shows the species reported for each of these four deep pools.

The most striking thing to note from Table 3 is the limited species overlap between the four pools. No species are reported to occur in all four of the pools and only two species, *Pangasius bocourti* and *Micronema sp.* are reported from three of the pools. It is also interesting to note that the two pools which are closest to each other, Ban Khanh Gneir, Phonthong District and Ban Seine Tay, Muang Khong District, both in Champassak Province of Lao PDR, have no species overlap. This lack of overlap can probably be attributed to a combination of the geographical position of the pools and differences in environmental parameters associated with each pool.

In addition to identifying stretches in the river with important deep pools, the study also identified stretches of the river that have relatively few deep pools. Two such stretches are: 1) the lower section of the river, from Kratie in the north, to the Mekong Delta in the south, and 2) the middle section of the river, from Loie in the north to Thakhek/Nakhon Phanom in the south.

The fact that certain stretches of the Mekong have a number of deep pools, while others have comparatively few, may have had a substantial impact on the ecological evolution of Mekong fishes (see discussion below).

It is also generally believed that the giant Mekong catfish, *Pangasianodon gigas*, spends the dry season in deep pools. Fishers in Xayaboury province, Lao PDR, reported the existence of a deep pool near Ban Muangliap, which they believe is a dry season habitat for the giant Mekong catfish. Fishers in Bokeo Province, which is near the borders of Thailand, Lao PDR and Myanmar, also believe that the giant catfish they catch originate from Xayaboury (Bouakhamvonsa 2001, personal communication).

Davidson (1975) reported on 'Pa beuk' (Lao name for giant catfish) fishing at a deep pool near Ban Ang, about 50 km upstream from Vientiane. This fishery was accompanied by a traditional ceremony, in which offerings were made in order to appease the spirits of the river (the ceremony is described in detail in Giles, 1935). At the time of writing his book, Davidson stated that this ceremony had ceased to exist.

2.1.5. Dolphins

The Mekong River dolphin, *Orcaella brevirostris*, is one of the most conspicuous animals in the Mekong, and at the same time, one of the most threatened. Although it is not, and should not be, considered a fishery resource, its ecology is deeply integrated with the ecology of Mekong fishes, and it is deeply dependant upon the existence of deep pool areas for its survival (Baird and Mounsouphum 1997).

The distribution of dolphins in the Mekong is restricted to the area from Kratie in the south, to the Khone Falls in the north. They are also found in the lower stretches of the Sesan sub-catchment. As described above, this area is also the most important in terms of deep pool fish habitats in the Mekong. This is not a coincidence since dolphins are known to spend most of their time in deep pools, from where they frequently undertake “hunting” migrations following groups of migratory fishes (Baird and Mounsouphum, 1997).

Without deep pool habitats, and the fishes they sustain, there would be no dolphins in the Mekong River.

2.2. Deep Pool Areas within Mekong Tributaries

Very little information exists on deep pools as fish habitats in tributaries of the Mekong.

Due to the presence of deep pools, certain stretches of the Nam Tha River in Nalee District in northern Lao PDR, are important fishing spots for a large geographic area. Local traditional management initiatives are already in place in order to conserve the fish resource (Viravong 2001, personal communication).

In the Sesan River, some important deep pool areas have been reported as becoming shallower in the past few years due to increased silt deposition resulting from the Yali Dam in the upper part of the basin (Fisheries Office of Ratanakiri Province, Cambodia, 2000). As an example, within the last three years, one deep pool in Voen Say district, was reported to have diminished from 7-8 meters to just half a meter in depth. As a consequence, many fish species have been reduced, or have almost completely disappeared in the area. These include *Pangasius krempfi*, *Pangasius conchophilus*, *Pangasius polyuranodon*, *Pangasius larnaudiei*, *Belodonthichthys dinema* and *Micronema micronema*. (Fisheries Office of Ratanakiri Province, Cambodia, 2000, page 26).

A similar problem has been reported from the Theun River in Lao PDR resulting from the Theun-Hinboun Dam (Terry Warren 2000, personal communication).

2.3. Hydrographic information

Finally, one important source of information should be recognised, although it does not refer to deep pools from a fisheries point of view. This is the updated *Hydrographic Atlas of the Lower Mekong River*, published by the Mekong River Commission. This publication may be of critical importance for inventory and classification purposes once certain areas have been identified as important deep pool fish habitats. The Atlas currently exists in printed form for the whole lower Mekong mainstream and will be available in digitised format in early 2003.

The existence of deep pools within the Mekong, and their geographic position in relation to other important fish habitats, appears to be one of the main factors influencing the fisheries ecology of the Mekong basin. For example, the location of deep pool areas (and equally important, the location of areas where deep pools are absent), may be one of the main factors responsible for the migratory habits of a large proportion of fishes. Three main migration systems for fishes have been identified within the Mekong mainstream (Coates *et al.* 2000). The geographic position of stretches within the mainstream containing a relatively-high number of deep pools may have been one of the main factors influencing the evolution of these three migration systems. The migration system of the lower basin (i.e. below the Khone Falls), is basically a migration between the important dry season habitats in deep-pool stretches of the north (Kratie-Stung Treng), and important flood season feeding habitats of the south (southern Cambodia-Mekong Delta-Tonle Sap). This, again, underlines the importance of viewing deep pools as an integrated part of a larger system.

Deep pools in the middle Mekong (i.e. from Khone Falls to about Loei) mainly serve as dry season habitats for fishes that spend the flood season on the floodplains of major tributaries.

The relative lack of deep pool areas along the stretch between Thakhek and Loei may be one of the main reasons for the apparent separation between the upper migration system above Loei, and the middle migration system between Khone Falls and Loei.

As can be seen from existing information, deep pools are used by a large number of species with different ecological characteristics. Both relatively sedentary species, such as *Boesemania microlepis*, and relatively migratory species, such as *Pangasius krempfi*, have been reported to use this habitat. This may be of importance in relation to future management options, because local management initiatives may, at the same time, serve both the management of local stocks **and** of migratory stocks (e.g. trans-boundary stocks)

It is interesting that the only existing information on deep pools in tributary systems of the Mekong basin relates to the siltation of pools caused by existing hydroelectric dams further upstream (Fisheries Office, Ratanakiri Province, Cambodia 2000; Terry Warren 2000, personal communication). Obviously, this is an issue that needs to be included in future Environmental Impact Assessments (EIAs) and Fisheries Impact Assessments (FIAs) when considering water management projects. For example, any siltation of the deep pools in the Kratie-Stung Treng area will have substantial implications for fisheries within the whole lower basin. This may have equal, or even more serious consequences, than the often-cited blockage of migration routes by dams.

Recommendations

4

Current knowledge about deep pools within the Mekong basin provides substantial indications of the importance of this habitat type for fisheries, and for the ecological integrity of the basin. The purpose of this report has mainly been to outline this current knowledge. The report is thus intended to serve as a tool for follow-up discussions about future needs and priorities in relation to deep pool habitats. The following points may be seen as an attempt to trigger this discussion.

- 1) Any future work in relation to deep pools should take a “systems approach”, i.e. the role of deep pools as integrated elements of larger systems should be recognised and prioritised. In other words, research and management activities in relation to deep pools should be based on their importance for the eco-system as a whole, rather than on their local importance.
- 2) The point of departure in relation to deep pools could be to make an inventory of important deep pool areas basin-wide (**note**: not necessarily individual deep pools). This has been initiated already, to some extent, based on current knowledge, but a more elaborate and focused study may be needed directly aimed at identifying important dry season refuge areas at the basin-wide level (carried out through focused interviews with local villagers and fishers). Following the identification of important deep pool areas, the *Hydrographic Atlas of the Lower Mekong Basin* could then be used to classify them, based on their hydrographic characteristics.
- 3) Because deep pools function as “sink habitats” during the dry season, they may offer an opportunity for future monitoring purposes in relation to the health of the environment and the state of the fisheries. However, appropriate parameters to use in such a monitoring programme must be identified. Discussions about what kind of parameters to focus on, and in turn what methods to use, should be the main activity related to the monitoring of deep pools in the near-term.
- 4) Further research into the ecological functioning and significance of deep pools may also be promoted. However, it is important to discuss priorities before jumping into *ad hoc* and non-coordinated research projects.
- 5) Discussions about how the issue of deep pools can be better included in future EIAs and FIAs of water management projects should be initiated.

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ANNEX

Table 1 List of Deep pools in Kratie and Stung Treng Provinces, Cambodia

N°	Name of pool	Length m	Width m	Depth m	Place
1	Pras song	300	40	10	Kratie
2	Phsot	800	100	18	"
3	Chroy Ban Tay	500	50	12	P. Prasop
4	Pak Vek	1000	40	15	Sam Bo
5	Ba Rang Kor	800	40	10-12	"
6	Yav	600	40	15	"
7	Ton Song Tlak	2000	40	15-40	"
8	A Chan	300	40	15	"
9	Pras Tho Vea Lech	200	40	15	"
10	Pras Tho Vea Thom	800	50	10	"
11	Kos Tbal	80	50	10	"
12	Chab Chnot	800	50	15	"
13	Pro Cheav	500	50	15	"
14	Chroy Sam Yong	400	40	15	"
15	Pra	1000	35	25	"
16	Kul Pram Bay Chrong	1500	35	15	"
17	Kos Dam Bong	800	35	20	"
18	Kandor Moui Roi	1000	200	40	"
19	Damrei -Boengcha	500	150	30	"
20	Ksach Mkak	200	20	10	"
21	Ksach Svay	150			"
22	Pras Tho Vea Keth	1000	150	40	"
23	Ka Peang-Sbeu	350	250	20	"
24	Chrok Tea	200	150	20	"
25	Kampong Phnov	500	150	20	"
26	Ta Chan	200	200	10	"
27	Yay Mao	300	50	10	"
28	Sa Kangkep	1500	50	15	"
29	Kos Kgner	400	200	30	"
30	Srer Korki	1500	500	50	"
31	Tro Lok	70	40	20	"
32	Pras Theart	1500	500	15	"
33	Ver Val	1500	30	15	"
34	Kul Runtas	1500	40	25	"
35	Kos Thnot	400	50	15	"
36	Kos Preng	300	150	20	"
37	Kantoy Kos Preng	700	100	15	"
38	Smar Kos Riel	100	50	10	"
39	Kantoy Kosrongeav	800	150	10	"

Stung Treng : 19

N°	Name of pool	Length m	Width m	Depth m	Place
40	Kambor	500	100	40-60	Thala
41	Voeng Kong	1000	300	30-50	"
42	O Svay	400	200	20	"
43	Svay	1200	500	30-50	"
44	Kaing Cham	500	200	40	"
45	Bong Kok	300	100	25	Siem Bok
46	Thnong	1000	600	20-40	"
47	Kaing Kombot	700	300	25	"
48	Treng	450	300	30	"
49	Sre Po	400	200	20-30	"
50	Phsot	250	100	20-25	"
51	Ba Pheap	800	200	20-30	"
52	Chro Long	2000	200	30-60	"
53	Kos TaKe	80	30	15-20	"
54	Thkong 'Preng'	200	150	20-30	"
55	Siam Bok	300	60	15-25	"
56	Thmor Thom	200	50	30	"
57	Kos Damloun	60	50	15	"
58	Tong Deng	1000	200	15-20	"

Source: Vannaren and Kin 2000.

Table 2 List of species reported to use deep pools as a dry season habitat

<i>Species</i>	Number of Reports
<i>Chitala ornata</i>	12
<i>Heligophagus waandersi</i>	10
<i>Paralaubuca typus</i>	10
<i>Wallago attu</i>	10
<i>Mastacembelus armatus</i>	9
<i>Micronema sp.</i>	9
<i>Puntioplites falcifer</i>	9
<i>Morulius chrysophekadion</i>	8
<i>Bagarius yarelli</i>	7
<i>Pangasius macronema</i>	7
<i>Pangasius polyuranodon</i>	7
<i>Probarbus jullieni</i>	7
<i>Probarbus labeamajor</i>	7
<i>Cyclocheilichthys enoplos</i>	6
<i>Hampala dispar</i>	6
<i>Hampala macrolepidota</i>	6
<i>Henicorhynchus siamensis</i>	6
<i>Pangasianodon hypophthalmus</i>	6
<i>Pangasius conchophilus</i>	6
<i>Pangasius krempfi</i>	6
<i>Pangasius pleurotaenia</i>	6
<i>Catlocarpio siamensis</i>	5
<i>Chitala blanchi</i>	5
<i>Pangasius larnaudiei</i>	5
<i>Barbodes gonionotus</i>	4
<i>Notopterus notopterus</i>	4
<i>Pangasius bocourti</i>	4
<i>Boesemania microlepis</i>	3
<i>-0000pBotia modesta</i>	3
<i>Cirrhinus microlepis</i>	3
<i>Cosmochilus harmandi</i>	3
<i>Hemibagrus nemurus</i>	3
<i>Pangasius sanitwongsei</i>	3
<i>Pangasius siamensis</i>	3
<i>Wallago leeri</i>	3
<i>Hypsibarbus malcolmi</i>	2
<i>Pangasius djambal</i>	2
<i>Tenualosa thibeaudeau</i>	2
<i>Trichogaster trichopterus</i>	2

<i>Species</i>	Number of Reports
<i>Bagarius bagarius</i>	1
<i>Bangana behri</i>	1
<i>Botia helodes</i>	1
<i>Channa striata</i>	1
<i>Chitala lopis</i>	1
<i>Cirrhinus molitorella</i>	1
<i>Hemibagrus wycki</i>	1
<i>Lalates hexanema</i>	1
<i>Lycotrichia crocodylus</i>	1
<i>Mekongina erythrospila</i>	1
<i>Osphronemus exodon</i>	1
<i>Osteocheilus hasselti</i>	1
<i>Pristolepis fasciata</i>	1
<i>Puntioptiles proctozysron</i>	1

Table 3 Comparison of species composition for the four most important deep-pool areas

Species	Ban Done Kao	Ban Khanh Gneir	Ban Seine Tay	Sambor
	Luang Prabang	Champassak	Khong Island	Kratie Prov.
<i>Pangasius djambal</i>				X
<i>Boesemania microlepis</i>			X	X
<i>Mastacembelus armatus</i>	X		X	
<i>Channa striata</i>		X		
<i>Laiides hexanema</i>		X		
<i>Pangasius siamensis</i>				X
<i>Pangasius pleurotaenia</i>			X	X
<i>Pangasius macronema</i>	X			X
<i>Pangasius larnaudiei</i>				X
<i>Pangasius krempfi</i>				X
<i>Pangasius bocourti</i>	X	X		X
<i>Pangasius conchophilus</i>				X
<i>Pangasianodon hypophthalmus</i>			X	
<i>Heligophagus waandersi</i>			X	X
<i>Micronema sp.</i>	X	X		X
<i>Bagarius yarely</i>			X	X
<i>Botia modesta</i>				X
<i>Henicorhynchus sp.</i>			X	X
<i>Cirrhinus microlepis</i>				X
<i>Morulius chrysophekadion</i>		X		X
<i>Mekongina erythrospila</i>		X		
<i>Hampala macrolepidota</i>	X			
<i>Hypsibarbus malcolmi</i>	X			
<i>Barbodes gonionotus</i>	X	X		
<i>Puntioplites falcifer</i>		X		
<i>Cyclocheilichthys enoplos</i>				X
<i>Probarbus jullieni</i>	X			X
<i>Probarbus labeamajor</i>			X	
<i>Paralaubuca typus</i>				X
<i>Lycothrissa crocodylus</i>		X		
<i>Tenualosa thibeaudeaui</i>			X	
<i>Chitala blanchi</i>		X		
<i>Chitala ornata</i>	X		X	X

Figure 1 Map of the Mekong mainstream showing the number of species reported to use deep pools at each survey station.

