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for
VOLUME 2

SUSTAINABLE HYDROPOWER MASTER PLAN FOR THE XE KONG BASIN IN LAO PDR

FINAL REPORT

A component of

Hydropower Development Alternatives for the Mekong Basin: Maintaining the Flows that Nourish Life

Submitted to
Government of Lao PDR

Submitted by
Natural Heritage Institute, San Francisco, California
In Association with the National University of Lao

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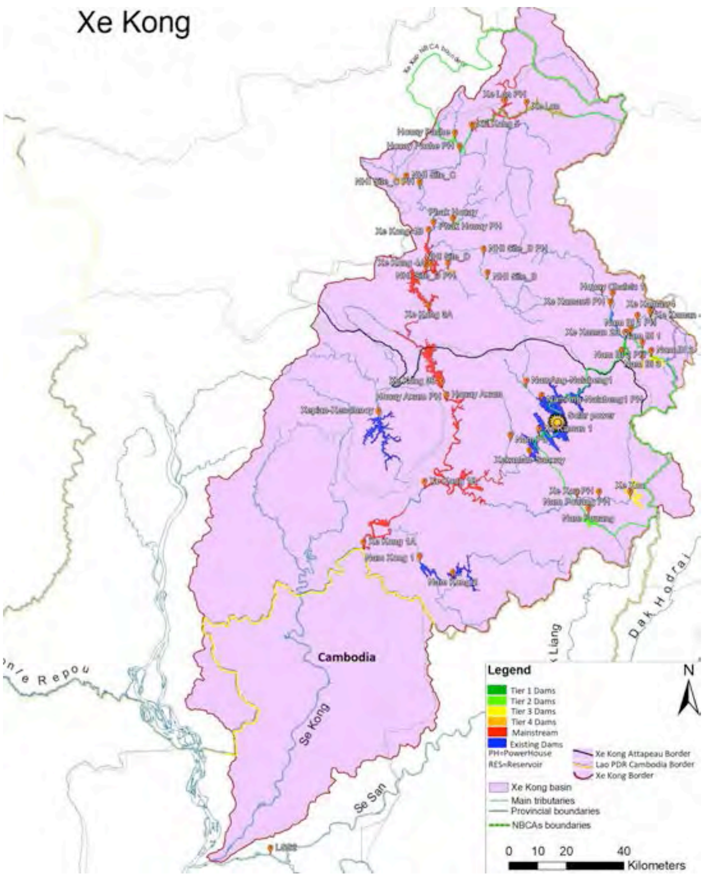

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Sustainable Hydropower Master Plan for the Xe Kong Basin in Lao PDR

Final Report

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Annex 1.1: NHI Team of Technical Experts

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1) Mr. Gregory Thomas, Project Manager/Chief of Party

   Mr. Thomas has over 35 years of experience as an environmental advocate, professor, and project manager. In addition to practicing natural resources law and planning, for the past 26 years Mr. Thomas has served as the founder and president of NHI. In this capacity, he has spearheaded many international projects focused on improving the management of developed river systems to protect biodiversity and restore natural values and environmental services, which have aggregated to several million USD in scale. His areas of expertise include water resources management and planning, hydropower reoperation, energy policy, international environmental law and conservation, and building negotiations and consensus processes for natural resources management projects.

2) Mr. George Annandale, Dam Engineering and Sediment Management Expert

   Dr. Annandale has more than 40 years of experience as a civil engineer specializing in water resources engineering. He offers services in the field of fluvial hydraulics, design and engineering; reservoir and water supply management; and hydrology and hydraulics. As a recognized expert in reservoir sedimentation management he has published numerous peer-reviewed papers and is author, co-author and contributing author to eight books on sedimentation and scour. He was named by International Water Power and Dam Construction as one of 20 engineers who globally made a significant contribution to dam engineering.

3) Mr. Lilao Bouapao, Social Science Expert

   Dr. Bouapao has over 20 years of experience in social sciences, water resources management, statistics and project management in tropical environments in Lao PDR, Viet Nam, Thailand and Cambodia. He is familiar with the environmental and social issues and key stakeholders involved in development efforts in SE Asia. His has served as a senior advisor to the International Finance Corporation, the Mekong River Commission and the Department of Water Resources of the Ministry of Natural Resources and Environment of Lao PDR. For the latter, he worked on the development of the Nam Ou River Basin Profile, revisions to the Lao PDR Water Law, and contributions to the Water Resources Strategy and Policy in Lao PDR. He has also provided advice on environmental and social aspects of the Nam Theun 2 Hydropower Project and the Don Sahong Hydropower Project for the power companies.

4) Mr. Kent Hortle, Fishery Mitigation Expert

   Kent Hortle has many years of experience as a project manager or specialist in fisheries and aquatic ecosystem assessment and management, mostly in developing countries such as Indo-China, Indonesia and Papua New Guinea. As an Adjunct Research Fellow at Charles Sturt University, Australia, and an independent consultant, Mr. Hortle has completed or contributed to more than 100 reports or publications, presented at several conferences on fish biology or limnology, and worked with clients such as the Don Sahong Hydropower Company, Challenge Programme on Water and Food, the Mekong River Commission (MRC), WorldFish, and Wetland Research & Management. His most recent full-time positions included Chief Technical Advisor for the MRC (2009-2011), Coordinator for the Assessment of Mekong Capture Fisheries Project (2001-2005), and management of the Environmental Monitoring Program for PT Freeport Indonesia (1995-2001). He holds a BSc Honours in Zoology from Monash University.

5) Mr. Erland Jensen, Informatics Expert

   Mr. Jensen has worked in a variety of positions in the Mekong River basin, including as a Chief Technical Advisor for the Mekong River Commission Secretariat and DANIDA. His expertise spans environmental impact analysis related to hydropower development, climate change, hydrology, sediment dynamics, nutrient processes and carbon balance to primary production and to fisheries productivity.

6) Mr. Prakash Kaini, Hydraulic Engineering Expert
Mr. Kaini is an experienced hydraulic engineer from Nepal with a PhD in Water Resources from Southern Illinois University, Carbondale, and a Masters in Hydropower Engineering from the Norwegian University of Science and Technology. He has held positions wiith Golder Associates in Colorado and is currently employed by the City of Aurora in Colorado. He has authored and co-authored several reports, articles and conference papers, including "Maintaining Sediment Flows through Hydropower Dams in the Mekong River Basin" that was co-authored with other members of the NHI Team and published in the Journal of Water Resources Planning and Management.

7) Mr. Philip Knight, Global Information Systems (GIS) Expert

8) Mr. Mathias Kondolf, Fluvial Geomorphology Expert
Dr. Kondolf is a fluvial geomorphologist, environmental planner and Professor of hydrology, river restoration and environmental planning at the University of California, Berkeley. His current research includes the Lower Colorado, Sacramento, Trinity, and Klamath Rivers of California/Oregon; the Apalachicola River, Florida; and the Lower Mekong River.

9) Mr. Martin Mallen-Cooper, Fishery Science and Fishway Biology Expert
Dr. Mallen-Cooper has been a fishway biologist for 30 years and has designed over 200 fishways in Australia and overseas, from fish locks and fish lifts on large dams to low-level pool-type and nature-like fishways. He works closely with engineers, managers and diverse interest groups, to develop solutions that are not only site-based but integrate ecological objectives over different spatial scales.

10) Mr. Peter Meier, Hydropower Economy Expert
Dr. Meier is a hydropower economist and consultant to the World Bank with extensive experience in risk assessment, and economic and financial analysis of hydro projects (in Asia including Trung Son (Vietnam), Dasu and Tarbela (Pakistan), Rampur and the Upper Krishna power projects (India), Nam Theun 2 (Laos)). He was formerly Chief Economist of Asia Power (a New Zealand based IPP), and has also advised ADB, KfW, UNDP, JBIC and many Governments (India, Philippines, and Vietnam) on tariff and power sector reforms, PPAs, environmental economics and investment appraisal.

11) Mr. Peter-John Meynell, Environmental and Natural Resources Expert
Peter-John is a freshwater biologist with more than 30 years of experience in dealing with environmental and development issues in South East Asia, South Asia and Southern and Central Africa. As well as being the team leader of the International Centre for Environmental Management's MK3 (Optimising Cascades or Systems of Reservoirs in Small Catchments) Project, he has led research in enhancing ecological diversity of reservoirs with constructed wetlands and environmental flow regimes.

12) Mr. Thomas B. Wild, Hydrologic and Sediment Modeling Expert
Dr. Wild is a Postdoctoral Fellow at the School of Civil and Environmental Engineering, Atkinson Center for a Sustainable Future at Cornell University. His specialty is developing and applying new modeling tools for solving water resources and environmental problems, especially in the areas of storm water management, fluvial water quality, and reservoir sediment management.

Annex 3.1:

Hydrology and Fisheries Analysis Conclusions

Prepared by Erland Jensen, 2016.

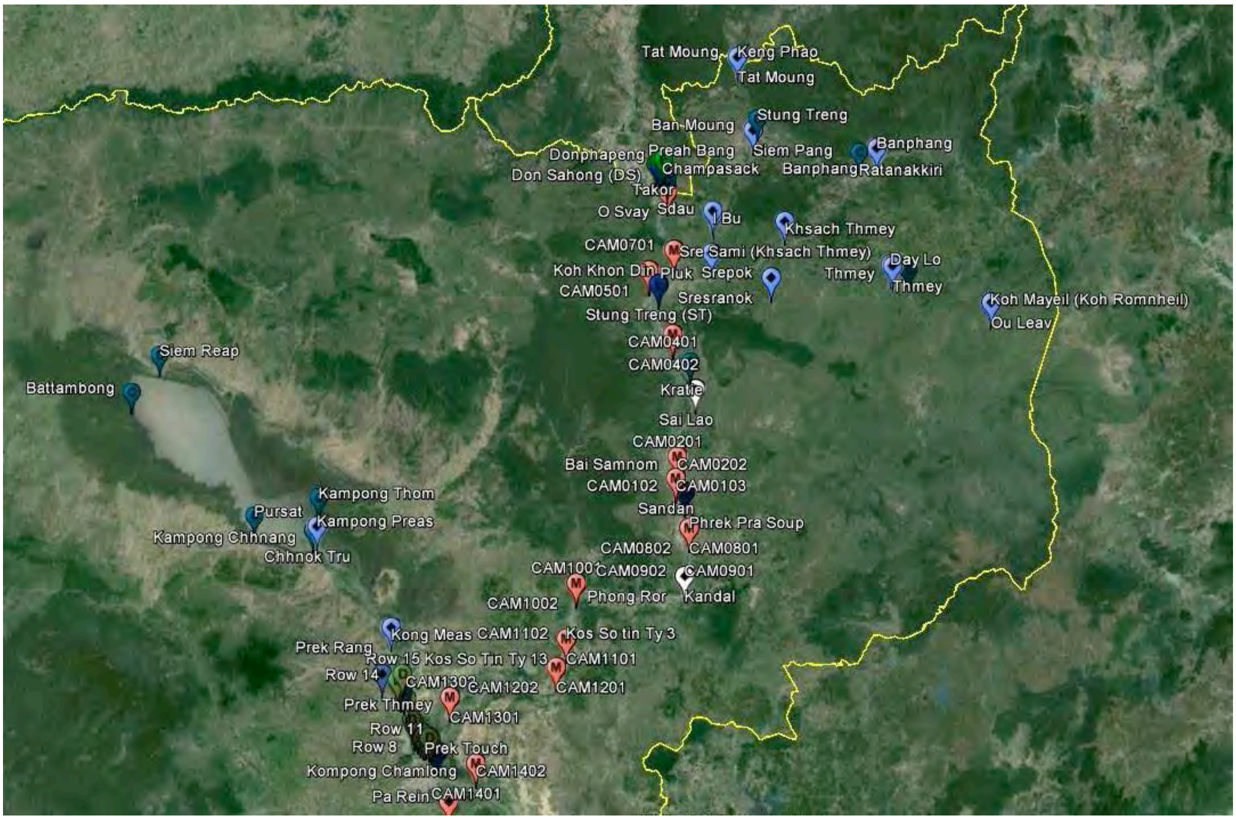

Figure 3.1-1. Map showing locations for fisheries catch, Dai fisheries, Lee trap fisheries, migration, larval drift and general catch in Cambodia. Data from these stations is used for analysis in technical reports (see reference list for details).

Definitions

Trend: Is an underlying pattern of behaviour in a time series, which could be partly or nearly completely hidden by the recognized amounts of unexplained variation in the time series (noise).

Variability: Denotes how stretched or squeezed a distribution is. Variability is typically measured by the quotient of mean and standard deviation.

Change: Is the transition from one state to another *significantly different* state, e.g. change in variability or trend. A α = 5% significance level is used.
See: https://en.wikipedia.org/wiki/Type_I_and_type_II_errors#Type_I_error

Trigger: An event that causes a particular action, process, or situation.

Pulse: A rapid rise in discharge.

Pulse rate: Change in discharge between 500 m^3/s and 2500 m^3/s per day.

Monotonic: A function is called *monotonic* if and only if it is either entirely increasing or decreasing.

Overfishing: The practice of commercial and non-commercial fishing which depletes a fishery by catching so many adult fish that not enough remain to breed and maintain the population. Overfishing exceeds the carrying capacity* of a fishery. (*the supportable population of a species, given the food, habitat conditions and other resources available within a fishery.)

CPUE: Catch per Unit Effort.

Hydrology

Change in water level

Downstream river water level changes due to the operation of hydropower dams was predicted by modelling (see [A]), and is now supported by monitoring by Mekong River Commission Secretariat (MRCS). For the Chinese dams the changes gradually took place after 2008 when the large Xiaowan and Nouzhadu dams were filled and commissioned. For the Vietnamese dams the changes gradually took place between 2002 and 2008, with the large dams Yali and Sesan 4 starting operation 2002 and 2010.

The change to higher water level in the dry season and lower water level in the wet season is documented by the hydrographs from Chiang Saen for the Chinese dams and from Ban Kamphun for the Vietnamese dams. The change is documented further downstream e.g. at the Prek Kdam station in the Tonle Sap River. The time when the up-going water level passes the long-term mean is delayed. The time when the down-going water level passes the long-term mean is also delayed, see Figures 3.1-2, 3.1-3 and 3.1-4.

These delays are evident in the hydrographs showing stages at Chiang Saen in the years 2004 to 2015, see Figure 3.1-5. In the years 2004-05 the water level follows the average (although with large fluctuations) but gradually, the delay appears and becomes very visible in 2014 and 2015 (see Figure 3.1-5).

Figure 3.1-2. Water level at Chiang Saen in Thailand south of the Chinese – Thai border. The black line shows long term average. The average from 1960 to 2008 is compared to the average from 2009-2015 where the Chinese dams were filling and commissioned (Green line), and to year 2014 as the most different from average year (red line).

Figure 3.1-3. Water level at Ban Kamphun covering the Se San and Sre Pok rivers. The black line shows long term average. The average from 1960 to 2001 is compared to the average from 2002-2008 where the Vietnamese dams were filling and commissioned (Green line), and to year 2008 as the most different year from average (red line). (The Yali dam was commissioned in 2010 and not included.)

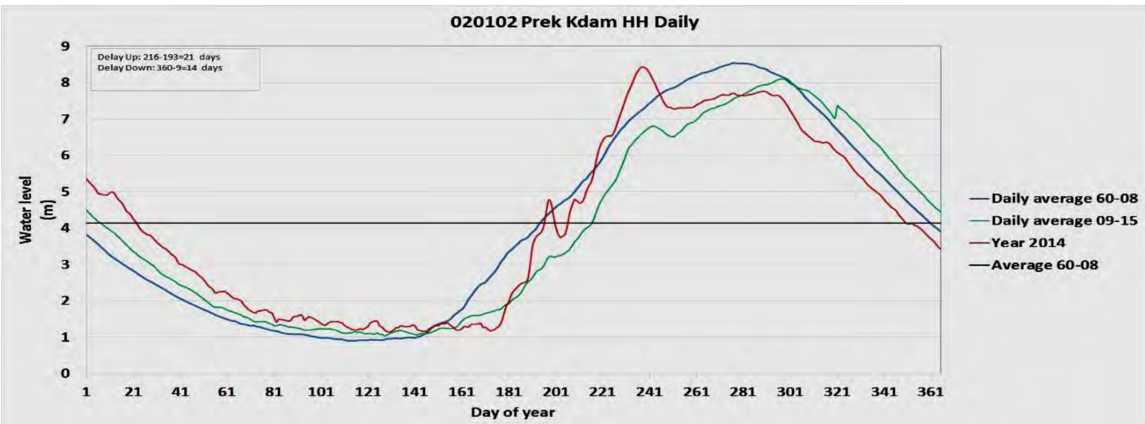

Figure 3.1-4. Water level at Prek Kdam 35 km into the Tonle Sap River showing the same trend as at Chiang Saen and Ban Kamphun. The black line shows long term average.

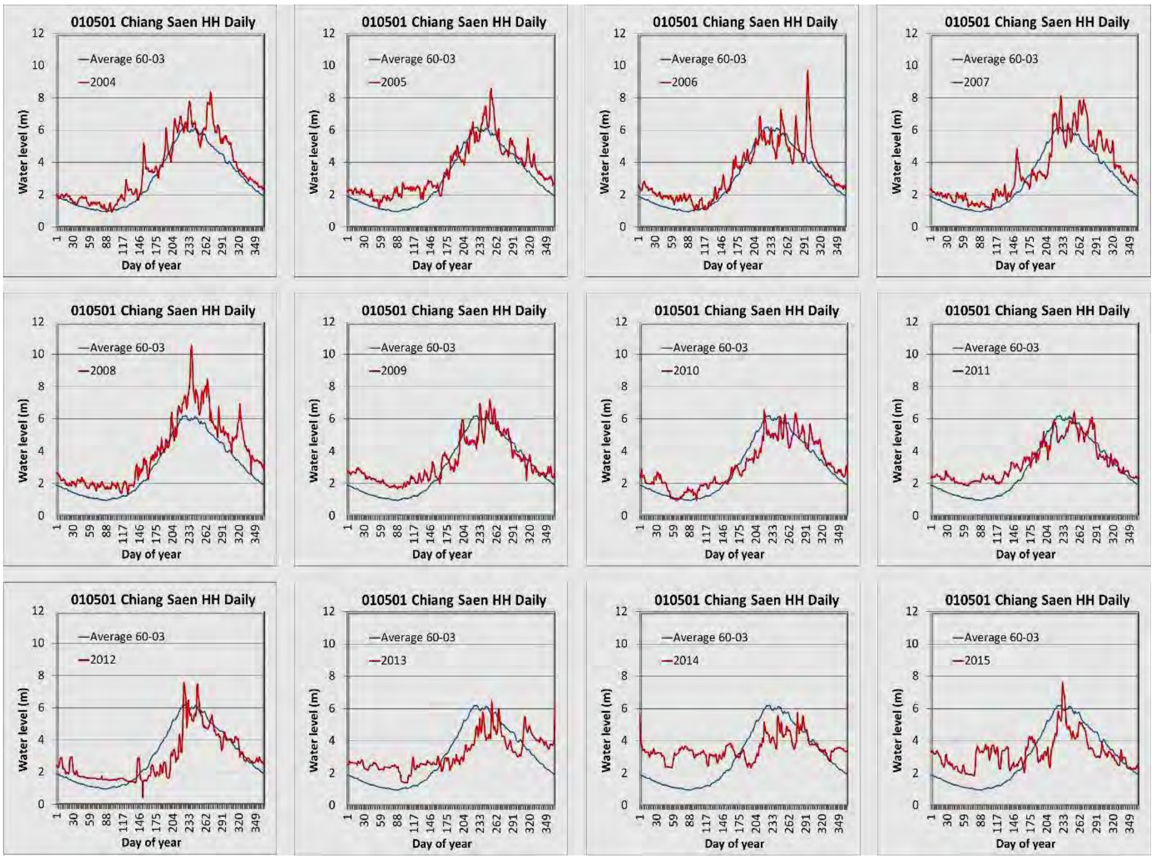

Figure 3.1-5. Water level at Chiang Saen from 2004-2015, long term average (blue) and by years (red) showing the gradual increased delay and change of water level in the dry and wet seasons.

Change of timing of in – out flow to the Tonle Sap Lake

The timing of the inflow and outflow to and from the Tonle Sap Lake has been rather constant during the years 1960-1971 and 1991 to 2014. The inflow is more chaotic than the outflow and can have several reversals, especially during the dry season, where small differences in water level between Phnom Penh port and Prek Kdam occurs. The inflow during the period 2009-2014 is on average delayed by 15 days and the out flow by 10 days compared to the long-term average form 1960-2008, see Table 3.1-1. These delays may not be significate but may reflect the delay of the up-going stage, see Figure 3.1-6.

Table 3.1-1. In flow 'Start day' of year was defined as the reversal from outflow to inflow with at least 20 days of consecutive inflow. In flow 'End day' of year was defined as the reversal from inflow to outflow with at least 50 days of consecutive outflow. (The 20 and 50 days excludes minor fluctuations.)

Table 1	Inflow day		Outflow day	
	Avg 2009-14	Avg 60-08	Avg 2009-14	Avg 60-08
Average	193.8	179.0	279.8	269.8
Diff	14.8		10.0	
Stdv	13.4	24.8	9.0	13.0
	T.test 60-08 to 09-14		T.test 60-08 to 09-14	
	0.057		0.046	
T.test, two tailed, different variance, α=0.05				

*Exclusive 1972-1990 because of invalid data.

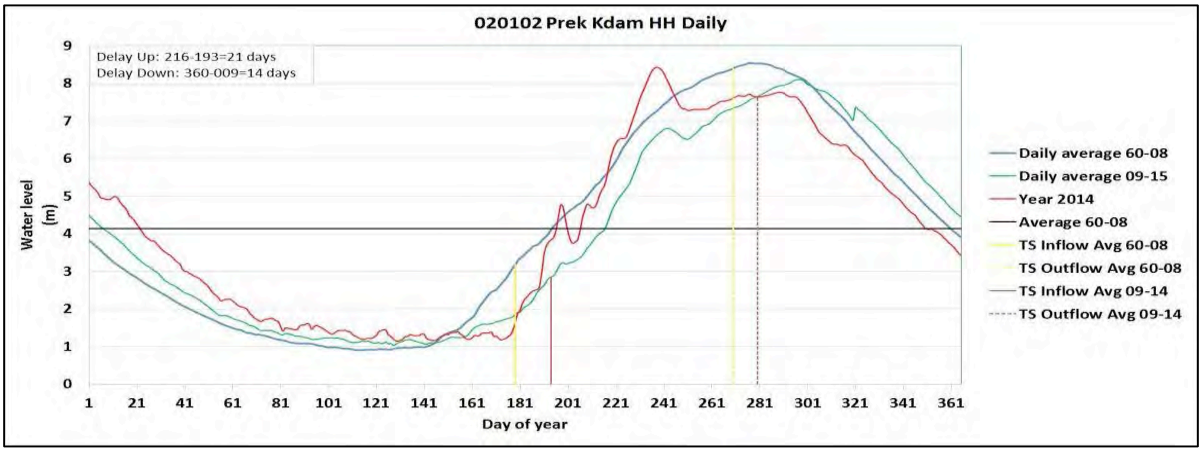

Figure 3.1-6. Prek Kdam hydrograph and Tonle Sap (TS) in and outflow average start end days 1960-08 (Yellow) and 2009-14 (Brown). Delay up and Down are the days between the long term daily average 1960-2008 (Blue graph) and the 2009-2015 daily average (Green graph) passing the annual average 1960-2008 (black line), 21 and 14 days respectively (Right Braces).

Change in the monsoon

No significant changes in the onset and offset of the monsoon (measured by precipitation) was found and therefore cannot have caused the changes in water level, delay of the up and down-going water levels and inflow to the Tonle Sap Lake, see [A].

Daily peaking and hourly variations

Hydropower creates daily and hourly variations in water level and discharge, typically during the evening. The variations created by Vietnamese dams are visible at the Ban Don and Voeun Sai monitoring station where water level peaks daily. At Ban Don the peaks are around 1-2 meters and at Voeun Sai around 0.5 meters, see Figure 3.1-7 and Figure 3.1-8.

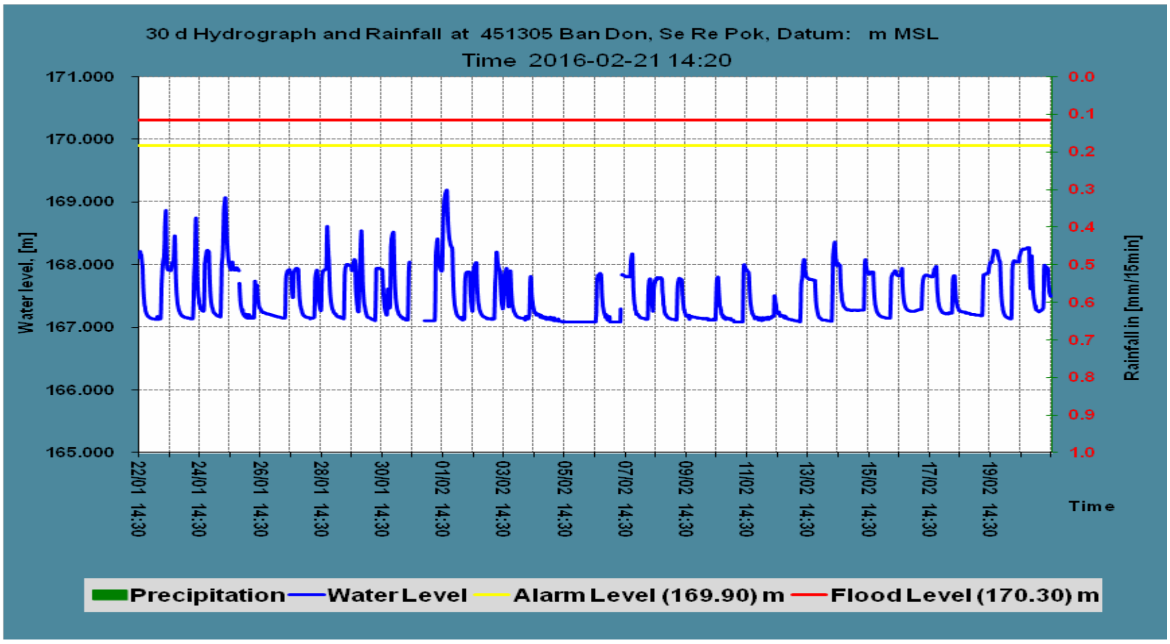

Figure 3.1-7. Ban Don hydrograph showing daily peaking of 1-2 meters. Ban Don station is just below the Sre Pok 4 hydropower dam.

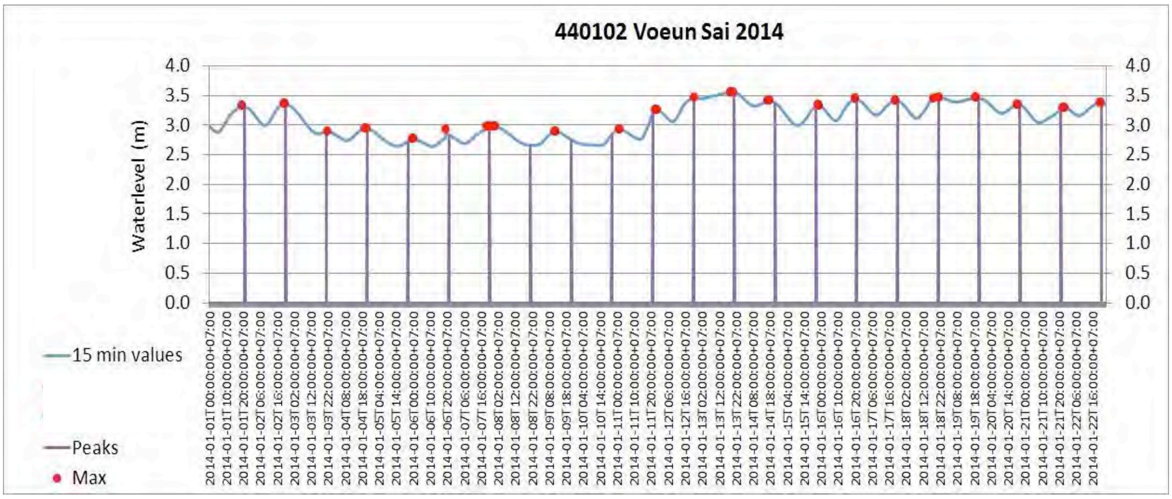

Figure 3.1-8. Variations in Water level at Voeun Sai monitoring station from 15 min sample frequencies. The peak water level marked with red dots. Hour 21:00 is marked with vertical bars. The daily peaking is around 0.5 meter. The Voeun Sai monitoring station is about 200 km downstream of the Vietnamese dams on the upper Sre Pok River. This distance delays the peaking from around 18:00 hours at the dam to around 21:00 hours at the monitoring station.

Fisheries

The yearly fish cycle for migratory species is assessed by the Dai catch fisheries, the Lee trap fisheries, the general catch and the larvae migration in combination with the MRCS hydrological data. Only species marked as important in the MRCS Fisheries databases were included. Examples of the combined data is shown in Figure 3.1-9 and 3.1-10.

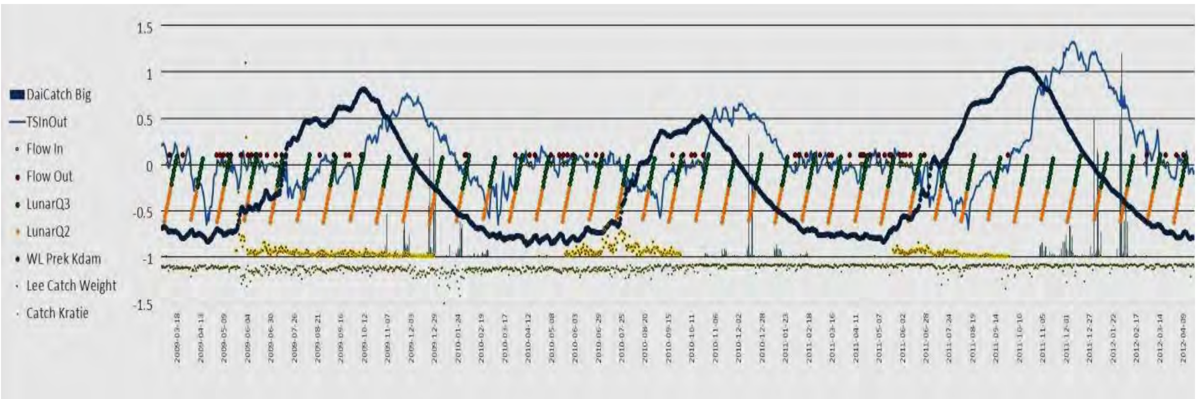

Figure 3.1-9. Combination of in-out flow to – from the Tonle Sap Lake Light blue line –pos=out, neg=in), water level at Prek Kdam (dark blue line), Dai catch (Light blue bars), lee trap catch (Yellow dots with black point), general catch (green dots –shown in negative) and Lunar phases Q2 and Q3 (Yellow-green dots forming tilted bars. For details, see [D], [E] and [F].

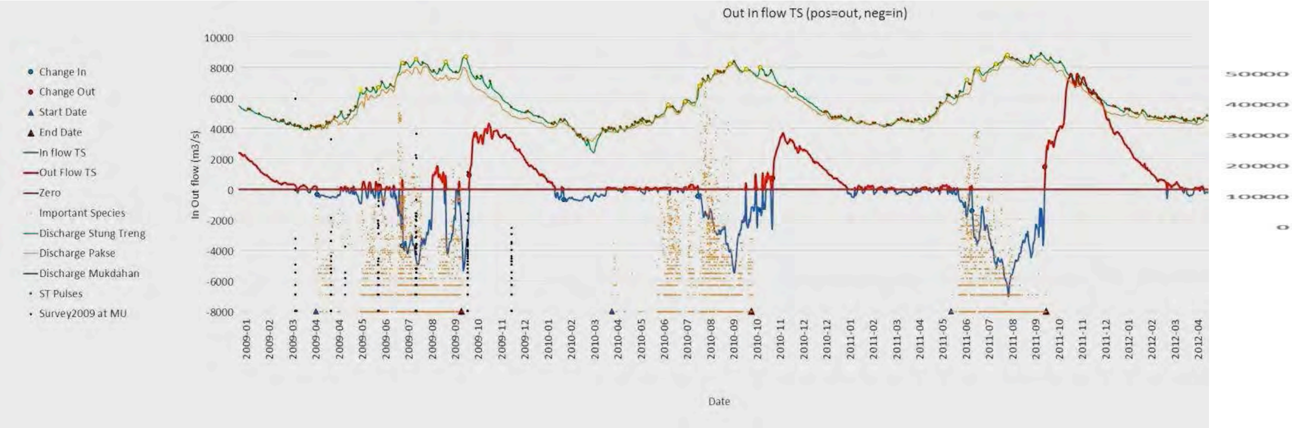

Figure 3.1-10. Combination of Tonle Sap Discharge (red and blue), Discharge at Pakse and Stung Treng, Larvae concentrations from MRCS databases (Brown dots –log scale), Larvae concentrations (Black dots log scale -Regional survey 2009), peak pulses with high larvae concentrations (Yellow dots on Stung Treng discharge). For further details, see [B].

The conclusions from the hydrological and fisheries datasets are:

- *The Dai catch* documents the out migration from the Tonle Sap Lake of migratory species. The large out migration normally starts in October and ends in February the following year (see Figure 3.1-9).

  Three triggers (T1, T2, T3) that all must occur were identified: (i) Down going water stage, (ii) reversal to outflow from the Tonle Sap Lake and (iii) Lunar phases Q2 and Q3. (See the light blue bars in Figure 9 that peak when the moon is in phase Q3 and Q4.) (Lunar phases: Four phases from new moon, first quarter, full moon and last quarter. Here the terms Q1, Q2, Q3 and Q4 are used.). For close up of Triggers, see example in Figure 3.1-12 and [D].

- *The Lee trap catch* documents the upstream migration from refuge in the mainstream to spawning grounds into Lao PDR and into the 3S and other Cambodian tributaries. This takes place at the start of the up-going water stage, typically from May-June to October. In 2009, the Lee trap monitoring continued into December and showed a continuous migration.

  One trigger (T4) was identified: The start of the up going water stage (see Figure 3.1-12).

- *The general catch* data show a continuous steady level over the year for mainstream stations. Tonle Sap Lake stations show the same peak at out migration time as the Dai catch. (See green dots in Figure 3.1-12, showed in negative to provide space in the graph and Figure 3.1-11A and 3.1-11B.)

  The max length, the number of individual species and weight show no monotonic change over the period from 2003-2013, indicating that overfishing does not take place and that variations in catch therefore is related to the changes in hydrology. (See [C]). However, individual species show monotonic decline in catch and max length, indicating overfishing for such species, while others show monotonic increase indicating they take over habitat from declining species (*Peng Bun et al.*, 2015). Such changes may also be caused by habitat, climate or hydrological changes.

No trigger identified.

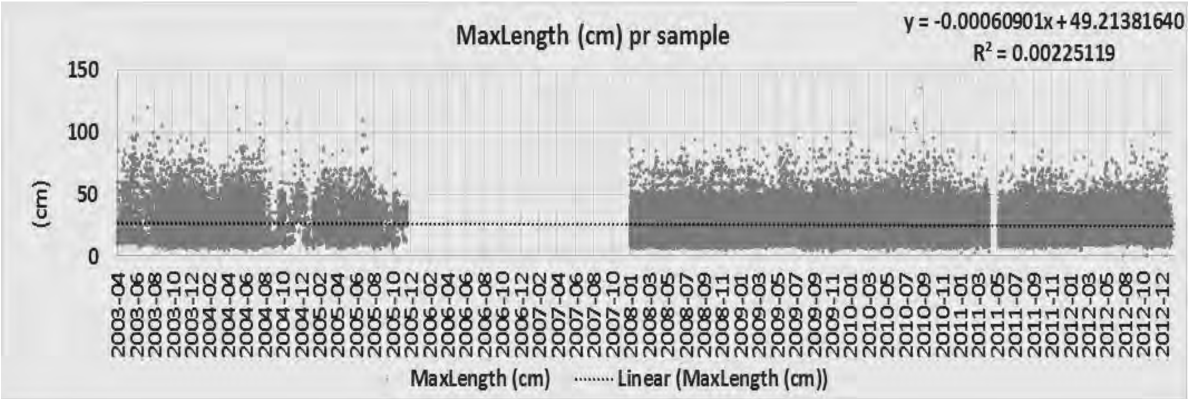

Figure 3.1-11A. Max length of species per sample show no monotonic change.

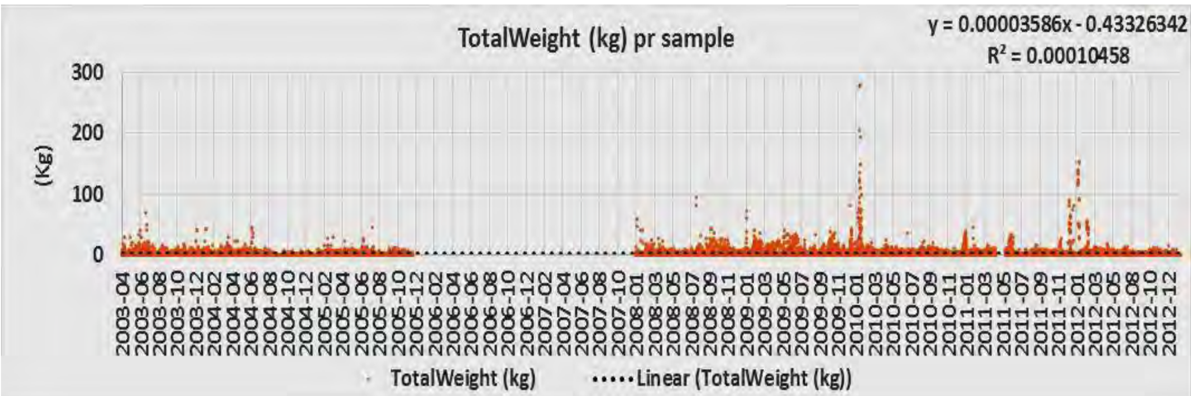

Figure 3.1-11B: Total weight per Sample show no monotonic change.

- *The larval drift* data from the national Cambodia larvae sampling places TS=Tonle Sap River and MU= Chaktomuk both LB=Left Bank, RB=Right bank and MB= Mid River were used (brown dots) and data from the RS=Regional survey 2009 (Black dots) (see Figure 3.1-12). In 2009, the regional survey (Black dots) and the national survey (Brown dots) show similar results but the regional survey spanned a longer period and show larvae concentrations also outside the national sampling period. Figure 3.1-10 shows the data sampling periods (Triangles on the -8000 line) and the larvae concentrations (log10 scale) per sample.

  The concentrations vary from very low to very high in synchronization with major discharge pulses, here measured at Stung Treng (Yellow dots on the green Stung Treng curve). Even when the stable inflow to the Tonle Sap Lake has not started, spawning takes place, see years 2009-2010 in Figure 3.1-10.

  One trigger identified (T5). The trigger for spawning is therefore the onset of major pulses, with a rate (Increase) of 500-2500 $m^3/s*day$. See [B] for details.

  The regional larvae survey (Black dots in Figure 3.1-10 and Figure 3.1-12) sampling in March and November-December show that larvae are drifting -and spawning takes place- also in the dry period.

Annual Migration Cycle

Based on the above observations the annual cycle of migration and spawning for floodplain species, driven by specific triggers, can be established.

Starting with the out migration from the flood plains (*Refuge migration*) triggered by falling water level in the Mekong at start of outflow from the Tonle Sap Lake and the occurrence of Lunar phases Q1 and Q2 (Triggers T1, T2 and T3), see Figure 3.1-12. As the flood plains disappear, the out migration is for refuge in the mainstream (deep pools) in the dry season.

Triggered by the next up-going stage (Trigger T4), migration further up-streams passing the Khong Falls and into tributaries in Cambodia and Lao PDR takes place (*Upstream migration – spawning*).

Spawning is triggered by high discharge pulses (Trigger T5) and larvae drift along with the pulse where different velocities and distances merge larvae of different ages between 2-50 days. Spawning takes place even if the inflow into the Tonle Sap Lake has not started (Larvae drift into the Vietnamese floodplains). When pulses are strong enough to reverse the flow into the lake, larvae drift with the current into the lake / flooded areas and the cycle continues over again (*Major larvae drift period*). See Figure 3.1-12.

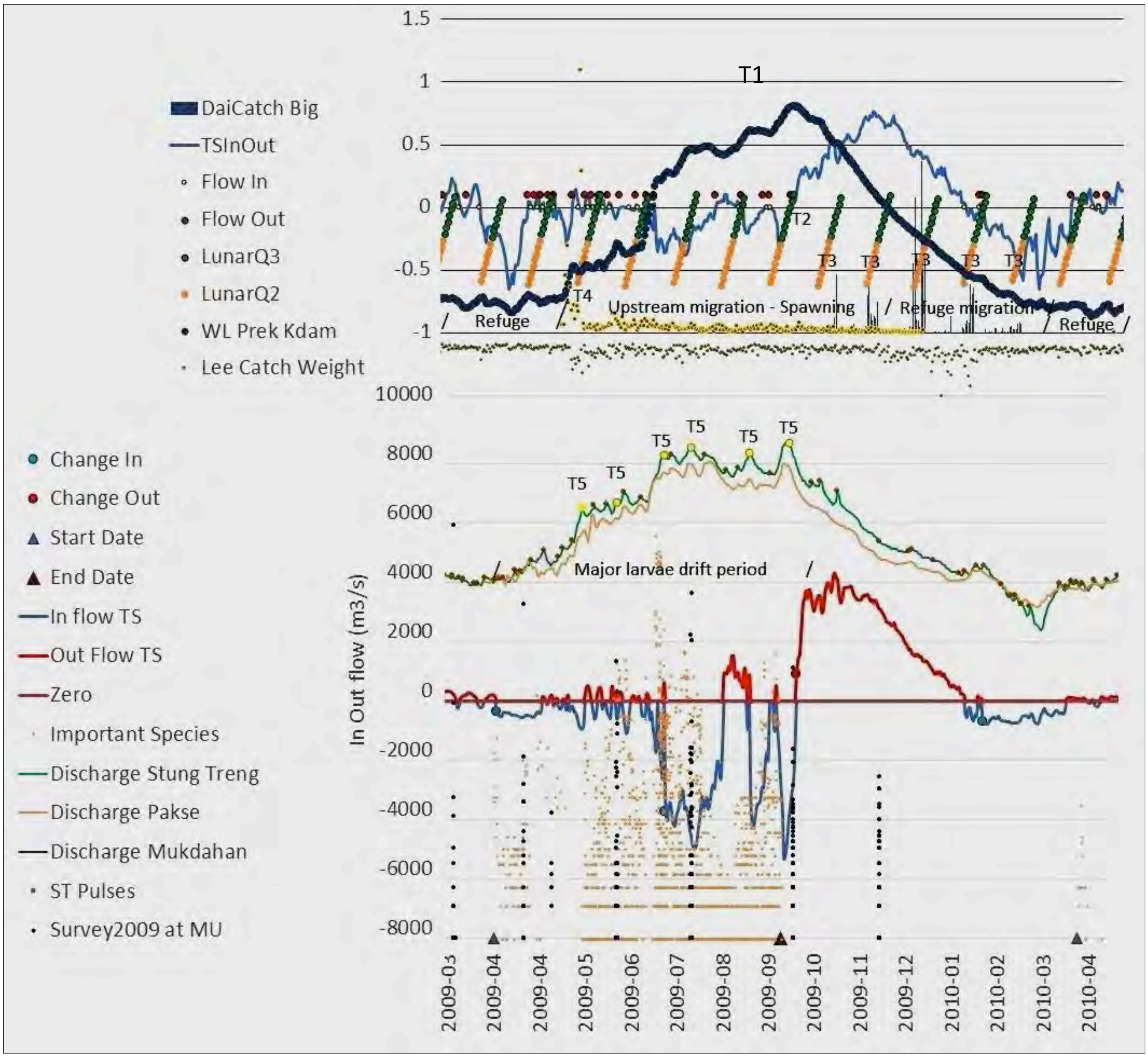

Figure 3.1-12. Example overview from Figures 9 and 10 of periods of migration, refuge, spawning and triggers (T1-T5). Note the larvae drift scale is a $\log_{10}$ scale. The larvae concentration is measured in numbers per unit volume of water.

DaiCatch Big: Cath of big fish in the Tonle Sap River during out migration end of the wet season.
Change In: Reversal of flow into the Tonle Sap Lake.
Change Out: reversal to flow out of the Tonle sap lake.
ST Pulses: Pulses measured at the Stung Treng Hydro-meteorological station
Survey 2009 at MU: Regional larvae survey at Mukdahan (Same place as the national surveys take place)

Change in Fisheries Catch by Hydrological Changes

During the period 2008-2013, only important species from Kandal Sang var, Kratie Koh khne, Ratanakiri Day Lo, Stung Treng Ou Run, Ratanakiri Fang, Stung Treng Pres Bang stations were used.

In *Halls et al.* (2013), a relation between a calculated Flood Index (FI; see definition in Table 2 explanation box and details in [A] and *Halls et al.,* 2013) and Dai catch by Weight and CPUE, provides a model to estimate these values based on the Flood Index.

"The model explains almost 70% of the variation in the observed catch rates .... and the model residuals are reasonably well behaved" (*Halls et al.,* 203). See explanation box under Table 3.1-2.

The remaining variation may be explained later by changes in Nutrients and Oxygen concentrations etc.

Using the model formulas, the expected mean sampled fish weight and CPUE is calculated for the periods 1991-2007 and for 2008-2014, indicating that the decline in the period 2008-2014 is related to the FI. (See Table 3.1-1. Explanation box.)

Table 3.1-2. *Mean sampled fish weight (all species combined) (Kg).

Period	FI	Weight (kg)	CPUE	Correlation	R^2
Avg 91-07	642266	0.011906	235.3466	**2004-14 Weight per haul - FI**	0.78
Avg 08-14	491227	0.009886	184.6469	**2004-14 Weight per haul - TF**	0.81
% diff	76.48	83.03	78.46	**TF - FI**	0.90

Table 3.1-2. Explanation box: (TS-GL: Tonle Sap Lake--Great Lake)

"A flood index (*FI*) is used to quantify both the extent and duration of the flood each year, (*y*):

Where (*FAy,d*) is the flooded area of the TS-GL System in year (*y*) on day (*d*), measured above the mean flooded area for the model period 1 January 1997 to 31 March 2009. *FIy = Σd (FAy,d)"* (*Halls et al*., 2013).

"The model predicts that fish biomass, indicated by the mean daily catch rate of a *dai* unit during the fishing season (October–March), increases exponentially with the (*FI*)… as follows:

CPUE = 83.88.$e^{1.6063E-06*FI_y}$ (*Halls et al*., 2013).

"The relationship between mean sampled fish weight (all species combined) and the flood index with fitted exponential model. *Weight* = 0.0054*e*1.231*E*–06*FI*. R2 = 0.59" (*Halls et al*., 2013).

The Flood Index is an approximation of the total through put of water in the Tonle Sap Lake, see Figure 3.1-13. The correlation between the Flood Index (FI) and the total Flow (TF) is 0.90, see Table 3.1-2. Relating the catch weight per haul to FI and TF gives high correlation coefficients. For the period 2004-2014, the coefficients are 0.78 and 0.81, indicating that the TF is a slightly better parameter than FI explaining the variations in Dai catch, see Figure 3.1-13.

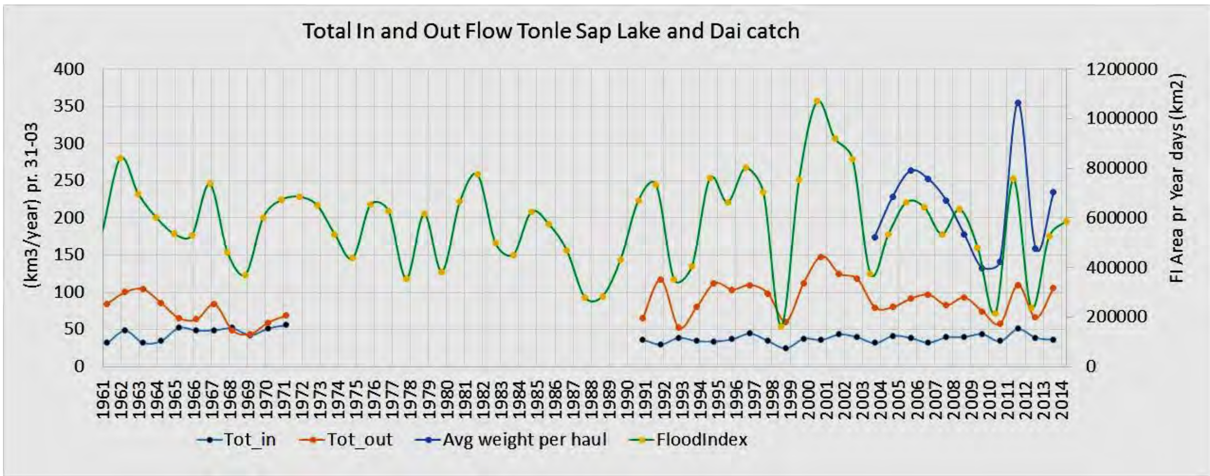

Figure 3.1-13. Tonle Sap Lake total in and out flow, Flood Index and Dai catch by weight of all species. Note the constant inflow around 40 km^3/Y.

The calculated decrease in table 1 in weight and CPUE can be explained by the change in total water volume in The Tonle Sap Lake, not by change in inflow from the Mekong River, which was almost constant around 40.2 km^3/Y with a standard deviation of 7.5 km^3/Y. The large variations if Total Flow (TF) comes from the Tonle Sap Lake catchment itself, see Figure 3.1-13. The expected change in inflow because of change in water level in the dry and wet seasons (See Figures 3.1-2-4) has so far not changed the Mekong inflow volume.

That the inflow is still almost constant may be due to the large variations in actual discharge (in and out) of the Tonle Sap Lake at specific water level differences between Phnom Penh Port and Prek Kdam stations, see Figure 3.1-14. The inflow timing related to the water level at Kampong Luang in the Tonle Sap Lake defines the actual discharge and therefore even lower water levels during the flooding season may still provide the same inflow volume.

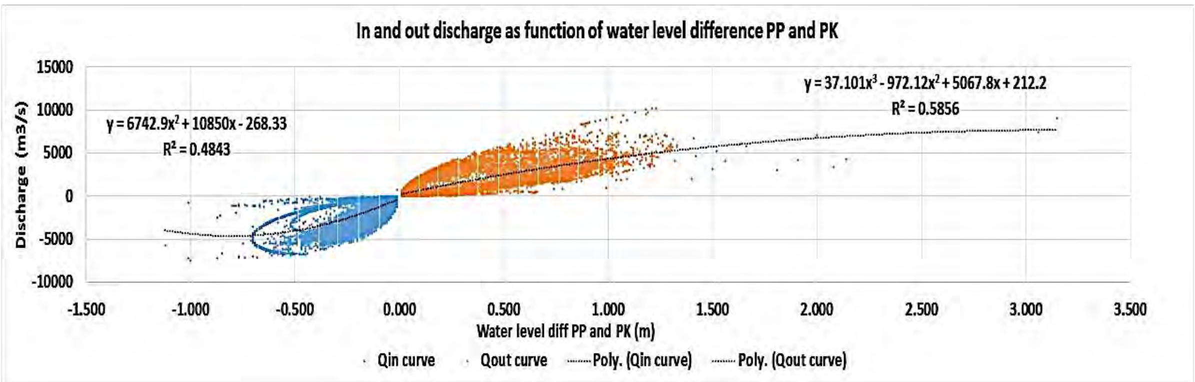

Figure 3.1-14. In (blue –negative) and Out (brown –positive) flow versus water level difference between Phnom Penh Port (PP) and Prek Kdam (PK) stations. For a specific water level, different large discharge variations can take place dependent on the concurrent water level at Kampong Luang in the Tonle Sap Lake. Note that for larger water level differences both for in and out flow the max discharge stabilizes around -5000 and 10000 m^3/s (See polynomial regression curves).

General Migration Trends

The general migration in the Mekong River was analysed for three groups of fish, Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The migration data is from the MRCS migration database for the years 1999 and 2000.

The pattern for floodplain species and for the Lee trap fisheries is the same with a bulk following the up going stage, see [E].

Tributary species follow this migration pattern but with two bulks per Year, one at the up going stage and one at the beginning of the dry season.

The riverine species (Mainstream) show migration pattern all year although with bulks in January and June, see Figures 3.1-15 and 3.1-16. For details see [F].

The all year migration can explain the large concentration of larvae monitored through the year and the extraordinary high concentrations during the floodplain fish migration during the up going stage, see [B].

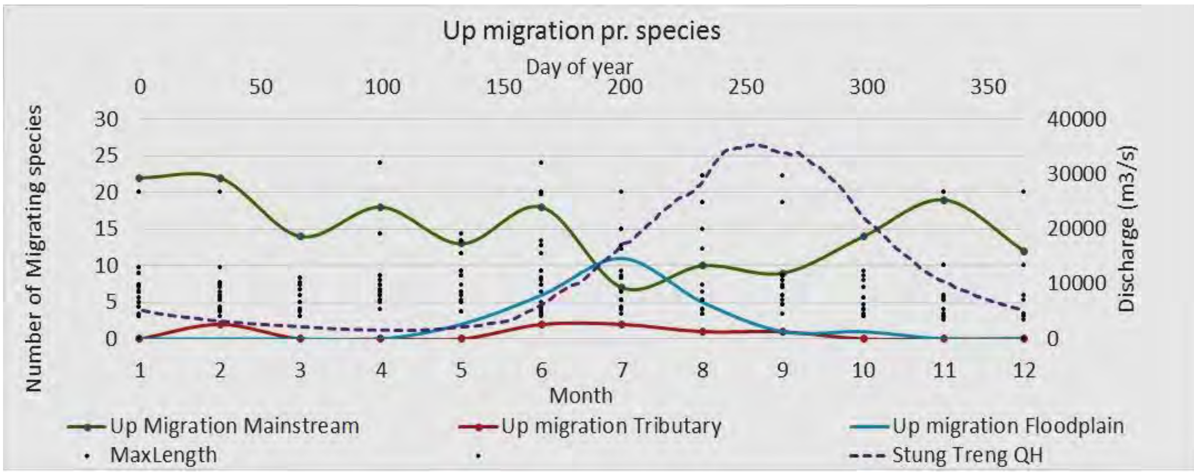

Figure 3.1-15. Up migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The 'Number of Migrating species' (N=17483) contains the total number of species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.

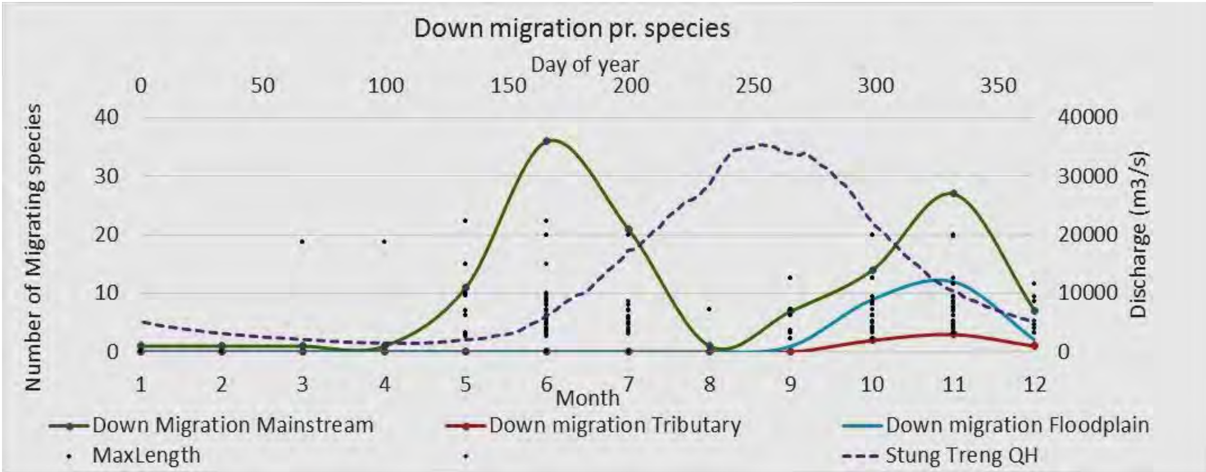

Figure 3.1-16. Down migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The 'Number of Migrating species' (N=17483) contains the total number of species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.

Conclusion

The conclusion is that migration takes place all year round, both for seeking refuge and for spawning. The present changes in hydrology to higher water levels in the dry season, lower in the wet season, the delay raising and receding stages and the delay of the annual inflow to the Tonle Sap Lake has not influenced the migration and spawning as no overall variation in max length of fish, weight or CPUE was found.

For some larger species monotonic decline in max length and catch has been reported as well as monotonic increase for other species (*Peng Bun et al.*, 2015). This may indicate overfishing of the large valuable species.

The rather large variations in catch can be explained by the variations in the Flood Index (FI) or slightly better by the Total Flow (TF) passing through the floodplains.

References:

Halls, A.S.; Paxton, B.R.; Hall, N.; Peng Bun, N.; Lieng, S.; Pengby, N.; and So, N (2013). The Stationary Trawl (*Dai*) Fishery of the Tonle Sap-Great Lake, Cambodia. MRC Technical Paper No. 32, Mekong River Commission, Phnom Penh, Cambodia, 142pp. ISSN: 1683-1489.

Peng Bun, N. Phen, C. and So, N. 2015. Declines in catches of some large and medium-sized species in Tonle Sap River. April 2015 *Catch and Culture* Volume 21, No. 17.

The summary of findings is taken from the following reports, some of which are also provide as annexes in Section 3 of the Master Plan:

[A] Hydro Meteorological and sediment assessment at Chiang Saen, Stung Treng, Kratie and Tonle Sap. 2015.

[B] Analysis of larvae sampling 2002-2013: Annex 3.4

[C] Analysis of Catch sampling 2003-2013: Annex 3.3

[D] Dai fisheries 1994-2014: Annex 3.5

[E] Lee trap fisheries 1994-2013: Annex 3.6

[F] Analysis of Migration data 1999-2000: Included in Annex 3.2

Annex 3.2:

Migration Report

Introduction

The Srepok, Sesan and Se Kong (Xe Kong) rivers ("3S") make up the largest tributary system in the lower Mekong River system, downstream of Khone Falls. They are critical habitats for migratory fish, which move within these systems and between the Mekong. The Lower Sesan 2 Dam, which is almost complete, blocks the Sesan and Srepok rivers from fish migration and replaces a large section of flowing riverine habitat with the lake-like habitat of a reservoir; this leaves the Xe Kong River as the only remaining free-flowing large tributary in the lower Mekong.

Hydropower dams are proposed for the Xe Kong River and the opportunity remains to do this strategically to minimize loses to fish production and livelihoods, and thereby minimize impacts on people. A key to fish productivity in the region is the migration of fish, which has been well established by many authors (Dugan *et al.,* 2010). Migrations of Mekong fish species into tributaries are well known and many artisanal fisheries are based around these migrations; however, the extent and distance that these migrations penetrate upstream in the Xe Kong River are unknown.

In the upper Xe Kong River the Tat Kalang waterfalls are reported to be 20 m high creating a barrier to fish migration (Baird and Shoemaker, 2008), but there are no specific hydraulic or physical data about the site to confirm this. The falls are located close to the Xe Kong 5 Hydropower Project dam site. The objective of this report is to provide information on what we do know about the Mekong—Xe Kong fish migration and also to assess the extent that the Tat Kalang falls are a barrier to fish migration, and thereby to inform a strategic hydropower plan.

Timing of the Fish Migrations in the Xe Kong River[1]

A wet season spawning migration

Based on anecdotal evidence, perhaps over 50 species of fish begin moving up the Xe Kong at the beginning of the rainy season in late April, May and June when waters begin to rise in the Xe Kong mainstream and its tributaries (Warren and Chantavong, 2013). The origins of the migration are from two main sources: 1) dry season refuge habitats (deep pools) in the Mekong mainstream in Cambodia close to the confluence of the Xe Kong and the Mekong, and 2) dry season refuge habitats (deep pools) in the lower and middle sections of the Xe Kong mainstream. The fish that arrive at the confluence have traveled there from the Tonle Sap Great Lake of Cambodia. At some stage in late December, and apparently under the influence of the full moon lunar phase, the density of fish (many of them small species less than 15 cm total length) reaches such a magnitude that its very presence triggers an upstream, non-reproductive, density-dependent migration.

There is little published data about fish migrations in the Xe Kong River Basin (see Figure 3.2-1). Baird (1995a), reported that the majority of fish species in the Sesan River in northeast Cambodia migrate to and from the Sesan River and the Mekong at various times of the year to spawn and shelter in the shallows, streams, pools and rice fields. Given that the Xe Kong has many similar characteristics, it is likely that the situation there is similar (Baird and Shoemaker, 2008). Baird *et al*. (1999) present information about the migrations of many species of fishes in

[1] Excerpts from a report by Terry Warren, prepared for the Natural Heritage Institute in 2016.

the Xe Kong Basin in Laos. However, "there is certainly much about the migrations of even the most important fish species that has yet to be documented" (Baird and Shoemaker, 2008). Some of the main fish migrations in the Xe Kong Basin are *tentatively* outlined below (Baird and Shoemaker, 2008).

May to July

"Every year during this period when the monsoon rains arrive and the rivers and streams start to swell, many species of fish begin to migrate up the Xe Kong from the Mekong, and from the lower areas of the Xe Kong into smaller tributaries. At this time, fish also migrate up the Sesan and Srepok Rivers (Baird, 1995a).

Some of the most prominent species that migrate at this time of year are the medium-sized cyprinid carps ("white fish"), *Scaphognathops bandanensis* (Pa pian), 2 *Mekongina erythrospila* (pa sa-i), *Labeo erythropterus* (now *Labeo pierrei*) (Pa va souang), *Bangana behri* (pa va na no), *Hypsibarbus malcolmi* (pa pak kom), *Cirrhinus molitorella* (pa keng), and possibly others. Most of these species enter tributaries to spawn during the monsoon season (Baird and Flaherty, 2004).

At around the same time of year, a number of species of "black fish," including *Channa striata* (Pa kho), *Clarias batratchus* (Pa douk), *Systomus orphoides* (Pa pok), *Trichogaster* spp. (Pa kadeut), Rasbora spp. (Pa sieu ao), and others, also enter streams and other wetlands, including lowland rice fields, where they reproduce (Baird *et al*., 1999, cited by Baird and Shoemaker, 2008). Also in May, a number of Pangasid catfish enter the Xe Kong from the Mekong River. One large species is *Pangasius krempfi* (Pa souay hang leuang), which migrates up the Mekong from the sea and brackish water areas in the Mekong Delta of Vietnam to spawn in freshwater during the rainy season (Roberts and Baird, 1995a; Hogan *et al.,* 2004, 2007, cited in Baird and Shoemaker, 2008). Other Pangasid catfishes migrate up the Xe Kong from the Mekong during this period, including *Pangasius larnaudei* (Pa peung), *Pangasius hypophthalmus* (Pa souay kheo), *Pangasius bocourti* (Pa nyang), and *Pangasius macronema* (Pa nyone thamada) (Baird *et al*. 1999; 2004 cited by Baird and Shoemaker, 2008). In addition, other large catfishes, *Wallago attu* (Pa khao) and *Wallago leeri* (Pa khoun), migrate up the Xe Kong's tributaries at the beginning of the rainy season" (Baird and Shoemaker, 2008).

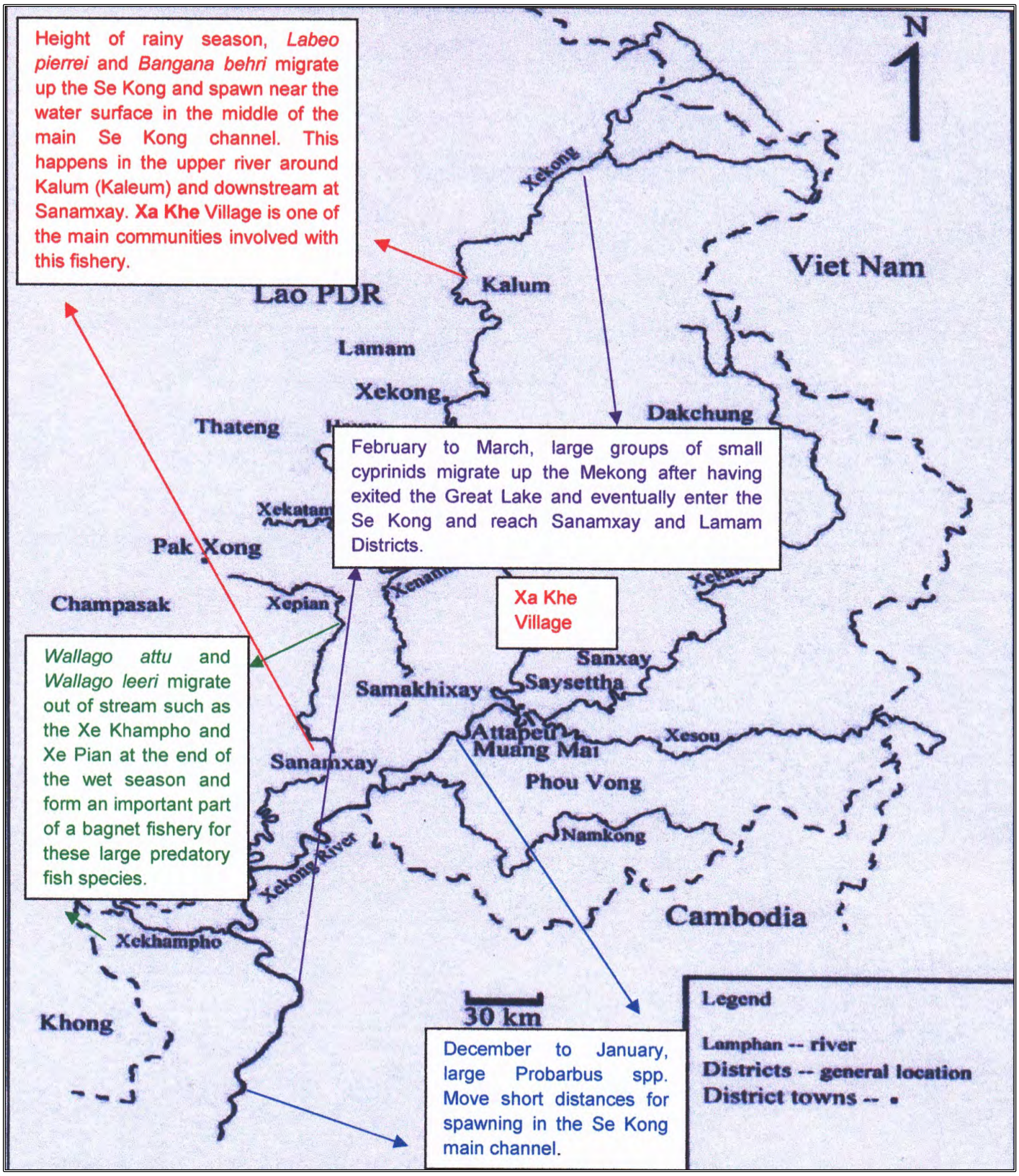

Figure 3.2-1. A map of the Xe Kong Basin showing the major cities, towns, provinces, districts and major river systems throughout the Xe Kong Basin in Laos (copied here with kind permission of Baird and Shoemaker, 2008).

July to September

At the height of the rainy season, between July and September, *Labeo erythropterus* (now *Labeo pierrei*) (Pa va souang) and *Bangana behri* (Pa va na no) migrate upriver and spawn near the surface of the water and in the middle of the channel of the Xe Kong. This happens both in the upper river in Kaleum District and in lower parts in Sanamxay District. Local people call the spawning behavior of this species *Pa oke peo*, which means "the fish go out to the main part of the channel". Floating gill nets (mong lai) are used to catch large spawning individuals at this time of year. These fish are caught throughout the mainstream Xe Kong River, but also along the Xe Kaman, where individual species can reach up to 20 kg. In the mainstream Xe Kong, some of these large *L. erythropterus* reportedly reach 20–30 kg. Sa Khe Village in Samakhixay District is one of the main communities involved in the fishery.

September to November

Wallago attu (Pa khao) and *Wallago leeri* (Pa khoun) migrate out of some medium sized lowland tributary streams, such as the Xe Khampho, Xe Pian, Tangao and Khaliang, at the end of the rainy season, and form part of important bagnet (chip) fisheries associated with this movement of these very large predatory fish. At the end of the monsoon season, many species of fish begin retreating from streams and wetlands, and move into larger perennial water bodies, especially large rivers. At this time, fence-filter traps (tone) and wing traps (li) are used to catch them. This is one of the most important fisheries for rural people in the Xe Kong Basin. It is the time of year when the largest quantities of fish are caught; often enough to make fish paste (Pa dek) for consumption throughout the year. People from many ethnic groups, and especially ethnic Lao people, also dry fish as "Pa katao" or simply "Pa tao" during this season, but it is especially common for dried fish to be prepared in the dry season. At this time, the *Pangasius krempfi* (Pa souay hang leuang) that migrated upriver at the beginning of the rainy season all migrate downriver into Cambodia and later Vietnam (Hogan et al. 2004; 2007, cited by Baird and Shoemaker, 2008). However, there are no fisheries associated with these migrations, as they probably travel down the strongest part of the main channel, where fishing is not possible at this time of year. Other large Pangasid catfish also move downriver, although some stay in deep-water areas for the duration of the dry season. The medium-sized cyprinid carps, *Scaphognathops bandanensis* (Pa pian), *Mekongina erythrospila* (Pa sa-i), *Hypsibarbus malcolmi* (Pa pak kom), *Labeo erythropterus* (Pa va souang), *Bangana behri* (Pa van na no), *Cirrhinus molitorella* (Pa keng), and others also migrate out of the Xe Kong's tributaries, moving back in to the Mekong at Stung Treng, northeast Cambodia. These fish then move down the Mekong, where they congregate near a place called Tong Deng in Khmer or Thong Deng in Lao near the Stung Treng–Kratie provincial border. Strangely enough, they then turn around and begin migrating up the Mekong past Khone Falls, with some migrating upriver as far as Thailand" (Baird and Flaherty, 2004).

December to January

"During this season, large *Probarbus jullieni* (Pa eun dta deng) and *Probarbus* l*abeamajor* (Pa eun khao) cyprinid carps migrate short distances for spawning purposes (Baird, 2006b, cited in Baird and Shoemaker, 2008). Villagers living along the lower Xe Kaman claim that these species are mainly found in the mainstream Xe Kong channel. There are various places along the Xe Kong where they are well-known, such as Ta-neum Village in Lamam District.

February to March

As water levels drop, large numbers of small cyprinids, including Henicorhynchus lobatus (Pa soi houa lem), H. siamensis (Pa soi houa po), Paralaubuca typus (Pa tep), Labiobarbus leptocheilus (Pa lang khon), Lobocheilus melanotaenia (Pa khiang khang lai), Cirrhinus microlepis (Pa phone mak koke), Botia spp. (Pa mou man), Crossocheilus reticulatus (Pa toke thoi), Thynnichthys thynnoides (Pa koum), and a number of others migrate from the Great Lake and Tonle sap River in the south up the Mekong and eventually into the Xe Kong. Baird et al. (2003, cited by Baird and Shoemaker, 2008), estimated that at least thirty-two species migrate up to Khone Falls from the Great Lake in Cambodia each year, and the same species are believed to migrate from the Great Lake up the Mekong and then to the Xe Kong in southern Laos. Essentially, these fish all migrate up the Mekong with some continuing upriver passed the Xe Kong confluence at Stung Treng town and others turning right into the Xe Kong (left bank tributary). Local people believe that these fish migrate back downriver at the beginning of the rainy season, although some may remain in the Xe Kong Basin all year. Baird et al. (2003, cited by Baird and Shoemaker, 2008) have demonstrated that the timing of these fish migrations is closely linked to lunar phases, although hydrological factors are also a significant factor (Warren et al., 1998).

On the Xe Xou, the fish are able to move upriver via the Xe Kong and Xe Kaman, to as far as the large rapids called "Pha Phawng" or "Brawng" in Brao. On both the Xe Kong and the Xe Xou rivers, large dams are now planned for, and these will represent bio-geographical barriers for fish migrations. On 24 February 2004, the first author observed large schools of Henicorhynchus lobatus (Treu riel in Brao and Pa soi in the Lao language) moving up the Nam Kong from the Xe Kong near Viangxai Village, which is about 18 km upstream from the mouth of the Nam Kong. Ethnic Brao villagers said that, for the Nam Kong, fish are able to migrate upriver as far as the Tat Heu Mam Waterfalls, which is about 20 km upstream from Viangxai and reaches 50 m in height during the dry season. During this season, there are also important migrations of small loach fish Nemacheilus and, or Schistura spp. (Pa it) up the Xe Kong and other large rivers in the basin. These fish do not move together with Henicorhynchus lobatus (Pa soi), but migrate along the edge of the Xe Kong during approximately the same season. In recent years, Pa soi runs have declined but Pa it migrations have become relatively more important to local livelihoods. These species are much more important for Xe Kong Basin livelihoods than they are for those living near the mainstream Mekong. All the fish species mentioned above are consumed by humans, and are of importance to local people" (Baird and Shoemaker, 2008).

Pa soi migrations: the farther up, the fewer fish

Henicorhynchus spp. (Pa soi) populations that migrate up the Xe Kong have long been extremely important for the livelihoods of local people. *Henicorhynchus* spp. are the most numerous of the approximately thirty-two species of small cyprinid fishes that migrate up the Xe Kong from the Cambodian Great Lake (Baird *et al.* 2003, cited by Baird and Shoemaker, 2008). However, in recent years the populations of these migratory species have become smaller and less frequent within the Xe Kong system. For example, in Sompoi Village, Sanamxay District, near the Cambodian border, there were reportedly three significant runs of *Henicorhynchus* up the mainstream Xe Kong River in 2004. However, upriver there were fewer migrations noticed by fishers. For example, in Done Chan Village, Lamam District, at the southern border with Attapeu, fishers reported two *Pa soi* migrations up the Xe Kong in 2004, but in the same year only one *Pa soi* migration was observed in Nava Keng Luang and Ta-neum villages, in Lamam District, not far upriver from Xe Kong City. Further upriver, north of Kaleum District center, in Kloung, Talang Mai, and Lai Po Villages, fishers reported that, historically, *Pa soi* used to migrate passed their villages every year, but that for the last three or four years they had not seen any!

These observations by fishers are significant in the light of recent claims by the MRC and the Department of Fisheries in Cambodia that *Henicorhynchus* spp. migrations from the Great Lake are not in decline, but that populations are instead fluctuating based on differences in annual flooding, with more flooding resulting in higher fish populations (see, for example, Hortle *et al.*, 2005, cited by Baird and Shoemaker, 2008). While hydrological factors are critical for Mekong fish production, including the species in question, the situation is likely to be much more complicated than annual fish production being based on hydrological factors alone. Other management factors certainly affect these fish stocks. Locals are claiming that the populations have steadily declined over a decade or so, with seasonal fluctuations based on hydrological patterns playing a role. Meusch *et al*. (2003, cited by Baird and Shoemaker, 2008), found that many of the households that they studied in Attapeu claim that they are no longer able to catch enough fish to preserve sufficient quantities of *Pa dek* (fermented fish) to eat over the year. This is probably largely due to declines in *Pa soi* migrations.

It appears likely that the main purpose of *Pa soi* fish migrations during the dry season is to distribute the population over a wide area so as to optimize these algae eaters' feeding opportunities (Roberts and Warren, 1994; Roberts and Baird, 1995; Baird *et al*., 2003, cited by Baird and Shoemaker, 2008). This means that *Pa soi* migrate upriver until reaching a point where the density of their numbers is below a certain level. If the density remains below this level, the migration will go no further. If the density increases above that level, the *Pa soi* migration will continue until another point where low density is reached and maintained, or the fish will migrate upriver as far as they physically can, before encountering bio-geographical barriers, in order to optimize their density within the maximum available habitat. This is likely why *Pa soi* migrations were observed every year in the past as far up the Xe Kong as Kaleum District, but in recent years they have not been seen. There are few, if any, fish reaching this part of the basin compared to previous years. This could either be because there are just as many fish as before, but they are being caught before they get far upriver, or because there are fewer fish overall than in the past.

Table 3.2-1. Summary of some of the main Mekong – Xe Kong Basin fish migrations referred to in this report.

Timing of migrations	Important families involved	River systems involved	Specific places along Xe Kong where migration is known to pass	Direction and from where to where approximately	Main triggers
Late April, May and June (Warren and Chantavong, 2013).	Cyprinidae, Siluridae, Bagridae, Sisoridae and Pangasiidae.	Mekong, Xe Kong, Sesan and Srepok.	Attapeu, Xe Kong City.	Upstream from deep pool habitats in the Cambodian Mekong, deep pool habitats in the Xe Kong and highly likely the Great Lake in Cambodia.	Rising water and general changes in physical and chemical characteristics.
May to July (Baird and Flaherty, 2004).	Cyprinidae and other families, but Cyprinidae is dominant.	Mekong, Xe Kong, Sesan and Srepok.	Attapeu, Xe Kong City.	Bi-directional and enter tributaries for spawning and later for dry-season refuge in lower reaches of rivers in deep pools.	As above.
July to September (Baird and Flaherty, 2004).	Cyprinidae and other families, but Cyprinidae is dominant.	Mekong and Xe Kong.	Upstream around Old Kaleum and Sanamxay District. Xa Khe Village in Samakhixay District.	Upstream spawning migration.	As above.
September to November (Baird and Flaherty, 2004).	Cyprinidae, Siluridae and certain members of Pangasiidae.	Xe Khampho, Xe Pian, Tangao, Khaliang streams, Xe Kong and Mekong	General movement downstream past all major cities and villages.	Downstream from Xe Kong tributaries back into the Xe Kong and eventually the Mekong in northeast Cambodia close to Thong Deng (Lao language). After a period of recuperation, some species then start moving back upstream again and may even reach areas in Thai international waters.	Falling water level.
December to January (Baird and Flaherty, 2004).	Cyprinidae and specifically two large species of barbine Cyprinid belonging to the Probarbus genus).	Xe Kong	Ta-neum Village, Lamam	Possibly bi-directional and moving specifically to historical breeding sites (deep pools) for spawning over a few days of weeks.	Lunar cycle and water level.

Timing of migrations	Important families involved	River systems involved	Specific places along Xe Kong where migration is known to pass	Direction and from where to where approximately	Main triggers
February to March (Baird and Flaherty, 2004).	Cyprinidae is dominant, but Cobitidae also important.	Great Lake of Cambodia, Tonle Sap River, Mekong, Xe Kong and Xe Xou.	Stung Treng, Attapeu and Xe Kong City, Old Kaleum in Kaleum District, Viangxai Village on the Nam Kong, Sompoi Village in Sanamxay District, Done Chan Village, Lamam District and Nava Keng Luang and Ta-neum Villages in Lamam District. .	Upstream to the 3S rivers and then migrate back downstream again at the beginning of the wet season, some having already spawned.	As above.

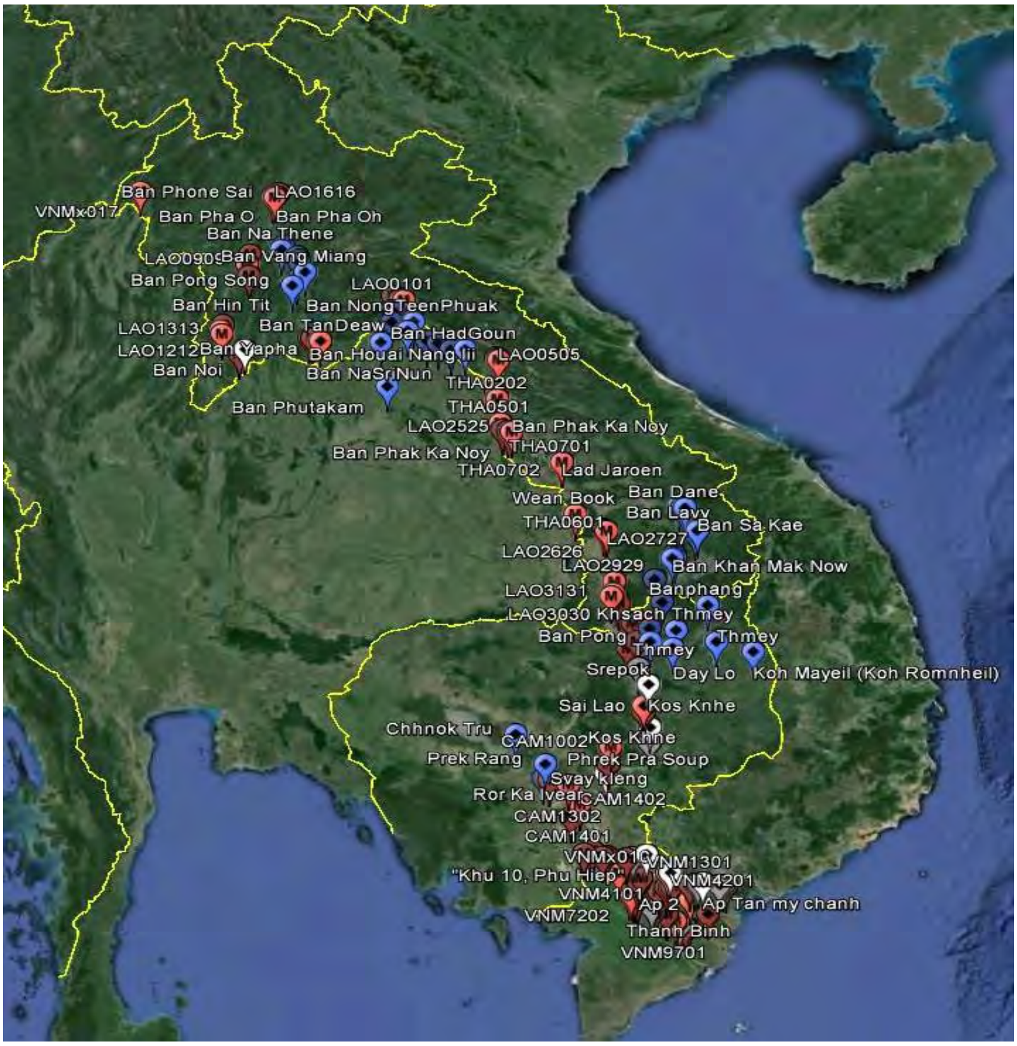

Figure 3.2-2. Location of migration MRCS monitoring sites.

Analysis of Migration Data: 1999-2000

Definitions

Trend: Is an underlying pattern of behaviour in a time series, which could be partly or nearly completely hidden by the recognized amounts of unexplained variation in the time series (noise).

Variability: Denotes how stretched or squeezed a distribution is. Variability is typically measured by the quotients of mean and standard deviation.

Change: Is the transition from one state to another *significantly different* state, ex change in variability or trend. A 5% significance level is used (p <0.05).

Trigger: An event that is the cause of a particular action, process, or situation.

Pulse: A rapid rise in water level and discharge of more than 500 m3/s per day to 2500 m^3/day.

Pulse rate: Change in discharge per day (m^3/s per day).

Monotonic: A function is called *monotonic* if and only if it is either entirely increasing or decreasing.

Overfishing: The practice of commercial and non-commercial fishing which depletes a fishery by catching so many adult fish that not enough remain to breed and replenish the population. Overfishing exceeds the carrying capacity of a fishery.

Migration monitoring

The specific purpose of this analysis is to assess any monotonic trends in the migration monitoring data from 1999-2001, the period where migration data is available in the Mekong River Commission Secretariat (MRCS) fisheries database (see Figure 3.2-2).

The migration data is classified per species into three migration groups:

1. Mainstream Longitudinal,
2. Tributary longitudinal and
3. Floodplain habitat lateral.

Up and downstream migration is registered with monthly intervals as start and end months.

Analysis is done for the Whole Mekong system, the 3S system and for the Xe Kong system.

The main aim is to get a temporal overview of the migration time for the three migration groups, both for up and downstream migration and relations to the flood pulse measured at Stung Treng average 1910-2015. For the riverine species, this is compared to the Dai catch and the Lee trap catch timing.

Migration timing—for all of the Mekong

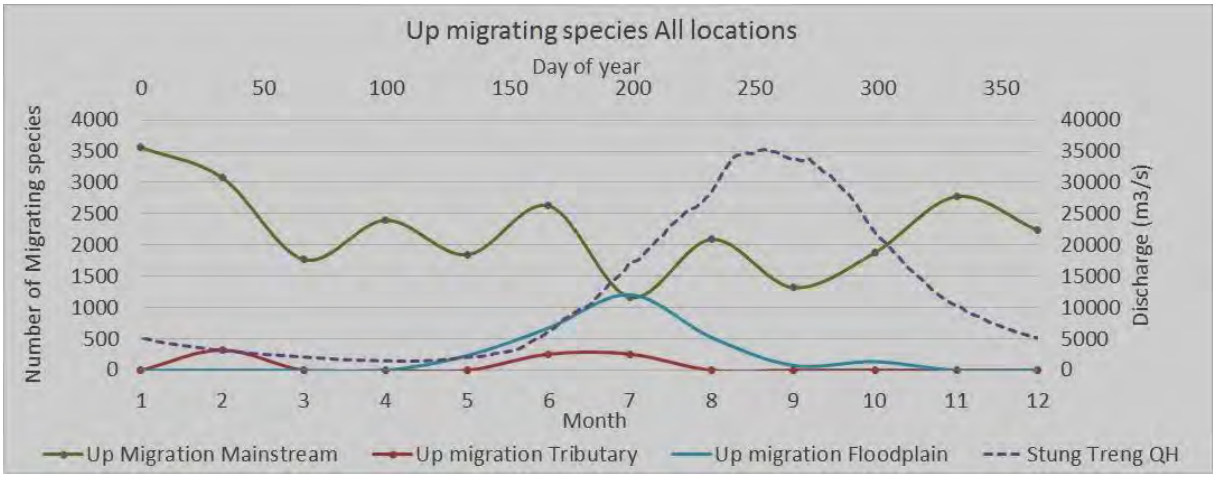

Figure 3.2-3. Up migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The 'Number of Migrating species' (N=17483) contains the total number of species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.

For the upstream migration, the floodplain species bulk corresponds to the Lee trap catch bulk upstream migration during the up going water stage in June - July, where floodplain species continue their up migration after refuge in the river (deep pools) during the dry season (Blue curve).

The tributary species also follow this pattern, but have an additional bulk early in the year around February (Red curve). The Riverine species migrate all year at a largely constant rate (Green curve); see Figure 3.2-3.

The flood plain species down migration timing shows two bulks, one right after the major upstream migration in July – August and one around October, similar to the tributary bulks (see Figure 3.2-4).

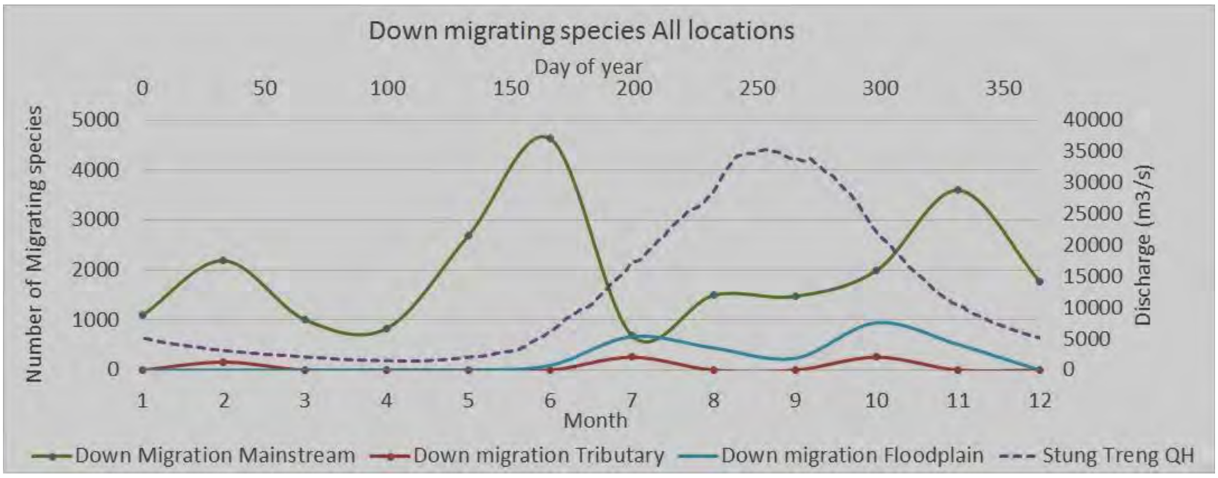

Figure 3.2-4. *Down migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The 'Number of Migrating species' (N=17483) contains the total number of species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.*

The mainstream longitudinal migration species show variation during the year, but have migration all year in line with the all year up migration shown in Figure 3.2-3.

This combination of floodplain and riverine species up and down migration can explain the year- round concentration of larvae drift. During the up going stage, the highest larvae concentrations are found as both floodplain and riverine species migrate for spawning, while the lower concentrations the rest of the year may be due to the riverine species distribution over the year.

Migration timing – pr. species

Reducing the total number observations to one observation per species for both up and down migration gives a similar picture as in Figures 3.2-3 and 3.2-4. At the peaks of up migration around 20-25 species were recorded and at the peak down migration of riverine species alone, about 25-35 species were recorded (see Figures 3.2-4 and 3.2-6). A total of 119 different migratory species were recorded migrating either up and/or down.

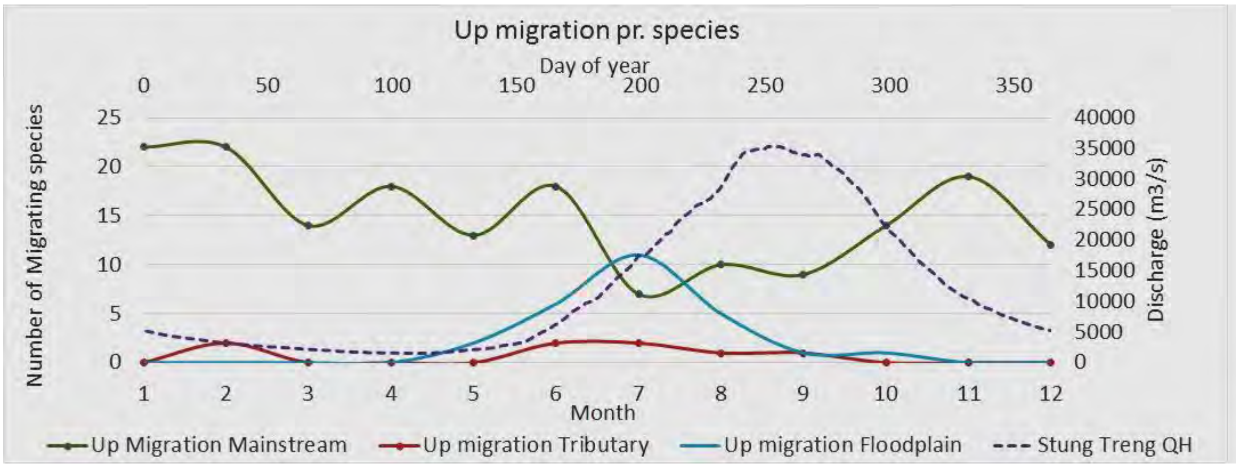

Figure 3.2-5. Up migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The 'Number of Migrating species' (N=119) contains the total number of individual species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.

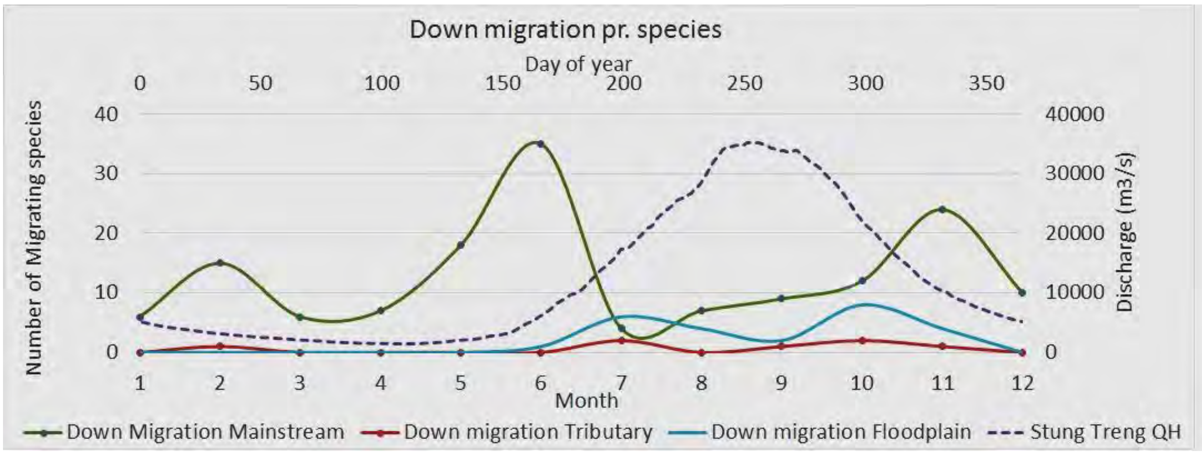

Figure 3.2-6. Down migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species. The 'Number of Migrating species' (N=119) contains the total number individual species found in the samples. The discharge (QH) is from Stung Treng 1910-2015.

Migration timing – Xe Khong

For the Xe Khong watershed, the variations are the same as for all of the Mekong migration (See Figures 3.2-3-4 and 3.2-7-8).

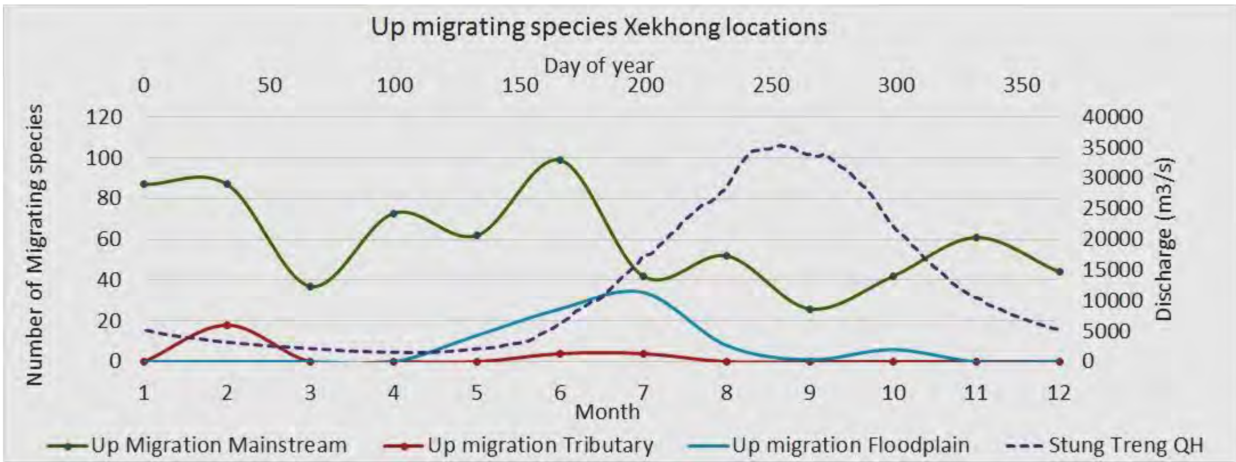

Figure 3.2-7. *Up migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species on the Xekhong River. The 'Number of Migrating species' (N=498) contains the total number of species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.*

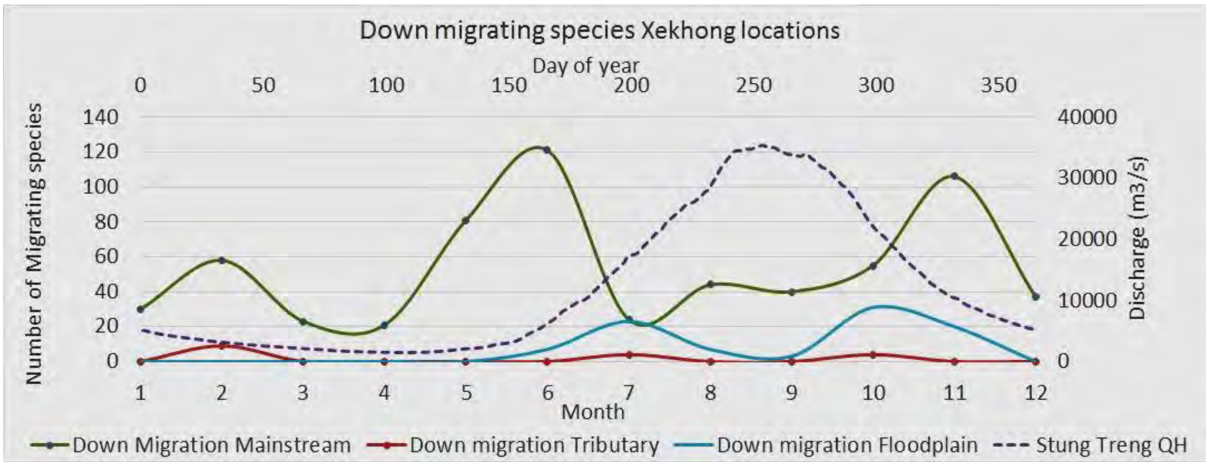

Figure 3.2-8. Down migration of Mainstream Longitudinal, Tributary longitudinal and Floodplain habitat lateral species on the Xekhong river. The 'Number of Migrating species' (N=498) contains the total number of species found in the samples. The discharge (QH) is from Stung Treng average 1910-2015.

Conclusions

The migration of Mainstream Longitudinal, Tributary Longitudinal and Floodplain Habitat Lateral species show distinct variations over the year for floodplain and tributary species both up and down, while mainstream species migrate up and down all year.

Migration is partly for refuge in deep pools during the dry season for floodplain and tributary species and for spawning for all species.

The timing with spawning can be seen in the larvae report (Annex 3.4 in this Master Plan).

Fish Migration Barriers in the Upper Xe Kong River and Developing Least-Impact Hydropower[2]

Methods

An on-site survey was done on 3-7 April 2016. Access was by road to the Xe Kong River 6.3 km upstream of the Tat Kalang Waterfalls and the survey was done by kayak over two days, finishing 12.8 km downstream of the most upstream waterfall. GPS coordinates, photographs and video were taken of the falls, habitats were recorded and fisher's catches were examined where possible.

Figures 3.2-9 and 3.2-10 show the reach surveyed in relation to the catchment and major features.

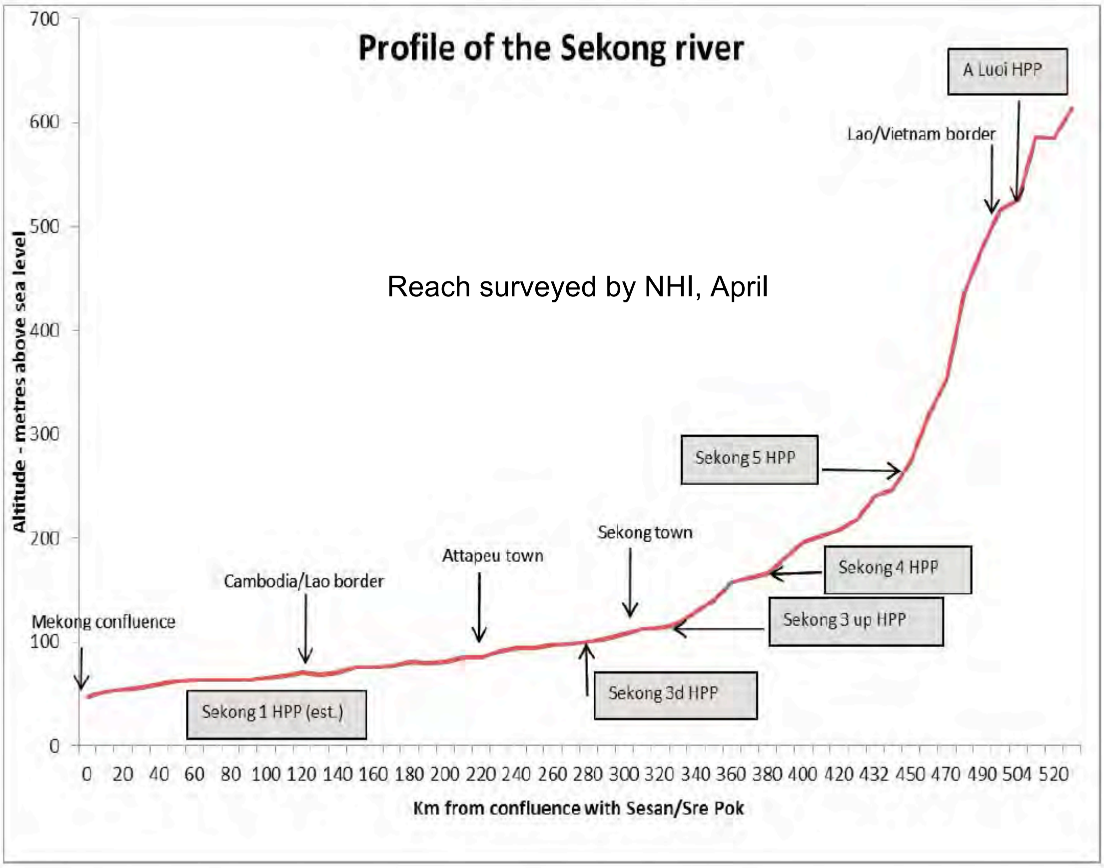

Figure 3.2-9. Profile of Xe Kong River showing major features, planned mainstem hydropower (Meynell 2014), and the reach surveyed by NHI in April 2016.

[2] Prepared by Martin Mallen-Cooper and Erland Jensen for the Natural Heritage Institute.

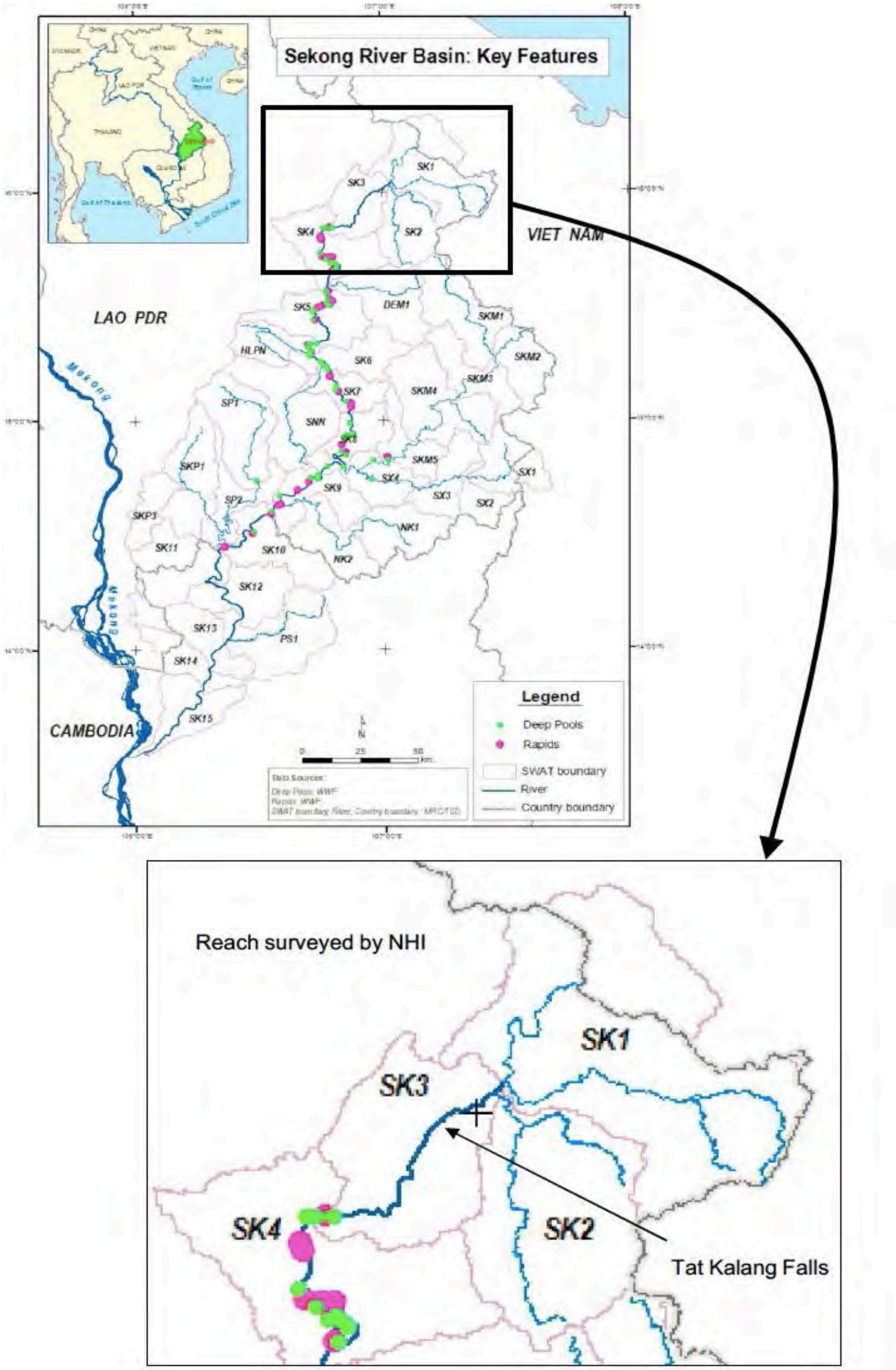

Figure 3.2-10. Map of the Se Kong catchment showing SWAT boundaries, deep pools (green symbols), rapids (pink symbols) (Meynell, 2014); and the reach surveyed by NHI in April 2016.

Results

Hydraulics – Fish Barrier

The Tat Kalang Waterfalls are a series of rapids rather than waterfalls. There are three main rapids and other smaller rapids which are spread over 12 river km and fall approximately 40 m from 287 m elevation to 248 m. The three main rapids (Table 3.2-2) have changes in elevation of 1 to 4 m but these are not vertical drops that are consistent across the river. The rapids have variable but low gradients with side channels that can be considered consistently passable by fish at low and high flows. We observed them at low flows and around all rapids there were paths of low water velocity and turbulence easily passable by fish.

Passage at high flows can also be inferred from the geomorphology. High water marks were visible on the sides of the valley and these regions had high roughness of large rocks; these create zones of low water velocity and turbulence at high flows which provide for the passage of fish. Direct evidence of these zones is shown by the numerous small deposits of sand on the sides of the channel. These were on the downstream sides of boulders, indicating the presence of low water velocities on the channel edge at high flows, which enables sand grains to settle.

From these observations, we conclude these rapids are not a barrier to fish movement at low or high flows.

Table 3.2-2. Locations of Tat Kalang rapids. Note that the elevations from the GPS are only accurate to within a few meters.

Rapid	Longitude	Latitude	Elevation
1	106.942527	15.984870	287.57
2	106.940934	15.982977	283.25
3	106.939363	15.980957	282.77

Figure 3.2-11. Rapid 1 showing high water velocity in the middle. On the edges are low water velocities passable by fish.

Figure 3.2-12. Rapid 3 showing a 1 m drop but low water velocities and low turbulence on the sides that are passable by fish.

Figure 3.2-13. Another small typical rapid.

Fish Catches

As this is a single survey of a short reach of river over two days in one season, it can only be considered a "snapshot" of the fish assemblage in the area. A few fishers were observed and they caught 10 species which are listed in Table 3.2-3.

Table 3.2-3. Fish species caught by fishers on 5 April 2016 near Ban Talouey, upstream of Tat Kalang rapids.

	Maximum Size (Fishbase) (cm)	Reported maximum weight in river reach	Migration month (MRC data)			
			Upstream		Downstream	
			Start	End	Start	End
CATFISHES (Siluriformes)						
Bagarius yarrelli (Sisoridae)	200	20 kg	1	2	8	9
Hemibagrus wyckioides (Bagridae)	130		4	5		
Clupisoma sinense (Schilbeidae)	31		3	6		
CARPS (Cypriniformes)						
Incisilabeo behri (Bagana behri)	60	10 kg			1	2
Hampala macrolepidota	70		6	7	11	12
Scaphiodonichthys acanthopterus	31					
Poropuntius normani	13					
Sikukia gudgeri	18					
Raiamas guttatus	30					
SPINY EELS (Synbranchiformes)						
Mastacembelus favus 70 cm	70					

Three groups of fishes were caught: catfishes, carps and one species of spiny eel. Two large fishes were present, *Bagarius yarrelli* (Figure 3.2-14), a predatory catfish, which is reported to grow to 20 kg locally and *Incisilabeo behri* (prev. *Bagana behri*) (Figure 3.2-15), which eats algae and grows to 10 kg locally. All the other species were small (< 30cm) (Figure 3.2-16). No mountain loaches, which have high endemism in the region, were caught but can be expected in the steeper shallower tributaries and in the headwaters.

Figure 3.2-14. Bagarius yarrelli, a predatory catfish.

Main-stem species that migrate long distances ("white fish") were not present, although they may be present in the wet season. The exception may be *Incisilabeo behri* which is present in the Sesan and Srepok rivers and migrates in the Mekong. It is known to migrate upstream in the Xe Kong and fishers target this spawning migration (Baird and Shoemaker, 2008). Certainly, the presence of this species and the others listed in Table 3.2-3 confirm the connectivity of this upper river reach with lowland reaches.

Table 3.2-2 includes a category of "migratory" from www.Fishbase.org. The scale of migration is unknown for these species although it appears to be short distances. For example, *Hampala macrolepidota* is abundant in Nam Ngum Reservoir (FishBase, 2016), presumably completing migrations upstream of the dam. Further discussion on fish migration in the upper Xe Kong River and implications for strategic hydropower are provided below.

Figure 3.2-15. Incisilabeo behri, a carp species that eats algae on rocks.

Figure 3.2-16. Typical small species caught. The lower 7 species are carp species with a catfish and a spiny eel at the top.

Habitats

The habitats of the Xe Kong River are described by Meynell (2014) in 10 km reaches from the headwaters to the confluence with the 2S system. In the reach near Tat Kalang rapids and the Xe Kong 5 HPP there is little detail as there had not been any ground survey.

In the 19 km reach (6.3 km upstream and 12.8 km downstream of Ban Taloeuy) surveyed by kayak in the present study, rocky habitats dominated with large amounts of exposed bedrock and large broken rock (Figure 3.2-13 and Figure 3.2-17). These provide a substrate for algae and grazing marks from large fish (probably *Incisilabeo behri*) in the wet season were common (Figure 3.2-18).

Riffle habitat was common and these were mainly medium-sized rocks and cobbles with small amounts of gravels. Pools were present between the riffle and rapids. Although no depth measurements were taken, the pools appear to be deep and presently provide refuge for large fish (e.g. 20 kg). Meynell (2014) lists the deep pools as confined to lower reaches, but did not have access to data further upstream. One fish that was caught has exopthalmia (bulging eyes) (Figure 3.2-19) indicating that it had been caught at depth and pulled rapidly to the surface.

Figure 3.2-17. Exposed bedrock of river channel. Note high sands on far bank deposited at higher flow.

Figure 3.2-18. Marks from fish grazing on algae at high water levels.

Figure 3.2-19. Exopthalmia (bulging eyes), a form of barotrauma, indicating that this fish had been caught at depth and pulled rapidly to the surface. The injury suggests that deep pools are present in this reach.

Figure 3.2-20. At the most downstream reach the valley and river broadens and sand bars with cobble form on the inside bends.

Figure 3.2-21. Tributary stream near Ban Talouey showing low turbidity (upper photo) and where it entered the turbid Xe Kong main-stem (lower photo).

Discussion

The Tat Kalang rapids immediately downstream of the Xe Kong 5 dam site are not a barrier to fish movements and the fish observed in the fisher's catches confirm it. These upper Se Kong reaches are sufficiently productive to support large fish (10-20 kg) and have deep pools that provide refuge in the dry season, with habitats that provide active feeding in the dry and wet seasons. The steep sided valley does not have floodplains or flooded forest and hence would not be as productive as lower reaches with these features.

The two larger species and some of the smaller species collected are known to migrate and further studies would almost certainly expand the migratory list. With the exception of *Incisilabeo behri* (the large algae grazer) these species migrate short to moderate distances and it is the maintenance and connection between spawning and feeding habitats that is essential to sustain populations. Many of these species require flowing water (lotic) habitats in which to spawn. A dam that has extensive riverine habitats upstream of the reservoir can sustain some of these species that do not need to migrate hundreds of kilometres. In the Nam Ngum Reservoir *Bagarius* species use rocky fast-flowing reaches upstream (Sinthavong Viravong pers. comm.). However, this is unlikely to apply to the proposed Xe Kong 5 HPP reservoir because an inundation map (Figure 3.2-21) shows that there would be little flowing water habitat upstream to sustain species requiring this type of habitat.

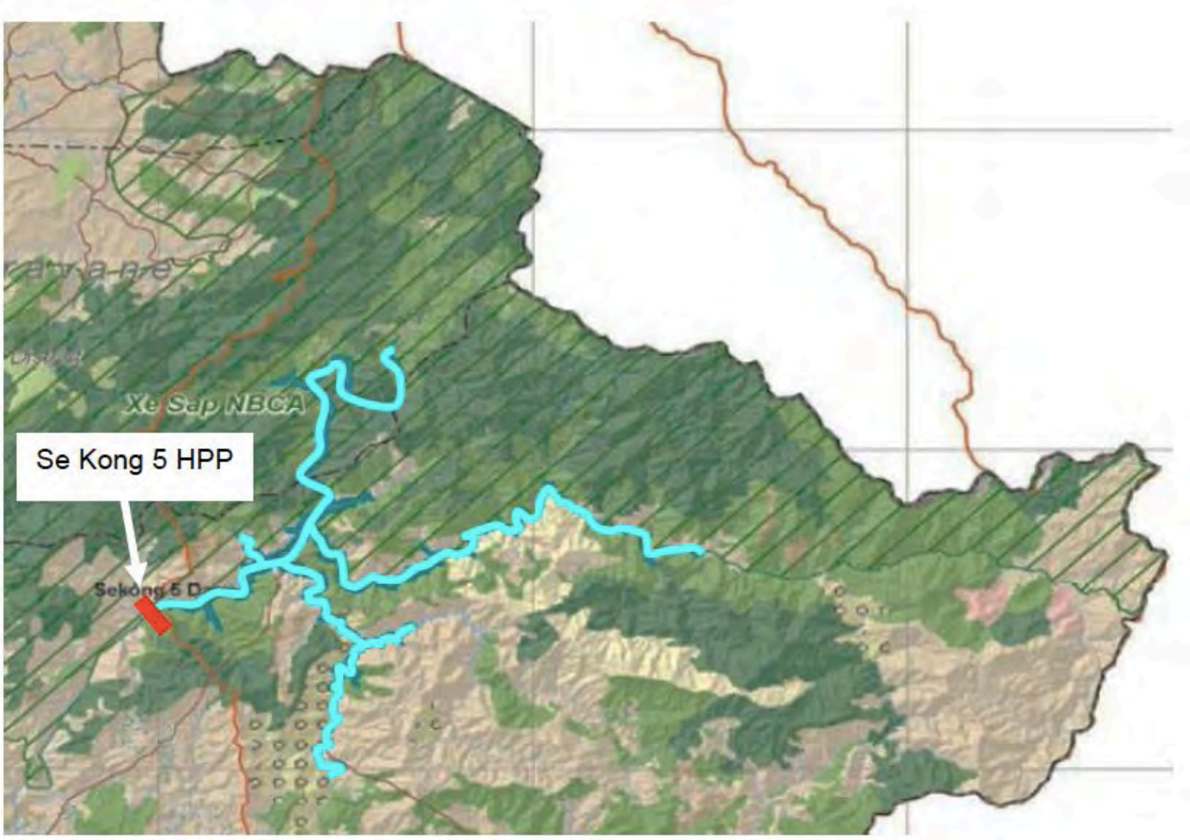

Figure 3.2-22. The upper Xe Kong catchment showing the river that would be inundated (light blue) from the proposed Xe Kong 5 Dam (red) (Norconsult, 2008).

From the limited observations of fish and limited fish distribution data presented in the EIA (Norconsult, 2008) there are potentially two models of fish distribution and migration in these upper reaches and each has different implications for balancing hydropower with impacts on society and the environment:

- Model 1 (Figure 3.2-22) assumes that: there are two zones of lowlands and uplands; long- distance and small-distance migratory fishes in the lowlands migrate upstream of the Xe Kong 5 dam site; and specialized upland species are present in high gradient upper tributaries.

- Model 2 (Figure 3.2-22) assumes that: there are three zones of lowlands, intermediate and uplands; long-distance migratory fishes in the lowlands do not migrate upstream of the Xe Kong 5 dam site; small-distance migratory fishes are present in the lowlands and the intermediate zone including upstream of the Xe Kong 5 dam site; and specialized upland species are present in high gradient upper tributaries.

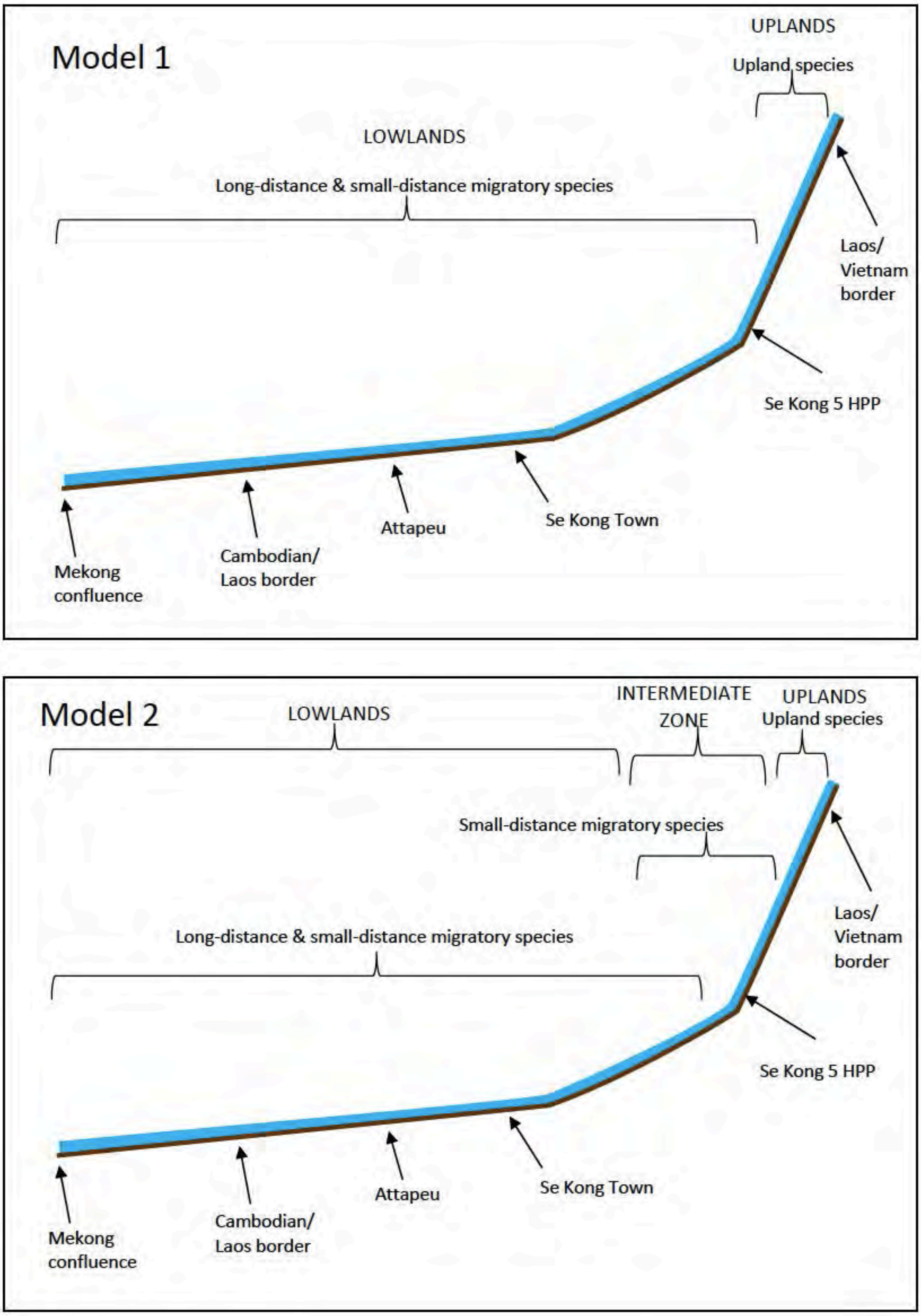

Figure 3.2-23. Model 1 (top figure) and Model 2 (bottom figure) of fish migration in the Xe Kong River.

The implications for hydropower are that high fish productivity is maintained by retaining fish migration corridors and the upstream extent of migrations could provide a strategic location for hydropower. In Model 1 long-distance and short-distance migrations overlap with the Xe Kong 5 HPP site and habitats become the limiting factor in upstream distribution. In Model 1, impacts on long-distance migratory species caused by the Xe Kong 5 dam would have broader impacts on Mekong fisheries, as has been discussed for the Sesan and Srepok rivers and the Lower Sesan 2 Dam (Ziv *et al.,* 2012).

In Model 2 long-distance migrations are downstream of the Xe Kong 5 dam-site and short distance migrations overlap with the site. In this scenario, the species with short-distance migrations contribute significantly to localised productivity, livelihoods and food security but would likely make little contribution to Mekong main-stem fisheries. If this model has validity then the Xe Kong 5 HPP may represent a more suitable compromise than downstream main-stem dams on the Xe Kong River which would impact migratory fishes from the Mekong River. <u>We recommend that fishers be surveyed to establish the distribution of migratory fishes and the seasonal (wet and dry) change in fish composition</u>.

Upland Species

In both models, upland species are present in upper tributaries. These are small specialized fish species adapted to high gradient mountain streams (Kottelat, 2001); they have high endemism and conservation value (Ziv *et al.,* 2012), and often provide a valuable food source for local villagers (Baird and Shoemaker, 2008). Although their generic habitats are known, their specific distribution in the upper Se Kong is unknown, which has a significant influence on the extent that the Xe Kong 5 HPP would impact these fish.

The proposed Xe Kong 5 HPP has a high dam (198 m) and inundates 40 km of the upper Xe Kong River (Norconsult, 2008). If the upland species are mainly in the headwaters upstream of this inundation then impacts are much less, but if they have key spawning or feeding habitats within the inundation area then the impacts are high and loss of species and biodiversity become likely. Understanding the distribution and use of these habitats would enable productive compromises; for example, if the inundation zone of the reservoir submerges a key spawning habitat, then the dam crest could be lowered or the dam operated at a lower level seasonally to ensure spawning. <u>Hence, a recommendation is to survey the distribution of upland species in the upper Xe Kong River and the habitats they are using</u>. This needs to include independent methods of sampling in a stratified design (e.g. tributary size by elevation), as well as surveys of fishers.

In the absence of a survey and detailed data on the specific habitat use of upland species, the alternative strategy to conserve biodiversity is to keep a representative selection of habitats. In hydropower development, including the upper Xe Kong system, this can be achieved by leaving some tributaries free-flowing and connected with the main-stem while damming others. Figure 3.2-24 shows examples of dam sites that are alternatives to the Xe Kong 5 HPP that would retain the upper Xe Kong River and tributaries free-flowing and thereby maintain diverse aquatic habitats for biodiversity.

The strategy of leaving representative habitats assumes that upland species within a catchment have well-mixed genetics within each species; hence, if a species becomes extirpated from a tributary, the assumption is that the genetic diversity of the species is retained in other nearby tributaries. For many species this is a sound assumption, but it is not universal and some species show little movement between sub-tributaries and this results in isolation and high genetic differentiation between populations (e.g. (Hughes *et al.* 2012)). For the upper Xe Kong this type of genetic information would take an extensive study.

An additional hydropower option that could be investigated for the upper Xe Kong system is the use of pumped storage, where two reservoirs are used: the upstream one generates electricity in peak periods and then off-peak electricity is used to pump water back upstream from the downstream reservoir.

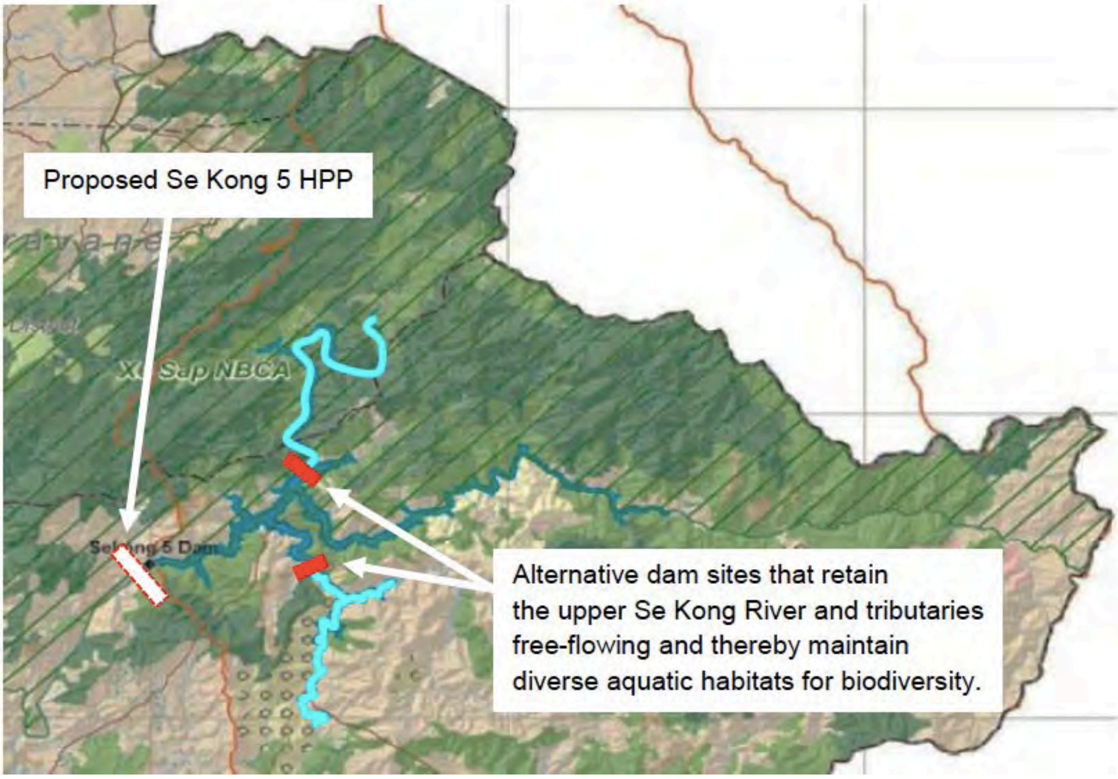

Figure 3.2-24. The upper Xe Kong catchment showing the river that would be inundated (light blue) from the proposed Se Kong 5 Dam (red).

Aquatic Productivity of the proposed reservoir of the Xe Kong 5 HPP

Where reservoirs replace flowing rivers, biodiversity declines (Kottelat, 2015) and the impounded water is almost universally less productive for fish. The reduction in productivity is a function of the original productivity of the river, the shape of the reservoir, the operation of water levels, and the extent of flowing river habitat retained upstream. Lowland floodplain rivers are more productive than upland rivers with no floodplains; shallow reservoirs with stable water levels are more productive than deep reservoirs with fluctuating water levels; and flowing river habitats upstream enable some spawning habitats to be retained and, if the river length is sufficient (e.g. >100 km), it provides for short-distance migrations.

The proposed Xe Kong 5 reservoir is in the upper reaches of the river with no floodplains so the original productivity is less than the lowland reaches of the river. However, the extent that lowland fish species are migrating to, and using the deep pools and habitats in the upper reaches is unknown, and hence the extent that lowland productivity is linked to fish use of upland habitats is unknown.

The proposed reservoir would be very deep and fluctuate 25 m in elevation, which prevents a productive littoral (edge) zone developing, while the extent of the reservoir leaves very little river habitat upstream. Hence, the Xe Kong 5 reservoir, as proposed and operated, will be very unproductive for fish. This highlights the importance of optimizing social and environmental outcomes downstream and this largely relates to environmental flows.

Environmental Flows

The Xe Kong 5 HPP is intended to capture flow in the early wet season (July and August) and release throughout the year, but with higher-than-natural flows in the dry season (Figure 3.2-25). Although the exact hydrograph would vary between wet and dry years, the seasonality of flows is generally retained.

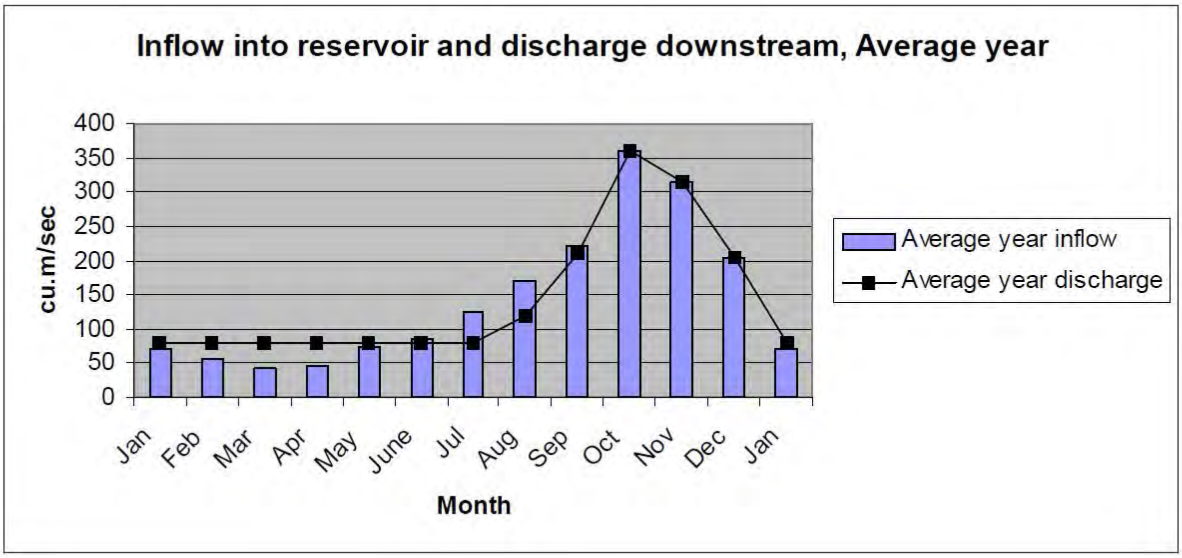

Figure 3.2-25. Example of monthly inflows (blue bar) and outflows (black symbols and line) from the Xe Kong 5 HPP, from the ESIA (Norconsult, 2008).

The main impact of changing flows on river ecology and productivity is the hourly variation within a day. The Xe Kong 5 HPP is intended to operate to meet peak daily energy demands. The ESIA (Norconsult, 2008) describes two proposed modes of operation: peaking for either 6 hrs (B6 mode) releasing 236 m^3 s^{-1} or peaking for 16 hrs (B16 mode) releasing 115 m^3 s^{-1} (Figure 3.2-26). Outside of these peaking periods a baseflow of 12 m^3 s^{-1} would be provided as an environmental flow for the river, which is equal to the minimum dry season flow. The combined mean daily flow of these regimes would be 80 m^3 s^{-1}.

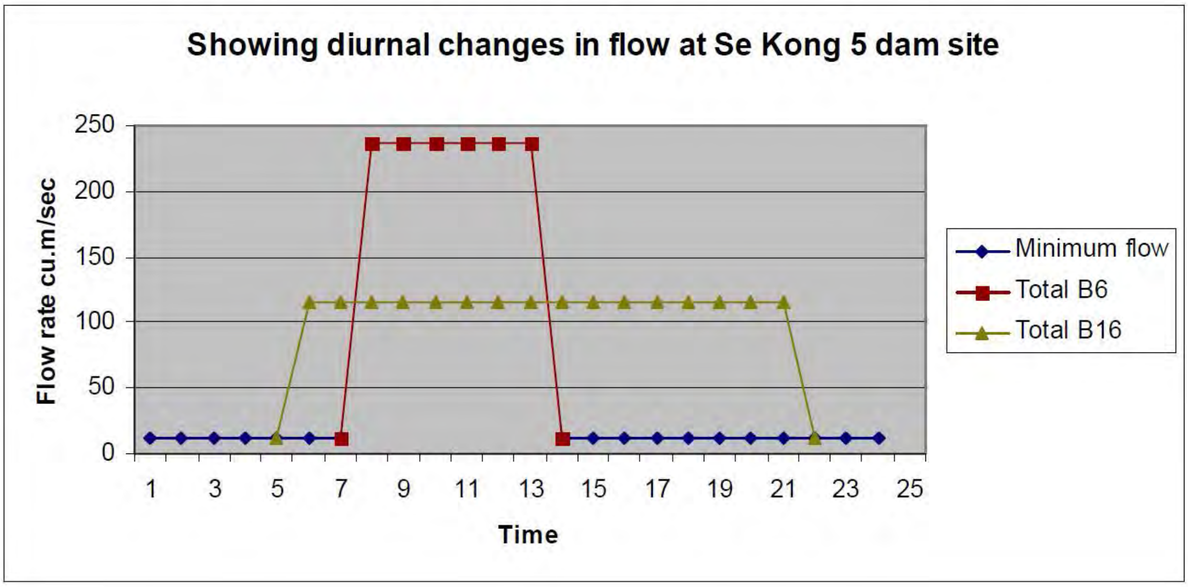

Figure 3.2-26. Example of hourly flows downstream of the Xe Kong 5 HPP under two operating modes of 6 hr and 16 hr hydropeaking (Norconsult, 2008).

This type of flow release, termed hydropeaking, severely reduces downstream aquatic productivity and interrupts the life cycles of fish. The daily fluctuations in water levels prevent algae forming in edge (littoral) and shallow zones of the river because they are dried out every day. For fish these fluctuations can stimulate them to spawn on inundated banks and vegetation, which is a common strategy for Mekong fishes, but in this case it leaves the eggs to dry out and die as the water recedes at the end of the hydropeaking period. Hence, the hourly variation in flows has a major impact on the river ecosystem, biodiversity and fish productivity.

The impact of hourly variation on flows, however, can be entirely mitigated. There are two main approaches: i) if there is a cascade of dams the lowest dam can be used for re-regulating and providing continuous baseload energy rather than peak energy, and ii) build a re-regulating weir downstream that holds the volume of the daily hydropeak which is then re-released to simulate the natural regime. The Xe Kong 5 HPP is not in a cascade of dams so the second approach would be appropriate if no further dams downstream were built.

Preliminary calculations of the daily hydropeaking volume suggest it is approximately 6.6 GL (gigalitres) and the re-regulating weir would need to be approximately 20 m high and located more than 5 km downstream. The weir would spread the hydropeak over 24 hours releasing a daily mean of 80 $m^3\ s^{-1}$. The re-regulating weir could also be used to add natural daily and weekly variation in flow. The river ecosystem would then be much less impacted – assuming that water temperatures were similar upstream and downstream of the dam – and would be based around a baseflow of 80 $m^3\ s^{-1}$ with natural variation, rather than 12 $m^3\ s^{-1}$ that fluctuates up to 115-236 $m^3\ s^{-1}$ daily. The added advantage of this approach is that the re-regulating weir can have small turbine and this can generate energy as it provides environmental flow.

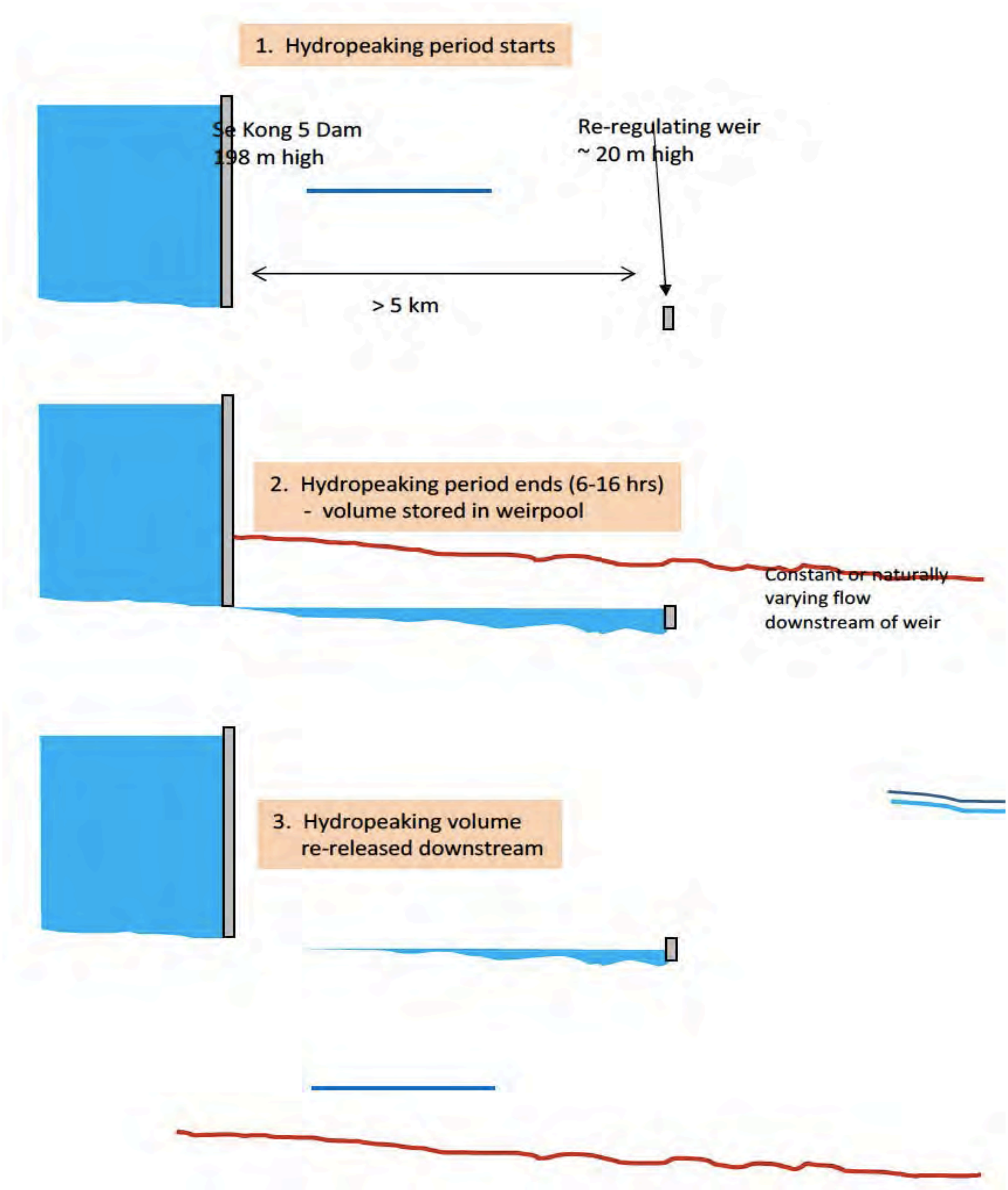

Figure 3.2-27. Diagram of a re-regulating weir downstream of Xe Kong 5 Dam.

Summary and Recommendations

The Tat Kalang rapids are not a barrier to fish movements but whether fish are migrating long distances from the Mekong or Xe Kong lowlands and moving upstream of the Xe Kong 5 HPP dam site remains unknown. The dam site may overlap with these migrations or be in an intermediate zone between uplands and lowlands where mainly short-distance migrants are present; if it is the former there are potentially much greater regional impacts.

In addition to potential impacts on migration and fish production the Xe Kong 5 HPP may have major impacts on biodiversity as the upland reaches of the Xe Kong have numerous small fish species that are endemic. The proposed reservoir would inundate extensive reaches of upland tributaries. The specific habitats of the endemic species, and whether they are found within the proposed reservoir area or further upstream, are unknown.

These two issues – the extent that lowland species use upland reaches and the distribution of upland endemic species - influences whether the Xe Kong 5 HPP project represents an acceptable tradeoff between fish and energy production, which leaves the very productive lowland reaches intact. To inform this we recommend:

i.) surveying fishers to establish the distribution of migratory fishes and the seasonal (wet and dry) change in fish composition in the upper reaches, and

ii.) a survey of the distribution of the upland species in the upper Xe Kong River and the habitats they are using. This needs to include independent methods of sampling in a stratified design, as well as surveys of fishers.

In the absence of these surveys and any further data we recommend that consideration be given to alternative sites for the Xe Kong 5 HPP that use tributaries upstream but leave the main stem of the Xe Kong free-flowing and leave a range of smaller tributaries free-flowing. These alternative sites may also include a pumped storage system, where water is pumped upstream in off-peak periods and hydro-electricity is generated in peak periods.

The proposed Xe Kong 5 HPP would have a major influence on downstream flows. The seasonality of flows is largely retained but hourly fluctuations to meet peak energy demands are predicted to be high. If the project proceeds then a re-regulating weir would be essential to eliminate hourly fluctuations and maintain a more natural hydrograph, which minimises losses to river productivity downstream. This assumes that the dam proceeds in a broader catchment-based Xe Kong hydropower strategy that did not include main-stem dams downstream of Xe Kong 5.

The Xe Kong 5 HPP has potential to have significantly less impacts on fish productivity of the lower Xe Kong than downstream dams. However, two key knowledge gaps on fish distribution and ecology, as described above, need specific investigation. If the project proceeded it would need to be in a larger Xe Kong hydropower strategy and a re-regulating weir would need to be included.

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Annex 3.3:

Analysis of Catch Sampling 2003-2013

Figure 3.3-1. Location of six stations in Cambodia used in this report: 1) Kandal Sang Var, 2) Kratie Koh Khne, 3) Ratanakiri Day Lo, 4) Stung Treng Ou Run, 5) Ratanakiri Fang, and 6) Stung Treng Pres Bang,

Definitions

Trend: Is an underlying pattern of behaviour in a time series, which could be partly or nearly completely hidden by the recognized amounts of unexplained variation in the time series (noise).

Variability: Denotes how stretched or squeezed a distribution is. Variability is typically measured by the quotients of mean and standard deviation.

Change: Is the transition from one state to another *significantly different* state, ex change in variability or trend. A 5% significance level is used (p <0.05)

Trigger: An event that is the cause of a particular action, process, or situation.

Pulse: A rapid rise in water level and discharge of more than 500 m^3/s per day to 2500 m^3/day.

Pulse rate: Change in discharge per day (m^3/s per day)

Monotonic: A function is called *monotonic* if and only if it is either entirely increasing or decreasing

Overfishing: The practice of commercial and non-commercial fishing which depletes a fishery by catching so many adult fish that not enough remain to breed and replenish the population. Overfishing exceeds the carrying capacity of a fishery.

CPUE: Catch per Unit Effort

Catch Sampling

The specific purpose of this analysis is to assess any monotonic trends in catch in the period from 2003-2013 (2006-2007 missing), the period where catch data is available in the MRCS fisheries database. The catch does not include Dai and Lee trap catches, only general catch.

Only important species are considered (Marked Imp or Yes) in the database. Data from six stations in Cambodia is used: Kandal Sang Var (413), Kratie Koh Khne (630), Ratanakiri Day Lo (794), Stung Treng Ou Run (688), Ratanakiri Fang (773), Stung Treng Pres Bang (778), see map (Figure 3.3-1) above. The numbers in brackets are the distances in km to the sea.

The reason for looking for monotonic trends is to see if the catch has been affected during the period. Especially overfishing and change in environment, ex. Hydrology, could make major changes affecting the catch.

To distinguish between overfishing and environmental impact it is assumed that overfishing will result in decline in mean weight of individual species, resulting in relatively fewer large fish and relatively more small fish, while change in hydrology would result in a general decline (or increase) in fish population but maintain the size ratio.

"Assuming that recruitment is constant, a decline in the mean weight of individuals in a population through time is indicative of increasing rates of exploitation as fewer large (older) individuals survive with time" (Halls *et al*., 2013: 101).

Catch individuals, length and weight

To assess the change, individuals, their max length and weight from the sampling data is used directly by looking at Individuals per Sample, Max length per Sample and weight per Sample.

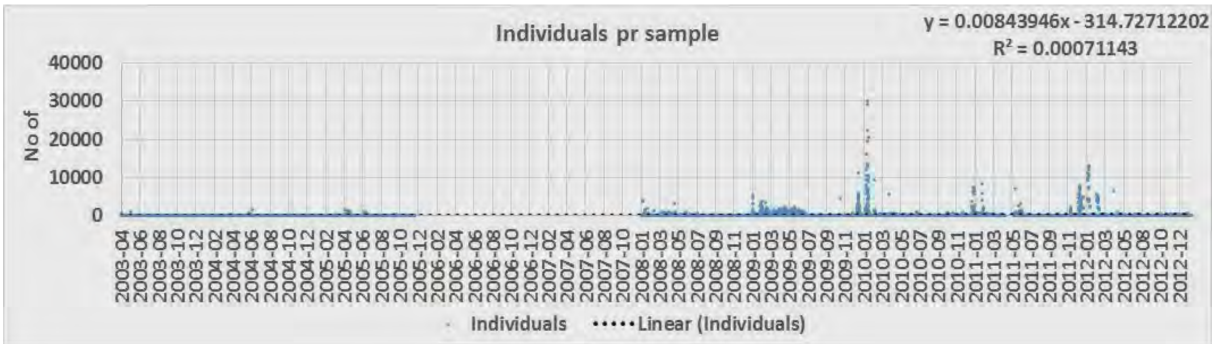

Figure 3.3-2. Number of individuals' pr. Sample. High values occur around January at the time of major migration from flooded plains (Tonle Sap Lake and the delta) takes place. (N=84927 samples). The trend line shows no monotonic trend. Note the huge numbers ex in 2010-01 related to catch at Kandal Sang Var during the out migration period from the Tonle Sap Lake.

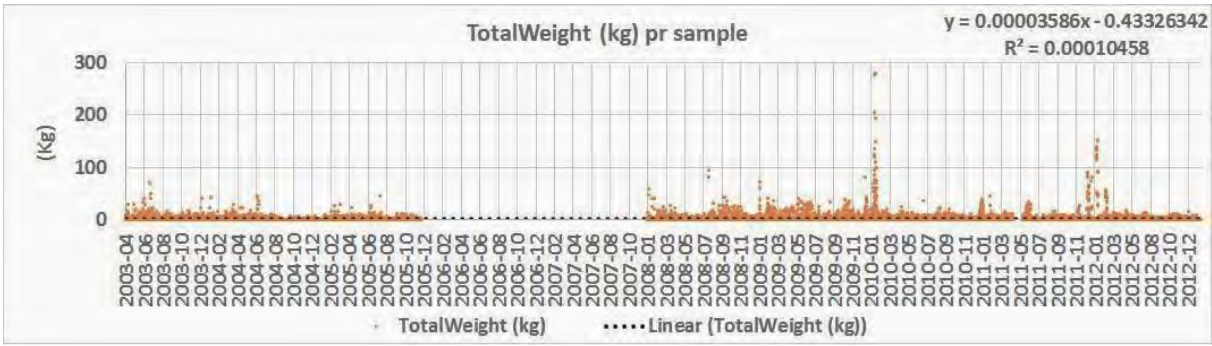

Figure 3.3-3. Total weight per sample. (N=84927 samples). The total weight pr. Sample shows the same pattern as the number of Individuals per Sample (fig 1). The trend line shows no monotonic trend.

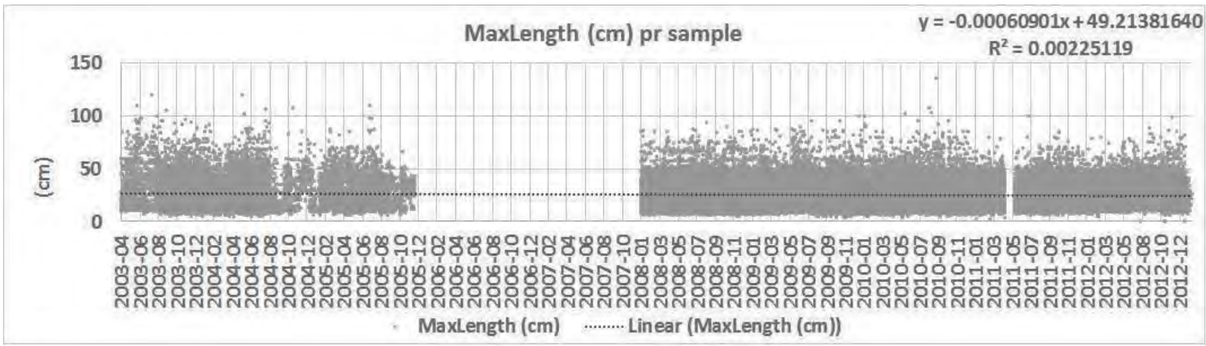

Figure 3.3-4. The Max Length per Sample. (N=84927 samples). The trend line shows no monotonic trend, the Max Length has remained constant over the period.

Large variations take place inter-annually, but no monotonic trend (decline or increase) was found for the max length, weight and number of individual species.

This is in line with the conclusions in Halls *et a*l., 2013 for Dai fisheries.

"Estimates of mean weight for all species combined as well as those species that contribute to the majority of the catch by weight have shown considerable variation during the fifteen-year monitoring period, but with no evidence of a continuous monotonic decline..." (Halls et al., 2013: 102).

For individual species changes in max length and catch has been recorded Bun, Phen and Nam 2015.

"In the absence of any clear trend in total catch, research has since looked at catches for different species in the fishery. Between 1998 and 2014, we found declining trends in catches of large species such as the Sutchi river catfish (*Pangasianodon hypophthalmus*) (maximum length: 130 cm).

Similar trends were observed for three mediumsized species, *Cyclocheilichthys enoplos* (maximum length: 74 cm), the small-scaled mud carp (*Cirrhinus microlepis*) (maximum length: 65 cm) and *Osteochilus melanopleura* (maximum length: 40 cm). By contrast, catches of small mud carps (*Henicorhynchus* spp.) trended upwards over the same period. At the same time, the total lengths of some fishes have been declining. Such changes may indicate the population is being "fished down" with declining production of large high-value species accompanied by increased production of small low-value short-lived species" (Ngor, Chheng and So, 2015:1).

"Apart from increased fishing effort, other factors behind the declining catches of these large and medium-sized fishes may be hydrological and hydraulic changes, habitat degradation, loss of habitat connectivity and climate change" (Ngor, Chheng and So, 2015:1).

Catch over distance

The distance to the sea is different for the monitoring stations used. With out-migration from flood plains of the delta and the Tonle Sap Lake to refuge in the river / deep pools, a constant catch level is provided at the 6 monitoring stations, see Figure 3.3-5.

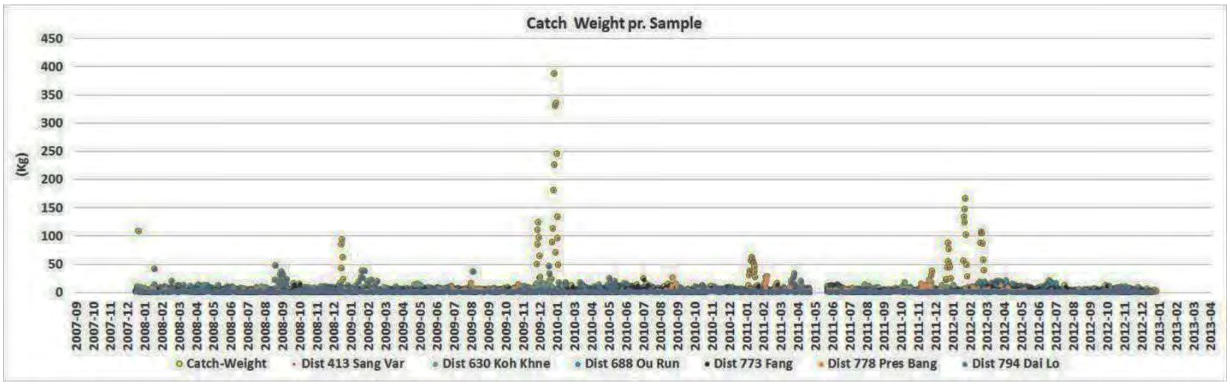

Figure 3.3-5. Catch weight per Sample at the six different monitoring stations (the number is the distance to the sea). Only Sang Var (Small dark dots) show different pattern due to the high catch rates during out migration from the Tonle Sap Lake. At other times the catch weight is at the same level for all stations.

Conclusions

The general catch shows no monotonic long time trend in overall catch, size or number of individuals although large inter-annual changes are observed. This is the same pattern found for the Dai fisheries in Halls *et al*., 2013.

The catch was also found stable and at the same size at all 6 stations apart from Sang Var that benefit from the out-migration from the Tonle Sap Lake at the end of the wet season.

Looking at individual large and medium species (valuable species) (Ngor, Chheng and So, 2015), has found decline in max length and catch but also found increase in max length and catch for other (less valuable) species.

References:

Halls, A.S.; Paxton, B.R.; Hall, N.; Peng Bun, N.; Lieng, S.; Pengby, N.; and So, N (2013) The Stationary Trawl (*Dai*) Fishery of the Tonle Sap-Great Lake, Cambodia. MRC Technical Paper No. 32, Mekong River Commission, Phnom Penh, Cambodia, 142pp. ISSN: 1683-1489.

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Annex 3.4:

Analysis of larvae sampling 2002-2013

Figure 3.4-1. Larvae sampling places used in this report. TS=Tonle Sap River, MU= Chaktomuk (Sometimes named CK), LB=Left Bank, RB=Right bank, MB= Mid 'bank', RS=Regional Survey 2009.

Definitions

Trend: Is an underlying pattern of behaviour in a time series, which could be partly or nearly completely hidden by the recognized amounts of unexplained variation in the time series (noise).

Variability: Denotes how stretched or squeezed a distribution is. Variability is typically measured by the quotients of mean and standard deviation.

Change: Is the transition from one state to another *significantly different* state, ex change in variability or trend. A 5% significance level is used (p <0.05)

Trigger: An event that is the cause of a particular action, process, or situation.

Pulse: A rapid rise in water level and discharge of more than 500 m3/s per day to 2500 m^3/day.

Pulse rate: Change in discharge per day (m^3/s per day)

Abbreviations

GL	Great Lake (Tonle Sap Lake)
TS	Tonle Sap
LP	Luang Prabang
NK	Nong Khai
NP	Nakhon Phanom
UB	Ubon Ratchathani
PK	Pakse
DS	Don Sahong
ST	Stung Treng
KT	Kratie
PP	Phnom Penh (Chaktomuk),
BS	Bassac River (Vinh Xuong, An Giang)
MK	Mekong River (Quoc Thai, An Giang)
IFReDI	Inland Fisheries Research and Development Institute
MRCS	Mekong River Commission Secretariat
MDS	Multi-Dimensional Scaling

Larvae Sampling

The specific purpose of this analysis is to identify triggers of spawning and to describe the larvae drift related to the hydrological changes in time and by location. This is important as changes in hydrology may impact the migration, reproduction and productivity.

The larvae analysis relates the hydrology to larvae drift in the Lower Mekong Basin, in particular around the Tonle Sap lake entrance in Phnom Penh and up-streams to Pakse in Lao PDR.

The hydrology data is the manual and telemetric data from MRCS and the larvae data is from the 2002-2013 data sampling by IFReDI and a Regional larvae survey in 2009. Important species are species listed as important in the MRCS fisheries species list and species for which larvae age can be calculated by a correlation with length.

The larvae sampling method in the Mekong River is standardized using Bongo nets of specific size at specific times and locations. A flow meter is attached to measure the water volume filtered. See MRC, 2013 a; Tharith, Sophat and Phanara, 2003 and locations on Figure 3.4-1 above.

Life Cycles

Quotation from Tharith, Sophat and Phanara, 2003, pg. 61:

> "As water levels on floodplains including the TS-GL system begin to fall, typically by mid–October, fish begin to migrate to refuge habitat including deep pools in the main channel. These migrations peak in January when catch rates in the *dai* fishery reach a maximum during the fishing season (October–March). As water levels begin to rise again in April, fish begin upstream migrations to spawning habitat in the main channel and tributaries. The *lee* trap fishery targets these upstream spawning migrations. Spawning typically occurs in June or July corresponding to the time of flow reversal in the Tonle Sap and the start of floodplain inundation. Larvae and adults return (often drifting passively with the flow) to colonise downstream floodplain habitat where they feed and grow until water levels begin to fall again in October. Drifting larvae are sampled by the larvae monitoring programme between June and September. Other species may remain resident in the main channel or on the floodplain throughout the year, or may exhibit similar migratory behaviour but, over smaller distances. Other generalist species may adopt more opportunistic behaviour according to the prevailing conditions" (See Figure 3.4-2).

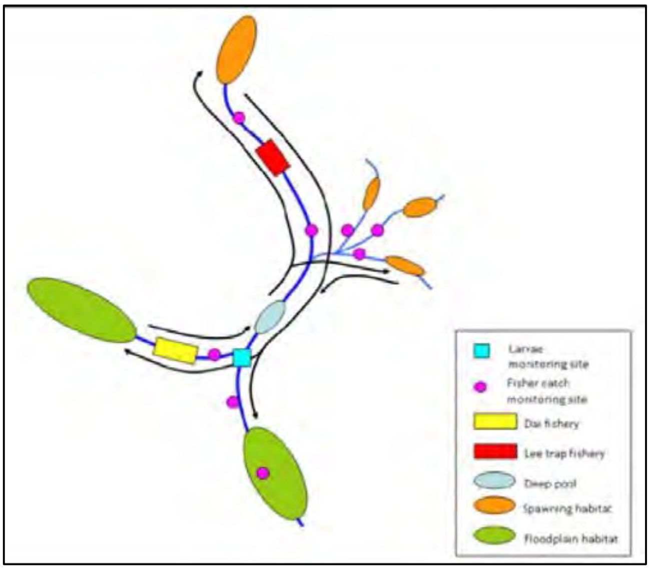

Figure 3.4-2. The generalized life-cycle and migration model for important whitefish species in the LMB. (Source: Tharith, Sophat and Phanara, 2003, Figure 33).

Similarity

The similarity of larvae species at different locations in the Mekong River is shown in Figure 3.4-3 below (MRC, 2015). Species sampled from Kratie to the Vietnamese delta show higher similarity and are quite different from samples further upstream at Don Sahong, Kratie etc. For a detailed explanation, see MRC, 2015.

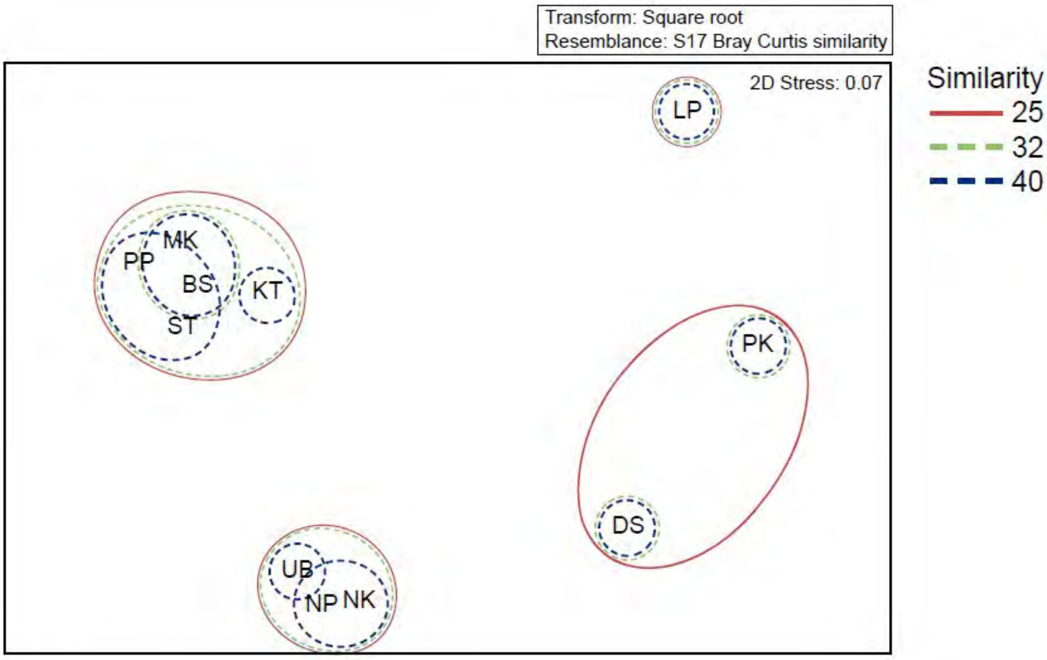

Figure 3.4-3. Average linkage cluster (a) and MDS (b) analyses on the species abundance (Bray Curtis similarity) of the fish larvae sampled by seine netting at 11 sites. The 11 sites in include: LP Luang Prabang, NK Nong Khai, NP Nakhon Phanom, UB Ubon Ratchathani, PK Pakse, DS Don Sahong, ST Stung Treng, KT Kratie, PP Phnom Penh (Chaktomuk), BS Bassac River (Vinh Xuong, An Giang), MK Mekong River (Quoc Thai, An Giang) (Source: MRC, 2015; Figure 3.13).

Triggers

For the Spawning and larvae drift the following triggers are considered:

- Discharge,
- Pater level and
- Pulses

Larvae Drift Pattern

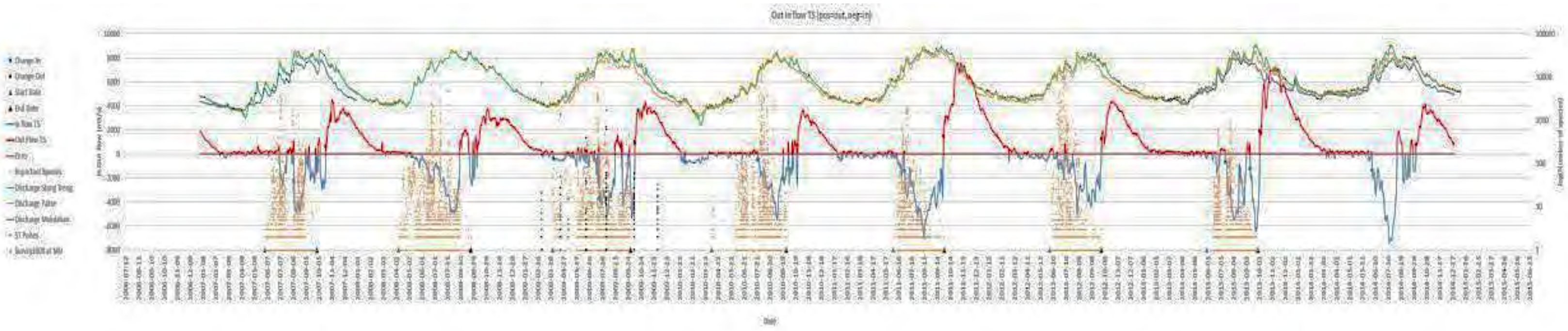

Figure 3.4-4. Larvae drift from Cambodian larvae surveys 2002-2013 and the regional survey 2009 compared to Tonle Sap in and out flow (Blue and red graphs), water levels at Stung Treng, Pakse and Mukdahan and pulses (sudden rise in water level) for important species. Large pulses that triggered spawning are marked with yellow dots, small pulses with small green dots on the green Stung Treng discharge curve. Triangles denote the start and end of the yearly sampling. Note the Log10 scale for Number of larvae pr. water volume pr. sample.

The larvae sampling by IFReDI normally starts around June and lasts until October, but in years 2009 and 2010 it started already in April and March. The regional survey had a single sampling starting early March 2009. Outside these periods larvae still drift, but no detailed sampling has taken place.

Specific high concentrations are found during the raising stage of the river. And, within the raising stage significant differences in larvae concentrations are measured (see Figure 3.4-4). (Note the $\log_{10}$ scale for number of larvae).

Relating these larvae drift peaks to the pulses in discharge, it is seen that the drift peak (number of larvae) occurs after high discharge pulses (Marked with yellow dots at their peak on the green discharge graph from Stung Treng). Between such pulses drift falls to a lower level. The regional survey in 2009 show same pattern, although fewer samples were taken (Black dots in 2009). At the beginning of the sampling periods 2009 and 2010 larvae were sampled outside the raising stage period showing lower levels that may exist during all the dry period.

The larvae species composition differs at different places on the Mekong. An overview can be seen in similarity graphs (Figure 2 in MRC, 2015).

Larvae Location in the River

Most IFReDI surveys are done at the right banks (RB) at the sampling sites, but sampling is also done both mid-stream (MB) and on the left banks (LB), see Figure 1 above for locations.

The location or drifting larvae in the Mekong River around Phnom Penh at the MU and TS sampling sites is quite similar at both banks and in the middle of the river (see Figure 3.4-5 and Figure 3.4-6).

The number of larvae per Volume water per Sample is largely the same in the years 2011, 2012 and 2013 at both the MU and the TS sampling sites on Left, Right and Mid-stream. Number of samples on the RB is much higher than on the MB and LB locations, but larvae concentrations are similar.

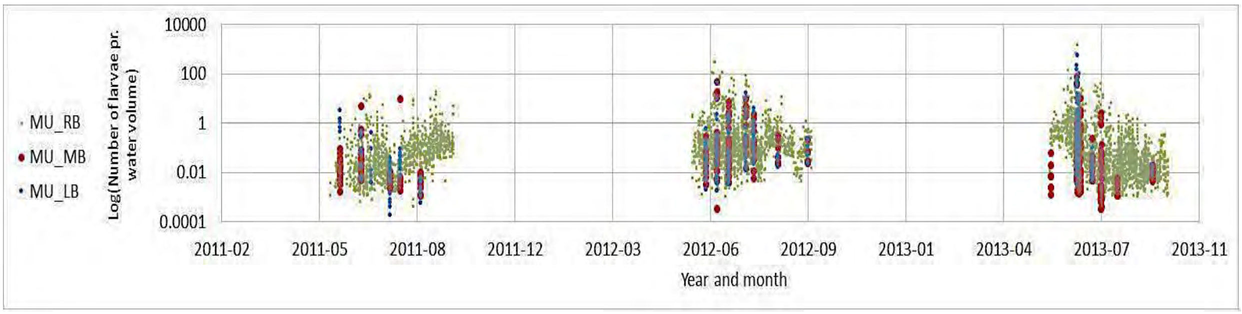

Figure 3.4-5. Number of larvae per sample and per water volume at the MU (Chaktomuk) sampling sites left (LB), mid (MB) and right (RB) banks.

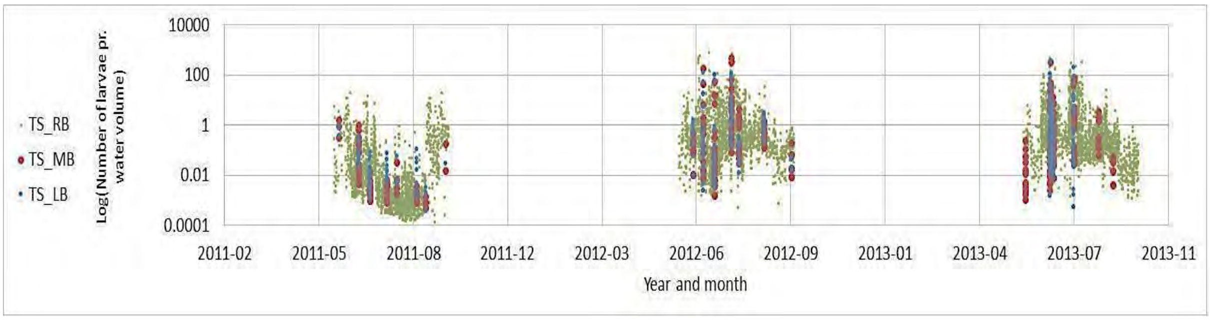

Figure 3.4-6. Number of larvae per sample and per water volume at the TS (Tonle Sap) sampling sites left (LB), mid (MB) and right (RB) banks.

The evenly distributed larvae contents exist even the velocity is quite different, at the same time, in the mainstream Mekong at MU and in the Tonle Sap river at TS (see Figure 3.4-6 and Figure 3.4-7).

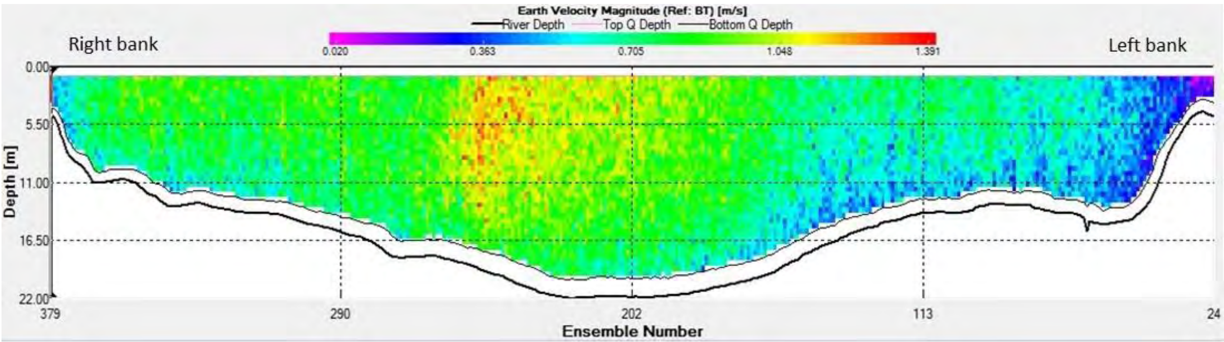

Figure 3.4-7. River cross section of the Mekong mainstream at the MU sampling site from 2003-07-03.

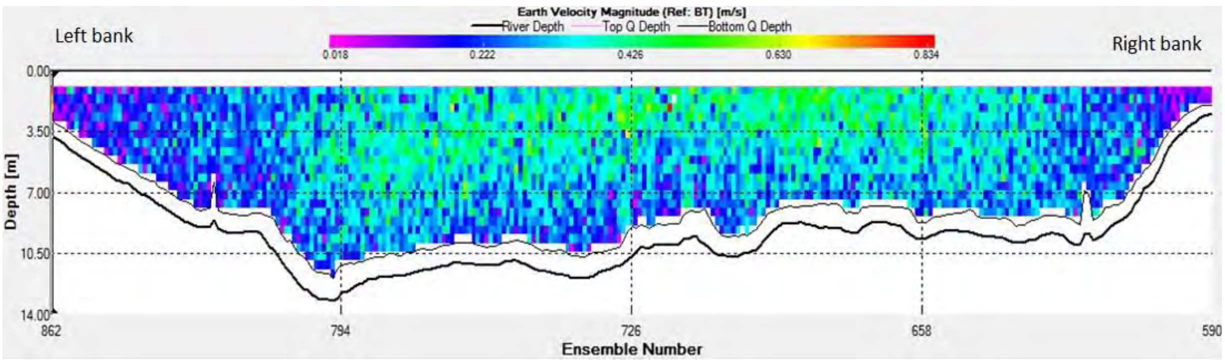

Figure 3.4-8. River cross section of the Tonle Sap River at the TS sampling site from 2003-07-03.

Pulse Size and Duration

The size and duration of the pulses that trigger spawning (see Figure 3.4-4) are significant. The rate (change in discharge/day) increases over the up-going stage period. Later pulses require still higher rate as they propagate already considerable water masses (see Figures 3.4-9, 3.4-10 and 3.4-11).

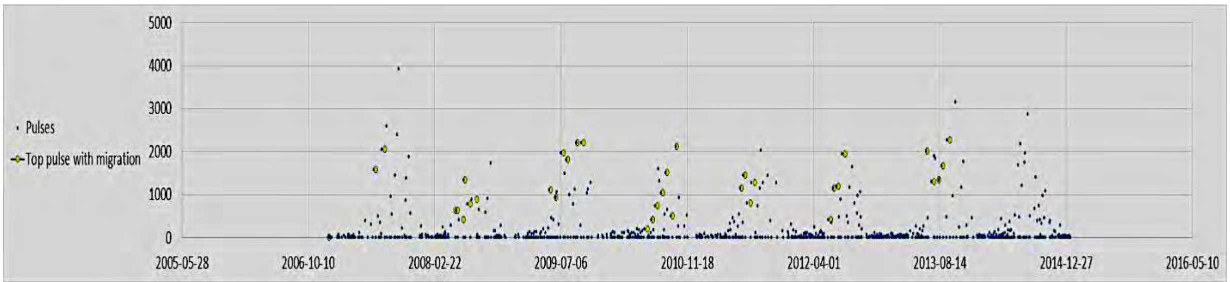

Figure 3.4-9. Spawning pulses: The rate is the discharge change (increase) per day at Stung Treng. Blue dots: all pulses. Yellow dots: Spawning triggering pulses, see Figure 3.4-4.

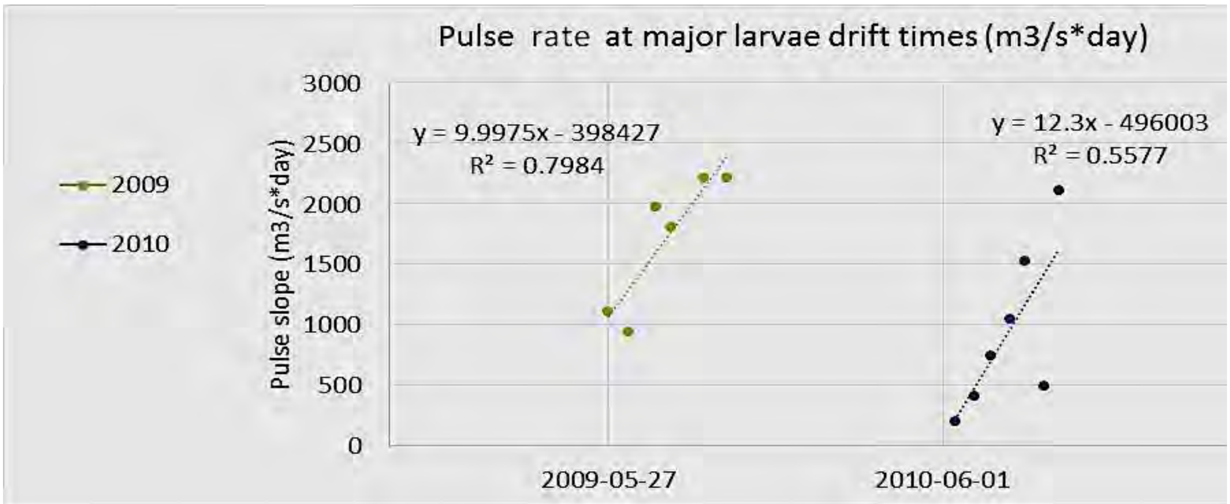

Figure 3.4-10. Rate of spawning pulses in 2009 and 2010. Later pulses increase with more than 2000 m3/s*day (Zoom of Figure 3.4-9).

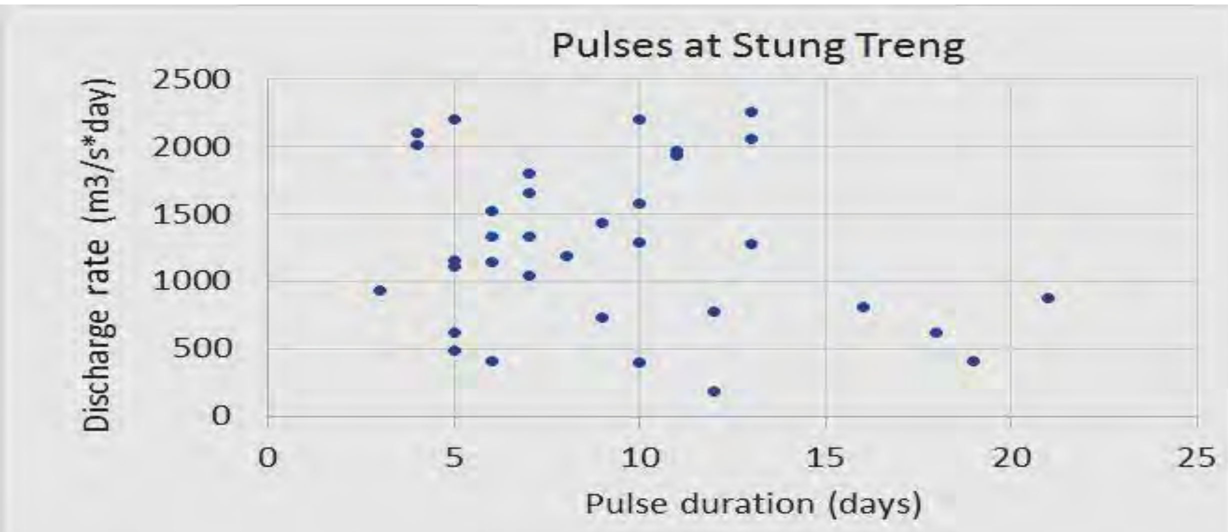

Figure 3.4-11. Rate of spawning triggering pulses and their duration at Stung Treng from 2006-2014. Low pulses can last longer than high pulses, otherwise the magnitude and duration is random.

Pulse Velocity

The propagation velocity of the pulses depends on the water level. The higher water level the faster the pulse moves. The time for the pulse to get to the Tonle Sap / Delta flood plain at Phnom Penh during the major spawning period, varies from around 35 to 2 days, dependent on the start place and different water levels. The variation is considerable over the year (See Figure 3.4-12).

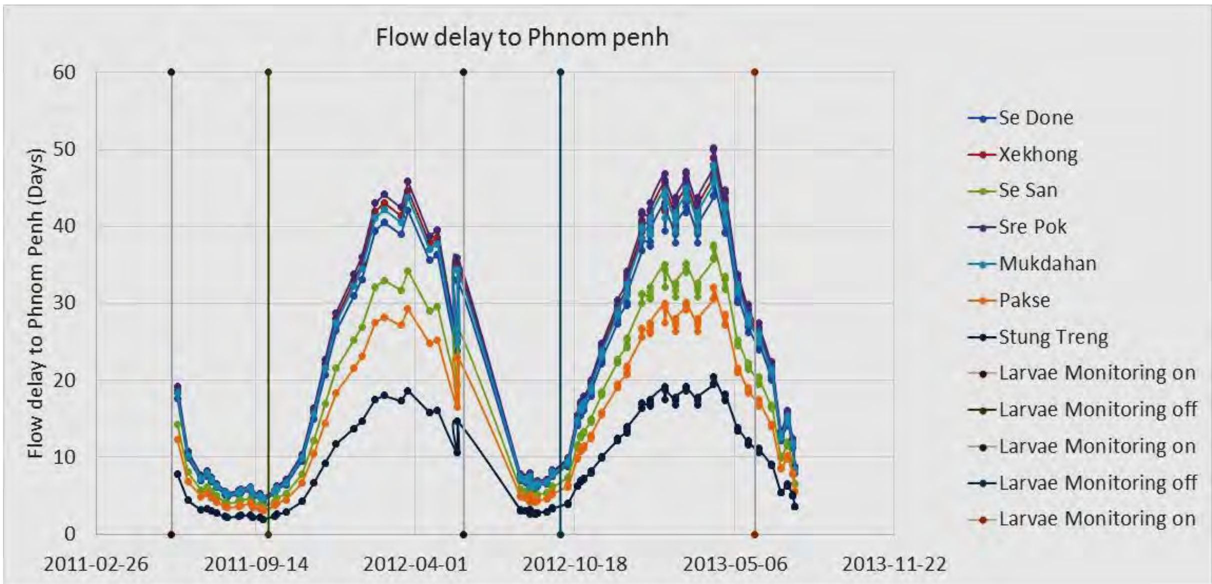

Figure 3.4-12. Flow delay from different locations to Phnom Penh. The vertical bars show the larvae sampling periods. The distances are measured from the top of a tributary or from a fixed location on the mainstream to Phnom Penh. The velocity measurements are from MRCS ADCP surveys in 2011- 2013.

Larvae Ages

Larvae ages are calculated by correlating larvae lengths and ages from MRC, 2013b. Second to fourth degree polynomials are calculated and restricted in validity between min and max larvae lengths registered in MRC, 2013b. Larvae age is then calculated using registered length in the MRCS larvae database as parameters to these polynomials. All polynomials have a R^2 higher than 0.95.

The age of larvae arriving at Phnom Penh varies considerably, from a few days to around 50 days (see Figure 3.4-13). The mixed ages at Phnom Penh can be explained by the pulses as spawning triggers.

When a major pulse starts upstream, mature fish start spawning. Eggs and larvae flow along with the pulse and as the pulse passes locations downstream, spawning starts there. A spawning cascade is created. When the pulse arrives at Phnom Penh it carries along high concentrations of larvae (and probably also the mature species returning to the floodplains).

The pulse velocity during the larvae sampling season varies with the discharge and in 2012-2013 varied between 35 and 3 days for equal distances (see Figure 3.4-13). The velocity is the average velocity measured by ADCP. Velocity along banks and river bed is lover and the age distribution between 2-50 days (see Figure 3.4-13) is in line with the average pulse velocity and the pulse diverse velocity between mid-stream, bed and banks.

As the larvae are evenly distributed across the river (see Figures 3.4-5 and 3.4-6), some will flow slower along the banks and a mix of ages from 2-50 days emerges. It is also possible that some larvae have come from further upstream than Se Done in Lao PDR or that some larvae already have grown to juvenile size and were not included in the larvae samples.

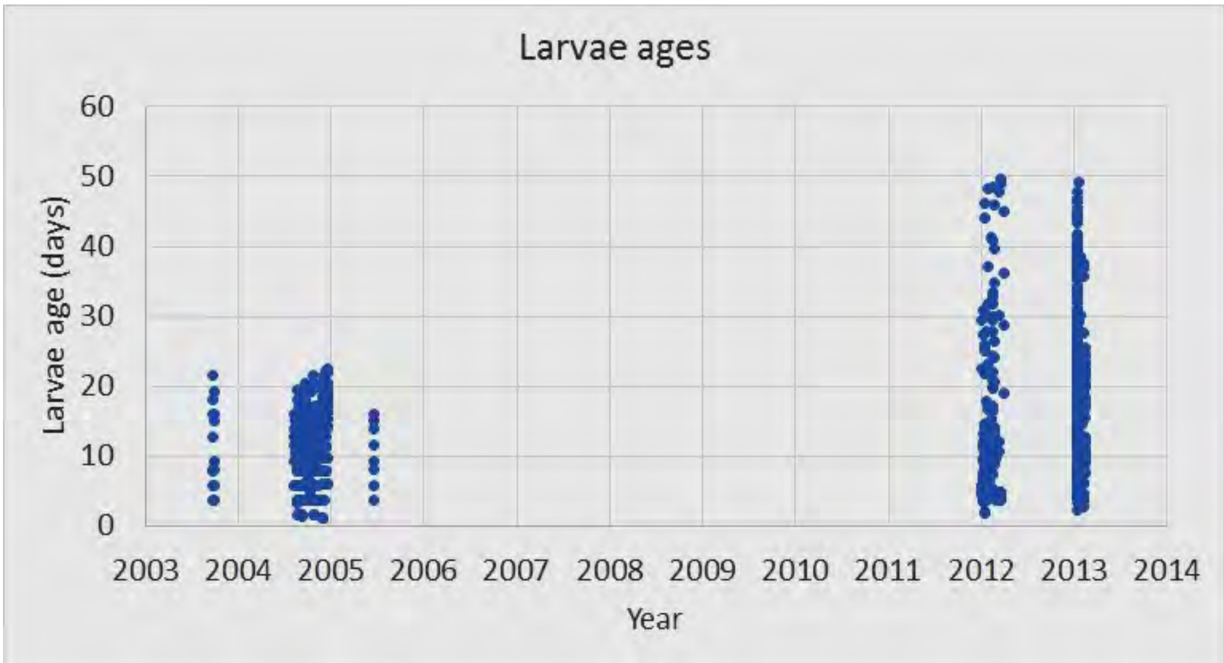

Figure 3.4-13. Age of larvae arriving at Phnom Penh sampling stations MU and TS. Data from 2003-2005 are probably less accurate than data from 2012-2013 as different sampling methods were used.

Arrival Time at Phnom Penh

The spawning trigged by large water pulses and the subsequent drift along with the pulse can explain that larvae arrive at the Tonle Sap river entrance at the time when the flow reverses into the lake and spreads into the Vietnamese delta floodplain.

The larvae ages (50-2 days) can be explained by the drift along the pulse at the various flow rates at midstream and along the banks or bed and form spawning in different locations when the pulse passes. The timing of arrival is then perfect, as the same large pulse provides the inflow to the Tonle Sap Lake and spreads into the southern floodplains–-magnificent orchestration by nature (see Figure 3.4-14).

Figure 3.4-14. Year 2008 larvae arrival time at the TS and MU monitoring stations in Phnom Penh. The arrows show the peaking of the larvae concentration aligned with the pulse peaks. For graph explanations, see Figure 3.4-4.

Conclusions

Spawning is triggered by the up-going stage and by large pulses, often with rates of 500 -2500 m^3/s per day. The larvae arrive at Phnom Penh, when reversal into the Tonle Sap Lake takes place by the same large pulses because the larvae drift with the pulse.

The concentration of different ages can be explained by a spawning cascade as the pulse moves down-stream-–when the pulse arrives at a specific location, fish start spawning; and a mix of drift velocities near banks, bottom and midstreams. The even distribution in the river between left, right banks and mid river suggest a mixed flow velocity creating a mixed age composition.

The triggers for the major spawning events are the increasing water level, discharge *and larger pulses.*

References:

MRC, 2015. Larval and Juvenile Fish Communities of the Lower Mekong Basin. MRC Technical Paper.

MRC, 2013a. Integrated Analysis of Data from MRC Fisheries Monitoring Programmes in the Lower Mekong Basin. MRC Technical Paper. No. 33, August 2013.

MRC, 2013b. A guide to larvae and juveniles of some common fish species from the Mekong River Basin. MRC Technical Paper. No. 38, August 2013.

Tharith, C.; Sophat, L. and Phanara, T. (2003) Fish larvae and juvenile drift at the confluence of four rivers near Phnom Penh: the Mekong upstream and downstream. The Tonle Sap and the Bassac River, June- September 2002. In: Poulsen, A. (ed.). Proceedings of the 5th Technical Symposium on Mekong Fisheries, 11th – 12th December 2002. *MRC Conference Series* No. 4, Mekong River Commission, Phnom Penh: 21-28.

Annex 3.5:
Dai fisheries 1994-2014

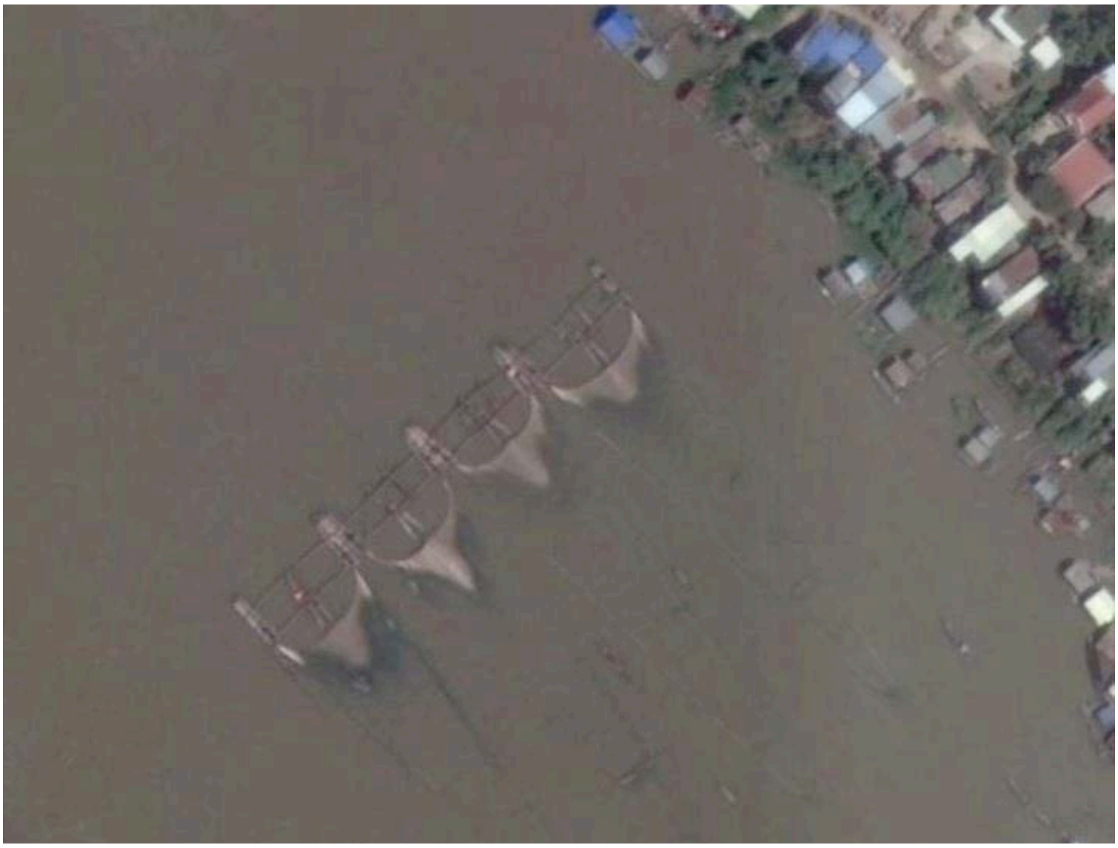

Figure 3.5-1. Dai catch row 3. Image Google Earth. 2016.

Definitions

Trend: Is an underlying pattern of behaviour in a time series, which could be partly or nearly completely hidden by the recognized amounts of unexplained variation in the time series (noise).

Variability: Denotes how stretched or squeezed a distribution is. Variability is typically measured by the quotients of mean and standard deviation.

Change: Is the transition from one state to another *significantly different* state, ex change in variability or trend. A 5% significance level is used (p <0.05).

Dai Fisheries

Dai fisheries or Bagnet fisheries, is a special kind of fisheries setup in the Tonle Sap River from Phnom Penh and around 35 km upstream. Today there are 14 rows numbered from 2-15 (Row 1 was removed), see Figure 3.5-2.

Bagnet fishers are allowed to set up operations middle of September and start catching early October. They continue fishing until March when the current out of the Tonle Sap River has become slow. Dai units are operated singly, but are joined with three to eight others in rows across the river, which sometimes form large barrages that leave just enough space for navigation.

The MRCS fisheries database contains Dai fisheries data from 1994 till 2014. The sampling has changed over time regarding both frequency and sites. A detailed description can be found in (Halls *et al.*, 2013).

This analysis does not calculate total catch or catch per unit effort (CPUE) but looks at the timing, trends and variability in the samples and links these to fish migration patterns and triggers. Since 2008 the data was divided into small and big fish catch samples. The distinction between big and small fish is made by the fishermen.

Figure 3.5-2. Dai fisheries row 2- 15 locations.

The migration pattern is described by temporal and locational trends correlated with migration triggers.

Triggers

For the Dai fisheries the following migration triggers are considered:

- Discharge, water level and current changes
- Lunar cycle (Phases)

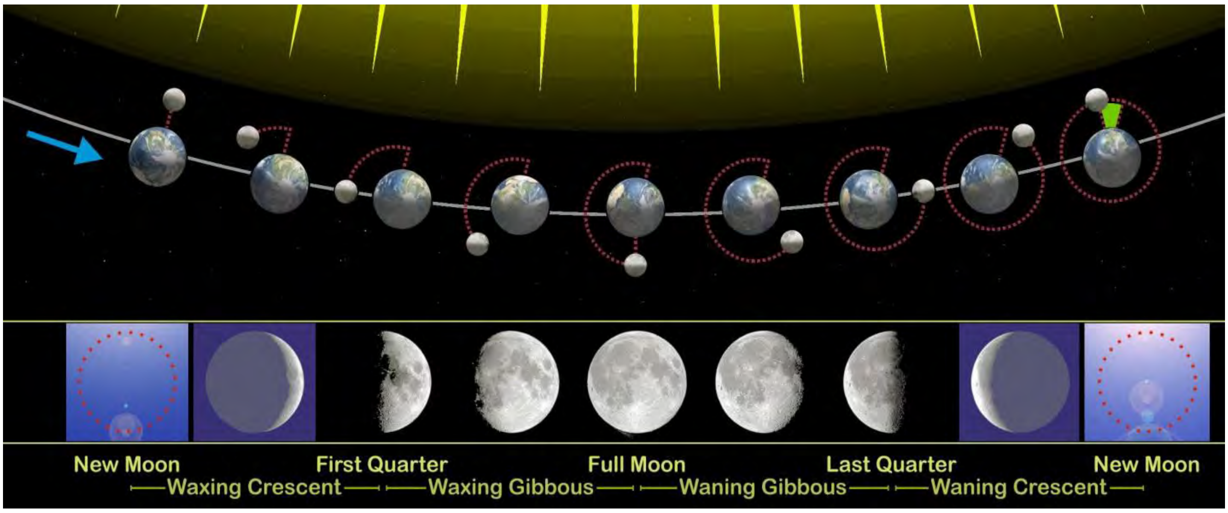

Figure 3.5-3. Lunar phases: Four phases from new moon, first quarter, full moon and last quarter. Here the terms Q1, Q2, Q3 and Q4 are used. Source: Wikipedia: https://en.wikipedia.org/wiki/Lunar_phase

Migration Pattern

The main migration pattern related to the Dai fisheries has been described before, see ex. Deap Loeung or Halls, et al., 2013.

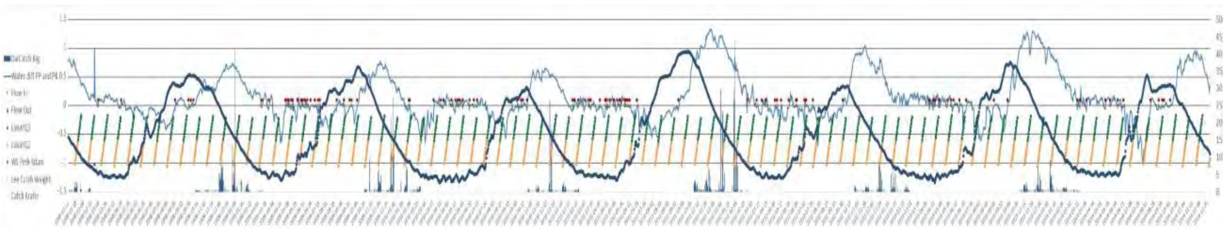

Figure 3.5-4. The combination of Dai Catch of Big fish from 2008 to 2014 with flow into and out of the Tonle Sap Lake, the Lunar cycles and water level at Prek Kdam hydro meteorological station. The zero (0) line divides the Tonle Sap inflow and outflow; negative values denotes inflow, positive values outflow. Red and yellow points show when flow changes from in to out (red) and from out to in (yellow).

From Figure 3.5-4 it can be seen that the migration out of the Tonle Sap Lake has at least three triggers, the start of the major outflow, the falling water level and the lunar phases. The actual start may not be recorded as the Dai fisheries sampling starts at different times in October or November, shortly after the flow reverses to outflow –and then at the time when the lunar phase enters Q2. During Q2 and Q3 the migration out is peaking, to slow down until the next Q2-Q3 period. A total of 5 such periods were recorded for big fish species from 2008 to 2014 ending at the time the water level in the Tonle Sap lake gets near its annual minimum of less than 2 km^3 of volume. For the Tonle Sap Lake area and volume, see NHI, 2016.

A high concentration of suspended sediments is mainly related to the inflow to the Tonle Sap Lake and is therefore not found to be a migration trigger (NHI, 2016).

Variability

Variability in Dai catch season

The start and end of the Dai fisheries is legally regulated from October to March and the start and end times of the year has not changed significantly over the period from 2008 to 2014. Average Start day of year was 296 (24.10) and average End day of year was 61 (02.03) the following year, see Figure 3.5-5.

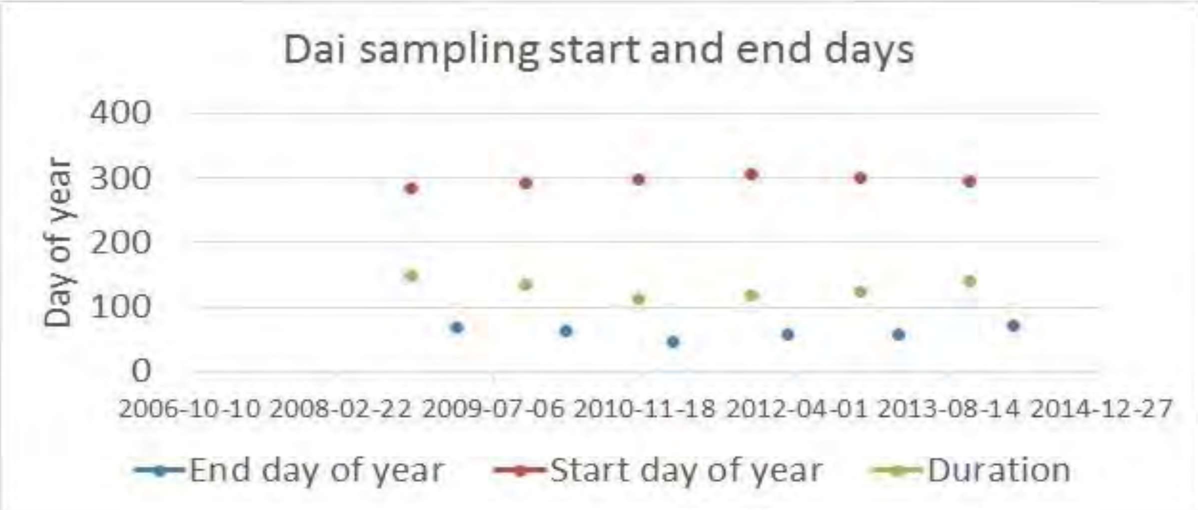

Figure 3.5-5. Start end day of year and duration in days of Dai fisheries.

The end day for the major inflow to the Tonle Sap Lake is also the start day for the major outflow which is on average day 280 of the year. This is 16 days (296-280) before the average Dai catch started in the period from 2009-2014 (see Table 3.5-1).

The average 10 days delayed start of the major outflow from the Tonle Sap Lake has not influenced the start of the Dai fisheries as it still starts later in October regulated by legislation (Table 3.5-1).

Table 3.5-1. Inflow day/outflow day to the Tonle Sap Lake.

	Inflow day		Outflow day	
	Avg 2009-14	**Avg 60-08**	**Avg 2009-14**	**Avg 60-08**
Average	193.8	179.0	279.8	269.8
Diff	14.8		10.0	
Stdv	13.4	24.8	9.0	13.0
	t-test 60-08 to 09-14		t-test 60-08 to 09-14	
	0.057		0.046	
t-test, two tailed, different variance, α=0.05				

*Exclusive 1972-1990 because of invalid data, see NHI, 2016.

Variability in catch

Dai catch sampling separated the catch into small and big species in 2008. Before that, both small and big species were mixed, see Figures 3.5-6 and 3.5-7. The sampling from Dai catch show large variability for both small and big important species. Especially for big species less than 10 species dominate the catches. Species numbers refer to MRCS Dai catch database and registered as important in the MRCS species list. Also over time (years) there are large variations. Of the 37 important species represented in the samples, 29 big species and 15 small species count low numbers. Temporally, there are large variations between years related to the Total Flow (TF) through the Tonle Sap Lake.

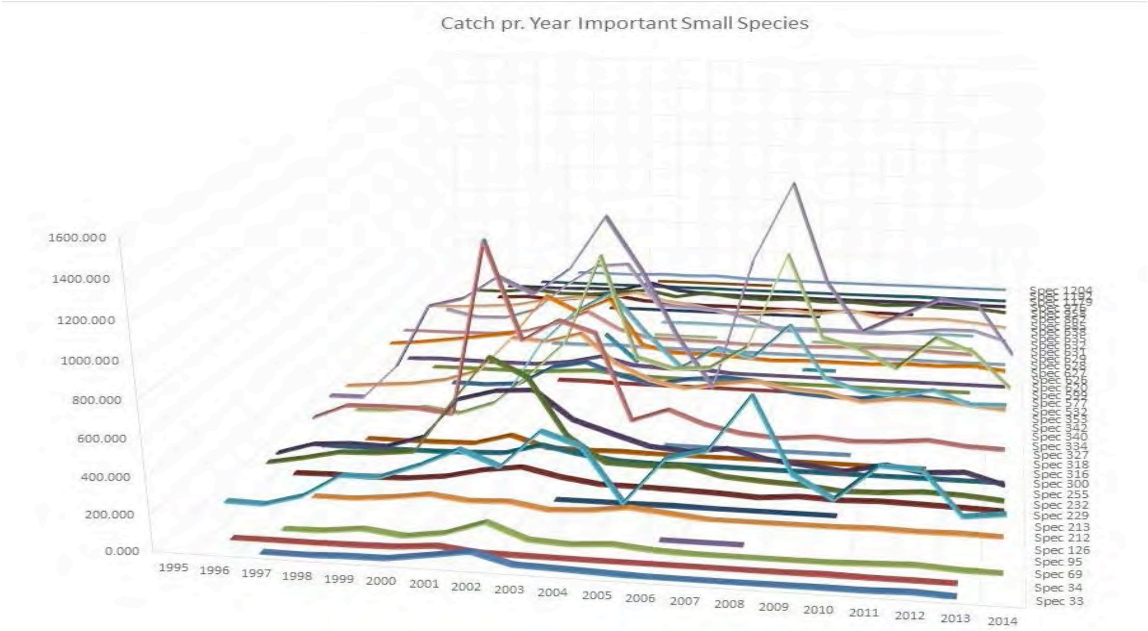

Figure 3.5-6. Sampling sizes of important small species 1994-2014 from Dai fisheries. Zoom for high resolution image.

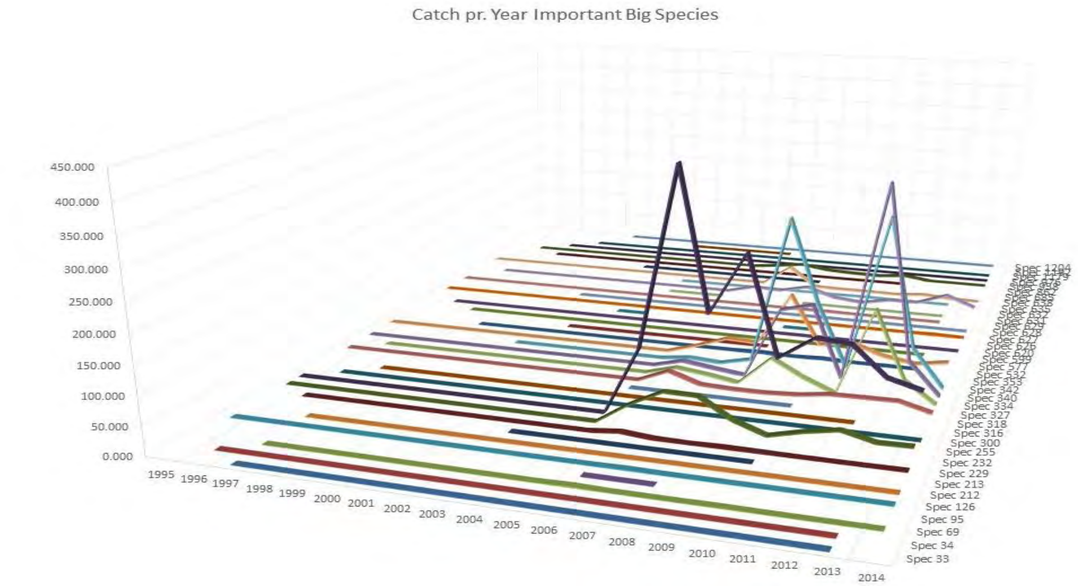

Figure 3.5-7. Sampling sizes of important big species 2008-2014 from Dai fisheries.

The Dai catch is closely related to the Total Flow (TF) passing through the Tonle Sap Lake.

In Halls *et al.* (2013), a relation between a calculated Flood Index (FI) (see definition in Table 3.5-2 explanation box and details in Halls et al., 2013)), and Dai catch by Weight and CPUE, provides a model to estimate these values based on the Flood Index.

"The model explains almost 70% of the variation in the observed catch rates .... and the model residuals are reasonably well behaved" (Halls *et al*., 2013). See explanation box under Table 3.5-2.

The remaining variation may be explained later by changes in nutrients and oxygen concentrations etc.

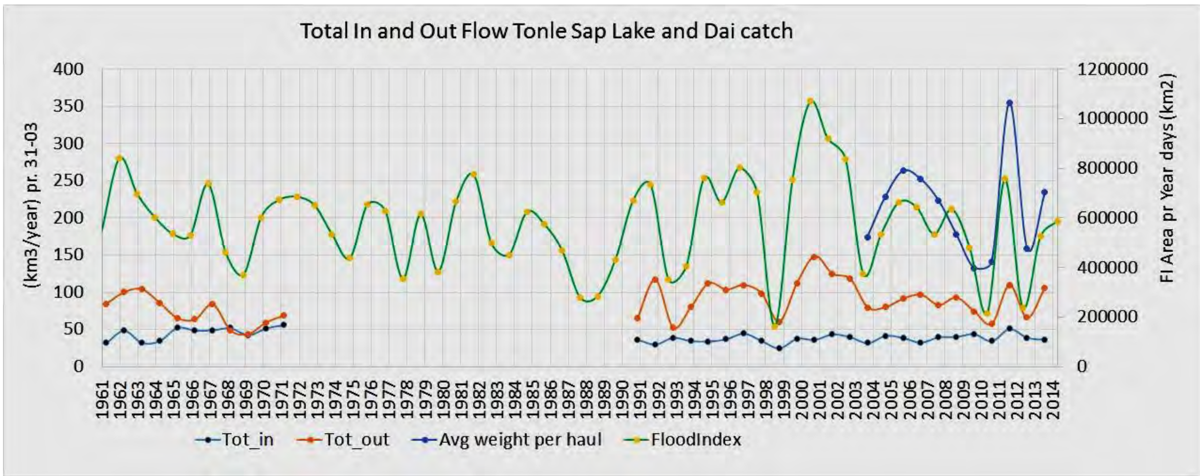

Figure 3.5-8. Tonle Sap Lake total in and out flow, Flood Index and Dai catch by weight of all species. Note the constant inflow around 40km3/Y form the Mekong River.

Using the model formulas, the expected mean sampled fish weight and CPUE is calculated for the periods 1991-2007 and for 2008-2014, indicating that the decline in fish weight and CPUE during the period 2008-2014 is related to the FI (see Table 3.5-2. Explanation box).

Table 3.5-2. *Mean sampled fish weight (all species combined). FI: Flood Index. TF: Total Flow

Period	FI	*Weight (kg)	CPUE	Correlation	R^2
Avg 91-07	642266	0.011906	235.3466	**2004-14 Weight per haul - FI**	0.78
Avg 08-14	491227	0.009886	184.6469	**2004-14 Weight per haul - TF**	0.81
% diff	76.48	83.03	78.46	**TF - FI**	0.90

Table 3.5-2 Explanation box: (TS-GL: Tonle Sap Lake -Great Lake). Halls *et al.*, 2013.

"A flood index (*FI*) is used to quantify both the extent and duration of the flood each year, (*y*):
Where (*FAy,d*) is the flooded area of the TS-GL System in year (*y*) on day (*d*), measured above the mean flooded area for the model period 1 January 1997 to 31 March 2009. $FIy = \Sigma d \ (FAy,d)$"

"The model predicts that fish biomass, indicated by the mean daily catch rate of a *dai* unit during the fishing season (October–March), increases exponentially with the (*FI*)… as follows:

$CPUE = 83.88.e^{1.6063E\text{–}06*FI}$"

"The relationship between mean sampled fish weight (all species combined) and the flood index with fitted exponential model. *Weight* = 0.0054*e*1.231*E*–06*FI*. R2 = 0.59."

The Flood Index is an approximation of the total Flow (TF) of water in the Tonle Sap Lake, see Figure 3.5-8. The correlation between the Flood Index (FI) and the Total Flow (TF) is 0.90 (see Table 3.5-2).

Relating the catch weight per haul to FI and TF gives high correlation coefficients. For the period 2004-2014 the coefficients are 0.78 and 0.81, indicating that the TF is a slightly better parameter than FI explaining the variations in Dai catch (see Figure 3.5-8).

The calculated decrease in Table 3.5-2 in mean samples fish weight and CPUE can be explained by the change in total Total Flow in The Tonle Sap Lake, not by change in inflow from the Mekong River, which was almost constant around 40.2 km^3/Y with a standard deviation of 7.5 km^3/Y. The large variations if Total Flow (TF) comes from the Tonle Sap Lake catchment itself (see Figure 8). The expected change in inflow because of change in water level in the dry and wet seasons (See Figure 3.5-1-3) has so far not changed the Mekong inflow volume.

Conclusions

The Dai catch fisheries from October to March are based on the out migration from the Tonle Sap Lake. During the down-going stage the major trigger is the lunar phases.

During Q2 and Q3 migration peaks and during the down going stage this happens 5 times (over 5 months). The sediment concentrations peak during the up-going stage and is not considered a trigger.

The catch is strongly correlated to the Total Flow of water passing through the Tonle Sap Lake.

References:

Loeung, D. The Bagnet (Dai) Fishery in the Tonle Sap River. Senior Researcher of the Project for Management of the Freshwater Capture Fisheries of Cambodia.

Halls, A.S.; Paxton, B.R.; Hall, N.; Peng Bun, N.; Lieng, S.; Pengby, N.; and So, N. (2013) The Stationary Trawl (*Dai*) Fishery of the Tonle Sap-Great Lake, Cambodia. MRC Technical Paper, No. 32. Mekong River Commission, Phnom Penh, Cambodia, 142pp. ISSN: 1683-1489.

NHI, 2016. Internal report. HM_Assessment.pdf

Annex 3.6:
Lee trap fisheries 1994-2013

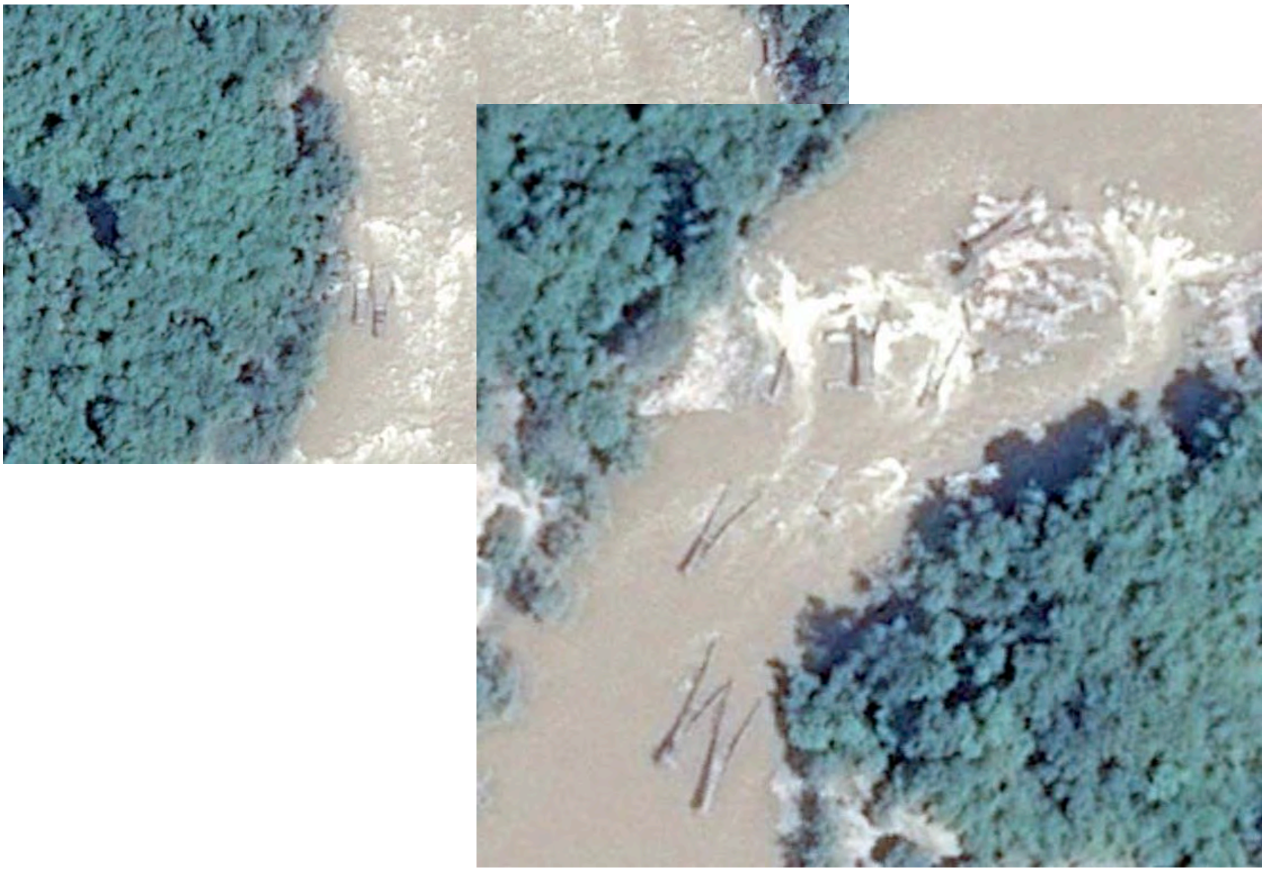

Figure 3.6-1. Lee traps fisheries on the Khone Falls.

Definitions

Trend: Is an underlying pattern of behaviour in a time series, which could be partly or nearly completely hidden by the recognized amounts of unexplained variation in the time series (noise).

Variability: Denotes how stretched or squeezed a distribution is. Variability is typically measured by the quotients of mean and standard deviation.

Change: Is the transition from one state to another *significantly different* state, ex change in variability or trend. A 5% significance level is used (p <0.05).

Lee Trap Fisheries

The monitoring of the Lee trap fisheries began in 1994 in the Hoo Som Yai channel below the Khone falls (see Figures 3.6-1 and 3.6-2).

Monitoring was conducted over a five-week period between May 24 and June 30 with samples collected three times each week until 2008, where the monitoring period was extended by three months until the end of September, as the traps are then either submerged or destroyed by rising flood waters (MRC, 2013).

The MRCS database contains Lee trap fisheries data from 1994 to 2013.

Figure 3.6-2. Lee trap fisheries sampling locations and locations of above images (Arrows).

This analysis does not calculate total catch or catch pr. unit effort (CPUE) but looks at the timing, trends and variability in the samples and links these to fish migration patterns and triggers. Since 2008 where sampling was extended and only data from this period is used.

The migration pattern is described by temporal and locational trends correlated with migration triggers.

Triggers

For the Lee trap fisheries, the following migration triggers are considered:

- Discharge
- Water
- level and
- Current changes

Migration Pattern

The migration pattern has been described before, see ex. MRC, 2013.

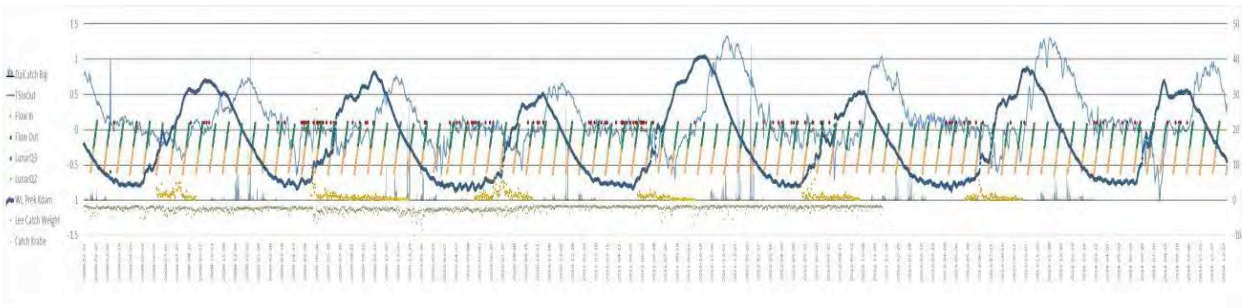

Figure 3.6-3. The combination of Lee trap catch from 2008 to 2013 with flow into and out of the Tonle Sap Lake, the Lunar cycles and water level at Prek Kdam hydro meteorological station. The zero (0) line divides the Tonle Sap inflow and outflow; negative values denotes inflow, positive values outflow. Red and yellow dots show when flow changes from in to out (red) and from out to in (yellow). Yellow dots mark the Lee trap fisheries per weight. Zoom for high resolution image.

The Lee trap fishery takes place during the up going stage of the Mekong River. In years 2009, 2010 and 2012, 2013 it is clear that the major catches take place at the first up going stage, after which it continues during the wet season at an almost constant level. In 2009, the registration continued until end of December and showed a gradual decline in catch weight, see Figure 3.6-2 – yellow dots, example arrow in 2012. The general catch further south at Kratie goes on all year (green dots under the x-axis).

As catch is almost constant after the initial peak, no visible connection to the Lunar phases is seen. The trigger is the up going stage / increased discharge and velocity.

The upstream migration LMS (Lower Mekong System) species in preparation for spawning, probably in the MMS (Middle Mekong System).

Conclusion

The Lee trap fishery starts with the up going stage of the Mekong River where a peak in catch occurs. Thereafter an almost constant but slightly falling catch level (measured by weight) was recorded. With an extended period in 2009 until December this trend continued during the whole period.

No relation to Lunar cycles were recorded. The trigger for the upstream migration is the increase in discharge / velocity.

References:

MRC, 2013. Integrated Analysis of Data from MRC Fisheries Monitoring Programmes in the Lower Mekong Basin. MRC Technical Paper, No. 33. August 2013.

Annex 5.1:

Fish Collection Sites and Species List of the Xe Kong Basin

Fish collection sites in the Xe Kong Basin.

NHI site number	Latitude	Longitude	Elevation (m)	Stream Size	Source	Project Site Number
1	14.5956	106.5564	80	large	Kotellat 2011	09-056
2	14.6086	106.5522	80	large	Kotellat 2011	09-057
3	14.6128	106.5536	80	large	Kotellat 2011	09-055, 09-059, 09-060
4	14.6200	106.5550	80	large	Kotellat 2011	09-058
5	14.6206	106.5528	80	large	MRCS	113
6	14.6350	106.5839	80	large	MRCS	112
7	14.6758	106.5858	82	large	MRCS	114
8	14.6794	106.4842	90	small	Kotellat 2011	09-052, 09-053
9	14.6925	106.4781	86	small	Kotellat 2011	09-051, 09-051A, 09-054
10	14.7253	106.4950	90	medium	Kotellat 2011	09-050
11	14.9000	107.1500	134	medium	MRCS	589
12	14.9072	106.8483	95	large	MRCS	117
13	14.9356	107.0519	160	small	Kotellat 2011	09-061, 09-061A
14	14.9386	106.8869	100	large	MRCS	116
15	14.9497	106.8839	110	small	MRCS	115
16	15.2450	106.7519	120	medium	Kotellat 2011	09-062
17	15.2586	106.7733	130	small	MRCS	120
18	15.2706	106.7436	119	large	MRCS	119
19	15.2908	106.9461	240	small	Kotellat 2011	09-066
20	15.2989	106.9031	206	small	Kotellat 2011	09-067
21	15.3089	106.7119	117	large	MRCS	118
22	15.3164	106.6408	153	small	Kotellat 2011	09-071, 09-072
23	15.4811	106.7247	143	large	Kotellat 2011	09-065
24	15.5047	106.7672	146	large	Kotellat 2011	09-064
25	15.5125	106.8008	162	small	Kotellat 2011	09-063
26	15.7150	106.8025	190	large	Kotellat 2011	09-068, 09-069
27	15.7344	106.7494	194	large	Kotellat 2011	09-070
28	15.9853	106.9423	320	large	Xe Kong 5 EIA 2008	Xe Kong 5 EIA 2008
29	14.7825	107.1558	158	small	Kotellat 2009	11-033
30	14.7925	107.4350	370	small	Kotellat 2009	11-032
31	14.9814	107.0611	201	small	Kotellat 2009	11-030
32	15.0064	107.0855	227	medium	Kotellat 2009	11-029
33	15.0578	106.6028	731	medium	Kotellat 2009	11-041
34	15.2300	107.1968	858	small	Kotellat 2009	11-031
35	15.3609	107.2030	1118	medium	Kotellat 2009	11-040
36	15.4553	107.2704	1197	small	Kotellat 2009	11-038
37	15.4848	107.1852	1225	small	Kotellat 2009	11-036
38	15.5121	107.3215	1112	small	Kotellat 2009	11-034
39	15.5177	107.2242	1188	small	Kotellat 2009	11-035
40	15.5209	107.3328	977	medium	Kotellat 2009	11-039
41	15.5735	107.2174	1166	medium	Kotellat 2009	11-037

Combined species list of MRCS, Kottelat 2009 & 2011, and the Xe Kong 5 EIA

Acanthocobitis sp. n. 'Xe Kong'
Acanthopsoides delphax
Acanthopsoides gracilentus
Acanthopsoides hapalias
Acantopsis sp.
Akysis ephippifer
Akysis inermis
Akysis varius
Albulichthys albuloides
Amblyceps serratum
Amblyrhynchichthys truncatus
Anabas testudineus
Anguilla marmorata
Annamia normani
Annamia sp. n. 'Bolaven'
Auriglobus nefastus
Bagarius bagarius
Bagarius suchus
Bagarius yarrelli
Bagrichthys macracanthus
Bagrichthys obscurus
Balitora annamitica
Bangana behri
Barbonymus altus
Barbonymus gonionotus
Belodontichthys truncatus
Botia helodes
Botia modesta
Brachirus harmandi
Catlocarpio siamensis
Channa gachua
Channa micropeltes
Channa striata
Chitala blanci
Chitala ornata
Cirrhinus jullieni
Cirrhinus microlepis
Cirrhinus molitorella
Cirrhinus spilopleura
Clarias batrachus
Clarias gariepinus
Clarias macrocephalus
Clupeichthys aesarnensis
Clupisoma sinensis
Cosmochilus harmandi
Crossocheilus atrilimes
Crossocheilus oblongus
Crossocheilus reticulatus
Cyclocheilichthys enoplos
Cyclocheilichthys repasson
Cyclocheilicthys enoplos
Cyclocheilicthys sp
Cynoglossus microlepis
Cyprinus carpio
Dasyatis laosensis
Datnioides undecimradiatus
Devario gibber
Doryichthys contiguus
Esomus metallicus
Garra cambodgiensis
Garra cyrano
Garra fasciacauda
Glyptothorax filicatus
Glyptothorax lampris
Glyptothorax laosensis
Glyptothorax zanaensis
Gyrincheilus aymonieri
Gyrinocheilus aymonieri
Gyrinocheilus pennocki
Hampala dispar
Hampala macrolepidota
Helicophagus waandersii
Hemibagrus nemurus
Hemibagrus spilopterus
Hemibagrus wyckioides
Hemimyzon khonensis
Hemimyzon sp
Hemisilurus mekongensis
Henicorhynchus cryptopogon
Henicorhynchus lineatus
Henicorhynchus lobatus
Henicorhynchus siamensis
Heterobagrus bocourti
Homaloptera confuzona
Homaloptera smithi
Homaloptera tweediei

Homaloptera yunnanensis
Hyporhamphus limbatus
Hypsibarbus lagleri
Hypsibarbus pierrei
Hypsibarbus sp.
Kryptopterus bicirrhis
Kryptopterus cryptopterus
Labeo chrysophekadion
Labeo dyocheilus
Labeo pierrei
Labeo pierri
Labiobarbus leptocheila
Labiobarbus siamensis
Laides longibarbis
Laocypris sp. n. 'Xe Kong'
Lates calcarifer
Lepidocephalichthys hasselti
Leptobarbus hoevenii
Lobocheilos melanotaenia
Lobocheilos rhabdoura
Lobocheilos sp
Luciosoma bleekeri
Luciosoma spp
Lycothrissa crocodilus
Macrochirichthys macrochirus
Macrochirichtys macrochirus
Macrognathus semiocellatus
Macrognathus siamensis
Macrognathus teaniagaser
Mastacembelus armatus
Mastacembelus favus
Mekongina erythrospila
Micronema apogon
Micronema bleekeri
Micronema cheveyi
Micronema micronemus
Monopterus albus
Monotrete cambodgiensis
Monotrete cochinchinensis
Monotrete suvattii
Monotrete turgidus
Mystacoleucus atridorsalis
Mystacoleucus marginatus
Mystus atrifasciatus
Mystus singaringan
Nemacheilus longistriatus
Nemacheilus pallidus
Nemacheilus platiceps
Neolissochilus blanci
Notopterus notopterus
Ompok bimaculatus
Onychostoma meridionale
Opsarius koratensis
Opsarius pulchellus
Osphronemus exodon
Osteochilus hasselti
Osteochilus hasseltii
Osteochilus lini
Osteochilus melanopleura
Osteochilus microcephalus
Osteochilus schlegeli
Osteochilus waandersii
Oxyeleotris marmorata
Pangasianodon hypophthalmus
Pangasius bocourti
Pangasius conchophilus
Pangasius krempfi
Pangasius kunyit
Pangasius larnaudii
Pangasius polyuranodon
Pangasius sanitwongsei
Pangasius siamensis
Pangasius sp. (juv.)
Pangio anguillaris
Pangio fusca
Papuligobius ocellatus
Parachela maculicauda
Paralaubuca barroni
Paralaubuca riveroi
Paralaubuca typus
Parambassis cf. siamensis
Parambassis siamensis
Plotosus canius
Poropuntius bolovenensis
Poropuntius carinatus
Poropuntius laoensis
Poropuntius lobocheiloides
Poropuntius normani
Pristolepis fasciata
Probarbus jullieni
Probarbus labeamajor
Pseudolais pleurotaenia

Pseudomystus siamensis
Pteropangasius micronemus
Pteropangasius pleurotaenia
Puntioplites falcifer
Puntioplites proctozysron
Puntis brevis
Puntius arotaeniatus
Puntius aurotaeniatus
Puntius brevis
Puntius rhombeus
Raiamas guttatus
Rasbora amplistriga
Rasbora atridorsalis
Rasbora borapetensis
Rasbora daniconius
Rasbora myersi
Rasbora paviana
Rasbora rubrodorsalis
Rasbora trilineata
Rhinogobius taenigena
Scaphiodonichthys acanthopterus
Scaphiodonichthys sp. n. 'Dakchung'
Scaphognathops bandanensis
Scaphognathops stejnegeri
Scatophagus argus
Schapioodonichthys acanthopterus
Schistura bolavenensis
Schistura clatrata
Schistura dorsizona
Schistura fusinotata
Schistura imitator
Schistura khamtanhi
Schistura nomi
Schistura sp.
Schistura sp. n. 'Bolaven'
Schistura sp. n. 'Dakchung'
Schistura tizardi
Serpenticobitis octozona
Sewellia diardi
Sewellia elongata
Sewellia sp
Sewellia sp. n. 'Dakchung'
Sewellia speciosa
Sikukia gudgeri
Sundasalanx mekongensis
Syncrossus beauforti
Systomus sp
Tenualosa thibaudeaui
Thynnichthys thynnoides
Tor laterivittatus
Tor sinensis
Tor tambra
Tor tambroides
Trichogaster trichopterus
Trichopsis schalleri
Trichopsis vittata
Wallago attu
Wallago leerii
Xenentodon canciloides
Yasuhikotakia nigrolineata

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MRCS Fish Catch Database.

Annex 5.2:

Roster of Contributors to the Findings and Conclusions from the Xe Kong Fishery Experts Workshop, Sept. 26 & 27, 2016

Annex 5.2: Roster of Contributors to Findings and Conclusions

The Findings and Conclusions from the workshop of Xe Kong fisheries experts reflects the inputs from participants in the workshop, providers of materials used in the workshop, individual consultations, and reviewers providing comments.

Lao Experts—listed alphabetically by given name

Expert	Affiliation	Nature of Contribution
Akhane Phomsouvanh	Deputy Director, Department of Livestock and Fisheries	Commenter
Bounthong Saphakdy	Director General, Department of Livestock and Fisheries	Commenter
Bouttavong Somvang	Director General, Ministry of Natural Resources and Environment	Participant in workshop
Douangkham Singhannouvong	Director General, Lao Aquatic Resources Research Center	Commenter
Kaviphone Phouthavong	Lao Aquatic Resources Research Center	Commenter
Oudom Phonekhampeng	Vice President, National University of Lao	Co-Host and participant in workshop
Phouvin Phouvasanh	Professor, National University of Lao	Participant in workshop
Sanhya Somvichith	Ministry of Energy and Mines	Participant in workshop
Seumee Soulita	Vice Director, Sekong Provincial Office of Agriculture and Forestry	Participant in workshop and commenter
Somphan Phanousit	Lao Aquatic Resources Research Center	Participant in workshop
Souvanny Phommakone	Department of Livestock and Fisheries	Commenter
Vienxay Sophachanh	Lao National Mekong Committee	Participant in workshop
Vilayphone Volaphine	Director, Attapeu Provincial Office of Agriculture and Forestry	Participant in workshop and commenter
Vithounlabandith Phathoummabud	Ministry of Energy and Mines	Workshop participant
Vonsine Vonginkham	Ministry of Natural Resources and Environment	Participant in workshop

Foreign Experts—listed alphabetically by surname

Expert	Affiliation	Nature of Contribution
Ian Baird	Professor, University of Wisconsin	Participant in workshop and commenter
Eric Baran	World Fish Center	Provided materials for workshop
Kent Carpenter	Professor, Old Dominion University	Commenter
Phen Chheng	Director General, Inland Freshwater Research and Development Institute of Cambodia	Participant in workshop and commenter
Ian Cowx	Professor, University of Hull	Provided materials for workshop
Ashley Halls	Consultant	Participant in workshop
Kent Hortle	Consultant	Participant in workshop
Erland Jensen	Consultant, NHI Team	Participant in workshop
Maurice Kottelat	Consultant	Individual Consultation
Martin Mallen-Cooper	Consultant, NHI Team	Participant in workshop
Peter-John Meynell	Consultant	Individual Consultation
So Nam	Mekong River Commission Secretariat	Participant in workshop
Voradeth Phonekeo	Mekong River Commission Secretariat	Participant in workshop
Gregory Thomas	NHI Team	Co-Host and Participant in workshop
Binh Dang Thuy	Professor	Participant in workshop
Terry Warren	NHI Team	Participant in workshop

Annex 5.3:

Executive Summary of the Findings and Conclusions from the Xe Kong Fishery Experts Workshop, Sept. 26 & 27, 2016 Lao Translation

ຜົນຂອງການສົນທະນາ ແລະ ສະຫຼຸບຂໍ້ຄິດເຫັນ

ຈາກ

ການສໍາມະນາບັນດາຜູ້ຊ່ຽວຊານດ້ານການປະມົງໃນແມ່ນໍ້າເຊກອງ

ນະຄອນຫຼວງວຽງຈັນ, ສປປ ລາວ

26 - 27 ກັນຍາ 2016

ໃນລະຫວ່າງວັນທີ 26 – 27 ເດືອນກັນຍາ ປີ 2016, ມະຫາວິທະຍາໄລແຫ່ງຊາດ ແລະ ອົງການ NHI (THE NATURAL HERITAGE INSTITUTE) ເຊິ່ງເປັນອົງການສາກົນທີ່ບໍ່ຂື້ນກັບລັດຖະບານ ໄດ້ຮ່ວມກັນຈັດກອງປະຊຸມສໍາມະນາບັນດາຜູ້ຊ່ຽວຊານດ້ານວິຊາການປະມົງ ໃນແມ່ນໍ້າເຊກອງ ເຊິ່ງໄດ້ມີຜູ້ຊ່ຽວຊານທາງດ້ານການປະມົງທັງໃນ ສປປ ລາວ ແລະ ສາກົນເຂົ້າຮ່ວມແລກປ່ຽນຄວາມຮູ້, ຜົນງານຈາກການຄົ້ນຄວ້າ ແລະ ທັງໄດ້ສະແດງຄວາມເຫັນຂອງຕົນຕໍ່ຈຸດປະສົງໃນການກະກຽມຮ່າງທີ່ສອດຄ່ອງທາງດ້ານວິທະຍາສາດໃນການສ້າງ “ແຜນງານດ້ານຄວາມຍືນຍົງໃນການພັດທະນາເຂື່ອນໄຟຟ້າ: SUSTAINABLE HYDROPOWER MASTER PLAN” ສໍາລັບອ່າງແມ່ນໍ້າເຊກອງ. ໃນການສໍາມະນາຄັ້ງນີ້ປະກອບມີແຂກທີ່ຖືກເຊີນເຂົ້າຮ່ວມ 22 ທ່ານ ແລະ ມີຜູ້ສັງເກດການເຂົ້າຮ່ວມອີກຈໍານວນເກືອບເທົ່າກັນກັບແຂກທີ່ຖືກເຊີນ ລວມໄປເຖິງນັກວິຊາການ ແລະ ພະນັກງານດ້ານນະໂຍບາຍຈາກບັນດາກະຊວງ ແລະ ອົງການຕ່າງໆໃນຂັ້ນສູນກາງ ແລະ ທ້ອງຖິ່ນ ທີ່ກ່ຽວຂ້ອງກັບວຽກງານການພັດທະນາເຂື່ອນໄຟຟ້າ ແລະ ວຽກງານດ້ານການຄຸ້ມຄອງການປະມົງ. ນອກຈາກນີ້ກໍຍັງມີພະນັກງານຈາກສໍານັກງານເລຂາທິການອົງການແມ່ນໍ້າຂອງ (MRCS) ແລະ ສະຖາບັນການຄົ້ນຄວ້າການປະມົງໃນແຫຼ່ງນໍ້າ ແລະ ການພັດທະນາ (IFREDI) ຈາກລາດສະອານາຈັກກໍາປູເຈຍ.

ບົດສະຫຼຸບຫຍໍ້

ຄຸນຄ່າພິເສດຂອງການປະມົງໃນແມ່ນໍ້າເຊກອງ

ແມ່ນໍ້າເຊກອງ ແລະ ແມ່ນໍ້າຂອງຕອນລຸ່ມຈາກບ່ອນທີ່ແມ່ນໍ້າທັງສອງພົບກັນນັ້ນໄດ້ປະກອບກັນເປັນສ່ວນທີ່ມີຄວາມອຸ ດົມສົມບູນທີ່ສຸດທາງດ້ານຜົນຜະລິດຂອງອ່າງແມ່ນໍ້າຂອງ. ຍ້ອນວ່າ ແມ່ນໍ້າເຊກອງ ແມ່ນສາຂາຫຼັກຂອງແມ່ນໍ້າຂອງທີ່ມີໃນຕອນລຸ່ມທັດຈາກນໍ້າຕົກຕາດຄອນພະເພັງລົງມາ ເຊິ່ງມັນຍັງເປັນບ່ອນທີ່ມີເງື່ອນໄຂໃນການເຄື່ອນຍ້າຍຂອງປາແບບອິດສະລະຢູ່ ນັບຈາກຕົ້ນນໍ້າຫາທະເລບ່ອນທີ່ແມ່ນໍ້າຂອງໄຫຼປ່ອງລົງໃສ່, ນີ້ແມ່ນເສັ້ນທາງທີ່ສັງລວມຄວາມມີຄຸນຄ່າ ແລະ ບໍ່ມີອົງປະກອບໃດທີ່ສາມາດທົດແທນໄດ້ສໍາລັບປະຊາກອນປາທີ່ມີການເຄື່ອນຍ້າຍໃນແມ່ນໍ້າຂອງ. ອ່າງແມ່ນໍ້າເຊກອງ ແມ່ນນັບໄດ້ວ່າເປັນສູນລວມຂອງຊະນິດປາຫຼາຍກວ່າ 213 ຊະນິດ. ມີຈໍານວນ 64 ຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍໄປມາ ແລະ 61

ຊະນິດປານີ້ເປັນຊະນິດປາທີ່ມີສະເພາະໃນທ້ອງຖິ່ນ (ພົບເຫັນສະເພາະໃນອ່າງແມ່ນ້ຳເຊກອງ) [14] [2], [3]. ຈຳນວນ 21 ຊະນິດປາແມ່ນໄດ້ຈັດຢູ່ໃນບັນຊີປະເພດປາທີ່ຖືກໄພຄຸກຄາມ ທີ່ກຳນົດໂດຍອີງການ IUCN. [1]. ອີກຫຼາຍກວ່າ 60 ຊະນິດປານັ້ນ ແມ່ນເປັນປາທີ່ມີທີ່ຢູ່ອາໃສສະເພາະໃນເຂດຕອນເທິງຂອງອ່າງແມ່ນ້ຳເຊກອງ. [1]; ຕອນລຸ່ມຂອງອ່າງແມ່ນ້ຳເຊກອງແມ່ນຕອບສະໜອງທາງດ້ານມວນສານຂອງປາທີ່ສູງສຸດ ແລະ ມີຄວາມອຸດົມຮັ່ງມີທາງດ້ານຊະນິດຫຼາຍກວ່າ.

ປາທີ່ມີການເຄື່ອນຍ້າຍໃນໄລຍະທາງໄກ ທີ່ໄດ້ເຂົ້າມາໃນແມ່ນ້ຳເຊກອງ ແມ່ນຈາກເຂດປາກແມ່ນ້ຳໃນປະເທດຫວຽດນາມ, ທະເລຕົງເລຊາບ ແລະ ພື້ນທີ່ໃກ້ຄຽງໃນບໍລິເວນນັ້ນ ແລະ ເຄື່ອນຍ້າຍມາຈາກແມ່ນ້ຳຂອງເຂດພາກໃຕ້ຂອງ ສປປ ລາວ ແລະ ທິດຕາເວັນອອກສ່ຽງເໜືອຂອງປະເທດກຳປູເຈຍ. ມີປາຫຼາຍຊະນິດທີ່ມີການເຄື່ອນຍ້າຍ ມີຄວາມຕ້ອງການແຫຼ່ງທີ່ຢູ່ອາໃສສະເພາະ ເຊັ່ນ ການໄຫຼຂອງນ້ຳ, ກ້ອນຫີນ, ພືດພັນຕ່າງໆ ແລະ ສິ່ງອື່ນໆ ເພື່ອໃຫ້ສາມາດມີການຂະຫຍາຍພັນສຳເລັດ. ເຂື່ອນຈະເປັນສິ່ງທີ່ເປັນຂໍ້ຈຳກັດຕໍ່ການຜ່ານເຂົ້າໄປຂະຫຍາຍພັນ ແລະ ແຫຼ່ງອາໃສຂອງອາຫານ ແລະການກັກຂັງນ້ຳກໍເປັນສິ່ງໜຶ່ງທີ່ເຮັດໃຫ້ແຫຼ່ງທີ່ຢູ່ອາໃສຈຳນວນໜຶ່ງຈົມລົງໃຕ້ພື້ນນ້ຳ.

ລະບົບນິເວດຂອງແມ່ນ້ຳເຊກອງທີ່ຢູ່ທາງດ້ານປະເທດກຳປູເຈຍ ແມ່ນມີລັກສະນະທີ່ເດັ່ນໄປດ້ວຍປ່າໄມ້ເຂດທົ່ງພຽງທີ່ເປັນປ່າມີນ້ຳຖ້ວມໃນເຂດບໍລິເວນແມ່ນ້ຳສາຍຫຼັກ ແລະ ບັນດາສາຂາຂະໜາດນ້ອຍຕ່າງໆ ໃນຂະນະທີ່ພາກສ່ວນທີ່ຢູ່ໃນ ສປປ ລາວ ທີ່ຢູ່ເໜືອແຂວງອັດຕະປືຂຶ້ນໄປ ແມ່ນມີລັກສະນະເດັ່ນທາງດ້ານຄວາມຄ້ອຍຊັນຂອງສາຍນ້ຳທີ່ຢຶດອອກໄປທີ່ມີພື້ນເປັນລັກສະນະຫີນດານ. ສິ່ງເຫຼົ່ານີ້ມັນໄດ້ກາຍເປັນເຂດທີ່ມີກະແສນ້ຳທີ່ໄຫຼໄວ ແລະ ເຂດວັງເລິກທີ່ເປັນບ່ອນທີ່ມີນ້ຳໄຫຼຄ່ອຍເປັນຈຳນວນຫຼວງຫຼາຍ, ສິ່ງເຫຼົ່ານັ້ນ ມັນໄດ້ຖືກອ້ອມຮອບດ້ວຍຫີນດານທີ່ມີຄວາມຄ້ອຍຊັນໃນເຂດແຄມຝັ່ງ. ເຂດທີ່ມີແຄມຝັ່ງເປັນພື້ນທີ່ດິນຊາຍ ແມ່ນຮັກສາບັນດາສາຂາແມ່ນ້ຳຂະໜາດນ້ອຍທີ່ໄຫຼປ່ອງລົງໃສ່ແມ່ນ້ຳໃຫຍ່ເຊັ່ນແມ່ນ້ຳເຊກອງ. ສິ່ງເຫຼົ່ານີ້ແມ່ນການປະສົມປະສານກັນທາງດ້ານລະບົບນິເວດທີ່ເອື້ອອຳນວຍໃຫ້ແກ່ຄວາມຫຼາກຫຼາຍທາງດ້ານຊະນິດພັນປາທີ່ມີເອກກະລັກໂດດເດັ່ນ ບໍ່ວ່າຈະເປັນທາງດ້ານການເຄື່ອນຍ້າຍຂອງປາ ແລະ ເປັນແຫຼ່ງທີ່ຢູ່ອາໃສສະເພາະຂອງປາຫຼາຍຊະນິດ. ມີປາຫຼາຍໆຊະນິດທີ່ເປັນຊະນິດປາທີ່ມີສະເພາະໃນແມ່ນ້ຳເຊກອງ ເນື່ອງຈາກຄວາມເໝາະສົມທາງດ້ານແຫຼ່ງທີ່ຢູ່ອາໃສທີ່ເປັນເອກະລັກ. ຊະນິດປາທີ່ມີການຂະຫຍາຍພັນໃນເຂດທົ່ງພຽງນ້ຳຖ້ວມ ທີ່ຢູ່ໄກ້ກັບບໍລິເວນໜ້ານ້ຳທີ່ມີການໄຫຼແບບອິດສະລະ, ໄຂ່ ແລະ ລູກປາໄວອ່ອນຈະຖືກພັດໃຫ້ແຂວນລອຍໄປນຳນ້ຳລົງສູ່ຕອນລຸ່ມ ກັບຈຸດສູງສຸດຂອງກະແສນ້ຳທີ່ໄຫຼລົງສູ່ເຂດພື້ນທີ່ທົ່ງພຽງນ້ຳຖ້ວມທີ່ເປັນບ່ອນອະນຸບານຂອງລູກປາເຫຼົ່ານັ້ນ. ລະບົບນິເວດໃນແມ່ນ້ຳເຊກອງທີ່ຢູ່ຕອນເທິງເໜືອແຂວງອັດຕະປືສາມາດເປັນບ່ອນທີ່ມີລັກສະນະສະເພາະທີ່ໂດດເດັ່ນ ແລະ ບໍ່ສາມາດທົດແທນໄດ້ໃນແມ່ນ້ຳສາຂາອື່ນໆ.

<u>ຜົນກະທົບຂອງເຂື່ອນໄຟຟ້າໃນແມ່ນ້ຳສາຍຫຼັກຕໍ່ກັບການປະມົງໃນແມ່ນ້ຳເຊກອງ:</u>

ການກັກເກັບນ້ຳຕາມລະດູການຢູ່ຕອນເທິງຂອງແມ່ນ້ຳໃນອ່າງເກັບນ້ຳຂອງເຂື່ອນໄຟຟ້າໃນອ່າງແມ່ນ້ຳເຊກອງອາດຈະສົ່ງຜົນຄື:

1. ເປັນແຫຼ່ງທຳມາຫາກິນທີ່ໝັ້ນຄົງຂອງທັງປາທີ່ມີການເຄື່ອນຍ້າຍ ແລະ ປາທີ່ບໍ່ມີການເຄື່ອນຍ້າຍ;
2. ຈຸດຕ່ຳສຸດຂອງການປ່ຽນແປງການໄຫຼຂອງນ້ຳໃນລະດູຝົນ;

3. ການເພີ່ມສູງຂຶ້ນຂອງລະດັບນໍ້າໃນລະດູແລ້ງ;
4. ການເກີດນໍ້າຖ້ວມໃນເຂດທົ່ງຮາບພຽງຕອນລຸ່ມຂອງແມ່ນໍ້າຈະເກີດຂຶ້ນຊ້າຊ້າກວ່າໃນຊ່ວງລະດູຝົນ;
5. ເປັນສາຍເຫດໃຫ້ມີຜົນສະທ້ອນຕໍ່ການປ່ຽນແປງຂຶ້ນລົງຂອງນໍ້າທີ່ໄຫຼໃນແຕ່ລະວັນ ແລະ ການເຊາະເຈື່ອນໃນແຫຼ່ງທີ່ຢູ່ອາໃສ;
6. ເຮັດໃຫ້ຕະກອນທີ່ແຂວນລອຍນຳນໍ້າລົງສູ່ຕອນລຸ່ມລຸດນ້ອຍລົງ ແລະ ທ້ອນໂຮມທາດອາຫານຕ່າງໆໄວ້ໃນອ່າງເກັບນໍ້າ.

ໂດຍອີງຕາມຄວາມຮ້າຍແຮງຂອງສິ່ງເຫຼົ່ານັ້ນ, ການປ່ຽນແປງທາງດ້ານອຸທົກກະສາດ ແລະ ພູມສັນຖານວິທະຍາອາດສົ່ງຜົນສະທ້ອນທີ່ເສຍຫາຍໃຫ້ແກ່ການເຄື່ອນຍ້າຍ, ການຂະຫຍາຍພັນ ແລະ ການຢູ່ລອດຂອງປາໃນເຂດພື້ນທີ່ທົ່ງຮາບພຽງນໍ້າຖ້ວມ ແລະ ຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍຕາມສາຍແມ່ນໍ້າ, ໂດຍສະເພາະແມ່ນລະບົບທີ່ເກີດຂຶ້ນໃນພາກສ່ວນປະເທດກຳປູເຈຍ [8].

ຜົນເກັບກູ້ປາ ແລະ ຄວາມຫຼາກຫຼາຍໃນແມ່ນໍ້າເຊກອງ ອາດມີລັກສະນະລຸດລົງອັນເນື່ອງມາຈາກສາຍເຫດ:

i) ການລຸດລົງຂອງປາທີ່ຜ່ານຂຶ້ນໄປໃນຕອນເທິງຂອງແມ່ນໍ້າ;
ii) ອັດຕາການລອດຕາຍທີ່ລຸດລົງຂອງປາທີ່ໃຫຍ່ເຕັມໄວ, ປານ້ອຍທີ່ຜ່ານເຄື່ອງຈັກປັ່ນໄຟຟ້າ ແລະ ທາງລະບາຍນໍ້າ;
iii) ການປ່ຽນແປງສະພາບຂອງແຫຼ່ງທີ່ຢູ່ອາໃສຈາກປະເພດນໍ້າໄຫຼມາເປັນນໍ້ານິ້ງ;
iv) ການດັດແປງຂອງການໄຫຼຂອງນໍ້າໃນຕອນລຸ່ມ ແລະ ການປ່ຽນແປງທາງດ້ານຄຸນນະພາບນໍ້າທີ່ເກີດຂຶ້ນຕາມມາ

ຄວາມເປັນໄປໄດ້ທີ່ປາມີການເຄື່ອນຍ້າຍຈະລອດຕາຍຜ່ານຂຶ້ນມາຕອນເທິງຂອງແມ່ນໍ້າ ແລະ ຜ່ານລົງຕອນລຸ່ມຂອງແມ່ນໍ້າ (ລວມໄປເຖິງຈຳພວກລູກປາທີ່ແຂວນລອຍຕາມກະແສນໍ້າ) ອັນເນື່ອງມາຈາກບັນດາປັດໃຈດັ່ງທີ່ກ່າວມາຂ້າງເທິງນັ້ນອາດຈະເປັນການປະຕິເສດທີ່ຈະສະໜັບສະໜູນຈຳນວນເຂື່ອນໄຟຟ້າທີ່ເພີ່ມຂຶ້ນໃນແມ່ນໍ້າເຊກອງ. ເຖິງແມ່ນວ່າ ເຂື່ອນທັງ 7 ແຫ່ງທີ່ມີແຜນຈະສ້າງໃນແມ່ນໍ້າເຊກອງ ສາມາດຜ່ານເກນມາດຕະຖານຂອງອົງການ MRC ສາມາດສ້າງທາງປາຜ່ານທີ່ມີປະສິດທິພາບເຖິງ 95% ຂອງຊະນິດປາສາມາດຜ່ານໄດ້ໃນເງື່ອນໄຂການໄຫຼຂອງນໍ້າ [11], ອັນໃດທີ່ຈະສາມາດເປັນຕົວແທນທີ່ດີໃນທາງປະຕິບັດ, ຜົນກະທົບທີ່ທະວີຄູນອາດຈະຍັງເປັນບັນຫາຕົ້ນຕໍທີ່ສົ່ງຜົນໃຫ້ມີການລຸດລົງທັງໃນດ້ານມວນສານ ແລະ ຄວາມຫຼາຍຫຼາຍທາງດ້ານຊະນິດພັນ.

<u>**ຂໍ້ຈຳກັດທາງດ້ານທ່າແຮງໃນການລຸດຜ່ອນຜົນກະທົບທີ່ອາດເກີດຈາກເຂື່ອນໄຟຟ້າ ຕໍ່ດ້ານການປະມົງໃນແມ່ນໍ້າເຊກອງ**</u>

ສິ່ງກີດຂວາງຂອງທາງປາຜ່ານ ແມ່ນອາດສາມາດລຸດຜ່ອນຜົນກະທົບໄດ້ ໂດຍການສ້າງທາງປາຜ່ານທຽບຂຶ້ນມາ ແຕ່ວ່າ ຜ່ານມາກໍຍັງບໍ່ມີທາງປາຜ່ານທຽມທີ່ມີປະສິດທິພາບໃນການນຳໃຊ້ກັບເຂື່ອນໄຟຟ້າທີ່ມີໃນແມ່ນໍ້າຂະໜາດໃຫຍ່ໃນເຂດຮ້ອນຊຸ່ມຄືດັ່ງແມ່ນໍ້າເຊກອງ. ມັນແມ່ນອ່າງເກັບນໍ້າທີ່ມີຜົນກະທົບອັນໃຫຍ່ຫຼວງຕໍ່ກັບການເຄື່ອນຍ້າຍຂອງປາ.

ຜົນກະທົບທາງປາຜ່ານຕໍ່ອ່າງເກັບນ້ຳ ເປັນຜົນກະທົບທີ່ບໍ່ສາມາດຫຼີກລ້ຽງໄດ້ ຫຼື ບໍ່ສາມາດລຸດຜ່ອນໄດ້: ໃນດ້ານທິດສະດີແລ້ວ ມັນແມ່ນສິ່ງທີ່ສາມາດເປັນໄປທີ່ຈະເປີດນຳໃຊ້ອ່າງເກັບນ້ຳເພື່ອຮັກສາອັດຕາຄວາມໄວຂອງການໄຫຼຂອງນ້ຳທີ່ພຽງພໍສຳລັບເຄື່ອງກົນຈັກ ແລະ ການເຄື່ອນຍ້າຍຂອງລູກປາຕະຫຼອດໄລຍະທາງເຖິງຈຸດນ້ຳທີ່ໄຫຼຜ່ານປະຕູນ້ຳ ແລະ ໃບພັດ. ແຕ່ເຖິງຢ່າງໃດກໍ່ຕາມການເປີດນຳໃຊ້ນ້ຳໃນລະບົບດັ່ງກ່າວ ແມ່ນຈະສົ່ງຜົນກະທົບຕໍ່ກັບການຜະລິດກະແສໄຟຟ້າ ແລະ ລາຍຮັບຈາກກິດຈະກຳດັ່ງກ່າວ, ກໍ່ໃຫ້ເກີດບັນຫາທີ່ມີຜົນກະທົບໂດຍກົງຕໍ່ກັບການແລກປ່ຽນທາງດ້ານການບຳລຸງຮັກສາທາງການປະມົງ ແລະ ຈຸດປະສົງຂອງເຂື່ອນໄຟຟ້າ. ປາຫຼາຍຊະນິດທີ່ມີການເຄື່ອນຍ້າຍໃນແມ່ນ້ຳເຊກອງແມ່ນຕ້ອງການນ້ຳທີ່ມີການໄຫຼຫຼາຍກວ່າແຫຼ່ງທີ່ຢູ່ອາໃສຫຼາຍໆແຫ່ງເພື່ອການຂະຫຍາຍພັນ. ເພາະສະນັ້ນ, ການກຳນົດພື້ນຂອງອ່າງເກັບນ້ຳທີ່ຈະສ້າງເຂື່ອນແມ່ນມີຄວາມຈຳເປັນທີ່ຈະຕ້ອງມີການປະເມີນຜົນກະທົບ ແລະ ການຕັດສິນໃຈທີ່ຕ້ອງຄຳນຶງເຖິງດ້ານຄວາມຍືນຍົງ. ເຖິງແມ່ນວ່າໂຄງການເຫຼົ່ານັ້ນຈະມີການນຳໃຊ້ເຂື່ອນແບບນ້ຳໄຫຼຜ່ານ ຫຼາຍ ຫຼື ໜ້ອຍກໍຕາມ ແຕ່ພວກເຂົາກໍ່ຍັງມີຄວາມຈຳເປັນທີ່ຕ້ອງມີການສ້າງອ່າງເກັບນ້ຳທີ່ຈຳເປັນໃນລະດັບຫົວຂອງເຄື່ອງກົນຈັກ ແລະ ນີ້ກໍແມ່ນຜົນກະທົບທີ່ສຳຄັນອີກອັນໜຶ່ງເຊັ່ນກັນ.

ການແຜ່ພັນແບບທຽມຂອງປາ ໂດຍມີຄວາມໝາຍທາງດ້ານການເພາະລ້ຽງໃນອ່າງເກັບນ້ຳ ແມ່ນບໍ່ສາມາດທົດແທນທາງດ້ານຊະນິດປາ, ຜົນຜະລິດ ຫຼື ທາງດ້ານຊີວິດການເປັນຢູ່ທີ່ໄດ້ມີການສູນເສຍໄປ ເມື່ອການທຳການປະມົງໃນແຫຼ່ງນ້ຳທຳມະຊາດແມ່ນມີການເຊື່ອມໂຊມໄປດ້ວຍການສ້າງເຂື່ອນ. ຟາມລ້ຽງປາ ໂດຍທົ່ວໄປແລ້ວແມ່ນສິ່ງທີ່ມີລັກສະນະແຕກຕ່າງ ແລະ ໂດຍທົ່ວໄປມັນກໍເປັນຊະນິດປາທີ່ມີມູນຄ່າທີ່ຕ່ຳ, ເປັນສິ່ງທີ່ເຮັດໃຫ້ຄວາມຫຼາກຫຼາຍຂອງປາມີການລຸດລົງ, ມີຄວາມແຕກຕ່າງທາງດ້ານທຶນ, ກຳມະສິດ ແລະ ໂຄງສ້າງຂອງການຕະຫຼາດ; ແລະ ມີຄວາມຊຳນິຊຳນານທີ່ແຕກຕ່າງກັນອອກໄປຫຼາຍກວ່າການຖືເອົາການຫາປາໃນແຫຼ່ງນ້ຳທຳມະຊາດ. ການຢູ່ລອດຂອງຊະນິດປາແມ່ນຈະບໍ່ຂຶ້ນກັບການເພາະລ້ຽງປາພຽງຢ່າງດຽວ ຫຼື ຊະນິດປາທີ່ປ່ອຍໄວ້. ພາຍໃຕ້ເງື່ອນໄຂທີ່ບໍ່ເຫັນພ້ອມທັງເງື່ອນໄຂດ້ານການເມືອງ ແລະ ເສດຖະກິດ ຫຼື ຍ້ອນວ່າການຂາດຜົນປະໂຫຍດທີ່ພຽງພໍ, ການເພາະລ້ຽງ ແລະ ການປ່ອຍປະຖິ້ມໄວ້ ແລະ ຊະນິດປາອາດມີຄວາມສ່ຽງຕໍ່ການສູນພັນ.

ຜົນກະທົບສະເພາະຂອງອ່າງເກັບນ້ຳ

ເຂື່ອນທີ່ຢູ່ຕ່ອນລຸ່ມໃນແມ່ນ້ຳເຊກອງ ອາດສົ່ງຜົນສະທ້ອນທາງລົບທີ່ໃຫຍ່ກວ່າຕໍ່ກັບການລອດຕາຍຂອງປາຊະນິດຕ່າງໆທີ່ມີການເຄື່ອນຍ້າຍໃນໄລຍະທາງໄກ ແລະ ຄວາມສຳເລັດໃນການຂະຫຍາຍພັນຂອງພວກມັນ ເມື່ອທຽບກັບເຂື່ອນທີ່ຢູ່ຕອນເທິງຂອງແມ່ນ້ຳ ເຊິ່ງສາຍເຫດເນື່ອງມາຈາກເຂື່ອນຕອນລຸ່ມຈະບໍ່ສາມາດຍອມຮັບກັບການເຄື່ອນຍ້າຍຂອງປາທີ່ມີຈຳນວນຫຼາຍຕໍ່ກັບພື້ນທີ່ແຫຼ່ງທີ່ຢູ່ອາໃສໃດໜຶ່ງ, ພື້ນທີ່ນ້ຳຖ້ວມທີ່ເຕັມໄປດ້ວຍການຂະຫຍາຍພັນ ແລະ ການດ້ານຫຼັກແຫຼ່ງທີ່ຢູ່ອາໃສ. ຂໍ້ແນະນຳຕໍ່ກັບທີ່ຕັ້ງຂອງເຂື່ອນໄຟຟ້າຂອງເຂື່ອນເຊກອງ # 1A ອາດກາຍເປັນສິ່ງກີດຂວາງທາງຂຶ້ນລົງຂອງຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍທັງໝົດທີ່ມີໃນອ່າງແມ່ນ້ຳເຊກອງທີ່ຢູ່ໃນຂອບເຂດ ສປປ ລາວ, ເຊິ່ງບໍ່ສະເພາະແຕ່ໃນແມ່ນ້ຳເຊກອງແຕ່ລວມໄປເຖິງສາຂາຕ່າງໆເຊັ່ນ ເຊກະມານ, ເຊຊູ ແລະ ນ້ຳກອງ ເຊິ່ງແມ່ນ້ຳເຫຼົ່ານັ້ນອາດເປັນບ່ອນທີ່ມີມູນຄ່າທີ່ສຳຄັນໃນການຂະຫຍາຍພັນຂອງປາທີ່ມີການເຄື່ອນຍ້າຍອີກຫຼາຍຊະນິດ. ມັນແມ່ນສິ່ງທີ່ສົມຄວນທີ່ຈະຕ້ອງໄດ້ມີການຄົ້ນຄິດກ່ຽວກັບເຂື່ອນ #1A ອາດມີຜົນກະທົບທີ່ມີລັກສະນະຄ້າຍຄືກັບເຂື່ອນເຊຊານ 2 ຕອນລຸ່ມໃນປະເທດກຳປູເຈຍ ເຊິ່ງກໍມີການກີດຂວາງທາງຂຶ້ນລົງຂອງປາສູ່ແຫຼ່ງຂະຫຍາຍພັນທີ່ສຳຄັນ.

ເຊກອງ # 5 ຈະເກີດມີນ້ຳຖ້ວມຍາວໄປຕາມແລວຂອງແມ່ນ້ຳ ແລະ ອາດເຮັດໃຫ້ນ້ຳໄຫຼກັບຄືນສູ່ເຂດພື້ນທີ່ປ່າປ້ອງກັນເຊເຊັດ (Xe Xet NPA). ໃນເມື່ອວ່າຂໍ້ພິຈາລະນາເຫຼົ່ານັ້ນມີການຍົກຂຶ້ນມາ, ຫຼັກການໃນການປ້ອງກັນລ່ວງໜ້າໄດ້ມີການແນະນຳວ່າ ມັນຄວນຈະຕ້ອງມີການລະມັດລະວັງ ເພື່ອຊອກຫາທາງເລືອກອື່ນໆທາງດ້ານທີ່ຕັ້ງຂອງເຂື່ອນ. NHI ໄດ້ມີການວິເຄາະຫາທີ່ຕັ້ງທີ່ເໝາະສົມ ໂດຍແນະນຳໃຫ້ວ່າ ທີ່ຕັ້ງຂອງຫວ້ຍອາຊຳ ເປັນທາງເລືອກທີ່ເໝາະສົມອັນໜຶ່ງ ເພື່ອທົດແທນຈາກແມ່ນ້ຳສາຍຫຼັກ.

ຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍ ແມ່ນໄດ້ມີປະກົດໃຫ້ເຫັນໃນໄລຍະ 56 km ຂຶ້ນໄປເໜືອເທິງແມ່ນ້ຳເຊກະມານ ເຊິ່ງນັບຈາກເຂື່ອນເຊກະມານຊັນຊາຍຫາປາກແມ່ນ້ຳ. ມີປາຂະໜາດນ້ອຍຫຼາຍຊະນິດທີ່ໄດ້ພົບເຫັນໃນແຫຼ່ງດັ່ງກ່າວ [2], [3]. ຊະນິດປາມີການເຄື່ອນຍ້າຍແມ່ນກໍປະກົດໃຫ້ເຫັນໃນ ເຊຊູ ເຊິ່ງໃນປະຈຸບັນແມ່ນຍັງບໍ່ທັນໄດ້ມີການກໍ່ສ້າງເຂື່ອນ. ມັນໄດ້ມີການເຊື່ອມຕໍ່ກັບເຊກະມານຢູ່ຕອນລຸ່ມຂອງເຂື່ອນຊັນຊາຍ ແລະ ກ່ອນທີ່ຈະເຖິງປາກແມ່ນ້ຳເຊກອງທີ່ອັດຕະປື. ສິ່ງນີ້ມັນໄດ້ສະແດງໃຫ້ເຫັນວ່າ ການໄຫຼຂອງເຊຊູແມ່ນມີການກີດຂວາງຈາກຍອດນ້ຳຕະຫຼອດຮອດປາກແມ່ນ້ຳທີ່ໄຫຼລົງສູ່ແມ່ນ້ຳຂອງໃນທະເລຈີນໃຕ້. ຢ່າງໃດກໍ່ຕາມ, ມັນກໍຍັງບໍ່ມີຂໍ້ມູນທີ່ພຽງພໍ ເພື່ອທີ່ຈະກຳນົດເຖິງຄຸນຄ່າຂອງບັນດາສາຍນ້ຳດັ່ງກ່າວ ໃນທາງການເຄື່ອນຍ້າຍຂອງປາ ເພື່ອຂະຫຍາຍພັນ ແລະ ການເພາະລ້ຽງ. ຖ້າສາຍນ້ຳດັ່ງກ່າວນີ້ ໄດ້ມີການກຳນົດວ່າມີຄວາມສຳຄັນຕໍ່ການເຄື່ອນຍ້າຍຂອງປາ, ສິ່ງທີ່ຄວນຈະຕ້ອງມີການເອົາໃຈໃສ່ແມ່ນ ການເປີດນຳໃຊ້ ເຂື່ອນເຊກະມານຊັນຊາຍ ໃນພື້ນທີ່ອ່າງຮັບນ້ຳ ແລະ ຮູບແບບການໄຫຼ ເພື່ອຈະນຳໄປສູ່ຄວາມຕ້ອງການຂອງຊະນິດປາເຫຼົ່ານັ້ນ. ສິ່ງນີ້ອາດຈະເຮັດໃຫ້ຕ້ອງມີການເປີດນຳໃຊ້ເຂື່ອນເຊກະມານຊັນຊາຍ ເຊັ່ນດຽວກັນກັບການດັດແກ້ຄືນລະບຽບການຂອງອ່າງເກັບນ້ຳ.

ຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍແມ່ນໄດ້ມີການພົບເຫັນໃນໄລຍະ ~75 km ໃນສາຂາແມ່ນ້ຳໃນນ້ຳກອງ ຈາກເຂື່ອນນ້ຳກອງ #2 ໄປຫາປາກແມ່ນ້ຳທີ່ໄຫຼລົງສູ່ແມ່ນ້ຳໃຫຍ່. ສາຍນ້ຳດັ່ງກ່າວນີ້ແມ່ນມີຄວາມເລິກ ແລະ ມີວັງເລິກຫຼາຍ. ສິ່ງເຫຼົ່ານີ້ອາດຈະມີຄວາມສຳຄັນຕໍ່ກັບປາທີ່ມີການເຄື່ອນຍ້າຍເພື່ອການຂະຫຍາຍພັນ. ຖ້າຫາກສາຍນ້ຳດັ່ງກ່າວມີການກຳນົດວ່າເປັນບ່ອນທີ່ມີຄວາມສຳຄັນສຳລັບປາທີ່ມີການເຄື່ອນຍ້າຍເພື່ອການຂະຫຍາຍພັນ, ສິ່ງທີ່ຄວນເອົາໃຈໃສ່ແມ່ນຈະຕ້ອງໄດ້ມີການເປີດນຳໃຊ້ ເຂື່ອນນ້ຳກອງ # 1 ເພື່ອຮັກສາຮູບແບບການໄຫຼຂອງສິ່ງແວດລ້ອມເຊັ່ນດຽວກັນກັບທີ່ໄດ້ກຳນົດມາຂ້າງເທິງນັ້ນ. ສິ່ງນີ້ອາດຈະເຮັດໃຫ້ຕ້ອງມີການເປີດນຳໃຊ້ເຂື່ອນ ເຊັ່ນດຽວກັນກັບການດັດແກ້ຄືນລະບຽບການຂອງອ່າງເກັບນ້ຳ.

ຫຼັກການທີ່ສຳຄັນ ແລະ ຂໍ້ສົມມຸດຕິຖານ:

- ໂດຍທົ່ວໄປແລ້ວ, ຕອນເທິງຂອງອ່າງໂຕ່ງຂອງແມ່ນ້ຳເຊກອງ ແມ່ນມີຄວາມສຳຄັນຫຼາຍທາງດ້ານຊະນິດປາທີ່ມີສະເພາະໃນທ້ອງຖິ່ນ [1]; ໃນຕອນລຸ່ມຂອງແມ່ນ້ຳ ແມ່ນມີຄວາມສຳຄັນທາງດ້ານມວນສານຂອງສິ່ງທີ່ມີຊີວິດລວມໄປເຖິງຄວາມຫຼາກຫຼາຍທາງດ້ານຊະນິດປາ. ຍຸດທະສາດໃນການພັດທະນາແມ່ນອາດຕ້ອງອີງໃສ່ຄວາມສົມດຸນກັນລະຫວ່າງການຮັກສາທາງດ້ານມວນສານ ແລະ ຄວາມຫຼາກຫຼາຍທາງດ້ານຊີວະນາໆພັນ.

- ອ່າງແມ່ນ້ຳເຊກອງ ແມ່ນສູນລວມຂອງປາຫຼາຍກວ່າ 213 ຊະນິດ. ມີ 64 ຊະນິດທີ່ເປັນປາທີ່ມີການເຄື່ອນຍ້າຍໄປມາ ແລະ ອີກ 61 ຊະນິດແມ່ນເປັນປາທີ່ຢູ່ສະເພາະໃນທ້ອງຖິ່ນ (ພົບສະເພາະແຕ່ໃນອ່າງແມ່ນ້ຳເຊກອງ)

[2], [3]. ມີຈຳນວນ 21 ຊະນິດຂອງປາເຫຼົ່ານັ້ນ ແມ່ນໄດ້ມີການຂຶ້ນບັນຊີໃນປື້ມແດງຂອງ IUCN ວ່າເປັນ "ຊະນິດປາທີ່ມີຄວາມສ່ຽງຕໍ່ໄພຂົ່ມຂູ່". [1]

- ໃນຂະນະທີ່ສ່ວນຫຼາຍຂອງຊະນິດປາທີ່ມີໃນແມ່ນ້ຳຂອງມີການຂະຫຍາຍພັນໃນຕອນຕົ້ນຂອງລະດູຝົນ, ບາງຊະນິດແມ່ນມີການຂະຫຍາຍພັນຕະຫຼອດທັງປີ [4] ແລະ ພວກມັນມີສອງຮູບແບບການເຄື່ອນຍ້າຍຂອງປາ ແລະ ການລອຍຕົວລົງຂອງລູກປາໃນຕອນລຸ່ມຂອງແມ່ນ້ຳຕະຫຼອດປີ [7]. ມີປາຫຼາຍຊະນິດທີ່ເຄື່ອນຍ້າຍຂຶ້ນໄປຕອນເທິງຂອງແມ່ນ້ຳເພື່ອຂະຫຍາຍພັນ, ຫາອາຫານໃນຕົ້ນລະດູຝົນ, ກັບການຂະຫຍາຍພັນທີ່ມີຢ່າງຫຼວງຫຼາຍ ຈາກເວລາດັ່ງກ່າວນີ້ຈົນເຖິງໄລຍະທີ່ມີການປ່ຽນແປງຂອງລະດູຝົນ. ປາທີ່ມີການເຄື່ອນຍ້າຍແມ່ນຈະອາໃສຢູ່ໃນວັງເລິກຕ່າງໆຕະຫຼອດຮອດທ້າຍລະດູຝົນ. ປາສ່ວນໃຫຍ່ໃນແມ່ນ້ຳເຊກອງແມ່ນມີຄວາມສຳຄັນຕໍ່ການບໍລິໂພກຂອງມະນຸດໂດຍອີງໃສ່ລັກສະນະດັ່ງກ່າວ.

ກຸນແຈສຳຄັນທີ່ກວດພົບໂດຍອີງໃສ່ຄວາມຮູ້ທີ່ມີໃນປະຈຸບັນ

ບັນຫາ 1: ສິ່ງໃດທີ່ກ່ຽວຂ້ອງເຖິງຄວາມສຳຄັນຂອງແຫຼ່ງທີ່ຢູ່ອາໃສຂອງປາໃນແມ່ນ້ຳເຊກອງ ໃນດ້ານທີ່ກ່ຽວພັນເຖິງລະບົບແມ່ນ້ຳຂອງ?

ການປະມົງໃນແມ່ນ້ຳຂອງ ແມ່ນມີຈຸດພິເສດທີ່ເປັນລັກສະນະສະເພາະໂດຍມີປາຈຳນວນຫຼາຍ ທີ່ມີການເຄື່ອນຍ້າຍໄລຍະໄກ ແລະ ໄລຍະໃກ້ ເພື່ອຄວາມສົມບູນທາງດ້ານວົງຈອນຊີວິດ ແລະ ການຂະຫຍາຍພັນ. ລະບົບອ່າງແມ່ນ້ຳຂອງແມ່ນໄດ້ປະກົດໃຫ້ເຫັນການເຄື່ອນຍ້າຍຂອງປາຂະໜາດໃຫຍ່ ທັງຢູ່ໃນຕອນລຸ່ມ ແລະ ຕອນເທິງຂອງນ້ຳຕົກ. ເປັນທີ່ຮູ້ກັນວ່າມີຈຳນວນຫຼາຍທີ່ສຸດຂອງປາແຕ່ລະຊະນິດ ແລະ ປະລິມານລວມທີ່ຫຼາຍທີ່ສຸດ ຂອງມວນສານທີ່ມີການເຄື່ອນຍ້າຍ ແມ່ນມີການເຄື່ອນຍ້າຍໃນເຂດ 3-S ສາຂາແມ່ນ້ຳ ຕະຫຼອດຮອດປາກແມ່ນ້ຳທີ່ໄຫຼລົງສູ່ແມ່ນ້ຳຂອງ, ພື້ນທີ່ທົ່ງພຽງນ້ຳຖ້ວມໃນປະເທດກຳປູເຈຍ, ທະເລຕົງເລຊາບ ແລະ ເຂດແມ່ນ້ຳຂອງເດວຕາ [4]. ປາທີ່ມີການເຄື່ອນຍ້າຍໄລຍະໄກ ທີ່ໄດ້ມີການນຳໃຊ້ຕອນຕົ້ນຂອງແມ່ນ້ຳເຊກອງ ຈາກແມ່ນ້ຳຂອງເດວຕາທີ່ປະເທດຫວຽດນາມ, ທະເລຕົງເລ ຊາບ ແລະ ພື້ນທີ່ໃກ້ຄຽງ, ຈາກແມ່ນ້ຳຂອງຕອນໃຕ້ຂອງລາວ ແລະ ຕອນຕາເວັນອອກສ່ຽງເໜືອຂອງປະເທດກຳປູເຈຍ. ມີຫຼາຍໆຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍແມ່ນມີຄວາມຕ້ອງການແຫຼ່ງທີ່ຢູ່ອາໃສທີ່ມີລັກສະນະສະເພາະ ເຊັ່ນນ້ຳໄຫຼ, ຫີນ, ພືດພັນ ແລະ ອື່ນໆ ເພື່ອໃຊ້ເຂົ້າໃນການຂະຫຍາຍພັນໃຫ້ມີຄວາມສົມບູນ. ເຂື່ອນໄຟຟ້າແມ່ນເປັນສິ່ງກີດຂວາງອັນໜຶ່ງຕໍ່ການເຂົ້າເຖິງແຫຼ່ງຂະຫຍາຍພັນ, ແຫຼ່ງທີ່ຢູ່ອາໃສໃນການຊອກຫາອາຫານ ແລະ ບ່ອນທີ່ເປັນນ້ຳຖ້ວມໃນແຫຼ່ງທີ່ຢູ່ອາໃສ ບ່ອນທີ່ມີລະດັບນ້ຳຄົງທີ່.

ແມ່ນໍ້ເຊກອງ ແມ່ນມີລັກສະນະສະເພາະທີ່ໂດດເດັ່ນ ເປັນສາຂາຫຼັກອັນສຸດທ້າຍຂອງລະບົບແມ່ນ້ຳຂອງທີ່ຍັງມີການໄຫຼໂດຍປັດສະຈາກສິ່ງກີດຂວາງນັບຈາກຍອດນ້ຳ ຕະຫຼອດຮອດໄລຍະທາງທີ່ໄຫຼລົງສູ່ທະເລຈີນໃຕ້. ຕາມເສັ້ນທາງຂອງມັນແລ້ວ ແມ່ນ້ຳເຊກອງແມ່ນໄຫຼຜ່ານປະເທດລາວ ເຊິ່ງມັນກຳເນີດຈາກຊາຍແດນປະເທດວຽດນາມໄຫຼຜ່ານປະເທດລາວ ແລະ ປະເທດກຳປູເຈຍ ແລ້ວໄຫຼປ່ອງລົງໃສ່ແມ່ນ້ຳຂອງ ແລະ ຈາກການໄຫຼຜ່ານເຂດສາຍນ້ຳ ຊຳບໍ, ປາກແມ່ນ້ຳຕົງເລຊາບ ແລະ

ເຂດເດວຕ້າໃນປະເທດຫວຽດນາມ. ໂອກາດຂອງປາທີ່ມີການເຄື່ອນຍ້າຍຈາກແຫຼ່ງອາໃສໃນລະບົບແມ່ນ້ຳຂອງ ແມ່ນໄດ້ມີການຕົກລົງກັນເພື່ອໃຫ້ບັນລຸໄດ້ສິ່ງທີ່ສຳຄັນທີ່ສຸດ ຫຼື ໃຫ້ມີຂອບເຂດການສູນເສຍທີ່ນ້ອຍທີ່ສຸດຄື:

- ມີເຂື່ອນໄຟຟ້າ 7 ແຫ່ງຂອງຄົນຈີນ ທີ່ໄດ້ສ້າງສຳເລັດແລ້ວໃນແມ່ນ້ຳລ້ານຊ້າງ ຕອນເທິງ ເຊິ່ງເປັນສິ່ງທີ່ກີດຂວາງການເຄື່ອນຍ້າຍຂອງປາໂດຍສົມບູນ.

- ເຂື່ອນໃນປະເທດໄທທີ່ສ້າງຂຶ້ນເພື່ອການຊົນລະປະທານ ແລະ ພະລັງງານໄຟຟ້າໃນເຂດພູພຽງໂຄລາດ (Khorat Plateau) ເປັນສິ່ງທີ່ມີຜົນກະທົບຕໍ່ການຂຶ້ນລົງຂອງປາຕະຫຼອດແມ່ນ້ຳມູນ ແລະ ແມ່ນ້ຳຊີໃນບາງສ່ວນໃນປີ.

- ມີເຂື່ອນໄຟຟ້າ 13 ແຫ່ງໃນປະເທດຫວຽດນາມທີ່ໄດ້ມີການກໍ່ສ້າງໃນແມ່ນ້ຳເຊຊານ ແລະ ເຊປອກ ທີ່ຈະເປັນສິ່ງກີດຂວາງການເຄື່ອນຍ້າຍຂອງປາໄດ້.

- ເຂື່ອນໄຟຟ້າໃນຕອນລຸ່ມຂອງແມ່ນ້ຳເຊຊານ 2 ອັນທີ່ມີແຜນຈະສ້າງໃຫ້ສຳເລັດໃນປີ 2017. ເຊິ່ງມັນຈະກາຍເປັນສິ່ງກີດກັ້ນການເຄື່ອນຍ້າຍຂອງປາເຂົ້າສູ່ເຊຊານ ແລະ ເຊປອກ ໃນຂະນະທີ່ປະເທດກຳປູເຈຍຍັງບໍ່ທັນມີທາງຜ່ານປາທີ່ໄດ້ຮັບຜົນດີ.

- ເຂື່ອນທີ່ສ້າງສຳເລັດແລ້ວ ແລະ ກຳລັງມີການກໍ່ສ້າງອີກຈຳນວນ 8 ແຫ່ງ ຢູ່ໃນສາຂາແມ່ນ້ຳໃນຕອນເໜືອຂອງ ສປປ ລາວ:
    - ນ້ຳກະດິງ (ນ້ຳເທີນ 2 ແມ່ນໄດ້ມີການກໍ່ສ້າງແລ້ວ; ເຂື່ອນເທີນຫີນບູນ ແມ່ນຢູ່ບໍລິເວນປາກແມ່ນ້ຳເທີນ ແລະ ແມ່ນ້ຳຍວງ ເຊິ່ງເປັນສາຍນ້ຳດຽວກັນກັບນ້ຳກະດິງ)
    - ນ້ຳງຽບ (ມີຈຳນວນ 2 ເຂື່ອນທີ່ໄດ້ກໍ່ສ້າງສຳເລັດແລ້ວ, ອີກ 1 ເຂື່ອນກຳລັງຢູ່ໃນໄລຍະກໍ່ສ້າງ)
    - ນ້ຳງື່ມ (ນ້ຳງື່ມ 1, 2 ແລະ 5 ແມ່ນຢູ່ໃນໄລຍະເປີດນຳໃຊ້ ແລະ ນ້ຳງື່ມ 3 ແມ່ນຢູ່ໃນໄລຍະພິຈາລະນາ)
    - ນ້ຳລີກ (ນ້ຳລີກ 2 ແມ່ນຢູ່ໃນໄລຍະເປີດນຳໃຊ້, ນ້ຳລີກ 1 ແມ່ນຢູ່ໃນການວາງແຜນຂັ້ນສຸດທ້າຍ)
    - ນ້ຳຄານ (ມີຈຳນວນ 1 ເຂື່ອນທີ່ໄດ້ມີການກໍ່ສ້າງແລ້ວ ແລະ ອີກ 1 ເຂື່ອນທີ່ກຳລັງມີການກໍ່ສ້າງ)
    - ນ້ຳອູ (#2, #5 and #6 ແມ່ນໄດ້ມີການກໍ່ສ້າງແລ້ວ, ການກໍ່ສ້າງ 1, 3, 4 ແລະ 7 ແມ່ນກຳນົດຈະເລີ່ມການກໍ່ສ້າງໃນປີ 2017)
    - ນ້ຳງາ (ມີຈຳນວນ 1 ເຂື່ອນທີ່ກຳລັງມີການກໍ່ສ້າງ)
    - ນ້ຳທາ (ມີຈຳນວນ 1 ເຂື່ອນທີ່ສ້າງ, ອີກ 1 ເຂື່ອນຢູ່ພາຍໃຕ້ການກໍ່ສ້າງ)

ເຂື່ອນໄຟຟ້າຈຳນວນ 2 ແຫ່ງ ທີ່ປະຈຸບັນແມ່ນກຳລັງມີການກໍ່ສ້າງໃນແມ່ນ້ຳຂອງ ເຊິ່ງມັນກໍ່ເປັນຜົນກະທົບຕໍ່ການເຄື່ອນຍ້າຍຂອງປາເຊັ່ນກັນ. ສິ່ງກີດຂວາງຕໍ່ທາງປາຜ່ານທີ່ເຂື່ອນໄຟຟ້າໄຊຍະບູລີ ໄດ້ມີການກໍ່ສ້າງນັ້ນຈະມີການລຸດຜ່ອນຜົນກະທົບໃນຂອບເຂດໃດໜຶ່ງດ້ວຍການສ້າງທາງປາຜ່ານທຽມ. ຮູ້ວ່າ ເຮືອນຈັກຂອງເຂື່ອນໄຊຍະບູລີ ໂດຍລວມແລ້ວແມ່ນມີສິ່ງທີ່ບໍ່ເກີດປະໂຫຍດ ແລະ ບໍ່ມີລັກສະນະສະເພາະທີ່ຈະເຮັດໃຫ້ປາທີ່ເຄື່ອນຍ້າຍລົງຕອນລຸ່ມສາມາດລອດຜ່ານໃບພັດຂອງເຄື່ອງຈັກໄປໄດ້. ເຂື່ອນໄຟຟ້າດອນສະໂຮງຈະເປັນສິ່ງທີ່ອັດຕັນຮູສະໂຮງ ເຊິ່ງເປັນຊ່ອງທາງການເຄື່ອນຍ້າຍທີ່ສຳຄັນຂອງປາ

ທີ່ຜ່ານຈາກເຂດນ້ຳຕົກໃນເຂດດັ່ງກ່າວ. ໂຄງການດັ່ງກ່າວນັ້ນແມ່ນຈະມີການດັດແປງຮູຊ້າງເຜືອກ, ຮູຄອນລານ ແລະ ຮູສະດຳ ແລະ ພ້ອມທັງມີການລຸດຜ່ອນການຫາປາໃນເຂດດັ່ງກ່າວ ໂດຍສະເພາະແມ່ນການຍ້າຍເຄື່ອງມືຫາປາຂະໜາດໃຫຍ່ທີ່ມີການກີດຂວາງທາງຂຶ້ນລົງຂອງປາ. ທາງຜ່ານປາທີ່ເຂື່ອນໄຊຍະບູລີຈະໄດ້ຮັບຜົນແນວໃດແດ່ ແມ່ນສິ່ງທີ່ຍັງບໍ່ສາມາດຮູ້ໄດ້. ໂດຍອີງໃສ່ປະສົບການໃນການສ້າງທາງປາຜ່ານທຽມໃນລະດັບສາກົນ [6], ສິ່ງເຫຼົ່ານີ້ແມ່ນເບິ່ງຄ້າຍກັບວ່າຈະໄດ້ຮັບຜົນພຽງແຕ່ບາງສ່ວນເທົ່ານັ້ນ. ເຂື່ອນອື່ນໆໃນ ສປປ ລາວ ແມ່ນຍັງບໍ່ທັນໄດ້ມີການປະເມີນ ລວມທັງເຂື່ອນປາກແບ່ງທີ່ປະຈຸບັນຍັງຢູ່ໃນການກວດຄືນຂອງອົງການ MRC. ເຂື່ອນເຫຼົ່ານັ້ນ ແມ່ນຈະເປັນສິ່ງກີດຂວາງແມ່ນ້ຳຂອງໂດຍຊິ້ນເຊີງ ແລະ ມັນຮຽກຮ້ອງໃຫ້ມີການສ້າງທາງປາຜ່ານທຽມ ໂດຍທີ່ບໍ່ຮູ້ວ່າຈະໄດ້ຮັບຜົນ ແລະ ປະສິດທິພາບຂອງມັນ.

ອີງໃສ່ຂໍ້ຈຳກັດໃນການເຂົ້າເຖິງ, ບັນດາເຂື່ອນໄຟຟ້າເຫຼົ່ານັ້ນ ແລະ ອ່າງເກັບນ້ຳຂອງ ພວກມັນແມ່ນເປັນສິ່ງທີ່ເຮັດໃຫ້ມີການລຸດລົງຂອງການເຂົ້າເຖິງແຫຼ່ງທີ່ຢູ່ອາໃສສຳລັບປາທີ່ມີການເຄື່ອນຍ້າຍສຳລັບການຂະຫຍາຍພັນ ແລະ ການ ເຕີບໃຫຍ່. ຜົນຜະລິດທາງດ້ານການປະມົງແມ່ນມີປະລິມານທີ່ສູງຂຶ້ນໂດຍກ່ຽວຂ້ອງກັບຂອບເຂດຂອງການຫາອາຫານ, ການຂະຫຍາຍພັນ, ບ່ອນລີ້ໄພ ແລະ ທີ່ຢູ່ອາໃສໃນການເຕີບໂຕ. ດັ່ງທີ່ຮູ້ກັນວ່າໄດ້ມີການສູນເສຍການເຂົ້າເຖິງແຫຼ່ງທີ່ຢູ່ອາໃສ, ການເຂົ້າເຖິງທີ່ຍັງມີປະກົດໃຫ້ເຫັນແມ່ນການເພີ່ມຄວາມສຳຄັນຂຶ້ນໄປເລື້ອຍໆໃນດ້ານຄວາມຍືນຍົງຂອງປະຊາ ກອນປາ ແລະ ການປະມົງ.

ສະຫຼຸບລວມແລ້ວ ອັດຕາສ່ວນຂອງອ່າງຮັບນ້ຳທີ່ປະກອບດ້ວຍ ແມ່ນ້ຳເຊກອງ ແລະ ແມ່ນ້ຳຂອງຕອນລຸ່ມຈາກປາກນ້ຳ ແມ່ນເປັນສ່ວນທີ່ສຳຄັນທາງດ້ານຜົນຜະລິດຂອງການປະມົງນ້ຳຈືດ. ຍ້ອນວ່າເຊກອງ ແມ່ນແມ່ນ້ຳສາຂາຕົ້ນຕໍຂອງແມ່ນ້ຳຂອງໃນຕອນລຸ່ມ ທັດຈາກຄອນພະເພັງລົງມາ ທີ່ຍັງມີການເຄື່ອນຍ້າຍຂອງປາແບບອິດສະລະ ຈາກຕົ້ນນ້ຳໄປຫາທະເລ, ສິ່ງເຫຼົ່ານີ້ແມ່ນການເຊື່ອມຕໍ່ທີ່ປະກອບເປັນສິ່ງທີ່ມີຄຸນຄ່າ ແລະ ບໍ່ສາມາດຫາສິ່ງໃດມາແທນໄດ້ ສຳລັບປະຊາກອນປາທີ່ມີການເຄື່ອນຍ້າຍໃນແມ່ນ້ຳຂອງ.

<u>ບັນຫາ 2:</u> ພາຍໃຕ້ຂອບເຂດອັນໃດທີ່ເຂື່ອນໄຟຟ້າໃນແມ່ນ້ຳເຊກອງຈະເປັນສາຍເຫດຂອງການລຸດລົງທາງການປະມົງໃນຕອນລຸ່ມ?

ເນື່ອງຈາກການປ່ຽນແປງການໄຫຼໃນແຕ່ລະລະດູການໃນແມ່ນ້ຳເຊກອງ, ເຂື່ອນໄຟຟ້າໃນຕອນເທິງຂອງແມ່ນ້ຳເຊກອງແມ່ນມີຄວາມຕ້ອງການທີ່ຈະຕ້ອງເກັບກັກນ້ຳໄວ້ໃນລະດູຝົນ ແລະ ປ່ອຍໃນລະດູແລ້ງ ເພື່ອສ້າງມູນຄ່າທາງດ້ານເສດຖະກິດ [9]. ເຂື່ອນທີ່ຢູ່ຕອນເທິງແມ່ນຈະມີລັກສະນະແບບນັ້ນ ເຊິ່ງຈະມີບ່ອນເກັບນ້ຳທີ່ສາມາດປ່ອຍໃຫ້ລົ້ນອອກ ແລະ ດ້ວຍເຫດນັ້ນຮູບແບບການໄຫຼຂອງນ້ຳໃນຕອນລຸ່ມຈຶ່ງມີລັກສະນະປ່ຽນໄປຕາມ.

ການເກັບກັກນ້ຳໃນລະດູການຢູ່ຕອນເທິງຂອງແມ່ນ້ຳໃນອ່າງເກັບນ້ຳຂອງເຂື່ອນໃນອ່າງແມ່ນ້ຳເຊກອງ ແມ່ນຈະສົ່ງຜົນຄື:

- ການຖ້ວມຂັງແຫຼ່ງທີ່ຢູ່ອາໃສແບບຖາວອນຂອງປາທີ່ມີການເຄື່ອນຍ້າຍ ແລະ ບໍ່ມີການເຄື່ອນຍ້າຍ ປາບາງຈຳນວນແມ່ນຈຳພວກທີ່ມີສະເພາະໃນທ້ອງຖິ່ນ

- ຈຸດປ່ຽນແປງການໄຫຼຂອງນ້ຳຕ່ຳສຸດໃນລະດູຝົນ
- ລະດັບນ້ຳສູງສຸດໃນລະດູແລ້ງ
- ການເກີດຂຶ້ນລ່າຊ້າຂອງນ້ຳທີ່ຖ້ວມຂັງໃນເຂດທົ່ງຮາບພຽງຕອນລຸ່ມ ທີ່ເກີດຂຶ້ນໃນໄລຍະເລີ່ມຕົ້ນລະດູຝົນ
- ການເກີດຂຶ້ນລ່າຊ້າຂອງການໄຫຼເຂົ້າ ແລະ ໄຫຼອອກຂອງນ້ຳໃນທະເລຕົງເລຊາບ
- ການຜັນຜວນໃນຮອບວັນຂອງກະແສນ້ຳໄຫຼ, ການເຊາະເຈື່ອນຂອງແຫຼ່ງທີ່ຢູ່ອາໃສ ແລະ ແຄມຕາຝັ່ງເນື່ອງຈາກການຜັນຜວນຂອງກະແສນ້ຳ
- ການລຸດລົງຂອງຕະກອນດິນ ແລະ ທາດສານອາຫານ ເນື່ອງຈາກການສ້າງອ່າງເກັບນ້ຳ

ອີງຕາມຄວາມຮຸນແຮງຂອງສິ່ງເຫຼົ່ານັ້ນ, ການປ່ຽນແປງທາງດ້ານອຸທົກກະສາດ ແລະ ພູມມິສາດ ອາດຈະສາມາດລຸດຜ່ອນການເຄື່ອນຍ້າຍ, ການຂະຫຍາຍພັນ ແລະ ການລອດຕາຍຂອງປາໃນພື້ນທີ່ນ້ຳຖ້ວມ ແລະ ຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍເຂົ້າໄປໃນແມ່ນ້ຳ ໂດຍສະເພາະລະບົບທີ່ມີໃນພາກສ່ວນປະເທດກຳປູເຈຍ [8]. ບັນດາຜົນກະທົບທີ່ເກີດມີໃນຕອນລຸ່ມຂອງການເກັບກັກນ້ຳໃນອ່າງຂອງອ່າງແມ່ນ້ຳເຊກອງ ອາດເປັນຜົນກະທົບທີ່ມີລັກສະນະເພີ່ມທະວີ ເຊິ່ງໃນປະຈຸບັນ ແມ່ນໄດ້ເລີ່ມເກີດເປັນຕົ້ນເຫດໂດຍການເກັບກັກນ້ຳໃນອ່າງໃນເຂື່ອນຕ່າງໆຢູ່ແມ່ນ້ຳລ້ານຊ້າງ, ເຂື່ອນໃນປະເທດຫວຽດນາມ ຢູ່ໃນແມ່ນ້ຳເຊປອກ ແລະ ເຊຊານ, ເຂື່ອນທີ່ມີໃນສາຂາແມ່ນ້ຳຕ່າງໆໃນປະເທດລາວ ແລະ ນອກຈາກນັ້ນ ກັບຜົນກະທົບອັນທ້າທາຍຈາກເຂື່ອນຕ່າງໆທີ່ຢູ່ໃນແມ່ນ້ຳຫຼັກເຊັ່ນ: ເຂື່ອນໄຊຍະບູລີ, ດອນສະໂຮງ ແລະ ປາກແບ່ງ ຫຼື ບໍ່ເຊັ່ນນັ້ນກໍ່ລຸດທາງດ້ານຜົນຜະລິດທາງການປະມົງ ແລະ ຄວາມຫຼາກຫຼາຍທາງດ້ານຊີວະນາໆພັນແມ່ນຍັງບໍ່ທັນເປັນສິ່ງທີ່ຈະແຈ້ງເທື່ອຢູ່ຕອນລຸ່ມປາກແມ່ນ້ຳ 3-S, ມັນຍັງມີຂໍ້ຈຳກັດທາງດ້ານຄວາມທົນທານທາງດ້ານຊີວະວິທະຍາຕໍ່ການປ່ຽນແປງທາງດ້ານທຳມະຊາດເຫຼົ່ານັ້ນ. ການພັດທະນາເຂື່ອນໄຟຟ້າທີ່ມີຢ່າງໜັກໃນລຳແມ່ນ້ຳເຊກອງ ຈະເປັນສ່ວນປະກອບໜຶ່ງທີ່ມີຕໍ່ຄວາມສ່ຽງທີ່ຈະເກີດໄພເປັນຢ່າງຍິ່ງ ທີ່ເປັນຈຸດເລີ່ມຕົ້ນຂອງສິ່ງອື່ນທີ່ຈະຕາມມາ ເຊິ່ງອາດມີຜົນເຮັດໃຫ້ຜົນຜະລິດທາງການປະມົງມີການລຸດລົງ ແລະ ຄວາມຫຼາກຫຼາຍທາງດ້ານຊະນິດປາ.

ສິ່ງທີ່ໜ້າຈະເກີດຂຶ້ນໄດ້ສຳລັບການເຄື່ອນຍ້າຍຂອງປາໃນເຂດຕອນເທິງ ແລະ ການລອດຕາຍລົງສູ່ແມ່ນ້ຳຕອນລຸ່ມ (ລວມທັງລູກປາໄວອ່ອນທີ່ລອຍມານຳນ້ຳ) ຍ້ອນບັນດາເງື່ອນໄຂຂ້າງເທິງນັ້ນ ສາມາດສະແດງໃຫ້ເຫັນແບບຢ່າງຂອງການລຸດລົງກັບການເພີ່ມຂຶ້ນຂອງຈຳນວນຂອງເຂື່ອນໄຟຟ້າໃນແມ່ນ້ຳເຊກອງ. ເຖິງແມ່ນວ່າ ຖ້າເຂື່ອນທັງ 7 ແຫ່ງທີ່ມີເປົ້າໝາຍສ້າງໃນແມ່ນ້ຳເຊກອງຫາກໄດ້ປະຕິບັດຕາມມາດຕະຖານຂອງ MRC ທີ່ຕ້ອງໄດ້ມີການຮັບປະກັນການຂຶ້ນລົງຂອງປາ 95% ຂອງຊະນິດປາ ພາຍໃຕ້ເງື່ອນໄຂທັງໝົດຂອງການໄຫຼຂອງນ້ຳ [11], ເຊິ່ງເປັນການສະແດງໃຫ້ເຫັນເຖິງການປະຕິບັດທີ່ດີໃນສາກົນ, ຜົນກະທົບແບບທະວີຄູນແມ່ນຍັງຄົງເປັນບັນຫາຕົ້ນຕໍໃນການຫຼຸດຜ່ອນທາງດ້ານມວນສານ ແລະ ຄວາມຫຼາກຫຼາຍທາງດ້ານຊະນິດປາ.

ເຂື່ອນທີ່ຢູ່ໃນຕອນລຸ່ມຂອງແມ່ນ້ຳເຊກອງ ອາດເປັນບັນຫາທາງລົບທີ່ໃຫຍ່ທີ່ສຸດຕໍ່ການລອດຕາຍຂອງປາທີ່ມີການເຄື່ອນຍ້າຍໄລຍະໄກ ແລະ ຄວາມສຳເລັດໃນການຂະຫຍາຍພັນຂອງພວກມັນ ຫຼາຍກວ່າເຂື່ອນທີ່ຢູ່ຕອນເທິງ ຍ້ອນວ່າ ເຂື່ອນທີ່ຢູ່ໃນຕອນລຸ່ມແມ່ນຈະເປັນສິ່ງທີ່ກີດຂວາງຄວາມສາມາດໃນການເຂົ້າເຖິງແຫຼ່ງທີ່ຢູ່ອາໃສເປັນຈຳນວນຫຼວງ ຫຼາຍ ແລະ ການຂະຫຍາຍພັນເພີ່ມຂຶ້ນໃນເຂດນ້ຳຖ້ວມ ແລະ ບ່ອນທີ່ຢູ່ອາໃສເພື່ອການເຕີບໃຫຍ່.

ຈຸດທີ່ຕັ້ງຂອງເຂື່ອນໄຟຟ້າທີ່ໄດ້ສະເໜີ ສໍາລັບເຂື່ອນໄຟຟ້າເຊກອງ # 1A ແມ່ນເປັນການກີດຂວາງທາງປາຜ່ານຊະນິດທີ່ມີການເຄື່ອນຍ້າຍ ສ່ວນໃຫຍ່ທີ່ເຂົ້າໄປໃນອ່າງແມ່ນໍ້າເຊກອງ ພາຍໃນເຂດ ສປປ ລາວ, ບໍ່ສະເພາະແຕ່ສາຍແມ່ນໍ້າເຊກອງ ແຕ່ລວມທັງ ເຊກະມານ, ເຊຊູ ແລະ ນໍ້າກອງ ເຊິ່ງແມ່ນໍ້າເຫຼົ່ານັ້ນອາດເປັນແຫຼ່ງທີ່ມີຄຸນຄ່າສໍາຄັນສໍາລັບການຂະຫຍາຍພັນຂອງຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍ. ຖ້າຫາກມີການພິຈາລະນາຢ່າງເໝາະສົມສໍາລັບເຂື່ອນໃນຈຸດ #1A ຈະມີຜົນກະທົບທີ່ເກີດຂຶ້ນຄ້າຍກັບເຂື່ອນໃນຕອນລຸ່ມຂອງແມ່ນໍ້າເຊຊານ 2 ໃນປະເທດກໍາປູເຈຍ ເຊິ່ງມັນໄດ້ເປັນສິ່ງກີດຂວາງການເຄື່ອນຍ້າຍຂອງປາເຂົ້າໄປສູ່ແຫຼ່ງຂະຫຍາຍພັນທີ່ອຸດົມສົມບູນ. ເຂື່ອນໃນຈຸດ #1A ອາດມີຜົນກະທົບທາງລົບທີ່ເປັນຕົ້ນຕໍໃຫ້ແກ່ການສ້າງລາຍຮັບໃຫ້ແກ່ຄອບຄົວ ແລະ ຊີວິດການເປັນຢູ່ຂອງຄົນທຸກຍາກໃນເຂດຊົນນະ ບົດ. ໃນຂະນະທີ່ ເຂື່ອນຕອນລຸ່ມຂອງແມ່ນໍ້າເຊຊານ 2, ສິ່ງອໍານວຍຄວາມສະດວກທີ່ເປັນທາງຜ່ານປາ ອາດເປັນສ່ວນໜຶ່ງຂອງການລຸດຜ່ອນຜົນກະທົບດ້ວຍການຕັນທາງຜ່ານປາໃນເຂດຕອນເທິງ ແຕ່ບໍ່ອາດຈະລຸດຜ່ອນຜົນກະທົບທີ່ເກີດຂຶ້ນໃນອ່າງເກັບນໍ້າໃນເລື່ອງການລອຍລົງຂອງລູກປາສູ່ຕອນລຸ່ມຂອງແມ່ນໍ້າ ແລະ ພື້ນທີ່ນໍ້າຖ້ວມທີ່ໃຊ້ໃນການປະສົມພັນ ແລະ ແຫຼ່ງທີ່ຢູ່ອາໃສເພື່ອການຈະເລີນເຕີບໂຕ (ເບິ່ງດ້ານລຸ່ມ).

ຍັງບໍ່ມີການເກັບຕົວຢ່າງຂອງຊະນິດປາໃນລໍາແມ່ນໍ້າທີ່ສະແດງໃຫ້ເຫັນວ່າ ປາຊະນິດໃດທີ່ຈະຖືກປິດຕັນຈາກເຂື່ອນເຊກອງ # 5. ຈົນຮອດດຽວນີ້ ມັນມີການຮັບຮູ້ວ່າໃນຕອນເທິງຂອງອ່າງໂຕ່ງແມ່ນມີຊະນິດປາທີ່ມີຢູ່ໃນສະເພາະທ້ອງຖິ່ນປະກອບຢູ່ຫຼາຍຊະນິດ. ຊະນິດປາທີ່ມີການເຄື່ອນຍ້າຍຈາກຕອນເທິງແມ່ນໍ້າລົງຕອນລຸ່ມຂອງຈຸດທີ່ຈະສ້າງເຂື່ອນເຊກອງ 5 ແຕ່ໃນຂອບເຂດເຫຼົ່ານັ້ນ ຈໍາພວກປາທີ່ມີການເຄື່ອນຍ້າຍໄປຕອນເທິງຈາກຈຸດທີ່ຕັ້ງຂອງເຂື່ອນ ແມ່ນຍັງບໍ່ທັນໄດ້ມີການບັນທຶກໄວ້ເທື່ອ. ເພາະສະນັ້ນ ພວກເຮົາຄາດຄະເນວ່າ ສິ່ງກີດຂວາງ ແລະ ການສ້າງພື້ນທີ່ກັກຂັງໄວ້ ໃນເຂື່ອນເຊກອງ #5 ອາດເກີດບັນຫາທີ່ໃຫຍ່ກວ່າກັບຊະນິດປາທີ່ມີຢູ່ສະເພາະແຕ່ໃນທ້ອງຖິ່ນຫຼາຍກວ່າໃນດ້ານມວນສານລວມ.

ການຫຼີກລ້ຽງຄວາມສ່ຽງທີ່ອາດເກີດໃນດ້ານນິເວດວິທະຍາ ໃນຂະນະທີ່ຂໍ້ມູນທີ່ຍັງບໍ່ພຽງພໍ ແມ່ນຫຼັກການທາງດ້ານວິທະຍາສາດ ທີ່ຕ້ອງມີຄວາມລະມັດລະວັງທາງດ້ານຍຸດທະສາດສໍາລັບການພັດທະນາເຂື່ອນໄຟຟ້າແບບຍືນຍົງ. ການເກັບກໍາຂໍ້ມູນໃນອະນາຄົດແມ່ນການແນະນໍາໃນລະດັບສູງໂດຍກອງປະຊຸມສໍາມະນາຂອງບັນດາຜູ້ຊ່ຽວຊານ ທີ່ກ່ຽວ ຂ້ອງກັບການເຄື່ອນຍ້າຍຂອງປາດ້ານເທິງຂອງຈຸດທີ່ຕັ້ງຂອງເຂື່ອນເຊກອງ #5, ກ່ອນຈະມີການຕັດສິນໃຈໃນການອະນຸ ຍາດການສ້າງເຂື່ອນດັ່ງກ່າວ. ໃນຂະນະທີ່ວ່າບໍ່ມີສິ່ງໃດທີ່ສະແດງໃຫ້ເຫັນເຖິງວຽກຕົວຈິງໃນພາກສະໜາມ, ຄວາມຫ່າງໄກສອກຫຼີກ, ຄວາມຫຍຸ້ງຍາກໃນການເກັບຕົວຢ່າງໃນຕອນເທິງຂອງສາຍນໍ້າໃນພື້ນທີ່ອ່າງໂຕ່ງ ອາດມີຄວາມຈໍາເປັນທີ່ຈະຮຽກຮ້ອງໃນການນໍາໃຊ້ເຕັກນິກທີ່ດີທີ່ສຸດ-ອັນດັບ 2 ເຊັ່ນວ່າ: ການແບ່ງເປັນຊັ້ນຂອງແຫຼ່ງທີ່ຢູ່ອາໃສໂດຍການໃຊ້ GIS, ການໃຊ້ຂໍ້ມູນຈາດລີໂມດເຊັນເຊີ (remotely sensed data) ແລະ ຕໍ່ດ້ວຍການປະເມີນວ່າມີຄວາມຫຼາກຫຼາຍທາງດ້ານຊະນິດພັນປາທີ່ໄດ້ມີການກ່ຽວພັນກັບຄວາມຫຼາກຫຼາຍທາງດ້ານແຫຼ່ງທີ່ຢູ່ອາໃສ. ຫຼັງຈາກນັ້ນ ສາຍນໍ້າທີ່ເປັນຕົວແທນ ຄວນມີການສະຫງວນໃນຂະນະທີ່ສາມາດມີການວາງແຜນຍຸດທະສາດໃນການພັດທະນາເຂື່ອນໄຟຟ້າ. ຕົວຢ່າງໃນຈຸດເຂື່ອນເຊກອງ #5 ຈະມີການຖ້ວມຂຶ້ນຂອງນໍ້າໃນລໍາແມ່ນໍ້າທີ່ຍາວກວ່າ ແລະ ນອກຈາກນັ້ນມັນກໍ່ຈະຍັງເຮັດໃຫ້ນໍ້າໄຫຼກັບຄືນສູ່ ປ່າປ້ອງກັນເຊເຊັດ (Xe Xet NPA). ຫາກມີການພິຈາລະນາຈາກສິ່ງດັ່ງກ່າວນັ້ນ, ຫຼັກການທີ່ແນະນໍາໃນການປ້ອງກັນລ່ວງໜ້າ ແມ່ນໄດ້ແນະນໍາວ່າ

ມັນຄວນຈະມີການລະມັດລະວັງໃນການຊອກຫາທາງເລືອກອື່ນໆທາງດ້ານຈຸດທີ່ຕັ້ງຂອງເຂື່ອນ. ອີງການ NHI ໄດ້ມີການວິເຄາະເຖິງຈຸດທີ່ຕັ້ງຂອງເຂື່ອນທີ່ເໝາະສົມ ທີ່ໄດ້ແນະນຳວ່າ ຫ້ວຍອາຊຳແມ່ນອາດເປັນທາງເລືອກທີ່ເປັນໄປໄດ້ທີ່ສາມາດສ້າງເຂື່ອນ ເພື່ອຫຼີກລ້ຽງໃນແມ່ນ້ຳສາຍຫຼັກ. ຢ່າງໃດກໍຕາມ ຍັງມີການຂາດແຄນທາງດ້ານຂໍ້ມູນທີ່ກ່ຽວຂ້ອງເຖິງຊະນິດປາທີ່ມີສະເພາະໃນທ້ອງຖິ່ນໃນຕອນເທິງຂອງແມ່ນ້ຳເຊກອງ, ຍັງບໍ່ທັນມີຂໍ້ມູນທີ່ເປັນພື້ນຖານທາງດ້ານວິທະຍາສາດໃນເວລານີ້ທີ່ພຽງພໍທີ່ຈະສາມາດປະເມີນວ່າ ຈຸດທີ່ຕັ້ງໃດທີ່ຈະມີຜົນກະທົບທີ່ໜ້ອຍທີ່ສຸດຕໍ່ຄວາມຫຼາກຫຼາຍທາງດ້ານຊີວະນາໆພັນ.

<u>ບັນຫາ 3:</u> ໃນຂອບເຂດໃດທີ່ສາມາດຕັນແລວນ້ຳ, ການຖ້ວມຂອງແຫຼ່ງຂະຫຍາຍພັນ ແລະ ແຫຼ່ງຫາອາຫານ ໂດຍບັນດາເຂື່ອນທີ່ຈະສ້າງຂຶ້ນໃນແມ່ນ້ຳເຊກອງ ທີ່ສາມາດລຸດຜ່ອນຜົນກະທົບດ້ວຍການສ້າງສິ່ງອຳນວຍຄວາມສະດວກໃຫ້ແກ່ການເຄື່ອນຍ້າຍຂອງປາ, ປ່ຽນການເປີດນຳໃຊ້ເຂື່ອນ ແລະ ການແຜ່ພັນແບບທຽມ (ໃນດ້ານການເພາະລ້ຽງ)?

ປັດໃຈອັນເປັນຕົ້ນຕໍທີ່ເຮັດໃຫ້ຜົນຜະລິດປາມີການລຸດລົງ ແລະ ຄວາມຫຼາກຫຼາຍທາງດ້ານຊີວະນາໆພັນ ຈາກການສ້າງເຂື່ອນໄຟຟ້າໃນແມ່ນ້ຳເຊກອງແມ່ນມີຄື:

- ການເຄື່ອນຍ້າຍຂອງປາໃນເຂດຕອນເທິງແມ່ນມີການລຸດລົງ
- ອັດຕາການຕາຍຂອງປາໃຫຍ່ເຕັມໄວ ແລະ ປາໄວໜຸ່ມທີ່ລອດຜ່ານໃບພັດ ແລະ ປະຕູນ້ຳ
- ການປ່ຽນແປງການໄຫຼຂອງນ້ຳໃນແຫຼ່ງທີ່ຢູ່ອາໃສ ເພື່ອໃຫ້ລະດັບນ້ຳມີຄວາມຄົງທີ່ໃນອ່າງເກັບນ້ຳ
- ການດັດແປງການໄຫຼຂອງນ້ຳໃນເຂດຕອນລຸ່ມ ແລະ ຄວາມຜັນຜວນຂອງກະແສນ້ຳ ເນື່ອງຈາກຄວາມແຕກຕ່າງຂອງການຮັບນ້ຳຈາກຈຸດປ່ຽນທາງອຸທົກກະສາດທີ່ເປີດນຳໃຊ້
- ການປ່ຽນແປງທາງດ້ານຄຸນນະພາບນ້ຳ

ການກີດກັນທາງຜ່ານຂອງປາ ແມ່ນສາມາດເຮັດໃຫ້ມີການລຸດຜ່ອນຜົນກະທົບລົງໄດ້ ໂດຍການສ້າງທາງປາຜ່ານແບບທຽມ ແຕ່ວ່າ ມັນກໍຍັງບໍ່ທັນມີຕົວຢ່າງທີ່ດີທີ່ສາມາດສະແດງເຖິງປະສິດທິພາບໃນການອຳນວຍຄວາມສະດວກໃຫ້ແກ່ການເຄື່ອນຍ້າຍຂອງປາໃນເຂື່ອນຂະໜາດໃຫຍ່ໃນແມ່ນ້ຳເຂດຮ້ອນຊຸ່ມທີ່ມີລັກສະນະຄ້າຍຄືແມ່ນ້ຳເຊກອງ. ປະສິດ ທິພາບໃນການນຳໃຊ້ທາງປາຜ່ານໃນການລຸດຜ່ອນບັນຫາສິ່ງກີດກັນຈາກການສ້າງເຂື່ອນຕໍ່ກັບການເຄື່ອນຍ້າຍຂອງປາໃນຕອນເທິງຂອງສາຍນ້ຳ ແມ່ນຍັງຂຶ້ນກັບແຕ່ລະອ່າງໂຕ່ງຂອງແມ່ນ້ຳ, ຂະໜາດຄວາມສູງຂອງເຂື່ອນ, ອັດຕາສ່ວນການໄຫຼຂອງນ້ຳໃນທາງປາຜ່ານ ແລະ ມອນສານໃນການເຄື່ອນຍ້າຍຂອງປາ (ລວມທັງປັດໃຈອື່ນໆ). ຂະໜາດຂອງການປ່ອຍນ້ຳອອກທີ່ມີຜົນດີຕໍ່ການສ້າງທາງປາຜ່ານໂດຍທົ່ວໄປແມ່ນປະມານ 10% ຂອງກະແສນ້ຳທີ່ໄຫຼເຂົ້າໃນອ່າງເກັບນ້ຳ [11], ໂດຍອີງໃສ່ພື້ນຖານປະສົບການຂອງສາກົນ. ນອກຈາກວ່າທາງປາຜ່ານແມ່ນເປັນປັດໃຈທີ່ເລີ່ມມີເຂົ້າໃນການອອກແບບ ແລະ ມີການທົດລອງໃນການເຈລະຈາຕໍ່ລອງກັບຜູ້ຜະລິດພະລັງງານ, ມັນຍັງແມ່ນສິ່ງທີ່ມີຄວາມຫຍຸ້ງຍາກຫຼາຍສຳລັບຜູ້ທີ່ເປີດນຳໃຊ້ເຂື່ອນໄຟຟ້າເພື່ອທີ່ຈະປ່ອຍນ້ຳໃນລະດັບ 10% ສຳລັບທາງປາຜ່ານ, ທີ່ຜ່ານມາ ນ້ຳທັງໝົດທີ່ໄດ້ແມ່ນນຳໃຊ້ເພື່ອການຜະລິດກະແສໄຟຟ້າ.

ຄວາມສູງຂອງຕີນປະຕູນ້ຳທີ່ຈະສ້າງ ສຳລັບທາງປາຜ່ານທີ່ມີປະສິດທິພາບໃນລະບົບອ່າງແມ່ນ້ຳຂອງ ແມ່ນໄດ້ມີການປະເມີນ ໂດຍອີງການ MRCS ໃນລະດັບ 30 m [11]. ເຖິງຢ່າງໃດກໍດີ, ປາແຕ່ລະຊະນິດແມ່ນມີຄວາມຕ້ອງການທີ່ແຕກຕ່າງກັນ. ເຖິງວ່າຈະມີປາຫຼາຍຊະນິດທີ່ມີການເຄື່ອນຍ້າຍຂຶ້ນລົງໃນແມ່ນໍ້ເຊກອງ ແລະ ລະບົບຕອນລຸ່ມຂອງແມ່ນ້ຳ, ມັນບໍ່ແມ່ນເລື່ອງງ່າຍທີ່ຈະອອກແບບສິ່ງອຳນວຍຄວາມສະດວກເຫຼົ່ານັ້ນ ຈະມີປະສິດທິພາບພາຍໃນການນຳໃຊ້ໄດ້ສຳລັບທຸກຊະນິດປາ. ເຖິງແມ່ນວ່າ ຖ້າມີມອນສານຫຼາຍແມ່ນສາມາດປັບໃຫ້ມັນມີຄວາມເໝາະສົມ ແຕ່ມັນກໍກ່ຽວພັນໄປເຖິງການລຸດລົງດ້ານຄວາມຫຼາກຫຼາຍທາງຊີວະນາໆພັນ.

ປາທີ່ສາມາດເຄື່ອນຍ້າຍລົງສູ່ຕອນລຸ່ມຂອງແມ່ນ້ຳໄດ້ສຳເລັດ ແມ່ນຂຶ້ນກັບສິ່ງທີ່ນຳມາກັ້ນ ເພື່ອປ້ອງກັນປາໂຕໃຫຍ່ລອຍລົງໄປໃນໃບພັດ ແລະ ການອອກແບບປະຕູນໍ້າລົ້ນ, ປະຕູນ້ຳ ແລະ ໃບພັດ. ອັດຕາການລອດຕາຍຂອງປາໃຫຍ່ທີ່ຜ່ານລົງຕອນລຸ່ມຂອງແມ່ນ້ຳໃຕ້ເຂື່ອນ ແມ່ນສາມາດລຸດຜ່ອນຜົນກະທົບໄດ້ ດ້ວຍຂະໜາດຂອງສິ່ງກີດກັ້ນ ຫຼື ພຶດຕິກຳຂອງປາເອງ ແຕ່ສິ່ງເຫຼົ່ານີ້ກໍຍັງບໍ່ທັນໄດ້ມີການຈັດຕັ້ງປະຕິບັດທີ່ເກີດຜົນສຳເລັດໃນເຂື່ອນທີ່ສ້າງໃນແມ່ນ້ຳຂະ ໜາດໃຫຍ່ໃນເຂດຮ້ອນມາກ່ອນ [6] ໃນປະຈຸບັນ, ແມ່ນຍັງບໍ່ມີໃບພັດທີ່ເຮັດໃຫ້ສາມາດຫຼີກລ້ຽງການຕາຍຂອງຊະນິດປາໃນແມ່ນ້ຳຂອງ ເຖິງແມ່ນວ່າຈະມີບ່າງສ່ວນທີ່ມີການພັດທະນາທີ່ດີຂຶ້ນກວ່າສິ່ງອື່ນໆແລ້ວກໍຕາມ.

ປາສາມາດໄດ້ຮັບບາດເຈັບ ແລະ ຕາຍໄດ້ຈາກໃບພັດເຊັ່ນ: i) ການປ່ຽນແປງຄວາມດັນຂອງນ້ຳແບບກະທັນຫັນ (barotrauma), ii) ການຕັດຂອງແຮງດັນ ແລະ iii) ການກະທົບຂອງໃບພັດ ແລະ ພາກສ່ວນອື່ນໆ. ໃບພັດທີ່ຕິດຕັ້ງຢູ່ປາຍຂອງທາງນ້ຳ ສິ່ງຜົນໃຫ້ເກີດການປ່ຽນແປງແຮງດັນທີ່ມີຜົນກະທົບສູງຫຼາຍຕໍ່ກັບຖົງລົມຂອງປາ ສິ່ງເຫຼົ່ານັ້ນແມ່ນບໍ່ສາມາດລຸດຜ່ອນລົງໄດ້ແບບງ່າຍໆ (ຕົວຢ່າງ: ຈຳພວກປາເກັດ) ແລະ ມັນຈະເກີດຜົນກະທົບກັບປາໜ້ອຍທີ່ສຸດຖ້າຫາກສາມາດລຸດຜ່ອນລົງໄດ້ແບບງ່າຍ (ຕົວຢ່າງ ປາໜັງບາງຊະນິດ). ໃນດ້ານທິດສະດີ ບາໂຣໂທຣມາ ສາມາດຫຼຸດຜ່ອນຜົນກະທົບໄດ້ໂດຍການນຳໃຊ້ໃບພັດທີ່ຕິດຕັ້ງໃນລະດັບເລິກ ແຕ່ວ່າສິ່ງເຫຼົ່ານີ້ກໍຍັງບໍ່ທັນມີການທົດສອບວ່າສາມາດນຳໄປໃຊ້ໄດ້. ການອັດແໜ້ນຂອງແກສໃນນ້ຳທີ່ສູງເກີນໄປໃນຕອນທ້າຍຂອງນ້ຳ ກັບລະດັບຄວາມດັນໃນການຈັດລຽງແຕ່ 105% ຫາ 110%, ແມ່ນສາມາດກໍ່ໃຫ້ເກີດພະຍາດຕຸ່ມໂພງໃນໂຕປາ. ປາຈະຕາພາຍໃນ 2 – 3 ຊົ່ວໂມງ ເມື່ອພວກມັນໄດ້ຮັບແກສເຂົ້າໄປໃນລະດັບ 140%. [12]

ການຕັດຂອງແຮງດັນແມ່ນກໍ່ໃຫ້ເກີດມີການຕາຍສູງໃນໄລຍະເປັນໄຂ່, ລູກປາເກີດໃໝ່ ແລະ ເພີ່ມການຕາຍຂຶ້ນຕື່ມອີກໃນໄລຍະລູກປາໄວອ່ອນ. ການກະທົບດັ່ງກ່າວນີ້ແມ່ນເປັນສາຍເຫດທີ່ມີລັກສະນະເພີ່ມຂຶ້ນໃນປາຂະໜາດ: ປາຂະໜາດນ້ອຍແມ່ນຈະມີຜົນກະທົບທີ່ໜ້ອຍກວ່າຈາກການກະທົບ ແລະ ອາດຈະສາມາດຜ່ານໃບພັດໄດ້ໃນລະດັບເລິກດ້ວຍອັດຕາການຕາຍທີ່ຕ່ຳ ແຕ່ໃນການຈັດຕັ້ງປະຕິບັດຕົວຈິງແມ່ນຈະມີຂໍ້ຈຳກັດຂະໜາດຂອງປາທີ່ລອດຜ່ານໃບພັດ ເຊັ່ນຂະໜາດລວງຍາວຂອງລຳໂຕປະມານ 300 mm; ປາທີ່ມີຂະໜາດໃຫຍ່ກວ່າຈະມີໂອກາດທີ່ຈະໄດ້ຮັບຜົນກະທົບຈາກສິ່ງດັ່ງກ່າວນີ້ສູງກວ່າ.

ຜົນກະທົບທີ່ເກີດຈາກອ່າງເກັບນ້ຳແມ່ນບໍ່ສາມາດຫຼີກລ້ຽງໄດ້ ຫຼື ລຸດຜ່ອນຜົນກະທົບໃນຂະໜາດທີ່ມີຄວາມເຊື່ອຖື ສິ່ງເຫຼົ່ານັ້ນແມ່ນປະກອບມີ 6 ປະເພດ:

- ການໄຫຼຂອງນ້ຳໃນບ່ອນທີ່ຢູ່ອາໃສທີ່ມີການຂະຫຍາຍພັນມີການລຸດລົງ
- ການຖ້ວມຂອງນ້ຳໃນພື້ນທີ່ປາທີ່ມີການຈະເລີນເຕີບໂຕ
- ການຕາຍຂອງໄຂ່ ແລະ ລູກປາໄວອ່ອນໃນລະດັບນ້ຳທີ່ຄົງທີ່ໃນອ່າງເກັບນ້ຳ
- ການຕົກຕະກອນຂອງດິນທີ່ເປັນຜົນທຳລາຍແຫຼ່ງປະສົມພັນ ແລະ ທີ່ຢູ່ອາໃສ
- ການປ່ຽນແປງຄຸນນະພາບນ້ຳ, ເກີດຂຶ້ນໂດຍການປ່ຽນແປງລະດູການ ແລະ ສິ່ງຜົນໃຫ້ເກີດ ອາໂນເຊຍ (anoxia) ໃນນ້ຳທີ່ລະດັບລຸ່ມ.
- ການປ່ຽນແປງທາງດ້ານອົງປະກອບຊະນິດ ແລະ ຜົນກະທົບໃນດ້ານຕ່ອງໂສ້ອາຫານ

ມີປາຊະນິດທີ່ມີການເຄື່ອນຍ້າຍໃນແມ່ນ້ຳຂອງຫຼາຍຊະນິດ ທີ່ຂະຫຍາຍພັນແລ້ວປ່ອຍໃຫ້ລູກປາແຂວນລອຍໄປຕາມນ້ຳ[1]. ການໄຫຼຂອງນ້ຳໃນອ່າງເກັບນ້ຳແມ່ນມີຄວາມສຳຄັນສຳລັບຂົນສົ່ງລູກປາ. ລະດັບການຕາຍຂອງລູກປາທີ່ລອຍລົງສູ່ຕອນລຸ່ມຂອງອ່າງເກັບນ້ຳທີ່ເປັນເປົ້າໝາຍໃນແມ່ນ້ຳເຊກອງ ອາດຂຶ້ນກັບ 2 ກຸນແຈທີ່ສຳຄັນ ຂອງລັກສະນະທາງດ້ານເຄື່ອງໄຮໂດລິກ:

i) ການປ່ຽນແປງໃນເຄື່ອງໄຮໂດລິກຈາກນ້ຳໄຫຼ ມາເປັນນ້ຳທີ່ຢຸດນິ້ງ. ນີ້ແມ່ນການປ່ຽນແປງຜູ້ໄລ່ລ້າ ທີ່ມີການກ່ຽວພັນກັບເຍື່ອ ໂດຍສະເພາະແມ່ນກັບລູກປາຂະໜາດນ້ອຍທີ່ປັບຕົວເຂົ້າກັບການຈັບເຍື່ອໃນນ້ຳໄຫຼ. ນີ້ແມ່ນອາດກ່ຽວພັນກັບການລຸດລົງທາງດ້ານຄວາມຂຸ້ນໃສຂອງນ້ຳ ເຊິ່ງຈະສົ່ງຜົນໃຫ້ດິນຕົມສາມາດຈົມລົງພື້ນນ້ຳໄດ້ງ່າຍ; ສິ່ງນີ້ແມ່ນສາມາດເຮັດໃຫ້ລູກປາໄດ້ຮັບຜົນກະທົບໄດ້ງ່າຍຕໍ່ການໄລ່ລ້າ.

ii) ບ່ອນທີ່ປາຢູ່ໃນຂະນະທີ່ນ້ຳໄຫຼຜ່ານລົງຈາກອ່າງເກັບນ້ຳ ຈະສົ່ງຜົນກະທົບໃຫ້ແກ່ຖິ່ງອາຫານໃນລູກປາແຕກໃໝ່ ແລະ ປາໄວອ່ອນທີ່ແຂວນລອຍນຳນ້ຳ (ໃນຈຳນວນເງື່ອນໄຂອື່ນໆ). ນອກຈາກວ່າ ລູກປາຈະເຂົ້າມາໃນອ່າງນ້ຳກ່ອນອາຫານທີ່ໃຊ້ລ້ຽງຊີບໝົດໄປ, ພວກມັນຈະບໍ່ສາມາດລອດໄດ້ ຖ້າແຫຼ່ງອາຫານທີ່ ເໝາະສົມຫາກບໍ່ມີໃນອ່າງເກັບນ້ຳ. ເຂື່ອນໄຟຟ້ານ້ຳຕົກແມ່ນຈະເກີດມີຜົນກະທົບທີ່ເພີ່ມພູນຂຶ້ນ.

ເຄື່ອງໄຮໂດລິກຂອງອ່າງເກັບນ້ຳ ແລະ ເວລາທີ່ຢູ່ອາໃສ ສາມາດກຳນົດໄດ້ໂດຍລະດັບນ້ຳທີ່ໄດ້ມີການເກັບກັກໄວ້ໃນອ່າງ ແລະ ອັດຕາທີ່ປ່ອຍອອກຈາກເຂື່ອນ. ໃນທາງທິດສະດີ, ມັນມີຄວາມເປັນໄປໄດ້ທີ່ຈະມີການຄວບຄຸມອ່າງເກັບນ້ຳໃນການເປີດນຳໃຊ້ ເພື່ອຮັກສາລະດັບການໄຫຼຂອງນ້ຳທີ່ເໝາະສົມກັບເຄື່ອງໄຮໂດລິກ ແລະ ການຂົນສົ່ງລູກປາໃນອ່າງອອກໄປສູ່

[1] Here we define larvae as the phase between hatching from the egg up to the time the fish is a juvenile. This larval phase can further be sub-divided into three stages: (i) Yolk-sac stage: after hatching the larva has a yolk sac, which is visibly attached to the anterio-ventral part of its body; (ii) Pre-larval stage: this stage begins when the eye is fully pigmented and the mouth and anus are open and the fish begins to feed on external prey; and (iii) Post-larval stage: during this stage, the urostyle completes upward flexion, the caudal, dorsal and anal fins develop, and the small fish begins to resemble a juvenile (Termvidchakorn, A. and K.G. Hortle, 2013).

ຈຸດທີ່ປ່ອຍນໍ້າລົ້ນ ແລະ ໃບພັດ ກ່ອນທີ່ພວກມັນຈະຕາຍໄປຍ້ອນການຂາດແຄນທາງດ້ານອາຫານ, ໂດຍການປະເມີນວ່າແຫຼ່ງອາຫານທີ່ເໝາະສົມແມ່ນໝົດໄປໃນອ່າງເກັບນໍ້າ. ເຖິງຢ່າງໃດກໍ່ຕາມ, ການຄວບຄຸມດັ່ງກ່າວອາດເປັນຜົນກະທົບຕໍ່ກັບການຜະລິດກະແສໄຟຟ້າ ແລະ ລາຍຮັບ, ເຊິ່ງມັນຈະສະແດງໃຫ້ເຫັນໂດຍກົງການແລກປ່ຽນລະຫວ່າງການຮັກສາການປະມົງ ແລະ ຈຸດປະສົງຂອງເຂື່ອນໄຟຟ້າ.

ໃນແມ່ນໍ້າເຊກອງ, ຊະນິດປາທີ່ມີຄວາມສໍາຄັນທາງດ້ານເສດຖະກິດທີ່ມີການເຄື່ອນຍ້າຍ ແລະ ຂະຫຍາຍພັນໃນລະຫວ່າງຕົ້ນລະດູຝົນ ເມື່ອປະລິມານການໄຫຼຂອງນໍ້າທີ່ຜ່ານອ່າງເກັບນໍ້າມີໃນລະດັບສູງກ່ອນລະດູແລ້ງ [10]. ສິ່ງເຫຼົ່ານີ້ຈະຊ່ວຍໃນການແຂວນລອຍຂອງລູກປາໄປຕະຫຼອດອ່າງເກັບນໍ້າ ແລະ ຜົນທີ່ຕາມມາສໍາລັບການເກັບກັກລະດັບນໍ້າໃນອ່າງ ແລະ ການຜະລິດກະແສໄຟຟ້າອາດຈະບໍ່ສາມາດເຮັດໄດ້ຫຼາຍ.

ເຖິງຢ່າງໃດກໍຕາມ, ມັນກໍ່ມີປາຫຼາຍຊະນິດທີ່ມີການຂະຫຍາຍພັນໃນຊ່ວງລະດູແລ້ງ. ການປະຕິບັດໃນໄລຍະຜ່ານມາກໍຍັງບໍ່ສາມາດເປັນທີ່ເຊື່ອຖືໄດ້ໃນການລອດຕາຍຂອງປານ້ອຍທີ່ມີການແຂວນລອຍໃນໄລຍະໄກ ຍ້ອນພື້ນທີ່ໃນການປະສົມພັນຂອງປາໃນໄລຍະນໍ້າທີ່ມີການໄຫຼຊ້າ. <u>ເວລາທີ່ມີຄວາມຊັບຊ້ອນທີ່ສຸດແມ່ນ ເມື່ອລູກປາແຂວນລອຍຜ່ານອ່າງເກັບນໍ້າ ເຊິ່ງອາດເກີດບັນຫາໃນຊ່ວງໄລຍະຕົ້ນລະດູຝົນ ເມື່ອການຂະຫຍາຍພັນແມ່ນເກີດຂຶ້ນໃນປະລິມານທີ່ຫຼາຍ ແຕ່ປະລິມານການໄຫຼຂອງນໍ້າແມ່ນຍັງບໍ່ມີລະດັບທີ່ສູງພຽງພໍທີ່ສະໜອງໃຫ້ແກ່ຄວາມຕ້ອງການຂອງກະແສນໍ້າໄຫຼໃນອ່າງເກັບນໍ້າ.</u>

ສະຫຼຸບລວມແລ້ວ ມັນແມ່ນອ່າງເກັບນໍ້າທີ່ມີຜົນກະທົບອັນຕົ້ນຕໍຕໍ່ການເຄື່ອນຍ້າຍຂອງປາ ສິ່ງເລົ່ານັ້ນແມ່ນບໍ່ສາມາດທີ່ຈະລຸດຜ່ອນລົງໄດ້ຢ່າງມີປະສິດທິພາບ. ປາທີ່ມີການເຄື່ອນຍ້າຍໃນແມ່ນໍ້າເຊກອງແມ່ນມີຄວາມຕ້ອງການນໍ້າທີ່ໄຫຼຜ່ານແຫຼ່ງທີ່ຢູ່ອາໃສ ເພື່ອການຂະຫຍາຍພັນ. ເຖິງແນວໃດກໍຕາມ ການປະເມີນລະດັບຂອບອ່າງນໍ້າເພື່ອຈຸດປະສົງໃນການເຮັດເຂື່ອນໄຟຟ້າ ສິ່ງທີ່ສໍາຄັນທີ່ຕ້ອງຮູ້ເຖິງຜົນກະທົບ ແລະ ນໍາມາພິຈາລະນາເພື່ອຄວາມຍືນຍົງ. ເຖິງແມ່ນວ່າ ຖ້າອ່າງນໍ້າເຫຼົ່ານັ້ນຈະມີການເປີດນໍາໃຊ້ຫຼາຍ ຫຼື ໜ້ອຍກໍຕາມເຊັ່ນກັບການໄຫຼຂອງນໍ້າ, ພວກເຂົາຍັງຕ້ອງການອ່າງເກັບນໍ້າເພື່ອສ້າງໃຫ້ໄດ້ລະດັບທີ່ເໝາະສົມກັບຫົວຂອງເຄື່ອງໄຮໂດລິກ ແລະ ສິ່ງເຫຼົ່ານີ້ມັນກໍ່ແມ່ນບັນຫາທີ່ຊັບຊ້ອນທີ່ສົ່ງຜົນກະທົບ.

ການແຜ່ພັນແບບທຽມຂອງປາ ແມ່ນໝາຍເຖິງການເພາະລ້ຽງໃນອ່າງເກັບນໍ້າ ແມ່ນບໍ່ສາມາດທົດແທນທາງດ້ານຊະນິດປາ, ຜົນຜະລິດ ຫຼື ຊີວິດການເປັນຢູ່ຂອງຄົນທ້ອງຖິ່ນທີ່ໄດ້ມີການສູນເສຍການຫາປາໃນທໍາມະຊາດທີ່ເສຍໄປ ໂດຍການສ້າງເຂື່ອນໄຟຟ້າ. ຟາມລ້ຽງປາໂດຍທົ່ວໄປແມ່ນມີຄວາມແຕກຕ່າງອອກໄປ ແລະ ປົກກະຕິແມ່ນເປັນຊະນິດທີ່ມີມູນຄ່າຕໍ່າ; ສິ່ງໜຶ່ງກໍເປັນການລຸດລົງຂອງຄວາມຫຼາກຫຼາຍຂອງຊະນິດພັນປາ; ຄວາມແຕກຕ່າງທາງດ້ານຕົ້ນທຶນ, ຜູ້ປະກອບການ ແລະ ໂຄງສ້າງທາງດ້ານການຕະຫຼາດ; ແລະ ມີຄວາມຕ້ອງການທາງດ້ານທັກສະຄວາມຮູ້ທີ່ແຕກຕ່າງກັນ ຫຼາຍກວ່າການຫາປາໃນແຫຼ່ງນໍ້າທໍາມະຊາດ. ການຢູ່ລອດຂອງຊະນິດພັນປາບໍ່ຄວນຂຶ້ນກັບພຽງແຕ່ເງື່ອນໄຂການລ້ຽງ ຫຼື ສິ່ງທີ່ກັກຂັງໄວ້. ພາຍໃຕ້ນະໂຍບາຍທາງດ້ານການເມືອງ ຫຼື ເງື່ອນໄຂທາງເສດຖະກິດທີ່ບໍ່ອໍານວຍ ຫຼື ຍ້ອນຜົນປະໂຫຍດທີ່ບໍ່ເໝາະສົມ, ການເພາະລ້ຽງ ແລະ ການປ່ອຍອາດມີການແຜ່ຫຼາຍ ແລະ ອາດມີຊະນິດທີ່ສູນພັນ.

ການພັດທະນາການລ້ຽງປາໃນອ່າງ ຫຼື ໃກ້ກັບພື້ນທີ່ອ່າງນໍ້າທີ່ສ້າງຂຶ້ນມາໃໝ່ ແມ່ນຈະສາມາດເກີດປະໂຫຍດໄດ້ໃຫ້ຜູ້ທີ່ຍ້າຍເຂົ້າມາຢູ່ໃໝ່ ຫຼື ຍາດພີ່ນ້ອງທີ່ຜູ້ທີ່ຢູ່ດັ້ງເດີມ ລວມທັງຜູ້ທີ່ມີທັກສະ ແລະ ປະສົບການທາງດ້ານເສດຖະກິດ ຫຼາຍກວ່າຊາວປະມົງທີ່ຢູ່ອາໃສໃນແຫ່ງດັ່ງກ່າວ, ຜູ້ທີ່ມີການສູນເສຍການຫາປາຈາກທໍາມະຊາດ ແລະ ເປັນຜູ້ທີ່ບໍ່ໄດ້ຮັບປະໂຫຍດຈາກອາຊີບການລ້ຽງປາ. ສິ່ງເຫຼົ່ານີ້ປົກກະຕິແລ້ວ ຈະຕ້ອງໄດ້ມີການພິຈາລະນາກັນຢ່າງກວ້າງຂວາງເພື່ອໃຫ້ມີຄວາມເທົ່າທຽມກັນ. ການຍົກປະສິດທິພາບຂອງປະຊາກອນປາທີ່ມີໃນອ່າງ ໂດຍການປ່ອຍປາທີ່ເປັນຊະນິດຕ່າງຖິ່ນ (ຊະນິດນໍາເຂົ້າ) ກັບລະບົບອາຫານທີ່ອຸດົມສົມບູນຂອງລະບົບນິເວດ ກັບຄຸນຄ່າທາງດ້ານອາຫານໃນລະບົບນິເວດທີ່ອາດຖືກທໍາລາຍຈາກຊະນິດປາທີ່ປ່ອຍລົງ ຫຼື ອາດຈະໄປປ່ຽນແປງໄປ ແລະ ບໍ່ສາມາດທົດແທນກັບຜົນຜະລິດທີ່ໜ້າຈະເກີດຂຶ້ນໃນອ່າງ.

ບັນດາຜູ້ເຂົ້າຮ່ວມໃນງານສໍາມະນາຄັ້ງນີ້ ກໍຍັງໄດ້ເນັ້ນໜັກກ່ຽວກັບຜົນກະທົບທາງດ້ານຄຸນນະພາບນໍ້າທີ່ກ່ຽວ ຂ້ອງ ຫຼື ເຮັດໃຫ້ເກີດມີຄວາມຮຸນແຮງຂຶ້ນດ້ວຍ ອ່າງເກັບນໍ້າອາດເປັນເງື່ອນໄຂເພີ່ມຂຶ້ນມາທີ່ຊ່ວຍໃຫ້ປາສາມາດລອດຕາຍ. ສິ່ງເຫຼົ່ານັ້ນແມ່ນປະກອບທັງແນວໂນ້ມຂອງອ່າງເກັບນໍ້າ ທີ່ຈັດແບ່ງລະດັບຄວາມຮ້ອນ, ປະລິມານອອກຊີເຈນທີ່ອາດສາມາດລຸດລົງ ແລະ ຄວາມເຂັ້ມຂຸ້ນຂອງສານພິດທີ່ຈະປົນມາກັບນໍ້າທີ່ໄຫຼເຂົ້າມາ (ຕົວຢ່າງ: ຈາກການຂຸດຄົ້ນບໍ່ແຮ່ຕ່າງໆ). ການເຊື່ອມໂຊມຂອງຄຸນນະພາບນໍ້າຈາກການຂຸດຄົ້ນແຮ່ຄໍາ ແລະ ຖ່ານຫີນ ແມ່ນເປັນສິ່ງສໍາຄັນອັນໜຶ່ງທີ່ສົ່ງຜົນໃຫ້ມີການລຸດລົງທາງການປະມົງໃນແມ່ນໍ້າເຊກອງ. ສານໂລຫະໜັກທີ່ປະປົນມາກັບການຂຸດຄົ້ນບໍ່ຄໍາ ອາດເປັນບັນຫາທີ່ສໍາຄັນ ແລະ ການປະປົນຂອງສານໂລຫະໜັກເຂົ້າໄປໃນອ່າງເກັບນໍ້າ ອາດກໍ່ໃຫ້ເກີດບັນຫາທີ່ເປັນອັນຕະລາຍຕໍ່ການບໍລິໂພກປາ [13]. ສິ່ງເຫຼົ່ານີ້ອາດເຮັດໃຫ້ມີການສູນເສຍແກ່ລັດຖະບານຂອງ ສປປ ລາວ ທີ່ປະຈຸບັນ ມີຄວາມພະຍາຍາມທີ່ຈະຄວບຄຸມຜົນກະທົບເຫຼົ່ານັ້ນ. ສິ່ງເຫຼົ່ານີ້ອາດແມ່ນຂໍ້ເສຍສະເພາະຊ່ວງໃດໜຶ່ງ ເຊັ່ນດຽວກັບລັດທະບານ ສປປ ລາວ ປະຈຸບັນແມ່ນກໍາລັງພະຍາຍາມໃນການຄວບຄຸມຜົນກະທົບເຫຼົ່ານັ້ນ. ສິ່ງເຫຼົ່ານີ້ແມ່ນການປຽບທຽບເພື່ອໃຫ້ເຫັນຄວາມແຕກຕ່າງຂອງສາຍເຫດທີ່ເຮັດໃຫ້ມີການເຊື່ອມໂຊມດ້ວຍເຂື່ອນໄຟຟ້າ ອັນທີ່ເປັນສິ່ງທີ່ຈໍາເປັນຖາວອນ ແລະ ຊີ້ຂາດ.

<u>ບັນຫາ 4:</u> ຄວນຈະມີການເປີດນໍາໃຊ້ເຂື່ອນໃນແມ່ນໍ້າເຊກອງ ແລະ ສາຂາແນວໃດ ທີ່ຈະສົ່ງຜົນຕໍ່ຮູບແບບການໄຫຼຂອງນໍ້າໃນເຂດຕອນລຸ່ມ ທີ່ມີຄວາມສໍາຄັນຕໍ່ການເຄື່ອນຍ້າຍຂອງປາເພື່ອການຂະຫຍາຍພັນ ແລະ ການຢູ່ລອດ?

ຈະມີເຂື່ອນອັນໃດໃນແມ່ນໍ້າເຊກອງທີ່ຄວນຕ້ອງມີການເປີດນໍາໃຊ້ ເພື່ອເຮັດໃຫ້ຮູບແບບການໄຫຼຂອງນໍ້າເຫຼົ່າ ນັ້ນຊ່ວຍເຮັດໃຫ້ເກີດຜົນດີຕໍ່ຄວາມຕ້ອງການໃນການເຄື່ອນຍ້າຍ ແລະ ການຢູ່ໃນທ້ອງຖິ່ນຂອງປາ, ໂດຍປົກກະຕິແມ່ນມີການອ້າງອີງວ່າ "ຄວາມຕ້ອງການປະລິມານການໄຫຼແບບທໍາມະຊາດ". ວິທີທາງໃນການເຂົ້າຫາໂດຍທົ່ວໄປແມ່ນ ການຮັກສາໄວ້ໃຫ້ຫຼາຍທີ່ສຸດຂອງການໄຫຼທີ່ປ່ຽນແປງຕາມລະດູການຂອງທໍາມະຊາດ ແລະ ອຸນຫະພູມ ໂດຍສະເພາະແມ່ນເພື່ອຫຼີກລ້ຽງການປ່ຽນແປງການໄຫຼຂອງນໍ້າທີ່ແຕກຕ່າງກັນຫຼາຍໃນແຕ່ລະຊົ່ວໂມງ ຫຼື ແຕ່ລະວັນ. ສິ່ງເຫຼົ່ານີ້ແມ່ນຄວາມຕ້ອງການໃນການປັບສົມດຸນໃນການປ່ອຍນໍ້າ ແລະ ຕ້ອງມີການປັບລະບຽບການໃນການປ່ອຍນໍ້າໄຫຼໃນຕອນລຸ່ມຂອງອ່າງເກັບນໍ້າ.

ປາທີ່ມີການເຄື່ອນຍ້າຍ ປະຈຸບັນແມ່ນມີຂຶ້ນໃນລະດັບ 56 km ໃນສາຍນໍ້າເຊກະມານ ທີ່ໄຫຼຈາກເຂື່ອນເຊກະມານ ຊຸ້ນໄຊ ຫາປາກແມ່ນໍ້າ. ປາຂະໜາດນ້ອຍຫຼາຍຊະນິດທີ່ມີການພົບເຫັນໃນແຫ່ງດັ່ງກ່າວ [2], [3]. ປາທີ່ມີການເຄື່ອນຍ້າຍກໍ ໄດ້ມີການພົບເຫັນໃນແມ່ນໍ້າເຊຊູ ທີ່ປະຈຸບັນຍັງບໍ່ທັນມີການພັດທະນາເຂື່ອນໄຟຟ້າ. ມັນໄດ້ມີການລວມເຂົ້າກັນໃນຕອນລຸ່ມ ຂອງເຊກະມານຂອງເຂື່ອນຊຸ້ນໄຊ ແລະ ກ່ອນປາກແມ່ນໍ້າທີ່ໄຫຼລົງສູ່ເຊກອງທີ່ແຂວງອັດຕະປື. ສະແດງໃຫ້ເຫັນວ່າ ເຊຊູແມ່ນ ມີກະແສນໍ້າທີ່ໄຫຼໂດຍບໍ່ມີສິ່ງກີດຂວາງຈາກຍອດນໍ້າລົງຫາປາກແມ່ນໍ້າ ລວມທັງແມ່ນໍ້າຂອງນັບແຕ່ປາກນໍ້າຢູ່ທະເລຈີນໃຕ້. ເຖິງຢ່າງໃດກໍຕາມ ຂໍ້ມູນທີ່ຈະນໍາມາຢືນຢັນເຖິງສະພາບຄວາມເປັນຈິງແມ່ນຍັງບໍ່ທັນມີພຽງພໍ ເພື່ອກໍານົດມູນຄ່າຂອງລໍານໍ້າສໍາ ລັບການເຄື່ອນຍ້າຍປາເພື່ອຂະຫຍາຍພັນ ແລະ ຈະເລີນເຕີບໂຕ. ຖ້າຫາກວ່າ ສາຍນໍ້າດັ່ງກ່າວໄດ້ມີການກໍານົດວ່າມີຄວາມສໍາ ຄັນສໍາລັບການເຄື່ອນຍ້າຍຂອງປາ, ສິ່ງທີ່ຕ້ອງເອົາໃຈໃສ່ແມ່ນການເປີດນໍາໃຊ້ເຂື່ອນເຊກະມານຊຸ້ນຊາຍ ເພື່ອປ່ອຍນໍ້າໃຫ້ເປັນ ໄປຕາມຮູບແບບຂອງທໍາມະຊາດ ດັ່ງທີ່ໄດ້ອະທິບາຍມາກ່ອນ. ນີ້ອາດແມ່ນຄວາມຈໍາເປັນທີ່ຕ້ອງໄດ້ເປີດນໍາໃຊ້ເຂື່ອນເຊກະ ມານຊຸ້ນໄຊ ລວມທັງການປັບຄືນລະບຽບການຂອງອ່າງເກັບນໍ້າ ຫຼື ການກໍ່ສ້າງແຍກໃນການເປີດເຂື່ອນເພື່ອປ່ອຍນໍ້າລົງສູ່ ຕອນລຸ່ມຄືນໃໝ່ ເພື່ອຕ້ານກັບນໍ້າທີ່ໄຫຼຕົກອອກມາຈາກເຂື່ອນຕອນເທິງ ໃນສາຍນໍ້າເຊກະມານ. ວິທີການທີ່ດີທີ່ສຸດ ແມ່ນ ການສ້າງເງື່ອນໄຂການໄຫຼຂອງນໍ້າຕາມສະພາບແວດລ້ອມ ແລະ ເງື່ອນໄຂທາງດ້ານຄຸນນະພາບນໍ້າ ສິ່ງເຫຼົ່ານີ້ ແມ່ນທຸກເຂື່ອນ ຈະຕ້ອງໄດ້ມີການຄໍານຶງເຖິງ.

ໂດຍການປະເມີນສາມາດບອກໄດ້ວ່າ ເຊກະມານ ແມ່ນປະກອບສ່ວນ 15% ຂອງນໍ້າທີ່ໄຫຼລົງສູ່ເຊກອງ, ການໄຫຼ ແມ່ນຜິດອອກໄປຈາກລະດັບການປ່ຽນແປງການໄຫຼຂອງນໍ້າ ແລະ/ຫຼື ການເກັບກັກນໍ້າໃນລະດູການທີ່ເຂື່ອນເຊກະມານຊຸ້ນ ຊາຍ ອາດເຮັດໃຫ້ມີພື້ນທີ່ນໍ້າຖ້ວມໃນຕອນລຸ່ມລຸດໜ້ອຍລົງ (ໂດຍສະເພາະສ່ວນທີ່ຢູ່ໃນປະເທດກໍາປູເຈຍ), ເຖິງແມ່ນວ່າຮູບ ແບບການໄຫຼຂອງນໍ້າ ແມ່ນຄວາມຈໍາເປັນທີ່ຕ້ອງນໍາມາຢືນຢັນໃນຂອບເຂດການລຸດລົງຂອງນໍ້າທີ່ເກີດຂຶ້ນ. ການເປີດນໍາໃຊ້ ເຂື່ອນໄຟຟ້າໃນອ່າງແມ່ນໍ້າຂອງ ແມ່ນໄດ້ປະກອບສ່ວນລະດັບນໍ້າໃນຮອບປີ ຈົນເຖິງຕອນລຸ່ມໃນພະນົມເປັນ. ເຖິງແນວໃດກໍ ຕາມ, ຜົນກະທົບທີ່ເກີດຈາກການປ່ຽນແປງໃນແຕ່ລະວັນ ແມ່ນຈະຂຶ້ນກັບແຕ່ລະທ້ອງຖິ່ນຫຼາຍກວ່າ [10].

ການເຄື່ອຍຍ້າຍຂອງປາກໍມີການປະກົດໃຫ້ເຫັນໃນໄລຍະ ~75 km ຕາມລໍາແມ່ນໍ້າກອງ ຈາກຈຸດເຂື່ອນນໍ້າກອງ #2 ໄປຫາປາກແມ່ນໍ້າ. ສາຍນໍ້າດັ່ງກ່າວນີ້ແມ່ນມີເຂດເລິກ ແລະ ວັງເລິກຢູ່ຫຼາຍແຫ່ງ. ມັນອາດມີຄວາມສໍາຄັນໃນການເຄື່ອນ ຍ້າຍຂອງປາເພື່ອການຂະຫຍາຍພັນ. ການສຶກສາແມ່ນຍັງມີຄວາມຕ້ອງການເພື່ອຢືນຢັນສິ່ງດັ່ງກ່າວ. ໃນເດືອນ 3 ປີ 2016, ກະຊວງພະລັງງານ ແລະ ບໍ່ແຮ່ ໄດ້ມີຂໍ້ຕົກລົງໃນການອະນຸຍາດໃຫ້ມີການກໍ່ສ້າງເຂື່ອນນໍ້າກອງ # 1 ໃນຕອນລຸ່ມຂອງຈຸດ ເຂື່ອນນໍ້າກອງ # 2. ສິ່ງດັ່ງກ່າວນີ້ ອາດຈະເປັນການສ້າງໃຫ້ເກີດມີອ່າງເກັບນໍ້າທີ່ສາມາດກັກເກັບນໍ້າໄວ້ໄດ້ຮອດເຂື່ອນນໍ້າກອງ # 2, ແລະ ເຖິງຢ່າງໃດກໍຕາມ ມັນກໍ່ຈະເປັນການທໍາລາຍແຫຼ່ງທີ່ຢູ່ອາໃສຂອງປາ.

ບັນຫາ 5: ລັກສະນະອັນໃດທີ່ເປັນແບບທຳມະຊາດຂອງລະບົບນິເວດວິທະຍາທີ່ຈະເປັນຜົນ ຖ້າເງື່ອນໄຂການໄຫຼຂອງນ້ຳໃນເຂດກອງທາກເຂົ້າມາປ່ຽນແທນໂດຍເງື່ອນໄຂຄືງທີ່ຂອງອ່າງເກັບນ້ຳ?

ສິ່ງກີດກັນທາງດ້ານອຸທົກກະສາດຂອງອ່າງເກັບນ້ຳ, ຄືດັ່ງທີ່ໄດ້ມີການອະທິບາຍມາໃນເບື້ອງຕົ້ນ, ແມ່ນເຮັດໃຫ້ການໄຫຼຂອງນ້ຳຊ້າລົງ ບັນດາຜົນກະທົບເລົ່ານັ້ນ ແມ່ນອາດບໍ່ພຽງພໍຕໍ່ການຮັກສາລູກປາທີ່ແຂວນລອຍມານຳນ້ຳ (Pelicice *et al*,. 2015). ໃນອ່າງເກັບນ້ຳທີ່ມີລັກສະນະຢຸດນິ້ງ ລູກປາບໍ່ສາມາດແຂວນລອຍ. ນອກຈາກນັ້ນແລ້ວ ພວກເຂົາຈະອຶດຫິວເນື່ອງຈາກຂາດແຄນທາງດ້ານໄຮນ້ຳສັດທີ່ເໝາະສົມ, ກາຍເປັນເຫຍື່ອໃຫ້ແກ່ປາຂະໜາດໃຫຍ່ ຫຼື ຈົມລົງພື້ນຕິດກັບຂີ້ຕົມ ແລະ ຫາຍໃຈບໍ່ອອກ ເນື່ອງຈາກຂາດແຄນອອກຊີເຈນ. ອ່າງເກັບນ້ຳອາດເປັນທີ່ຢູ່ອາໃສຂອງນັກລ້າຕ່າງໆ ແລະ ເປັນຕົ້ນເຫດໃຫ້ມີອັດຕາການຕາຍຂອງປານ້ອຍທີ່ເຄື່ອນຍ້າຍລົງຕອນລຸ່ມຂອງແມ່ນ້ຳມີລະດັບສູງ (Jepsen *et al.*, 1998). ອ່າງເກັບນ້ຳແມ່ນສາມາດເປັນສາຍເຫດໃຫ້ການເຄື່ອນຍ້າຍຂອງປາໃຫຍ່ມີການເກີດຂຶ້ນຊ້າ, ນອກຈາກສັນຍານທີ່ແຮງຂອງກະແສນ້ຳໃນອ່າງເກັບນ້ຳ ປາຈຳນວນໜຶ່ງແມ່ນໄດ້ຍ້ອນກັບລົງໄປຕອນລຸ່ມຄືນໂດຍຜ່ານທາງລະບາຍ ນ້ຳກ່ອນທີ່ມັນຈະພະຍາຍາມຂຶ້ນໄປຕໍ່ຜ່ານທາງປາຜ່ານອີກຄັ້ງ (Jepsen *et al.*, 1998). ປາທີ່ເຄື່ອນຍ້າຍຂຶ້ນມາຈະບໍ່ປະສົມພັນ ຫຼື ໄຂ່ຈະຕາຍ. ຜົນກະທົບທາງດ້ານອຸທົກກະສາດເຫຼົ່ານີ້ ແມ່ນປົກກະຕິແລ້ວແມ່ນກ່ຽວຂ້ອງກັບເຂື່ອນໃນແມ່ນ້ຳຂອງ ເຊິ່ງຂຶ້ນກັບຄວາມລາດອຽງຂອງການກັກເກັບນ້ຳ ຍ້ອນການຕົ້ນເຂີນຂອງອ່າງແມ່ນ້ຳຂອງຕອນລຸ່ມ. ດ້ວຍເຫດນີ້ ກຳລັງແຮງຂອງນ້ຳທີ່ມີການປ່ຽນແປງ ສາມາດເປັນສິ່ງທຳລາຍລ້າງປະຊາກອນປາທີ່ມີການເຄື່ອນຍ້າຍໄດ້ ໃນຂະນະທີ່ອຸທົກກະສາດ (ນ້ຳທີ່ປ່ອຍອອກ) ແມ່ນຍັງຮັກສາການປ່ຽນແປງໃນປະລິມານທີ່ນ້ອຍ ເຊັ່ນດຽວກັນກັບເຂື່ອນໄຟຟ້າແບບນ້ຳໄຫຼຜ່ານ.

ຕໍ່ກັບການປ່ຽນແປງເຫຼົ່ານັ້ນ, ຊະນິດປາໃນແມ່ນ້ຳໃນທ້ອງຖິ່ນ ໂດຍທົ່ວໄປແມ່ນມີປະລິມານທີ່ຕົກຕ່ຳລົງ ອັນເນື່ອງມາຈາກຄວາມບໍ່ສາມາດໃນການສຳເລັດວົງຈອນຊີວິດຂອງພວກມັນ, ມີການແທນທີ່ດ້ວຍຊະນິດປາທີ່ມີຢູ່ໃນນ້ຳນີ້ງ, ເປັນການສວຍໂອກາດ ຫຼື ຊະນິດປາຕ່າງດ້າວ ອັນທີ່ມີຄວາມທົນທານຫຼາຍກວ່າ ແລະ ສາມາດແຜ່ຂະຫຍາຍໃນສະພາບເງື່ອນໄຂນ້ຳນີ້ງເຂົ້າມາແທນ. ຮ້າຍແຮງໄປກວ່ານັ້ນ, ມັນອາດເປັນຊະນິດຕ່າງດ້າວທີ່ມີການທຸລະກິດປາຊະນິດ ອື່ນໆ, ທີ່ເຫັນເປັນຕົວຢ່າງໃນທາງການລ້ຽງ ແລະ ເປັນສິ່ງທີ່ຫຼີກລ້ຽງທາງດ້ານຫົວໜ່ວຍການລ້ຽງ (ຕົວຢ່າງ: ປາໃນ ແລະ ປານິນ) ພວກມັນສາມາດໄດ້ຮັບປະໂຫຍດຈາກສ່ວນໃຫຍ່ຈາກການປ່ຽນແປງທາງດ້ານສະພາບແວດລ້ອມ. ຊະນິດທີ່ອາໃສຢູ່ໃນລຳນ້ຳ ແມ່ນມີທ່າອ່ຽງທີ່ຈະມີການສູນເສຍໃນວົງກວ້າງ, ຊະນິດປາທີ່ເຄື່ອນຍ້າຍທີ່ສຳຄັນທາງດ້ານເສດຖະກິດ ແລະ ປົກກະຕິແລ້ວພວກມັນແທນທີ່ໂດຍມູນຄ່າທີ່ຕ່ຳ, ຊະນິດທີ່ມີຂະໜາດນ້ອຍ ຫຼື ຊະນິດຕ່າງດ້າວທີ່ມີການທຸລະກິດປາຊະນິດອື່ນ. ໃນທຳນອງດຽວກັນ, ບາງຈຳພວກແມ່ນສາມາດນຳໃຊ້ອ່າງເກັບນ້ຳເພື່ອຫາອາຫານ ແລະ ສຳເລັດວົງຈອນຊີວິດຂອງພວກມັນ ຖ້າຫາກສາມາດເຂົ້າເຖິງແຫຼ່ງຂະຫຍາຍພັນໃນແຫຼ່ງທີ່ຢູ່ອາໃສທີ່ເປັນນ້ຳໄຫຼໃນສາຍນ້ຳ ຫຼື ໃນສາຂາແມ່ນ້ຳທີ່ຢູ່ຕອນເທິງຂອງອ່າງເກັບນ້ຳ. ຂະໜາດຂອງຜົນກະທົບ ແມ່ນຮ້າຍແຮງຂຶ້ນ ຖ້າແຫຼ່ງທີ່ໃຊ້ໃນການຂະຫຍາຍພັນອັນຕົ້ນຕໍ ແມ່ນຢູ່ໃນເຂດໃກ້ຄຽງຕອນເທິງຂອງນ້ຳຈາກເຂື່ອນ ແລະ ມີການຖ້ວມຂັງໂດຍອ່າງເກັບນ້ຳ. ມີບາງຊະນິດທີ່ມີການເຄື່ອນຍ້າຍໄລຍະສັ້ນ ກໍສາມາດລອດຕາຍໃນອ່າງເກັບນ້ຳ ຖ້າຫາກພວກມັນມີຂະໜາດລວງຍາວຂອງກະແສນ້ຳໄຫຼທີ່ພຽງພໍໃນແຫຼ່ງທີ່ຢູ່ອາໃສໃນສາຍນ້ຳທີ່ຢູ່ຕອນເທິງ. ຊະນິດປາເຫຼົ່ານັ້ນແມ່ນສາມາດມີການແຜ່ຂະ ຫຍາຍໃນອ່າງເກັບນ້ຳ ແລະ ມີສ່ວນປະກອບທີ່ແຜ່ຫຼາຍໃນການຫາປາທົ່ວໆໄປ,

ເຖິງຢ່າງໃດກໍຕາມ,   ຜົນຜະລິດລວມຂອງປາແມ່ນມີລັກສະນະລຸດລົງເມື່ອທຽບກັບລະບົບແມ່ນ້ຳໃນທຳມະຊາດ.   ອາດກາຍເປັນທະເລຊາບທີ່ມີຜົນຜະລິດສູງ (Eutrophic lakes).

ຊ່ອງຫວ່າງຂອງຄວາມຮັບຮູ້ ທີ່ເປັນສິ່ງຮີບດ່ວນທີ່ຕ້ອງໄດ້ ມີການຈັດຕຽມການສ້າງມູນລະນິທິທີ່ເຂັ້ມແຂງສຳລັບ ແຜນພັດທະນາເຂື່ອນໄຟຟ້າໃນອ່າງແມ່ນ້ຳເຊກອງ

ສິ່ງທີ່ກ່າວຕໍ່ໄປນີ້ ແມ່ນກ່ຽວກັບຊ່ອງຫວ່າງຂອງຄວາມຮັບຮູ້ທີ່ໄດ້ມີການກຳນົດຂຶ້ນໃນການສຳມະນາທີ່ຈຳເປັນຕ້ອງໄດ້ມີການເຕີມເຕັມຕື່ມ ເພື່ອໃຫ້ມີຄວາມເຂົ້າໃຈທັງໝົດກ່ຽວກັບຜົນກະທົບຂອງແຜນການພັດທະນາໃນອ່າງແມ່ນ້ຳ ເຊກອງ ແລະ ການປະມົງໃນແມ່ນ້ຳຂອງ. ບັນຫາອີກຫຼາຍໆອັນ ແມ່ນຈະຮຽກຮ້ອງໄລຍະເປັນປີ ເພື່ອທີ່ຈະສາມາດມີຄຳຕອບ ແລະ ຈະບໍ່ສາມາດແກ້ໄຂຄືນກ່ອນທີ່ຈະສ້າງຮ່າງແຜນແມ່ບົດໃນການພັດທະນາເຂື່ອນໄຟຟ້າແບບຍືນຍົງມີການນຳ ເຂົ້າມາໃຊ້. ແທນທີ່ການປະຕິບັດຕົວຈິງ, ກະຊວງຊັບພະຍາກອນທຳມະຊາດ ແລະ ສິ່ງແວດລ້ອມ ຄວນຮຽກຮ້ອງໃຫ້ພວກເຂົາຕ້ອງມີການເພີ່ມຕື່ມໃນກະກຽມການສຶກສາຜົນກະທົບທາງດ້ານສິ່ງແວດລ້ອມຕື່ມ ເປັນອົງປະກອບໜຶ່ງໃນການໂຄງການສ້າງເຂື່ອນໄຟຟ້າໂດຍທົ່ວໄປ ເຊັ່ນດຽວກັນກັບຢູ່ໃນໄລຍະກະກຽມເງື່ອນໄຂເພື່ອການມີສິດສຳລັບ ຂໍ້ຕົກລົງການສຳປະທານເພື່ອສ້າງໂຄງການ. ບັນຫາອັນໃດທີ່ສາມາດເພີ່ມຕື່ມເຂົ້າໃນລະດັບອ່າງໂຕ່ງ, ພວກເຂົາຄວນຈະຕ້ອງມີເງື່ອນໄຂຖືກຕ້ອງຕາມໜ້າທີ່ຂອງ MRC.

ນິເວດວິທະຍາແມ່ນມີຄຸນຄ່າຫຍັງ ສຳລັບການປະມົງໃນແມ່ນ້ຳເຊກອງ ສິ່ງເຫຼົ່ານັ້ນແມ່ນຄວາມສ່ຽງທີ່ເກີດຈາກການພັດທະນາເຂື່ອນໄຟຟ້າບໍ່?

- ອັດຕາສ່ວນຂອງການເກັບກູ້ປາໃນອ່າງແມ່ນ້ຳຂອງທີ່ຕ້ອງການຈາກແຫຼ່ງທີ່ຢູ່ອາໃສໃນເຊກອງທີ່ຢູ່ໃນລາວ ເພື່ອບາງເງື່ອນໄຂໃນວົງຈອນຊີວິດຂອງພວກມັນ? ການປະເມີນທີ່ດີກ່ຽວກັບຜົນກະທົບທີ່ມີຕໍ່ການເກັບກູ້ປາໃນປະ ເທດກຳປູເຈຍ ແລະ ຫວຽດນາມ ຈາກສະພາບທີ່ອາດມີການສູນເສຍແຫຼ່ງຂະຫຍາຍພັນ ແລະ ການຕາຍຂອງລູກປາໃນອ່າງເກັບນ້ຳໃນແມ່ນ້ຳເຊກອງ ໃນ ສປປ ລາວ ແມ່ນຫຍັງ? What is the fraction of fish

- ແຫຼ່ງທີ່ຢູ່ອາໃສສຳລັບປາທີ່ມີການເຄື່ອນຍ້າຍເພື່ອປະສົມພັນໃນແມ່ນ້ຳເຊກອງ ແມ່ນແນວໃດ ແລະ ມີຢູ່ໃສ? (ເບິ່ງແຜນທີ່ເຂດນ້ຳໄຫຼໄວ ແລະ ຈຸດການສ້າງເຂື່ອນດ້ານລຸ່ມ).

ແມ່ນຫຍັງຄືວຽກພາກສະໜາມໃນອະນາຄົດທີ່ຈຳເປັນຕ້ອງມີການປະຕິບັດກ່ອນຈະມີການຕັດສິນໃຈໃນການກຳນົດຈຸດເຂື່ອນໄຟຟ້າໃນສາຂາຂອງເຊກອງ ແລະ ພື້ນທີ່ອ່າງໂຕ່ງຕອນເທິງ?

- ມີຂໍ້ມູນທີ່ດີສຳລັບເນື້ອຫາກ່ຽວກັບເຂື່ອນທີ່ສາມາດເພີ່ມຂຶ້ນໄດ້ໃນເຊກະມານທີ່ໄດ້ມີການກຳນົດຈຸດແລ້ວ (ເບິ່ງແຜນທີ່ຄັດຕິດ) ອາດມີຜົນກະທົບຕໍ່ກັບແຫຼ່ງທີ່ຢູ່ອາໃສສຳຄັນຂອງປາທີ່ມີໃນທ້ອງຖິ່ນ. ຂໍ້ມູນເຫຼົ່ານັ້ນບາງສ່ວນ

ແມ່ນມາຈາກ ການລາຍງານຂອງທ່ານ Dr. Maurice Kottelat [2], [3] ແລະ ໃນບົດ EIA ສໍາລັບໂຄງການເຊປຽນ-ເຊນໍ້ານ້ອຍ [5]. ເຖິງຢ່າງໃດກໍຕາມ, ກໍຍັງບໍ່ທັນມີຜູ້ໃດໄດ້ສຶກສາຕົວຈິງໃນຫ້ວຍອາຊໍາ.

- ມີຂໍ້ມູນຈໍານວນເລັກນ້ອຍທີ່ໄດ້ມີການກ່າວເຖິງຊະນິດປາທີ່ມີໃນທ້ອງຖິ່ນໃນຕອນເທິງຂອງແມ່ນໍ້າເຊກອງ, ການສໍາຫຼວດແມ່ນຍັງມີຄວາມຈໍາເປັນອັນຮີບດ່ວນເພື່ອເປັນຂໍ້ມູນພື້ນຖານໃນການປະເມີນທາງເລືອກລະ ຫວ່າງຈຸດຫ້ວຍອາຊໍາ ຫຼື ວ່າຄວນຈະເປັນ ເຊກອງ # 5 ເພື່ອພັດທະນາເຂື່ອນໄຟຟ້າ. ເຖິງແມ່ນວ່າ ຈຸດ # 5 ອາດຈະມີການຖ້ວມຂຶ້ນຂອງສາຍນໍ້າຫຼາຍກວ່າ ແລະ ອາດຈະເຮັດໃຫ້ນໍ້າໄຫຼໄປເຖິງປ່າປ້ອງກັນເຊເຊັດ. ສິ່ງນີ້ອາດຈະປະກອບເຂົ້າກັນເປັນຄວາມສໍາຄັນພື້ນຖານໃນການມີຂໍ້ແນະນໍາໃນຈຸດ ຫ້ວຍອາຊໍາ. ການປະຕິບັດວຽກພາກສະໜາມຄວນຈະຕ້ອງມີການກໍານົດທັງຊະນິດປາ ແລະ ແຫຼ່ງທີ່ຢູ່ອາໃສ ກັບການປົກປ້ອງແຫຼ່ງທີ່ຢູ່ອາໃສທີ່ເປັນຕົວແທນ.

- ເຊຊູ ອາດແມ່ນສາຍນໍ້າທີ່ມີຄຸນນະພາບສູງທາງດ້ານແຫຼ່ງທີ່ຢູ່ອາໃສຂອງປາທີ່ມີການເຄື່ອນຍ້າຍ. ມັນມີຄວາມຈໍາເປັນອັນຮີບດ່ວນທີ່ຈະຕ້ອງຮູ້ເຖິງຄຸນຄ່າຂອງການປະມົງໃນແຫ່ງດັ່ງກ່າວ ກ່ອນການຕັດສິນໃຈໃນການ ສ້າງເຂື່ອນເຊກອງ # 1, ເຊິ່ງເຂື່ອນນີ້ອາດຕັນທາງເຂົ້າສູ່ເຊຊູ. ມັນກໍມີຄວາມຈໍາເປັນເຊັ່ນດຽວກັນທີ່ຈະຕ້ອງຮູ້ເຖິງການໄຫຼຂອງນໍ້າຈາກອ່າງເກັບນໍ້າຊັ້ນຊາຍ ວ່າຈະກັນທາງຜ່ານປາຈາກແຫຼ່ງທີ່ຢູ່ອາໃສໃນເຊຊູ.

ການເກັບຕົວຢ່າງປາ ແມ່ນມີຄວາມຈໍາເປັນທີ່ຕ້ອງໄດ້ປະຕິບັດໃນນໍ້າກອງ ແລະ ຕອນລຸ່ມຂອງອ່າງເກັບນໍ້າຂອງນໍ້າກອງ #1 ແລະ ອ່າງເກັບນໍ້າຂອງນໍ້າກອງ #2 ເພື່ອປະເມີນຜົນກະທົບສໍາລັບນະໂຍບາຍໃນການເປີດນໍາໃຊ້ສໍາລັບອ່າງເກັບນໍ້າເຫຼົ່ານັ້ນ ເພື່ອການເຄື່ອນຍ້າຍຂອງປາໃນສາຍນໍ້າຈົນເຖິງປາກແມ່ນໍ້າ. ການເກັບຕົວຢ່າງແມ່ນຄວນຈະຕ້ອງໄດ້ມີການປະຕິບັດໃນຮອບປີ ລວມທັງລະດູຝົນ ແລະ ລະດູແລ້ງ. ການວັດແທກໂດຍກົງແມ່ນອາດຈະເປັນສິ່ງທີ່ມີຄວາມເຊື່ອຖືໄດ້ຫຼາຍກວ່າ, ການບອກເລົ່າຈາກທ້ອງຖິ່ນກໍແມ່ນຂໍ້ມູນທີ່ຄວນຈະຕ້ອງເກັບກໍາເພື່ອສຶກສາ.

ຂໍ້ມູນອັນໃດທີ່ມີຄວາມຕ້ອງການທີ່ຈະໄດ້ເພີ່ມເພື່ອຄວາມໝັ້ນໃຈໃນການຕັດສິນໃຈໃນການອອກແບບ ແລະ ເປີດນໍາໃຊ້ເຂື່ອນໄຟຟ້າໃນອ່າງແມ່ນໍ້າເຊກອງ?

- ຈຸດໃດແມ່ນຈຸດເລີ່ມຕົ້ນຂອງການໄຫຼເພື່ອສ້າງສົມມຸດຖານໃນອ່າງເກັບນໍ້າໃນເຊກອງ ສິ່ງເຫຼົ່ານັ້ນແມ່ນພຽງພໍທີ່ຈະຫຼີກລ້ຽງການເກີນກໍານົດທາງທີ່ຢູ່ອາໃສໃນເວລາປານ້ອຍລອດຕາຍ? ແມ່ນສິ່ງໃດທີ່ຈະມີຜົນກະທົບຕໍ່ການຜະລິດກະແສໄຟຟ້າໃນເວລເປີດນໍາໃຊ້ເຂື່ອນ ເພື່ອຮັກສາການໄຫຼຂອງນໍ້າ?

- ຈຸດຕໍ່າສຸດຂອງຄວາມອົດທົນທີ່ປາຊະນິດສໍາຄັນທີ່ມີການເຄື່ອນຍ້າຍທີ່ທົນໄດ້ແມ່ນແນວໃດໃນສາຍນໍ້າ/ໃນສະພາບແວດລ້ອມພື້ນທີ່ນໍ້າຖ້ວມຕອນລຸ່ມຂອງເຊກອງໃນລາວ ເພື່ອການດັດແປງຄວາມສາມາດບັນຈຸນໍ້າໃນເຂື່ອນ?

- ຜົນກະທົບອັນໃດທີ່ອາດເກີດຂຶ້ນຈາກສິ່ງທີ່ເວົ້າມານັ້ນສໍາລັບ ເຊກະມານຊັ້ນຊາຍ ໃນການປ່ຽນແປງພື້ນທີ່ນໍ້າຖ້ວມໃນເຂດຕອນລຸ່ມຂອງສາຍນໍ້າໃນ ອັດຕະປື ແລະ ໃນປະເທດກໍາປູເຈຍ ແລະ ສິ່ງເຫຼົ່ານັ້ນຈະມີຜົນກະທົບແນວໃດຕໍ່ກັບປາທີ່ມີການເຄື່ອນຍ້າຍເພື່ອການຂະຫຍາຍພັນ ແລະ ການລອດຕາຍ?

ສິ່ງໃດທີ່ເປັນຊ່ອງວ່າງຂອງຄວາມຮັບຮູ້ທີ່ສຳຄັນສຳລັບຄວາມໝັ້ນໃຈໃນການຕັດສິນໃຈທີ່ກ່ຽວຂ້ອງກັບຍຸດທະສາດການລຸດຜ່ອນຜົນກະທົບທາງການປະມົງ?

- ປະສົບການຂອງສາກົນແມ່ນມີໜ້ອຍແດ່ ກັບການຂະຫຍາຍພັນທຽມປາໃນອ່າງເກັບນ້ຳ ທີ່ຈະເປັນຍຸດທະສາດໃນການລຸດຜ່ອນຜົນກະທົບຂອງການສູນເສຍສຳລັບການສູນເສຍການປະມົງໃນທຳມະຊາດ? ການສຳຫຼວດແມ່ນມີຄວາມຈຳເປັນຕ້ອງໄດ້ຄຳນວນເຖິງຄວາມແຕກຕ່າງທາງມູນຄ່າທາງເສດຖະກິດ ແລະ ນິເວດວິທະຍາ ຂອງຊະນິດປາ , ລັກສະນະການແຜ່ກະຈາຍທີ່ເທົ່າທຽມ ແລະ ໄພອັນຕະລາຍໃນແງ່ເຕັກນິກການເພີ່ມປະຊາກອນ.

ຈະມີເຕັກນິກວິເຄາະທີ່ທັນສະໄໝອັນໃດທີ່ຈະສາມາດໃຊ້ເຂົ້າໃນການສຶກສາ ເພື່ອປັບປຸງຄວາມເຂົ້າໃຈຕໍ່ກັບຮູບແບບໃນການເຄື່ອນຍ້າຍຂອງປາໃນແມ່ນ້ຳເຊກອງ ແລະ ແມ່ນ້ຳຂອງລົງໄປຮອດປາກແມ່ນ້ຳ?

- ເພື່ອປັບປຸງຄວາມເຂົ້າໃຈຕໍ່ກັບປາຊະນິດໃດມີການເຄື່ອນຍ້າຍຂຶ້ນໄປຕາມສາຍນ້ຳເຊກອງ ໃນເວລາໃດ ແລະ ມີຈຳນວນເທົ່າໃດ ແລະ ຈຳນວນທີ່ນຳມາສົນທະນາໃນການສຳມະນາ ລວມໄປເຖິງການກວດກາທາງກຳມະພັນ ຕະຫຼອດຮອດສິ່ງທີ່ສິງໃສກໍໄດ້ຍົກໃຫ້ເຫັນຈາກຜູ້ເຂົ້າຮ່ວມບາງທ່ານໃນການສຳມະນາ ເຊິ່ງເປັນສິ່ງທີ່ມີຄ່າຫຼາຍ. ການກວດກາກຳມະພັນ ສຳລັບ ໂຄງການ PEER ແມ່ນໄດ້ມີການກຳນົດແລ້ວ, ລວມໄປທັງຊະນິດທີ່ມີໃນດ້ານລຸ່ມ, ສະຖານທີ່ ແລະ ເວລາໃນຕາຕະລາງ:

ຊະນິດປາ	ຊື່ອື່ນໆ	ເພີ່ມຕື່ມໃໝ່	ການເກັບຮັກສາ	ປາກເຊ	ເຊກອງ	ອັດຕະປື	ລວມ
Scaphognathops bandanensis			DNAl	32	8		
Scaphognathops stejnegeri		ມີ	DNAl	39	10		
Mekongina erythrospila							
Botia modesta						2	
Pangasius larnaudii							
Pangasius conchophilus			DNAl	60			
Henicorhynchus lobatus				1			
Henicorhynchus siamensis				3			
Ompok bimaculatus	*Ompok siluroides*		DNAl	60	21		
Trichopodus trichopterus			DNAl		63		
Macrognathus siamensis			DNAl	1		1	
Puntioplites proctozysron							
Puntioplites falcifer		ມີ	DNAl	60	29	64	
Polynemus borneensis	*Polynemus melanochir*						
Boesemania microlepis							
Hemibagrus cf melanurus	*Hemibagrus spilopterus*	ມີ	EtOH	60	65		
Helicophagus leptorhynchus		ມີ	EtOH	64	52	56	

Osteochilus hasselti		ມີ	EtOH		15	9	
Raiamas guttatus		ມີ	EtOH	6	9		
Probarbus jullieni		ມີ	EtOH	16			
				402	**272**	**132**	**806**

ກຳນົດເວລາ	ບຸລິມະສິດ	ສະຖານທີ່	ສະຖານທີ່ສະເໜີ	ເສັ້ນຂະໜານ	ເສັ້ນແວງ
ລໍຖ້າເງິນລົງທຶນ	2	ເດວຕາ ຫວຽດນາມ	ອ່າງຢາງ	10.546944°	105.334750°
ຕົ້ນເດືອນທັນວາ	1	ແມ່ນ້ຳເຕີງເລຊາບ	ການໂດ	11.830540°	104.813370°
ຕົ້ນເດືອນທັນວາ	1	ແມ່ນ້ຳສາຍຫຼັກ	ກຣາຕິ	13.135810°	106.067830°
ຕົ້ນເດືອນທັນວາ	1	ສະຕັງແຕຣງ/ກຣາຕິ	ໂຟຣກ (ບ້ານປອງ)	13.559088°	106.171089°
ກາງເດືອນຕຸລາ & ເດືອນມັງກອນ	1	ປາກເຊ	ຈຳປາສັກ	15.117935°	105.787220°
ກາງເດືອນຕຸລາ & ເດືອນມັງກອນ	1	ອັດຕະປື	ອັດຕະປື	14.805693°	106.834478°
ກາງເດືອນຕຸລາ & ເດືອນມັງກອນ	1	ໄກ້ກັບອັດຕະປື	ບ້ານເຊຊູ 3	14.747832°	106.952433°

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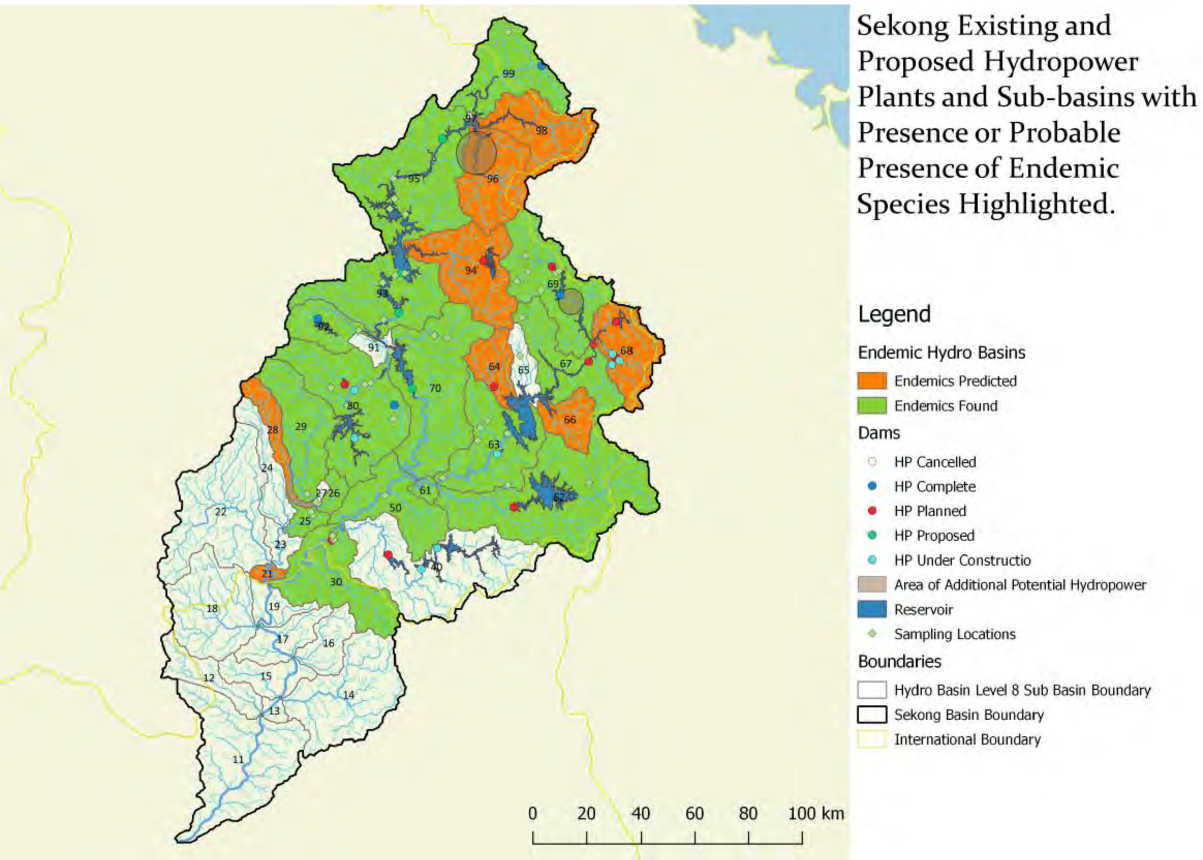
Appendix 7.1:

Assessing the Presence of Endemic and Endangered Species in the Mekong River Basin

Assessing the presence of endemic and rare and endangered species in the Sekong river basin

A report for the Natural Heritage Institute



By Peter-John Meynell and Philip Knight

July 2017

NOTE:
The names of some of the dam sites have changed, or been removed from the Master Plan, since this report was produced. For example, Xe Kong 3up and Xe Kong 3d, on the mainstem, are now called Xe Kong 3B and Xe Kong 3A, respectively. Other changes are noted on page 32.

Table of Contents

1 Introduction

This report has been prepared for the Natural Heritage Foundation as part of the development of sustainable hydropower plan for the Sekong river basin. It provides an initial proof of concept to see if potential river reaches where rare and endemic fish species may be located in the Sekong river basin, from existing river reach classification and knowledge about the distribution of fish species. If the approach proves useful then it can be applied to other tributaries in the Lower Mekong Basin.

The objectives of the study are:

1. To identify ecologically important river reaches in the Sekong, especially for endemic, rare and threatened fish and other aquatic species.
2. To compare the areas identified for possible additional hydropower with these and other ecologically important river reaches in the Sekong
3. To identify areas that should not be developed for hydropower because of their potential habitats for rare and endemic fish species

The study is therefore focused on assessing the siting options for sustainable hydropower by identifying river reaches that may be inundated, which have a high probability of being critical habitats for endemic species, which could thus be pushed towards extinction. In doing this we are using data which describes the character of the river reaches, highlighting those river reach types where endemic species are most likely to be found, and rare river reaches which may give rise to endemism.

2 Method

The method brings together several data sets that provide information on the river reach classification types and fish and other aquatic species recognised from the Sekong river basin together with information from earlier ichthyological surveys. These datasets are:

1. River reach classification of the Greater Mekong sub-region prepared for WWF Greater Mekong by Lehner and Dallaire 2014 (Lehner, 2014). This classifies small sections of the rivers (river reaches) between 0.5 – 3 km in length according to the classes based upon hydrological size, physio-climatic class, and geomorphological class, as shown in Figure 2-1. These classes provide the basic description of the different types of rivers where endemic fish species have been found in the past, and allows a comparison with river reaches elsewhere in the basin which have been identified as potential sites for hydropower development.

Figure 2-1: Structure of the river reach classification

Hydrologic classes	***Physio-climatic classes***	***Geomorphologic classes***
Small river	Montane grasslands	Six main stem categories
Medium river	Coniferous forests	High stream gradient *(yes/no)*
Large river	Montane karst	Presence of floodplain *(yes/no)*
Main stem	High elevation karst	Presence of sediment *(yes/no)*
	Low elevation karst *(merged 'medium' and 'low', i.e. < 750 m)*	Presence of sediment and floodplain *(yes/no)*
	High elevation moist broadleaf forests	
	Low elevation moist broadleaf forests *(merged 'medium' and 'low', i.e. < 750 m)*	
	Dry broadleaf forests *(any elevation, but virtually all occurrences are < 750 m)*	
	Flooded forests and grasslands	
	Large delta	
	Mangroves	

2. IBAT (Integrated Biodiversity Assessment Tool)[1] database which provides datasets on Protected areas, Key Biodiversity Areas (KBAs) and IUCN Red listed species. Of particular interest for this study are the datasets of aquatic species that have been red list assessed arranged by HydroBasin. HydroBasins are sub-basins or smaller catchments making up the larger basins; for this assessment, we use HydroBasins level 8. The aquatic species that have been included in these datasets are fish, Odonata (dragon flies), Molluscs (snails), crustacea, and aquatic plants. During the red listing process their ranges have been predicted in each sub-basin, and their red list status (Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD)) provided. (IUCN, 2017)

   This IUCN Redlist freshwater dataset has been compiled by the species specialists completing the IUCN Redlist assessments for those freshwater taxonomic groups in the Greater Mekong sub-region. The association of particular species with each hydrobasin is based upon the known or expected ranges of these species; it is a prediction that these species are likely to be found in these sub-basins. In some cases, this will be based upon field surveys, but for most species it remains a prediction of their likely range, rather than proven occurrence. Nevertheless, in the absence of field data, it is a useful dataset to work for this study.

3. Ichthyological surveys principally carried out in the Sekong by Kottelat in 2009 and 2011 (Kottelat M. , Fishes of the Xe Kong drainage in Laos - Report for WWF Aquatic Resources Management to Improve Rural Livelihoods of the Xe Kong Basin, 2009) (Kottelat M. , 2011). The locations and species found including endemic species and potentially new species to science have been georeferenced and linked with the prevailing river reach types in those areas. In addition to these ichthyological surveys the comprehensive catalogue of fish species found in SE Asian rivers (Kottelat M. , 22 November 2013) was consulted to identify

[1] www.ibat_alliance.org

fish species whose holotype was first described from the Sekong and their type locality. This includes earlier fish type descriptions by Kottelat and Tyson Roberts. More recent village surveys of migratory fish on the Sekong by Terry Warren and Dr Phouvin Phousavanh for Natural Heritage Institute in 2016 have also been considered, especially for the listing of 55 migratory species moving up the Sekong.

The synthesis of these different datasets and their comparison has been pulled together using GIS, so that the following maps and comparative listings of the data have been prepared:

1. Map and analysis of the river reach types for the Sekong river basin. This has been further divided into the HydroBasins Level 8 found in the Sekong
2. Analysis of the rarity of river reach types, broken down into three categories – Rare river reach types (1 – 20 %) Medium rare (21 – 40%), Common (41 – 60%). The rarity of river reaches has been mapped, showing the distribution of different types.
3. Analysis of the predicted distribution of endangered fish species in the sub-basins of the Sekong, according to Critically Endangered species, Endangered and Vulnerable species. Analysis of the numbers of endemic species found in the different sub-basins.
4. Comparison of the river reach type composition of the sub-basins where endemic species and species that are potentially new to science are found, with sub-basins where existing and proposed hydropower dams and reservoirs are located.

A simple risk rating of hydropower projects in the Sekong for the inundation of the preferred habitats of the endemic fish species has been prepared by considering the size of the reservoir in lengths of river reaches inundated, the proportion of rare river reaches in each reservoir and the proportion of high gradient and high elevation river reaches that are inundated. The dimensions for each of these are rated on a relative scale of 1 – 3, and these are then multiplied together to give a risk score. The risk scores are then grouped to give the risk ratings e.g. High (9 – 12), Medium (5 – 8) and Low (1 – 4) (see Table 4-6).

3 Results

3.1 Analysis of river reach types in the Sekong

The river network in the Sekong river basin are shown Figure 3-1 and the constituent river reach classes are shown in Figure 3-2.

The analysis of the river reaches by size shows that large river reaches (average annual flow between 100 – 1,000 m^3/sec) mostly flow through dry broadleaf forest regions and that the rarest (less than 10%) of the large river reaches are those that flow through dry broadleaf forest regions with floodplains, and those that flow through moist broadleaf forest regions at low elevations and with low gradient. (Table 3-1)

Table 3-1: Analysis of large river reach lengths in the Sekong

Combined Class Code	Description	Sum of Reach Length	% of Total Simple Hydrological Class
24103	Large river, in dry broadleaf forest region, with floodplains	18.51	3.07
23101	Large river, in moist broadleaf forest region at low elevation, with low gradient	39.39	6.53
24105	Large river, in dry broadleaf forest region, with floodplains and sediment	221.42	36.70
24101	Large river, in dry broadleaf forest region, with low gradient	324.01	53.70

The largest proportion of the medium sized rivers (average annual flow 10 – 100 m^3/sec) flow through dry broadleaf forest regions with low gradient, while the rarer reaches flow through moist broadleaf forest regions at high elevation with both high and low gradient and at low elevation with high gradient. (Table 3-2).

Table 3-2: Analysis of Medium river reaches in the Sekong

Combined Class Code	Description	Sum of Reach Length	% of Total Simple Hydrological Class
33302	Medium river, in moist broadleaf forest region at high elevation, with high gradient	14.22	1.59
33102	Medium river, in moist broadleaf forest region at low elevation, with high gradient	31.69	3.54
33301	Medium river, in moist broadleaf forest region at high elevation, with low gradient	43.25	4.83
33101	Medium river, in moist broadleaf forest region at low elevation, with low gradient	145.52	16.26
34103	Medium river, in dry broadleaf forest region, with floodplains	161	17.99
34101	Medium river, in dry broadleaf forest region, with low gradient	499.43	55.80

The largest proportion of small rivers (average annual flow 1 – 10 m^3/sec) flow through dry broadleaf forest regions with low gradient. The rarest river reaches are those that flow through a karst region at high and low elevation followed by those flowing through moist broadleaf forest regions at low elevation and with low and high gradients. There is also a rare river reach type that flow through dry broadleaf forest region with high gradient. (Table 3-3).

Table 3-3: Analysis of small river reaches in the Sekong

Combined Class Code	Description	Sum of Reach Length	% of Total Simple Hydrological Class
48100	Small river, in karst region at low elevation	4.82	0.14
48300	Small river, in karst region at high elevation	6.87	0.20
43101	Small river, in moist broadleaf forest region at low elevation, with low gradient	173.64	4.96
43102	Small river, in moist broadleaf forest region at low elevation, with high gradient	256.39	7.33
44102	Small river, in dry broadleaf forest region, with high gradient	329.47	9.42
43301	Small river, in moist broadleaf forest region at high elevation, with low gradient	404.61	11.57
43302	Small river, in moist broadleaf forest region at high elevation, with high gradient	500.5	14.31
44101	Small river, in dry broadleaf forest region, with low gradient	1822.02	52.08

The commonest small headwater streams with average annual flows of less than 1 m^3/sec, are those that flow through dry broadleaf forest regions and through moist broadleaf forest regions at high elevation. The rare small headwater reaches flow through karst regions at high and low elevation, and that flow through moist broadleaf forest regions at low elevation. (Table 3-4)

Table 3-4: Analysis of small headwater streams in the Sekong

Combined Class Code	Description	Sum of Reach Length	% of Total Simple Hydrological Class
58100	Small headwater stream, in karst region at low elevation	5.66	0.08
58300	Small headwater stream, in karst region at high elevation	17.71	0.25
53100	Small headwater stream, in moist broadleaf forest region at low elevation	701.02	9.77
53300	Small headwater stream, in moist broadleaf forest region at high elevation	2313.33	32.25
54100	Small headwater stream, in dry broadleaf forest region	4135.52	57.65

The distribution of the rare river reaches is shown in Figure 3-3 and Table 3-5. One of the hypotheses of this paper is that rare river reaches are more likely to provide the more isolated and different habitats necessary for the development of endemic species. It is therefore a necessary first step to identify where the rare reaches occur. Rarity is arbitrarily taken as the river reach classes with less than 10% of the lengths of river reaches in the same size class.

Figure 3-1: River reach network in the Sekong River Basin

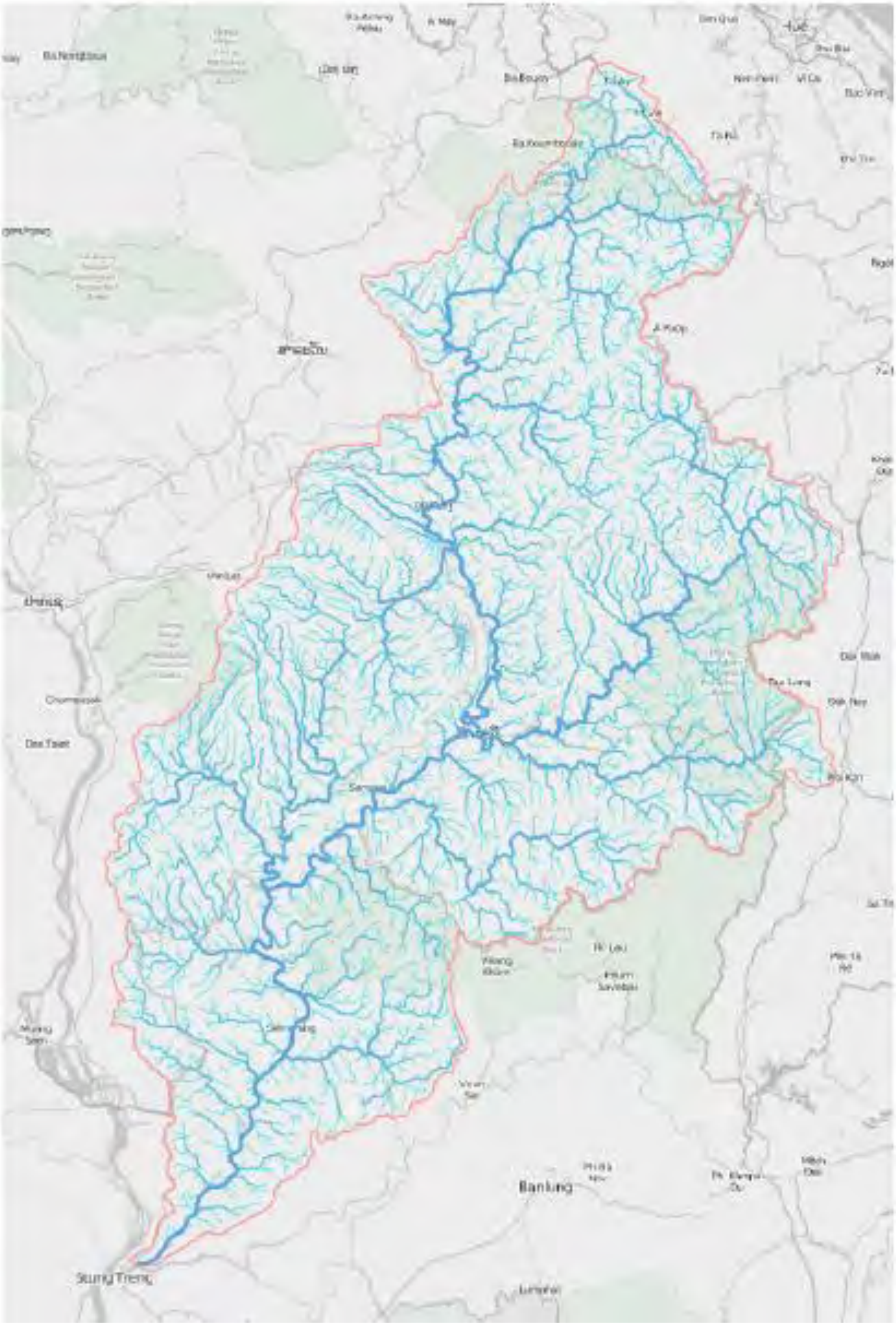


Figure 3-2: Sekong River Reach classification with sub-basins

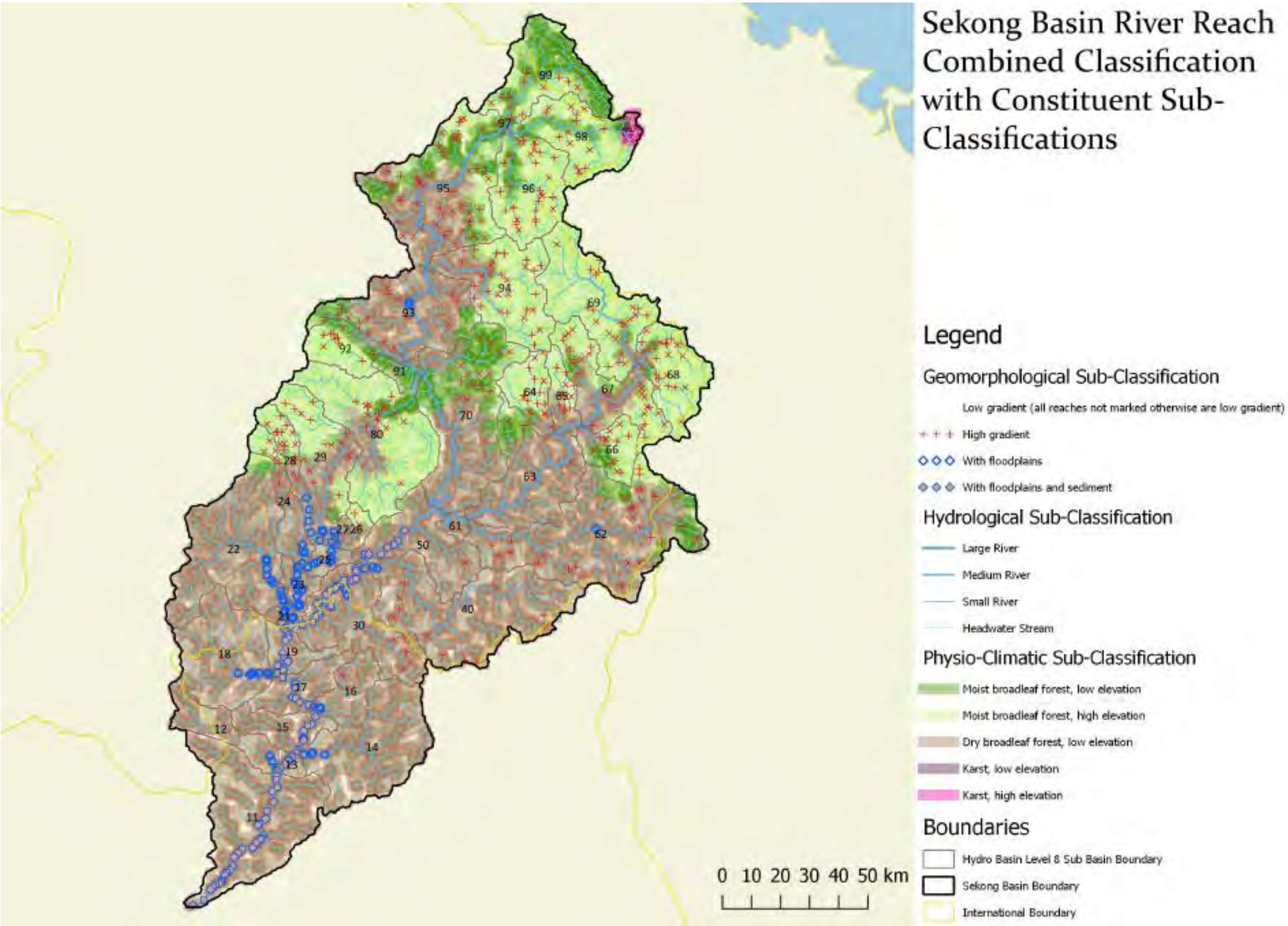


Figure 3-3: Distribution of rare river reaches in the Sekong River basin

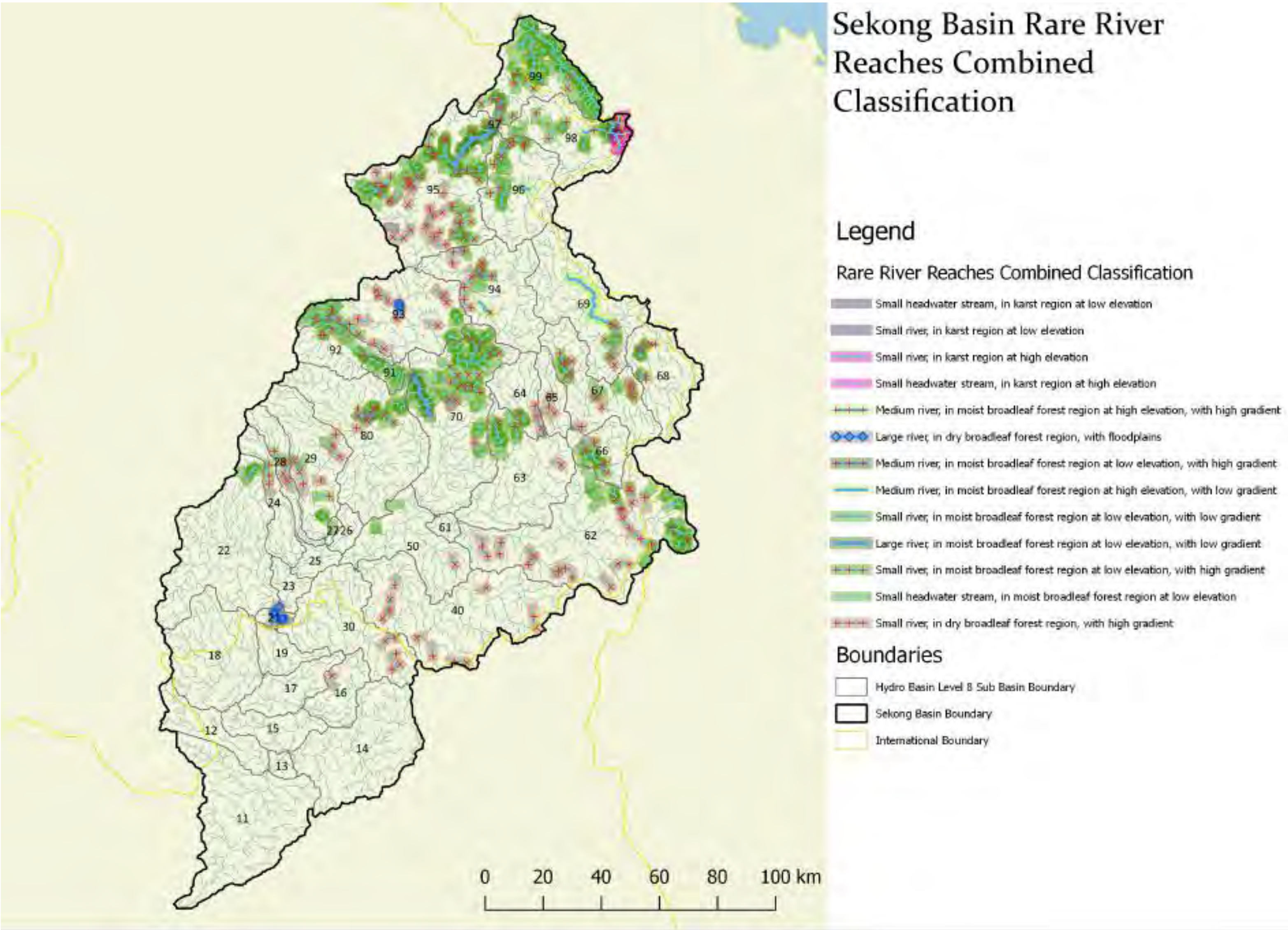
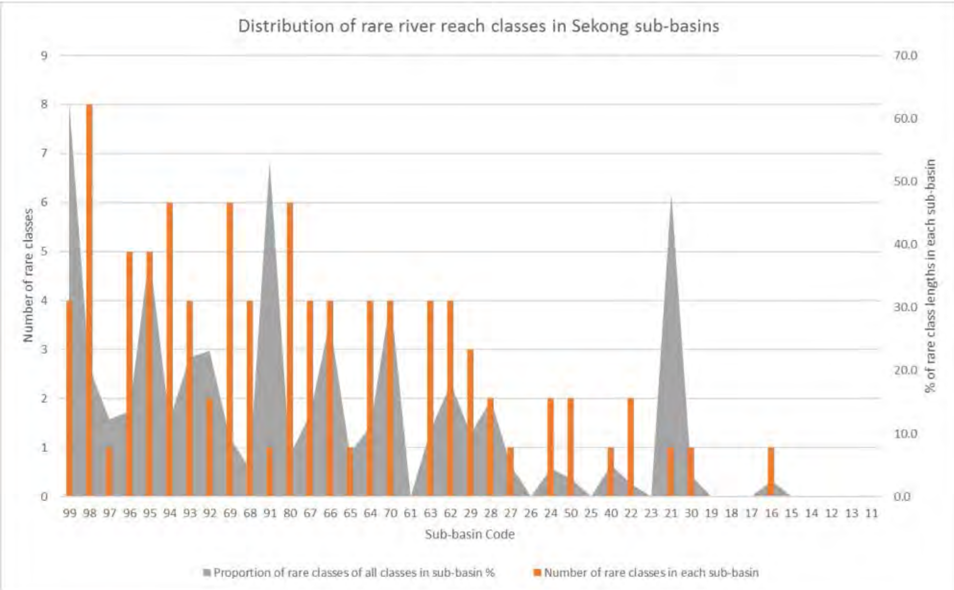


Table 3-5: Lengths (km) of River reach classes in each sub-basin, with rare river reach classes highlighted

Class ID	Class Description	Sub-basin Code 99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64
23101	Large river, in moist broadleaf forest region at low elevation, with low gradient					22.79											
24101	Large river, in dry broadleaf forest region, with low gradient					66.25		51.64				7.71		16.93		10.03	
24103	Large river, in dry broadleaf forest region, with floodplains							3.97									
24105	Large river, in dry broadleaf forest region, with floodplains and sediment																
33101	Medium river, in moist broadleaf forest region at low elevation, with low gradient	34.62	41.82	4.78	27.13				2.38	2.21	5.01		24.91				
33102	Medium river, in moist broadleaf forest region at low elevation, with high gradient	6.92			3.14		4.8			2.03	6.06		8.74				
33301	Medium river, in moist broadleaf forest region at high elevation, with low gradient				5		5.66			32.59							
33302	Medium river, in moist broadleaf forest region at high elevation, with high gradient		4.15				1.09			1.54	4.66		2.78				
34101	Medium river, in dry broadleaf forest region, with low gradient						37.49	3.47	13.69	11.9	8.29	7.9	18.21	38.11	6.41		
34103	Medium river, in dry broadleaf forest region, with floodplains																
43101	Small river, in moist broadleaf forest region at low elevation, with low gradient	71.22	14.46		8.94	22.52					0.64		0.46	2.84	5.75		0.64
43102	Small river, in moist broadleaf forest region at low elevation, with high gradient	27.22	9.11		17.89	63.63	1.57	22.17	11.44	3.29			8.73	9.14	7.3		3.04
43301	Small river, in moist broadleaf forest region at high elevation, with low gradient		16.23		26.58	1.75	45.25		11.79	71.41	55.05		106.2	10.32	3.21	8.39	16.65
43302	Small river, in moist broadleaf forest region at high elevation, with high gradient	7.45	29.05		47.15	8.19	54		14.51	43.4	48.39		19.38	41.32	20.38	30.28	45.73
44101	Small river, in dry broadleaf forest region, with low gradient					33.89	3.14	86.91		1.57		9.38	53.22	3.3	5.78	8.3	7.41
44102	Small river, in dry broadleaf forest region, with high gradient					61.12	29.77	29.4		5.32			0.89	14.07	5.75	7.74	11
48100	Small river, in karst region at low elevation		4.82														
48300	Small river, in karst region at high elevation		6.87														
53100	Small headwater stream, in moist broadleaf forest region at low elevation	123.4	10.9	0.67	12.65	100.8	8.08	45.26	27.51	4.11	2.03	36.38	20.9	19.16	18.43		2.5
53300	Small headwater stream, in moist broadleaf forest region at high elevation	95.07	189.9		204.6	107.4	202.1	5.28	85.51	335.4	156.5		357.7	136.1	58.16	25.23	62.89
54100	Small headwater stream, in dry broadleaf forest region					158.4	29.28	207.8	1.16	3.12	6.34	6.98	30.05	57.17	3.15	21.52	4.16
58100	Small headwater stream, in karst region at low elevation		3.46			2.2											
58300	Small headwater stream, in karst region at high elevation		17.71														
Grand Total		**365.9**	**348.5**	**5.45**	**353.1**	**649**	**422.2**	**455.9**	**168**	**517.8**	**293**	**68.35**	**652.2**	**348.5**	**134.3**	**111.5**	**154**
	Number of rare classes in each sub-basin	4	8	1	5	5	6	4	2	6	4	1	6	4	4	1	4
	Proportion of rare classes of all classes in sub-basin %	62.5	20.5	12.3	13.5	38.6	12.1	22.1	23.2	9.4	4.6	53.2	6.5	13.0	27.7	6.9	11.2

Class ID	70	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11	Grand Total
23101	16.6																									39.39
24101	60.22	15.83	73.28							22.12																324.01
24103															14.54											18.51
24105										23.88						49.86	23.62		26.74		18.53			9.32	69.47	221.42
33101	2.66																									145.52
33102																										31.69
33301																										43.25
33302																										14.22
34101	24.29	1.74	1.54	91.48	40.19					11.89		95.9	35.19			20.91		1.94				28.89				499.43
34103				4.43	4.62		31.09		7.84		15.99	1.54	20.72	31.09		8.84		13.74		3.73		10.81	6.56			161
43101	21.78		8.78	10.99									4.62													173.64
43102	44.4		4.07	7.93	4.42	5.88			5.16																	256.39
43301					31.76																					404.61
43302				6.38	22.94	37.92		7.57	16.46																	500.5
44101	97.42		90.18	175.5	19.97	4.89		10.03	60.88	64.4		138.8	200.4	4.02		83.24	26.98	195.3	37.18	47.86	24.26	143.3	55.49	1.99	127.1	1,822.02
44102	8.4		2.18	64.57	21.52	10.33			2.96	2.68		34.43				13.55				3.79						329.47
48100																										4.82
48300																										6.87
53100	138		29.13	72.43	11.11		2.08			6.75			8.72													701.02
53300	39.45		13.15	29.92	121.8	30.93		12.42	29.69				14.13													2,313.33
54100	221.9	19.7	190.5	408.9	90.36	15.3	9.19	12.04	56.48	195.5	34.76	403.3	393.5	35.24	15.65	230.3	41.59	199.7	92.77	94.92	87.36	304.2	84.21	17.79	351.4	4,135.52
58100																										5.66
58300																										17.71
Grand Total	**675.2**	**37.27**	**412.8**	**872.5**	**368.7**	**105.3**	**42.36**	**42.06**	**179.5**	**327.2**	**50.75**	**673.9**	**677.2**	**70.35**	**30.19**	**406.7**	**92.19**	**410.7**	**156.7**	**150.3**	**130.2**	**487.2**	**146.3**	**29.1**	**548**	**########**
Number of rare classes in each sub-basin	4	0	4	4	3	2	1	0	2	2	0	1	2		1	1	0	0	0	1	0	0	0	0	0	
Proportion of rare classes of all classes in sub-basin %	31.5	0.0	10.7	17.9	10.0	15.4	4.9	0.0	4.5	2.9	0.0	5.1	2.0	0.0	48.2	3.3	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	

Figure 3-4: Distribution of rare river reach classes by sub-basin



3.2 Distribution of river reach classes in the Sekong sub-catchments

There are 41 sub-basins delineated at HydroBasin Level 8. These are shown superimposed on the river reach class map in Figure 3-2 and Figure 3-3. Note that the high sub-basin code numbers are those in the upper catchment, thus the code numbers 91 – 99 are sub-basins in the headwaters of the Sekong itself, whilst numbers 61 – 69 cover the Xe Kaman. The sub-basin code numbers are described below.

Sub-basin Code	Description
99	Upper catchment in Vietnam
91 - 99	Upper catchment – Se Sap
80	Eastern catchment of Bolevan Plateau
70	Sekong mainstem through Sekong province
63 - 69	Xe Kaman
62	Xe Xou
61	Confluence between Sekong and Xe Kaman
40	Nam Khong
30	Attapeu Plain
22 - 29	Southern catchment of Bolevan – Se Pian, Se Namnoy
21	Confluence between Sekong with Se Pian
11 – 19, 30	Mainly in Cambodia

An analysis of the distribution of the lengths of river reach classes in each sub-basin is provided in Table 3-5 which also has the rare river reach classes highlighted. The distribution of rare river reach types is shown diagrammatically in Figure 3-4. This clearly shows that the lower sub-basins have relatively few or no rare river reaches, in comparison to those in the highlands of the Sekong, Xe Kaman and Bolevan. The Sub-basins that stand out with both high rare river reach diversity and proportions are 99 – 91, which generally have between 4 – 6 rare reach classes and depending upon the size of the sub-basin may have proportions of rare river reaches between 10 up to 60%. Sub-basin is a small basin with only one rare river reach class (Small headwater stream, in moist broadleaf forest region at low elevation) but making up a large proportion in a small area. The Sub-basin with the highest proportion is 99 which has 4 rare river reach classes making up 60% of all the river reaches in the sub-basin. Sub -basin 98 is also interesting in that it is the only Sub-basin which has karst river reaches.

The Xe Kaman sub-basins (62 – 69) have similar if slightly lower rare river reach profiles, usually about 4 rare river reach classes with a proportion between 10 – 20%. Sub-basin 80 on the Bolevan has a high diversity of rare river reaches, 6, but a low proportion about 10% largely because of the total length of river reaches (662 km or 10 times the lengths of 91). The lower reaches are distinguished by having few rare reach lengths. Sub-basin 21 is also interesting because it has one of the rare large river reaches (Large river, in dry broadleaf forest region, with floodplains) which makes up a high proportion of a relatively small sub-basin at the confluence of the Sekong with the Xe Pian.

3.3 Other aquatic species distribution in the Sekong river basins

The following analysis of aquatic species has been drawn from the IBAT database, drawing on the IUCN Red listing of Freshwater species. The database records the probable presence of aquatic species (aquatic plants, molluscs (gastropods and bivalves), insects - dragon flies, crustacea (shrimps, prawns and crabs), and fish) in each of the hydrobasins listed above. This indication of probable presence is based upon the known ranges and habitats of the species that have been assessed by Red Listing of threatened species. It is based upon expert judgement of the assessors, rather than on definitive presence recorded by surveys. It is noted that IBAT data does not exist for sub-basin 70, which is why it is missing from the tables or coloured grey on the maps.

The database thus provides a probable distribution of these aquatic groups in the sub-basins. The focus for this paper is upon fish, but the highlights of other groups are briefly described first.

3.3.1 Aquatic Plants

According to the IBAT database the Sekong basin lies within the ranges of 121 species of aquatic plants of which 113 are of Least Concern on the IUCN Red list and 8 are Data Deficient. Whilst most of the plant species are widely distributed throughout the basin, a few species are reported to have a very limited distribution through the sub-basins. These are *Blyxa quadricostata* and *Cryptocoryne mekongensis,* both of which are restricted to Sub-basins 18, 22 and 24 or the eastern sides of the Bolevan plateau; and *Sagittaria pygmaea* which is similarly restricted.

3.3.2 Mollusca

From the IBAT database of Mollusca, the Sekong sub-basins contain 74 species of which 3 are Near Threatened, 48 are of Least Concern and 3 are Data Deficient. The three Near Threatened species were first described from the Siphandone area, a recognised hotspot for mollusc biodiversity, but these appear to be quite widely distributed in the Sekong. There is one probable endemic to the Sekong, *Anulotaia mekongensis,* which is Data Deficient and found in the southern Bolevan and in some of the lower sub-basins in Cambodia. The species list is provided in Annex 2.

3.3.3 Odonata

The Sekong lies in the range of 98 species of dragonflies, of which 90 are considered to be of Least Concern on the IUCN Red list and 9 are Data Deficient. Many of the species are widely distributed throughout the Sekong basin. Of the Data Deficient species several are probably endemic to the Sekong - *Amphithemis kerri* and *Protosticta robusta* both found in the upper Sekong sub-basins 91 – 99; *Leptogomphus baolocensis* found in the southern Bolevan sub-basins; *Macromia septima* widely distributed but the genus needs a review; The list of species is provided in Annex 1.

3.3.4 Crustacea

The IBAT database records 11 species of crustacea of which 9 are of Least Concern and 2 are Data Deficient. There are 5 species of Macrobrachium, including the long distance migratory species *M. rosenbergi*, which is restricted to the lower sub-basins up to the confluence of Xe Kaman with Sekong. There is also an endemic crab, *Vietopotamon aluoiense,* which was first described in A Luoi in Vietnam and is found in the top nine sub-basins, and a Laos endemic crab, *Pupamon pealianoides,* found in 30 of the sub-basins – both are data deficient. Sub-basins 99 and 62 appear to be the most biodiverse with 9 and 8 species respectively, compared to the others which have 3 – 5 species each. The full list of crustacea is found in Annex 3.

3.4 Distribution of Fish in the Sekong sub-basins

3.4.1 Threatened fish species

The IBAT database lists 259 species, of which 2 are Critically Endangered *Catlocarpio siamensis* and *Pangasius sanitwongsei*, both found in the lower sub-basins of the Sekong, though the latter will migrate up into sub-basins 61 and 80 and around the southern Bolevan. The distribution of Critically Endangered species is shown in Figure 3-5 and Figure 3-6.

Figure 3-5: Distribution of Critically Endangered fish species in the Sekong sub-basins

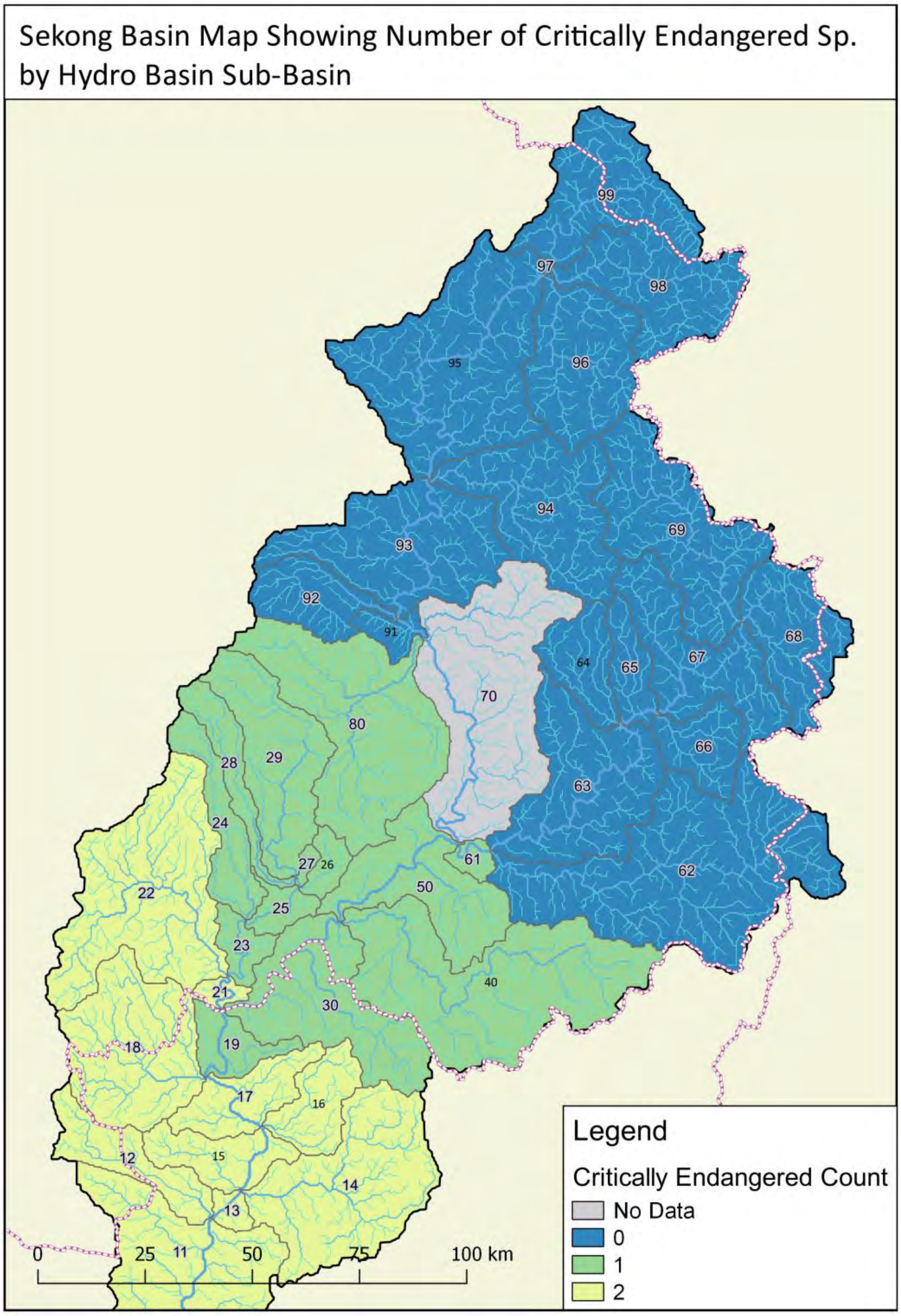
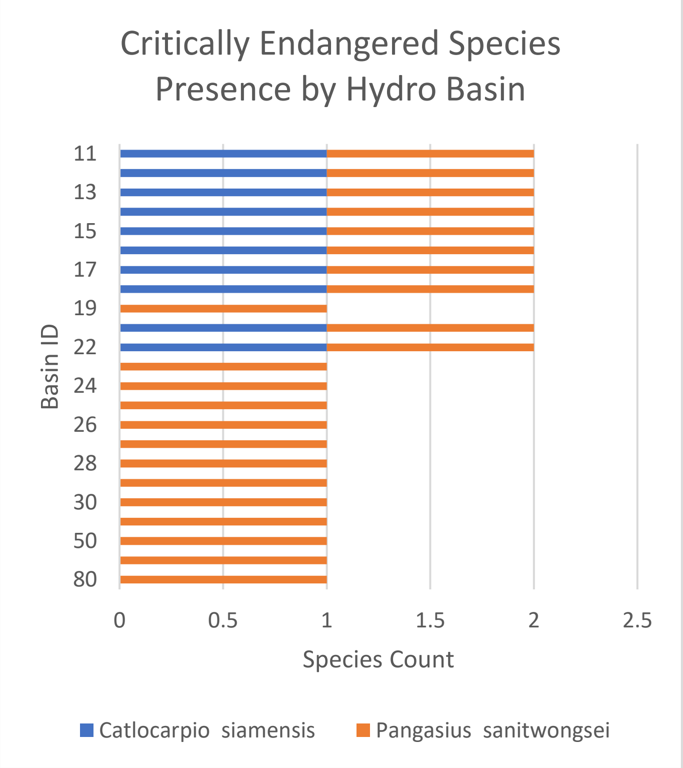


Figure 3-6: Critically Endangered fish species by sub-basin in the Sekong



There are 9 Endangered species found in the Sekong sub-basins, three of which are restricted to the lower sub-basins - *Laubuca caeruleostigmata, Pangasianodon hypophthalmus* and *Probarbus labeamajor* and six of which are found in the upper sub-basins and on the Bolevan - *Poropuntius bolovenensis, Poropuntius consternans, Poropuntius lobocheiloides, Poropuntius solitus, Schistura bairdi, Schistura bolavenensis,* and many of these are also endemic to the Sekong.

It can be seen from Figure 3-7 and Figure 3-8, that sub-basin 21 hosts the highest number of Endangered fish species with a total of 7, sub-basins 80 and 91 – 99 host 5 Endangered species, the southern Bolevan sub-basins and the lower sub-basins in Cambodia host 4 Endangered species, but the Nam Khong and Xe Kaman do not appear to host any Endangered fish species. Sub-basin 21 appears to be at a meeting point of suitable habitats for most of these species.

Figure 3-7: Distribution of Endangered fish species in the Sekong sub-basins

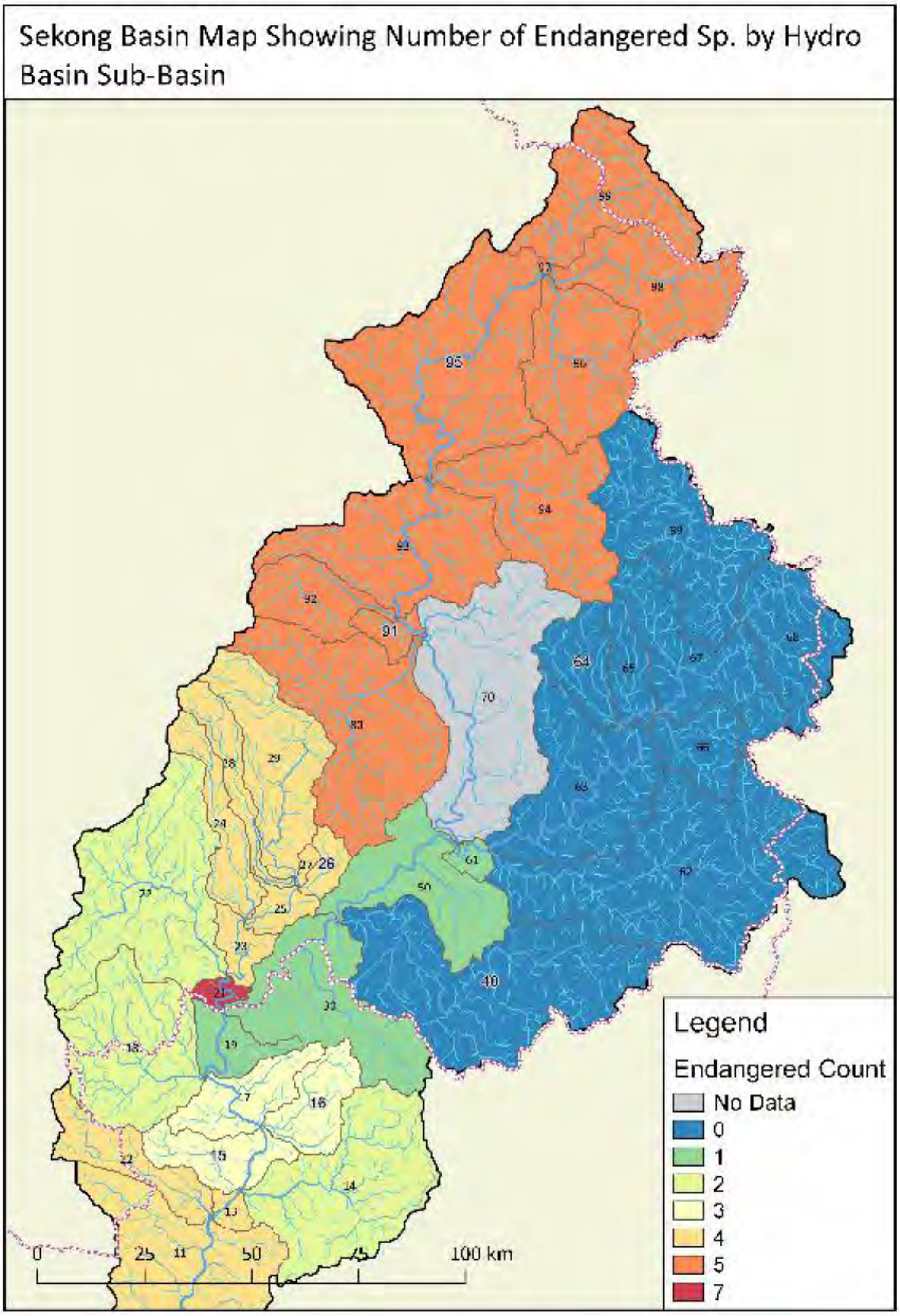
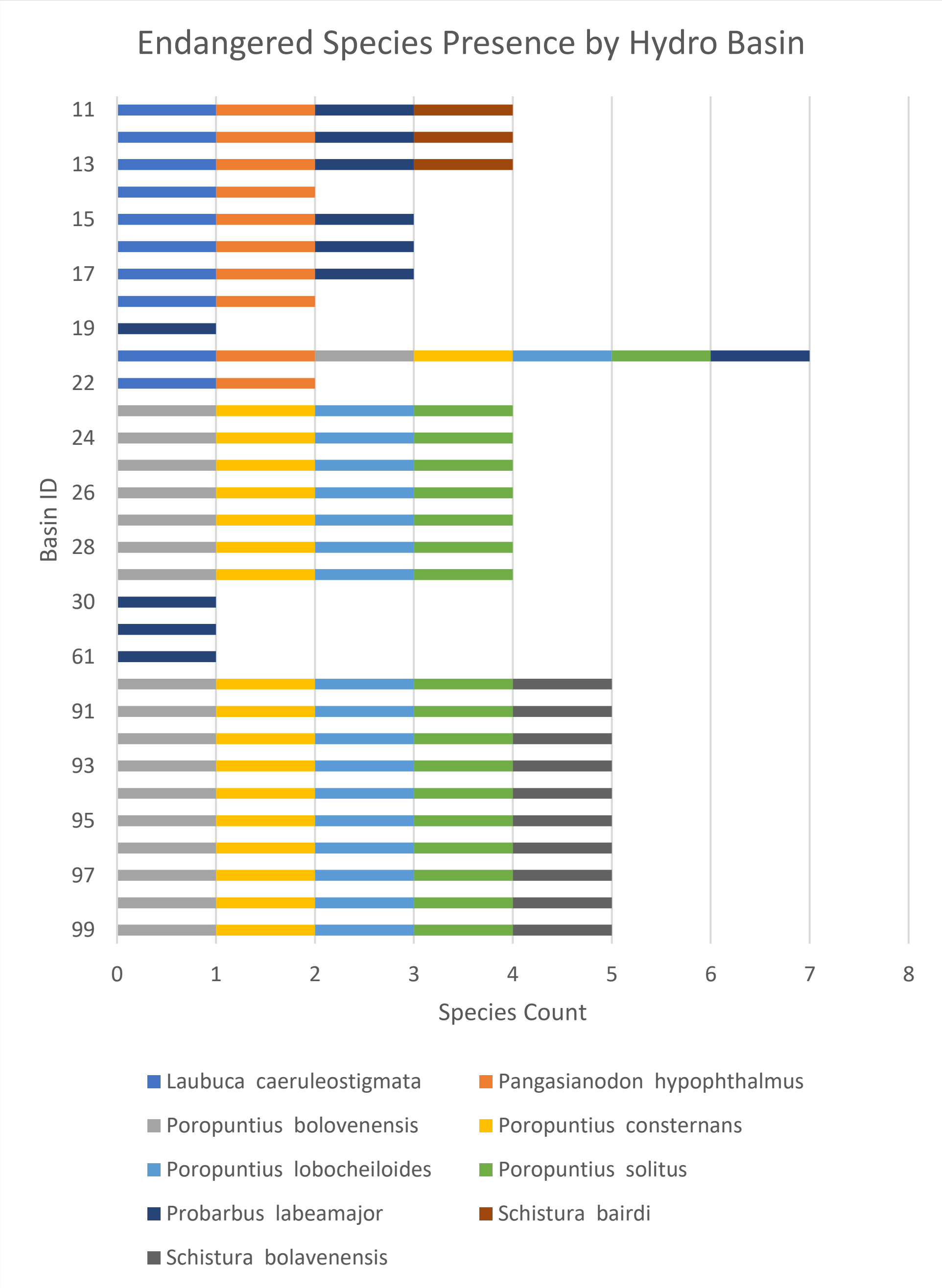


Figure 3-8: Endangered fish species by sub-basin in the Sekong



There are 12 Vulnerable fish species found in the Sekong sub-basins (see Figure 3-9 and Figure 3-10). Three of these are found in the upper sub-basins *Bangana behri, Labeo pierrei*, and *Yasuhikotakia nigrolineata* as well as in a few of the other sub-basins. *Schistura kontumensis* is restricted to the Xe Xou and upper Xe Kaman sub-basins, while the others - *Datnioides undecimradiatus, Epalzeorhynchos munense, Hypsibarbus lagleri, Osphronemus exodon, Oxygaster pointoni, Pangasius krempfi, Scaphognathops bandanensis,* are mainly found in the lower Sekong sub-basins and the southern Bolevan sub-basins. These have between 7 and 10 Vulnerable fish species. As before sub-basin 21 has the highest diversity of Vulnerable fish species. The Nam Khong hosts only three Vulnerable fish species *Labeo pierrei, Epalzeorhynchos munense* and *Osphronemus exodon. Cirrhinus microlepis* is only found in the three lowest sub-basins in Cambodia.

Figure 3-9: Distribution of Vulnerable fish species in the Sekong sub-basins

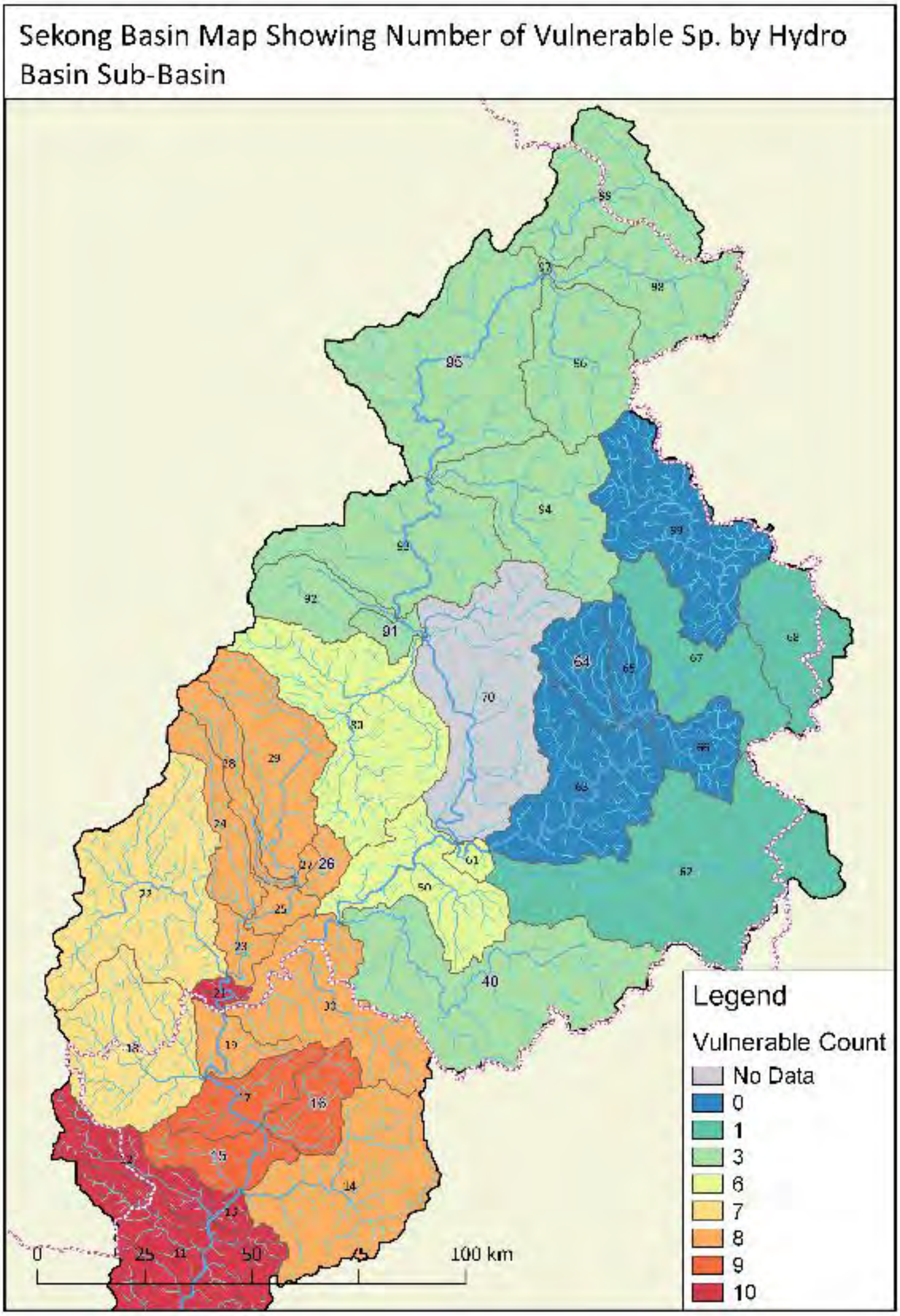
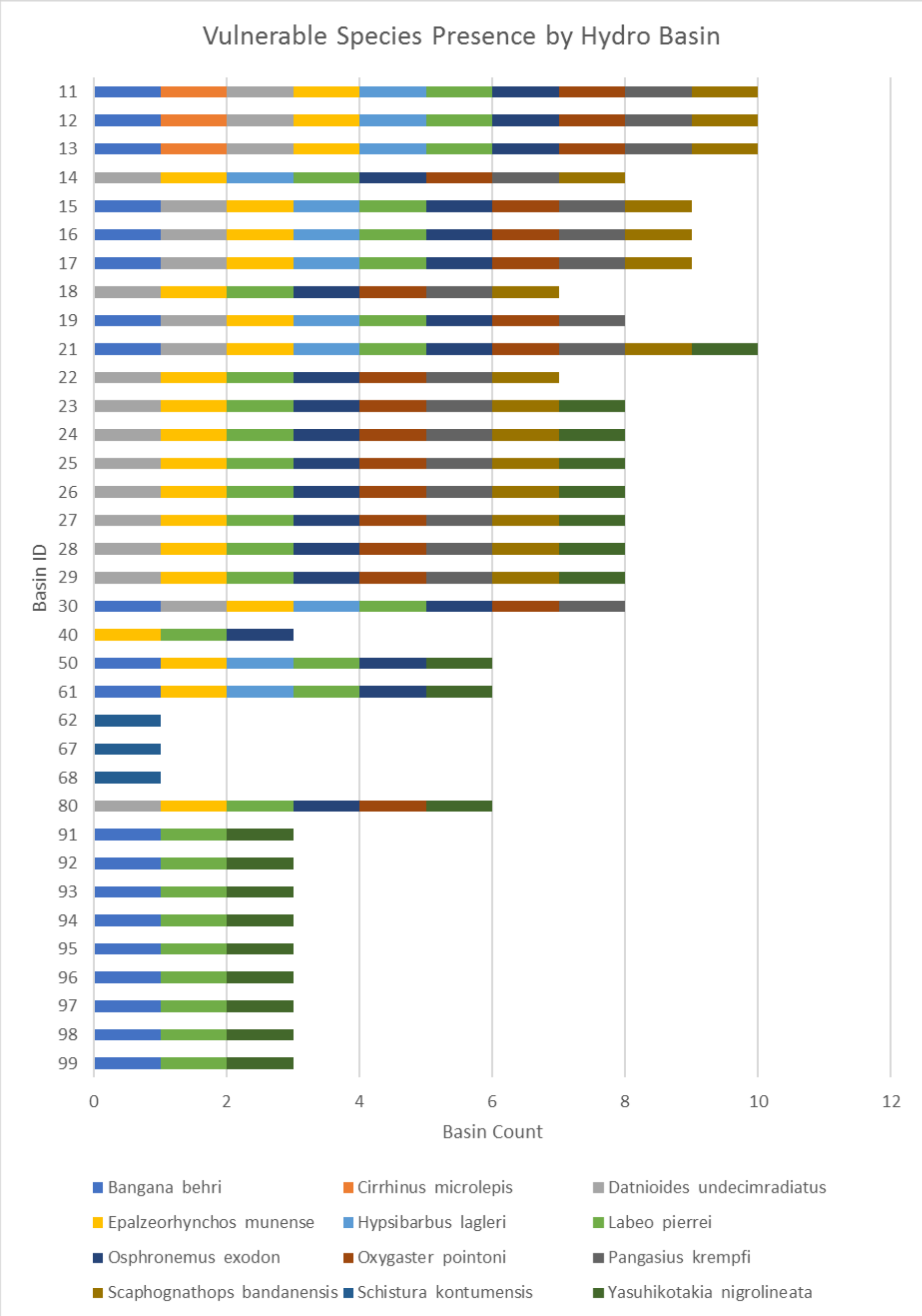


Figure 3-10: Vulnerable fish species by sub-basin in the Sekong



3.4.2 Migratory fish species

The distribution of the important migratory fish species listed by Warren and Phouvin during their consultations with villagers in the upper parts of the Sekong in 2016, has been mapped as shown in Figure 3-11 and Figure 3-12. As expected the highest numbers of migratory fish species are predicted to be found in the lower reaches of the Sekong, especially in Cambodia. In the lower parts of the basin in Lao, about 10 – 15 species are predicted to be found in the Xe Pian tributary and in the mainstem up to Attapeu. Above Attapeu in the Sekong and Xe Kaman, between 5 – 10 migratory species are predicted through the IUCN Redlist freshwater database.

Figure 3-11: Distribution of migratory fish species in the Sekong sub-basins

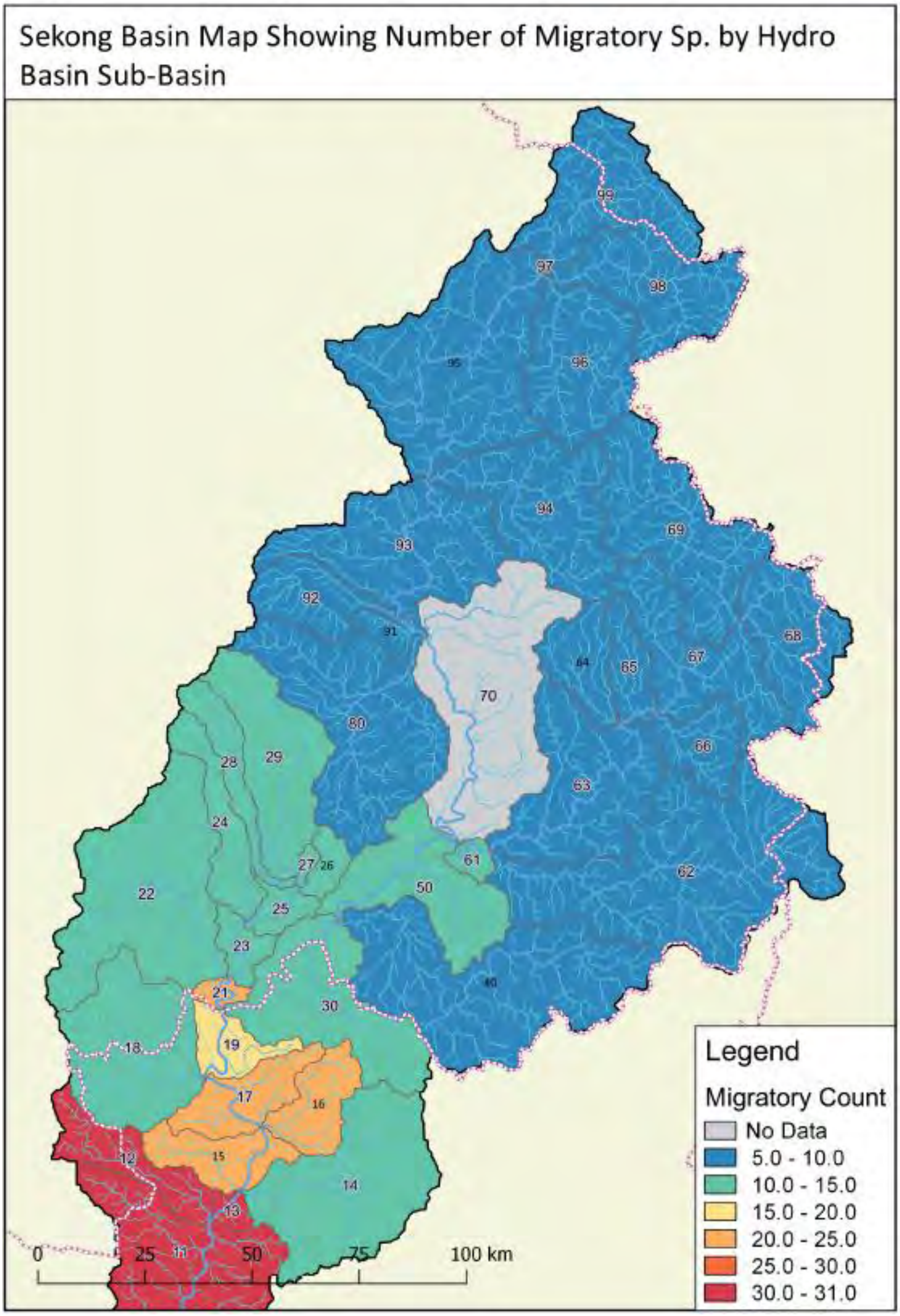
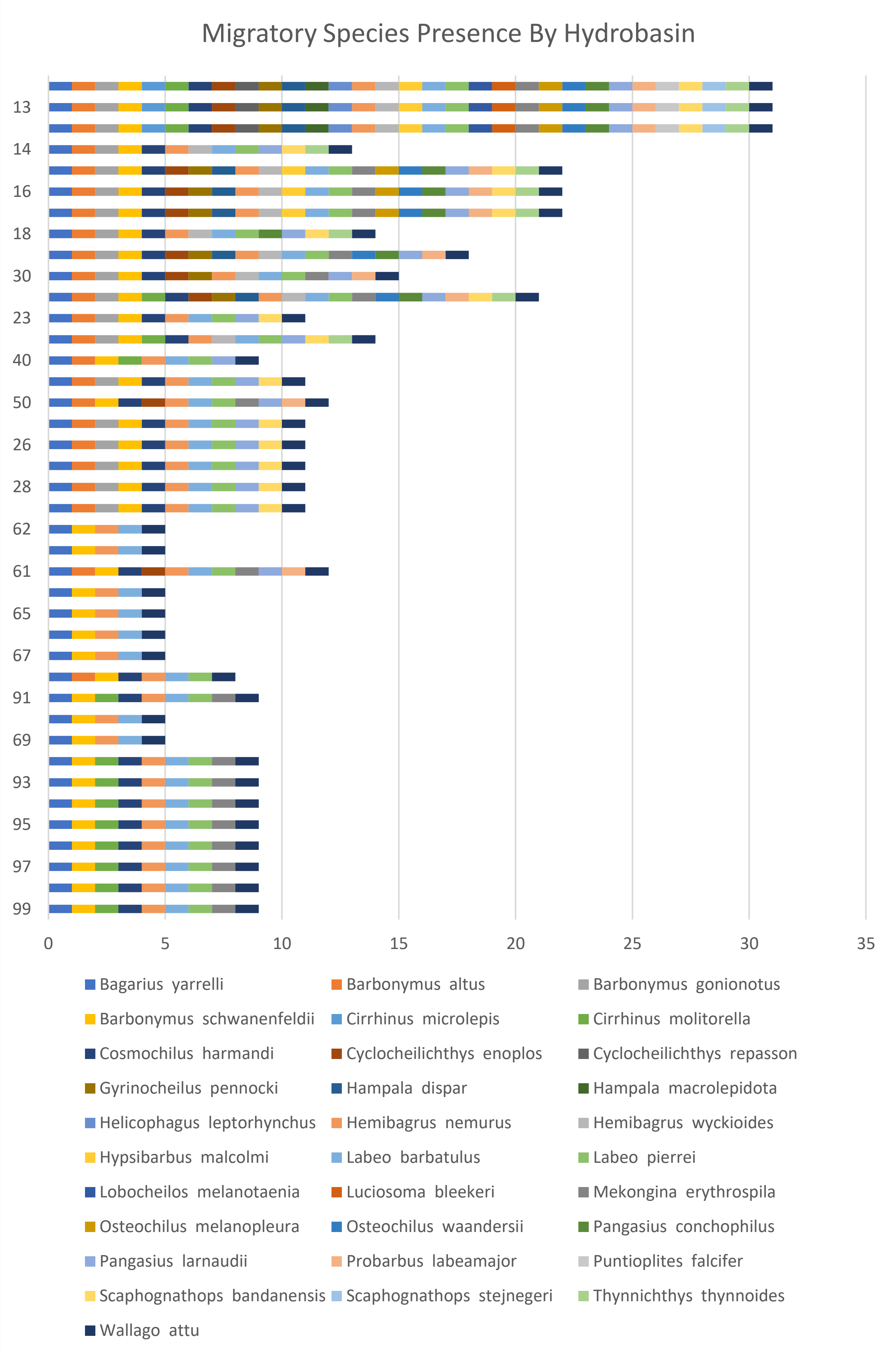


Figure 3-12: Migratory fish species by sub-basin in the Sekong



3.4.3 Endemic fish species

When considering the distribution of endemic species of fish (see Figure 3-13 and Figure 3-14) the opposite pattern to diversity of threatened species exists with the upper Sekong sub-basins 91 – 99 having the highest number of endemics – 10 species. Sub-Basin 61 – the confluence of the Sekong with the Xe Kaman also has 10 endemics, and site no 21, the confluence of the Sekong with the Xe Pian has 9 endemics. The Bolevan sub-basins (23 – 29, 80 and 50) have 8 endemics and it is probable that sub-basin 70 would have a similar number (if the IBAT data existed). The Xe Kaman has 4 endemic species, while the Xe Xou and Nam Khong have 2 endemic fish species.

Figure 3-13: Distribution of Endemic fish species in the Sekong sub-basins

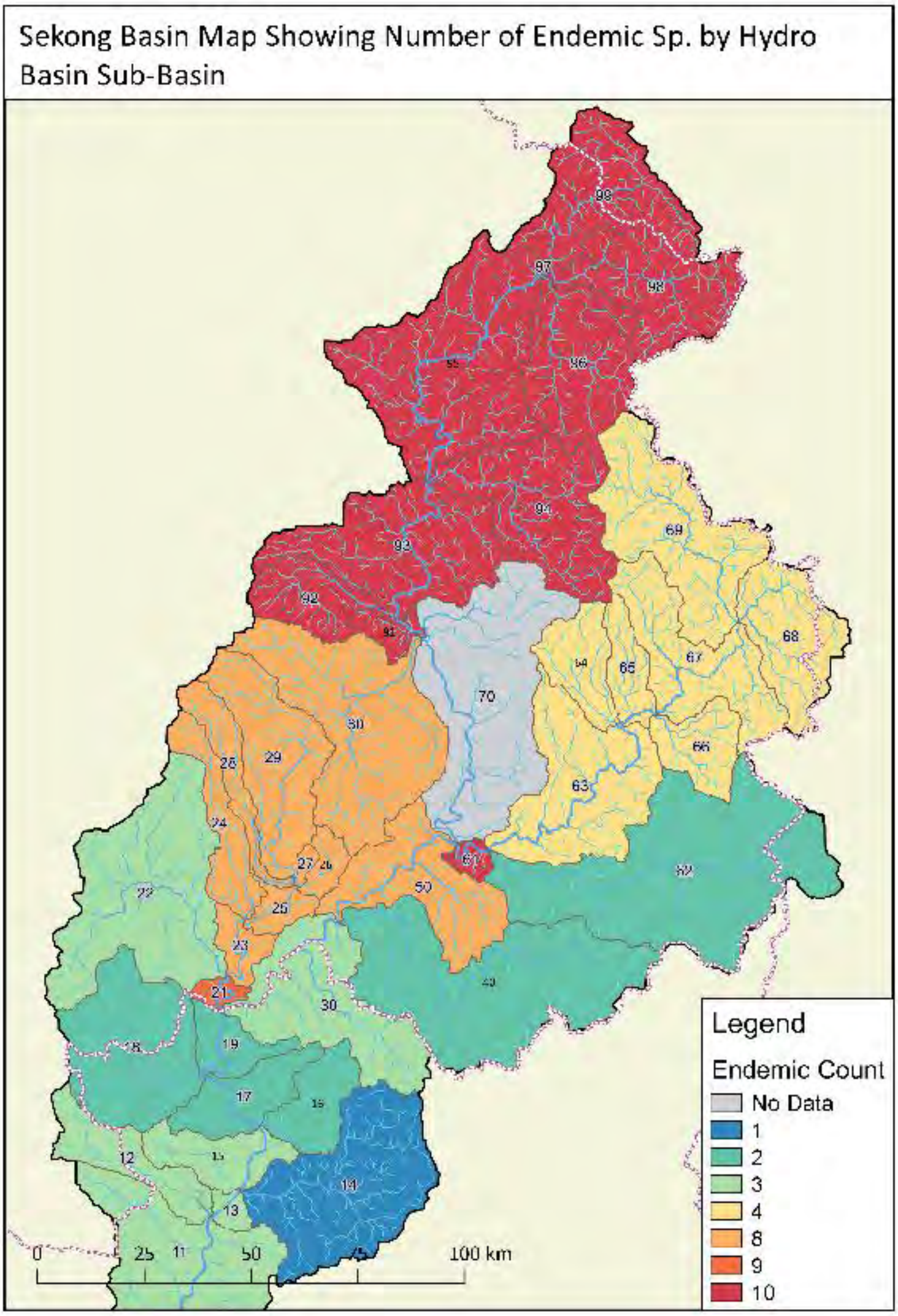
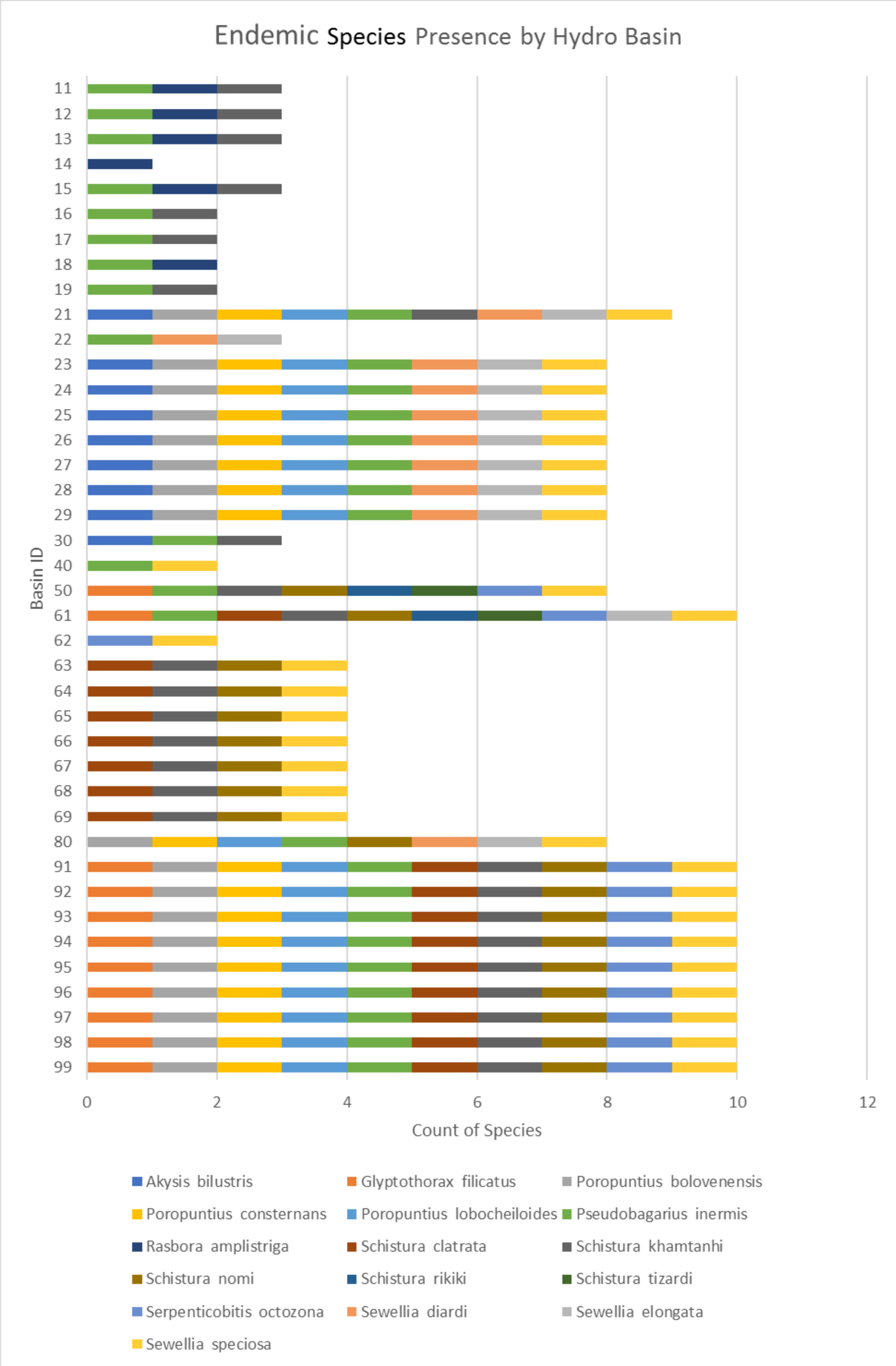


Figure 3-14: Endemic fish species by sub-basin in the Sekong



3.5 Highlighting endemic fish species sub-basins

The surveys of fish species in the Sekong and Xe Kaman carried out by Kottelat in 2009 and 2011, and his earlier surveys in early 2000 when he was compiling the book Fishes of Lao, have been used to identify the locations and sub-basins of endemic species. These surveys also include species that Kottelat identifies as species new to science (these are described as sp. n. with a location e.g. (Annamia sp. n. 'Bolaven'), and species which are also probably new but which have a close resemblance to other species (these are described as aff. with specific name of similar species e.g. Glyptothorax aff. zanaensis). In addition, the catalogue of fish species found in SE Asian rivers (Kottelat, 22 November 2013) has been used to identify the locations and sub-basins where the holotypes of fish have been found in the Sekong river basin. These have been plotted in a matrix of the sub-basins in Table 3-6 and expressed graphically in Figure 3-15.

While recognising that such an analysis is highly dependent upon where surveys have been carried out, rather than representing actual distributions, we can see that the sub-basin with the most number of endemic fish species is sub-basin 80 on the eastern catchment of the Bolevan plateau. Next there appears to be a strong grouping of sub-basins – 61, 62, 63, and 70 with a number of similar endemic species. There is another grouping of sub-basins 69, 93 and 95 with similar endemic species.

3.6 Preferred habitats of endemic fish species in the Sekong

An analysis of the preferred habitats of the fifteen endemic fish species of the Sekong is shown in Table 3-7. This shows that:

- 3 fish are high elevation species, *Glyptothorax filicatus, Poropuntius aluoiensis, Poropuntius bolovenensis*
- 2 fish prefer cooler water - *Poropuntius consternans, Poropuntius lobocheiloides,* i.e. found in higher elevations
- 10 species are found in streams, and 5 in rivers – of these 6 species are only found in streams and 1 is only found in the larger rivers – 4 are found in both rivers and streams
- 9 species prefer fast flowing water – 2 in riffles, 8 in rapids and 5 around waterfalls
    - Riffles - *Schistura nomi, Schistura rikiki*
    - Rapids - *Poropuntius consternans, Poropuntius lobocheiloides, Schistura clatrata, Schistura tizardi, Serpenticobitis octozona, Sewellia diardi, Sewellia elongate, Sewellia speciosa*
    - Waterfalls - *Poropuntius consternans, Poropuntius lobocheiloides, Sewellia diardi, Sewellia elongate, Sewellia speciosa*
- 4 species like clear water - *Poropuntius bolovenensis, Poropuntius consternans, Poropuntius lobocheiloides, Pseudobagarius inermis*
- Only 1 fish is found around muddy bottoms, *Akysis bilustris,* which also occurs in sandy bottoms*. Glyptothorax filicatus* also occurs in sandy bottoms
- 5 species occur in gravel and stony bottoms - *Pseudobagarius inermis, Schistura clatrata, Schistura nomi, Schistura tizardi, Serpenticobitis octozona*
- 3 are found in rocky bottoms - *Glyptothorax filicatus, Poropuntius consternans, Poropuntius lobocheiloides*

This analysis shows that most of the endemic species are found in the upper reaches, generally smaller streams and rivers, in fast flowing water, i.e. high gradient, with gravel, stones and rocky bottoms. They are most often found around riffles, rapids and waterfalls.

Table 3-6: Endemic fish species found in the Sekong and its sub-basins

		Sub-basin Code																																						
Species Binomial	**Endemic**	**99**	**98**	**97**	**96**	**95**	**94**	**93**	**92**	**69**	**68**	**91**	**80**	**67**	**66**	**65**	**64**	**70**	**61**	**63**	**62**	**29**	**28**	**27**	**26**	**24**	**50**	**25**	**40**	**22**	**23**	**21**	**30**	**19**	**18**	**17**	**16**	**15**	**14**	**13**	**12**	**11**
Acanthocobitis sp. n. 'Xe Kong'	new																																1									
Akysis bilustris	Holotype in Sekong																										1															
Annamia sp. n. 'Bolaven'	new												1																													
Glyptothorax filicatus	Holotype in Sekong	1																1			1																					
Glyptothorax aff. zanaensis	probably new																			1	1																					
Laocypris sp. n. 'Xe Kong'	new																			1	1				1																	
Pangio aff. anguillaris	probably new																											1					1									
Pangio aff. fusca	probably new																											1					1									
Poropuntius bolovenensis	Holotype in Sekong												1																													
Poropuntius consternans	Holotype in Sekong												1																													
Poropuntius lobocheiloides	Holotype in Sekong												1																													
Pseudobagarius inermis	Holotype in Sekong																				1																					
Rasbora amplistriga	Holotype in Sekong																	1																								
Rasbora aff. atridorsalis	probably new							1																																		
Rasbora aff. daniconius	probably new																			1					1																	
Scaphiodonichthys sp. n. 'Dakchung'	new									1																																
Schistura clatrata	Holotype in Sekong					1		1		1				1				1		1	1																					
Schistura diminuta	Holotype in Sekong												1																													
Schistura khamtanhi	Holotype in Sekong					1		1	1									1			1																					
Schistura nomi	Holotype in Sekong							1											1																							
Schistura rikiki	Holotype in Sekong																		1																							
Schistura tizardi	Holotype in Sekong							1					1						1	1																						
Schistura sp. n. 'Bolaven'	new												1																													
Schistura sp. n. 'Dakchung'	new									1				1																												
Serpenticobitis octozona	Holotype in Sekong							1					1								1																					
Sewellia elongata	Holotype in Sekong												1																													
Sewellia diardi	Holotype in Sekong												1					1																								
Sewellia speciosa	Holotype in Sekong					1		1					1					1		1																						
Sewellia sp. n. 'Dakchung'	new									1																																
Tor aff. tambra	probably new																				1																					
Tor aff. tambroides	probably new					1												1			1																					
Yasuhikotakia splendida	Holotype in Sekong																					1																				
Total number of likely endemic species		**1**	**0**	**0**	**0**	**4**	**0**	**7**	**1**	**4**	**0**	**0**	**14**	**2**	**0**	**0**	**0**	**7**	**3**	**6**	**9**	**1**	**0**	**0**	**2**	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Note that although holotypes of *Rasbora amplistriga a*nd *Schistura khamtanhi* were first described from the Sekong, they are also found in Mekong mainstream around Khone Falls, so they are not strictly endemic only the Sekong.

Table 3-7: Preferred habitats of endemic fish species

Name	Preferred habitat (from IUCN Redlist description)	Elevation	Streams	Rivers	Fast flowing	Riffles	Rapids	Waterfalls	Clear water	Cool water	Muddy bottom	Sandy bottom	Stony bottom	Rocky bottom	Submerged vegetation
Akysis bilustris	Observed in streams and rivers, on sandy to muddy bottom with submerged vegetation and/or debris		x	x							x	x			x
Glyptothorax filicatus	inhabits hillstreams with a swift current, clear water and a substrate of rocks/sand.	High	x		x							x		x	
Poropuntius aluoiensis	Found in the upper parts of a river catchment.	High	x												
Poropuntius bolovenensis	It is found in clear rocky streams approximately 800–1,200 m asl. It feeds mainly on insects and does not do well in reservoirs. The species migrates short distances - probably not truly migratory, but undertakes local or short distance movements	800 – 1,200 masl	x						x						
Poropuntius consternans	Streams with clear, cool and fast water, over stones, rocks, rapids and waterfalls.		x		x		x	x	x	x				x	
Poropuntius lobocheiloides	Streams with clear, cool and fast water, over stones, rocks, rapids and waterfalls.		x		x		x	x	x	x				x	
Pseudobagarius inermis	This species inhabits a variety of habitats from swift creeks to riffles in streams and rapids in large rivers. All of the habitats had a stony substrate and swift current; most of them had clear water (during the dry season).		x	x	x				x				x		
Schistura clatrata	This species was collected in rapids, stretches of rivers with stone bottom (Kottelat 2000).			x			x						x		
Schistura nomi	Observed in streams with moderate to fast water, in riffles, over gravel to stone substrate.		x		x	x							x		

Name	Preferred habitat (from IUCN Redlist description)	Elevation	Streams	Rivers	Fast flowing	Riffles	Rapids	Waterfalls	Clear water	Cool water	Muddy bottom	Sandy bottom	Stony bottom	Rocky bottom	Submerged vegetation
Schistura rikiki	Observed in Xe Kong main river, in riffles, over gravel to stone substrate.					x									
Schistura tizardi	This species was collected in rapids, stretches of the main river with stone bottom and smaller tributaries (Kottelat 2000).		x	x			x						x		
Serpenticobitis octozona	Found in rapids and fast flowing waters in the mainriver and larger tributatries. Also in stretches of river with large gravel (M. Kottelat pers. comm. 2011).		x	x	x		x						x		
Sewellia diardi	Found in fast flowing waters in rapids and waterfalls (Roberts 1998).				x		x	x							
Sewellia elongata	This species is found in very fast flowing water, rapids and waterfalls (M. Kottelat pers. comm. 2011).				x		x	x							
Sewellia speciosa	This species is found in fast flowing water, rapids and waterfalls (M. Kottelat pers comm. 2011).				x		x	x							

Figure 3-15: Number of likely endemic fish species found in Sekong sub-basins

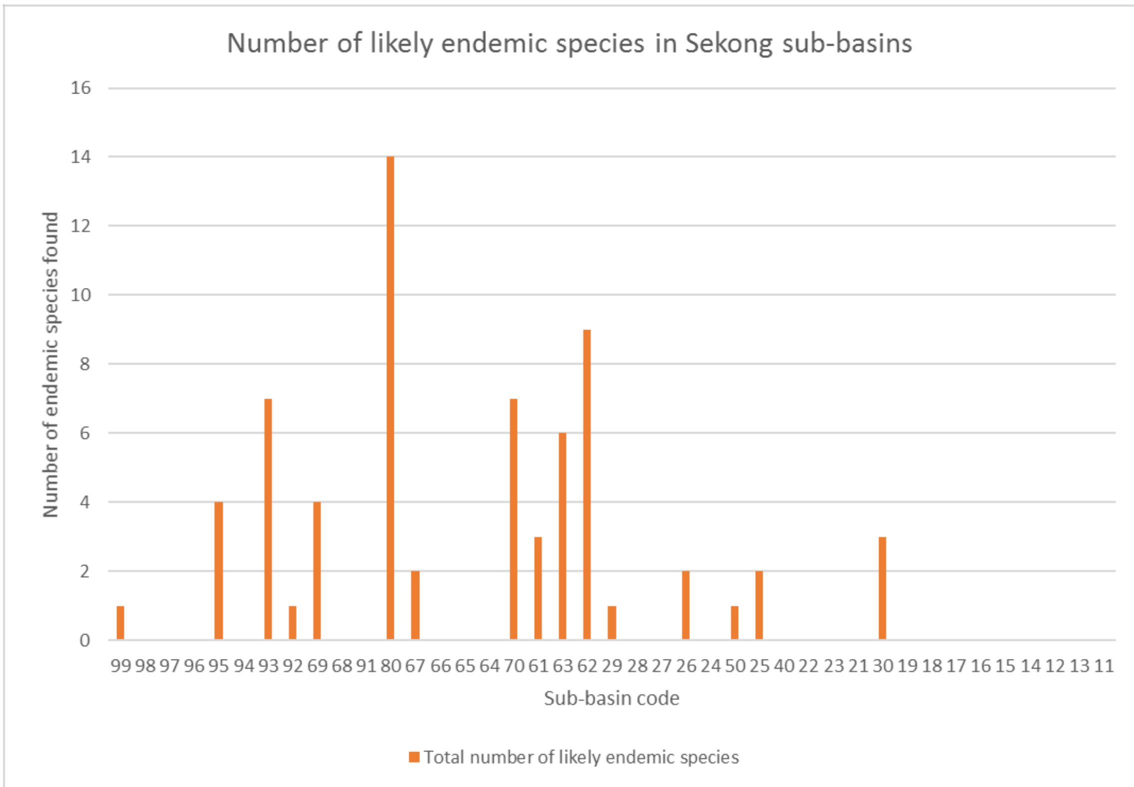
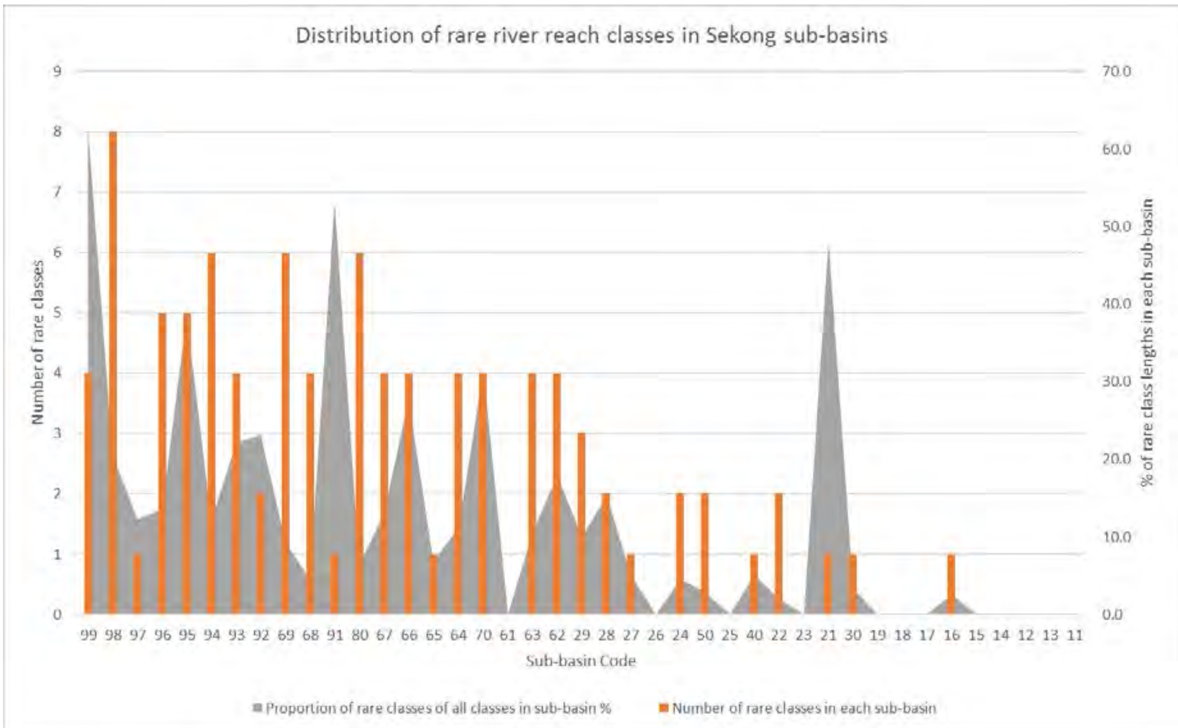


Figure 3-16: Distribution of rare river reach classes in Sekong sub-basins



When the distribution patterns of the endemic species and the rare river reaches are compared in Figure 3-15 and Figure 3-16, the sub-basin with the highest number of endemic species – sub-basin 80 also has 6 different rare river reach classes, although the proportion of these is fairly low in such a large sub-basin. The grouping of sub-basins 69, 93 and 95 all have high numbers of rare reach classes, and high proportions. Similarly, the grouping of sub-basins 70, 62 and 63 shows at least 3 – 4 different rare river reach classes with a proportion of 15 – 25% coverage.

It is interesting that sub-basin 61, a very small sub-basin with high proportion of endemic species reported as present in the IBAT database, has no rare river reach classes nor surveyed endemics. Its importance as a location for endemics is probably because it lies at the confluence between the Sekong and Xe Kaman catchments. Similarly, sub-basin 21 also has no surveyed endemics, but a high proportion of endemic species on the IBAT database, is also a small sub-basin on the confluence between the Sekong and Xe Pian.

A more detailed analysis of the character of the rare river reaches in the sub-basins with the highest numbers of surveyed endemics is shown in Table 3-8: This shows that there is a lot of similarity between these sub-basins.

- Sub-basins 95 and 70 contain all the rare “Large river, in moist broadleaf forest region at low elevation, with low gradient”
- All 7 of the sub-basins share significant proportions (over 70% of the total lengths of rare river reach) of
    - Small river, in moist broadleaf forest region at low elevation, with high gradient
    - Small river, in dry broadleaf forest region, with high gradient
    - Small headwater stream, in moist broadleaf forest region at low elevation
- 5 of the sub-basins share significant proportions (43%) of “Small river, in moist broadleaf forest region at low elevation, with low gradient”
- Sub-basins 69 and 80 share
    - Medium river, in moist broadleaf forest region at low elevation, with high gradient
    - Medium river, in moist broadleaf forest region at high elevation, with high gradient
- The karst streams are only represented by sub-basin 95

Table 3-8: Distribution of rare river reaches in each of the sub-basins with high proportions of endemic fish species

Class ID	Class Description	Sub-basin Code							Grand Total	% of total class lengths in selected sub-basins
		95	93	69	80	70	63	62		
23101	Large river, in moist broadleaf forest region at low elevation, with low gradient	22.79				16.6			39.39	100.0
24101	Large river, in dry broadleaf forest region, with low gradient	66.25	51.64			60.22	73.28		324.01	93.2
24103	Large river, in dry broadleaf forest region, with floodplains		3.97						18.51	21.4
24105	Large river, in dry broadleaf forest region, with floodplains and sediment								221.42	0.0
33101	Medium river, in moist broadleaf forest region at low elevation, with low gradient			2.21	24.91	2.66			145.52	25.5
33102	Medium river, in moist broadleaf forest region at low elevation, with high gradient			2.03	8.74				31.69	68.3
33301	Medium river, in moist broadleaf forest region at high elevation, with low gradient			32.59					43.25	88.4
33302	Medium river, in moist broadleaf forest region at high elevation, with high gradient			1.54	2.78				14.22	70.8
34101	Medium river, in dry broadleaf forest region, with low gradient		3.47	11.9	18.21	24.29	1.54	91.48	499.43	53.0
34103	Medium river, in dry broadleaf forest region, with floodplains							4.43	161	2.8
43101	Small river, in moist broadleaf forest region at low elevation, with low gradient	22.52			0.46	21.78	8.78	10.99	173.64	42.8
43102	Small river, in moist broadleaf forest region at low elevation, with high gradient	63.63	22.17	3.29	8.73	44.4	4.07	7.93	256.39	72.8
43301	Small river, in moist broadleaf forest region at high elevation, with low gradient	1.75		71.41	106.2				404.61	81.6
43302	Small river, in moist broadleaf forest region at high elevation, with high gradient	8.19		43.4	19.38			6.38	500.5	66.3
44101	Small river, in dry broadleaf forest region, with low gradient	33.89	86.91	1.57	53.22	97.42	90.18	175.5	1,822.02	31.6
44102	Small river, in dry broadleaf forest region, with high gradient	61.12	29.4	5.32	0.89	8.4	2.18	64.57	329.47	72.9
48100	Small river, in karst region at low elevation								4.82	0.0
48300	Small river, in karst region at high elevation								6.87	0.0
53100	Small headwater stream, in moist broadleaf forest region at low elevation	100.8	45.26	4.11	20.9	138	29.13	72.43	701.02	74.9
53300	Small headwater stream, in moist broadleaf forest region at high elevation	107.4	5.28	335.4	357.7	39.45	13.15	29.92	2,313.33	69.8
54100	Small headwater stream, in dry broadleaf forest region	158.4	207.8	3.12	30.05	221.9	190.5	408.9	4,135.52	33.1
58100	Small headwater stream, in karst region at low elevation	2.2							5.66	38.9
58300	Small headwater stream, in karst region at high elevation								17.71	0.0
Grand Total		**649**	**455.9**	**517.8**	**652.2**	**675.2**	**412.8**	**872.5**	**12,170.00**	

When these rare river reach types are compared to the other sub-basins, that do not have reported endemic fish species, the following similarities stand out, indicating that these basins have an increased probability of hosting endemic fish species. These are shown in Table 3-9. Note that the basins without any rare river reach classes have been hidden.

- Almost all sub-basins listed contain "Small headwater stream, in moist broadleaf forest region at low elevation" making up the remaining 41% of this class in the Sekong, but this does not help in distinguishing between the sub-basins likely to have endemic species.
- There appears to be a similarity in sub-basins 99, 98, 96, 94, and 68, i.e. the upper Sekong and upper Xe Kaman
- There appears to be another grouping of sub-basins 28, 29, 64, 66, and 67, (i.e. Lower Xe Kaman and central Bolevan Plateau) which contain a predominance of
    - Small river, in dry broadleaf forest region, with high gradient
    - Small river, in moist broadleaf forest region at low elevation, with high gradient
    - Small river, in moist broadleaf forest region at low elevation, with low gradient
- Sub-basin 98 contains all the small rivers in karst region at high and low elevation and almost all the small headwater streams in karst region at high and low elevation.

Table 3-9: Distribution of rare river reach classes in sub-basins without reported endemic species

		Sub-basin Code																						% of total
Class ID	Class Description	99	98	97	96	94	92	68	91	67	66	65	64	29	28	27	24	50	40	22	30	16	Grand Total	class
33102	Medium river, in moist broadleaf forest region at low elevation, with high gradient	6.9			3.1	4.8		6.1															31.7	66.0
33301	Medium river, in moist broadleaf forest region at high elevation, with low gradient				5.0	5.7																	43.3	24.7
33302	Medium river, in moist broadleaf forest region at high elevation, with high gradient		4.2			1.1		4.7															14.2	69.6
43101	Small river, in moist broadleaf forest region at low elevation, with low gradient	71.2	14.5		8.9			0.6		2.8	5.8		0.6							4.6			173.6	62.8
43102	Small river, in moist broadleaf forest region at low elevation, with high gradient	27.2	9.1		17.9	1.6	11.4			9.1	7.3		3.0	4.4	5.9		5.2						256.4	39.9
44102	Small river, in dry broadleaf forest region, with high gradient					29.8				14.1	5.8	7.7	11.0	21.5	10.3		3.0	2.7	34.4		13.6	3.8	329.5	47.8
48100	Small river, in karst region at low elevation		4.8																				4.8	100.0
48300	Small river, in karst region at high elevation		6.9																				6.9	100.0
53100	Small headwater stream, in moist broadleaf forest region at low elevation	123.4	10.9	0.7	12.7	8.1	27.5	2.0	36.4	19.2	18.4		2.5	11.1		2.1		6.8		8.7			701.0	41.4
58100	Small headwater stream, in karst region at low elevation		3.5																				5.7	61.8
58300	Small headwater stream, in karst region at high elevation		17.7																				17.7	100.0
Grand Total		**365.9**	**348.5**	**5.5**	**353.1**	**422.2**	**168.0**	**293.0**	**68.4**	**348.5**	**134.3**	**111.5**	**154.0**	**368.7**	**105.3**	**42.4**	**179.5**	**327.2**	**673.9**	**677.2**	**406.7**	**150.3**	**12170.0**	
	Number of rare classes in each sub-basin	4.0	8.0	1.0	5.0	6.0	2.0	4.0	1.0	4.0	4.0	1.0	4.0	3.0	2.0	1.0	2.0	2.0	1.0	2.0	1.0	1.0		
	Proportion of rare classes of all classes in sub-basin %	62.5	20.5	12.3	13.5	12.1	23.2	4.6	53.2	13.0	27.7	6.9	11.2	10.0	15.4	4.9	4.5	2.9	5.1	2.0	3.3	2.5		

4 Comparing the sub-basins with probable presence of endemic species with hydropower locations

4.1 Existing and proposed hydropower projects in the Sekong

There are four existing hydropower projects the are operating in the Sekong basin. These are:

- Houay Ho on the Bolevan Plateau
- Houay Lamphan on the north-east of the Bolevan
- Xe Kaman 3, in the upper Xe Kaman near the Laos/Vietnamese border
- A Luoi and A Lin plants which divert water from upper reaches of the Sekong in Vietnam.

There are four others that are under construction:

- Xe Kaman 1 located where the Xe Kaman river emerges from the hills
- Xe Kaman – Sansay the regulating hydropower project below Xe Kaman 1
- Nam Khong 2 on the Nam Khong tributary
- Nam Khong 3 immediately upstream of Nam Khong2

There are 5 dams planned or proposed on the Sekong mainstem:

- Xe Kong downstream on the border with Cambodia
- Xe Kong 3d and Xe Kong 3up *Now called Xe Kong 3A and Xe Kong 3B, respectively.*
- Xe Kong 4A and Xe Kong 4B
- Xe Kong 5

There are 9 other dams on the tributaries:

- Xe Kaman 2A and Xe Kaman 2B
- Xe Kaman 4A and Xe Kaman 4B
- Dak E Mule
- Nam Kong 1
- Xe Katam
- Xe Nam Noy 5
- Xe Xou

These existing, under construction and planned hydropower projects are shown in Figure 4-1, together with the Protected Areas and Key Biodiversity Areas in the Sekong Basin. In addition, the Natural Heritage Institute have identified several alternative dam sites, instead of the planned the current configurations of the mainstem dams. These are shown in Figure 4-2.

- A_2
- A_3
- A_4
- A_5
- A_7
- A_8
- A_9

- Xe Kong_US1 *Xe Xet, not included in the Master Plan.*
- Xe Kong_US2 *Xe Lon*
- Xe Kong_US3 *Houay Axam*
- Xe Kong_US6 *NHI_B*
- *Dak E Mule Downstream*
- *Houay Pache*
- *Xe Xou, now eliminated from the Master Plan.*

Figure 4-1: Existing, under-construction and planned hydropower projects with Protected Areas and Key Biodiversity Areas in the Sekong basin

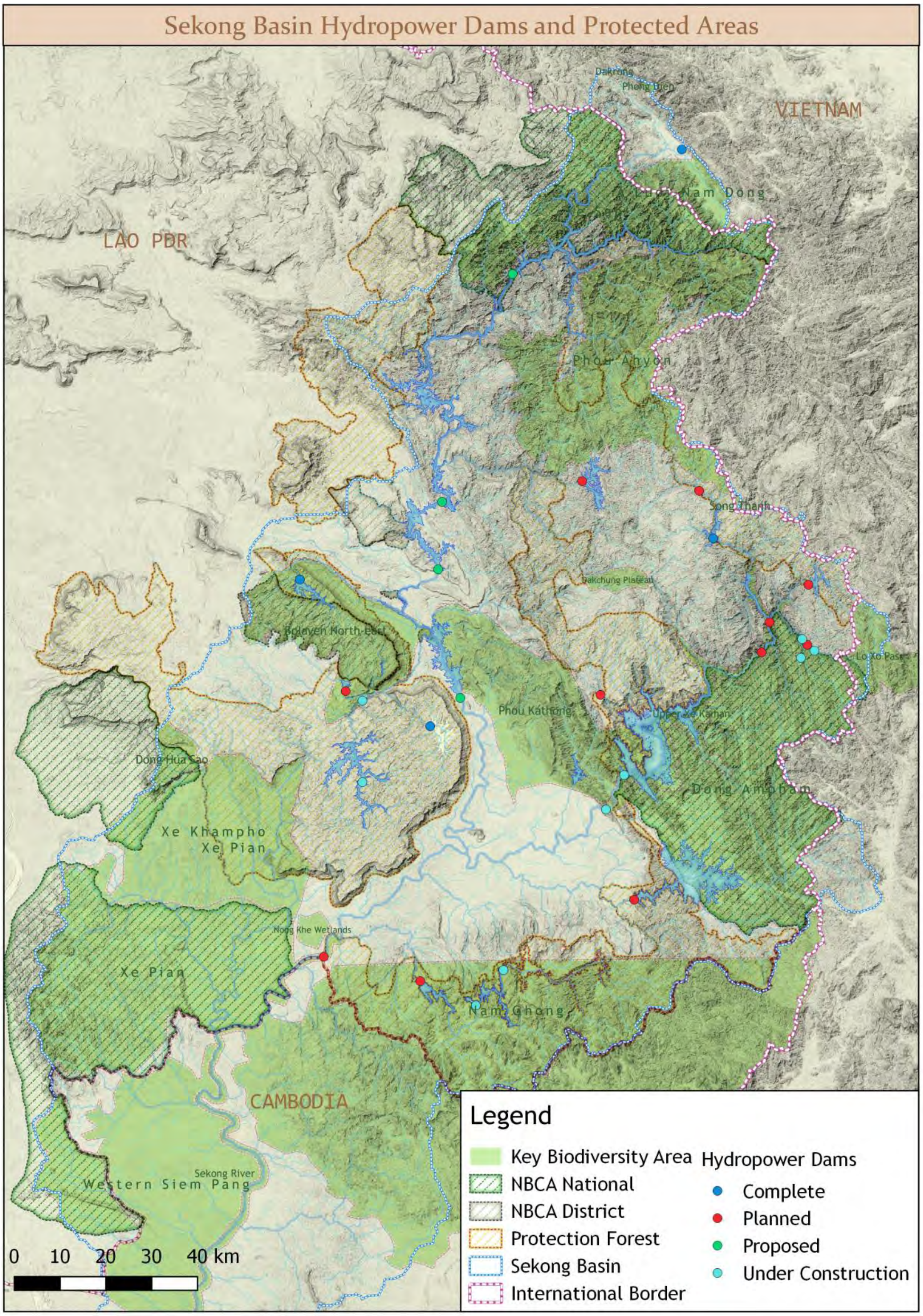


Figure 4-2: Alternative sites for hydropower project proposed by NHI

4.2 Analysis of existing and proposed hydropower projects with rare river reach types

The distribution of the different types of river reach in each of the existing and proposed reservoirs has been analysed to assess the extent to which they contain rare river reach types, and river reach types likely to contain habitats favourable for endemic species. The existing and under-construction reservoirs are shown in Table 4-1. The analysis shows that all (100%) of the river reaches inundated by the A Luoi reservoir in Vietnam are rare (less than 5% of the river reaches in that size class), while 68% of the river reaches inundated by Xe Kaman 3 are rare river reach types and 40% of the river reaches inundated by Houay Ho and Houay Lamphan on the Bolevan are rare types.

Of the rare river reach types inundated, the ones most at risk by existing and under-construction hydropower projects, are the *Medium river, in moist broadleaf forest region at high elevation, with low gradient* of which 26% has been inundated by Xe Kaman 3, and 14% of the common *Medium river, in dry broadleaf forest region, with low gradient* will be inundated by Xepian-Xe Namnoy, Xe Kaman 1 and Nam Khong 2 and 3, and 16% of the *Small river, in moist broadleaf forest region at high elevation, with low gradient* have been inundated by the reservoirs on the Bolevan Plateau (Houay Lamphan, Houay Ho and Xepian-Xenamnoy).

Considering the reaches which are preferred by endemic species, the, both Xe Kaman 3 and Houay Lamphan have a relatively high proportion of high gradient river reaches – 24% and 12% respectively. Three of the existing and under-construction plants have 100% of their reservoirs at high elevation (over 700 masl – Houay Lamphan, Houay Ho, and Xe Kaman 3. Xepian-Xenamnoy has 62% of river reaches at high elevation. The same four hydropower plants have significant proportions at both high elevation and with high gradient.

The distribution of river reach types in the planned hydropower projects is shown in Table 4-2. The projects that have high proportions of rare river reaches are Xe Katam and Xe Kaman 4a which both have 100% of rare river reaches, especially *medium and small rivers in moist broadleaf forest region at high elevation and high gradients*; Xe Nam Noy 5 HPP has nearly 80% of rare river reaches, especially the small rivers in *moist broadleaf forest region at high elevation with low and high gradients*. Dak e Mule has 54% of rare river reaches, especially *small rivers in moist broadleaf forest regions at high elevation and low and high gradients*. Xe Kong 5 has 87% of rare river reaches including about half of the lengths of large river reaches in *moist broadleaf forest at low elevation and low gradients*, the medium and small rivers in *moist broadleaf forest at low elevation and high and low gradients*. Xe Kong 3d also has 58% of rare reaches, including a similar length of the rare *Large moist broadleaf forest region at low elevation and low gradient*, as Xe Kong 5. These 2 mainstem dams (Xe Kong 3d and Xe Kong 5), would inundate 72% of this river reach type.

21% of the *Large river reaches in dry broadleaf forest regions with floodplains* would be inundated by Xe Kong 3up. About 23% of the *rare medium rivers in moist broadleaf forest regions at low elevation and low gradient* and 35% of those *medium rivers in moist broadleaf forest regions at high elevation and high gradients* would be lost by Xe Kaman 4b and Xe Katam.

The reaches inundated by Xe Kaman 4a and Xe Katam would all be high gradient reaches (100%), and the reservoirs of Xe Kaman 4a and 4b, Dak e Meule, Xe Katam and Xe Nam Noy 5 would all be (100%) high elevation reaches. These same HPP have significant proportions of reaches at high elevation and high gradient.

Table 4-1: Distribution of river reach types inundated by existing and under construction reservoirs

River size	Ecoregion	Elevation	Gradient	Geomorphology	Rare Class	total length of river reach type in Sekong	Houay Lamphan	Houay Ho	Xepian-Xenamnoy	Xekaman-Xanxay	Xekaman 1	Xekaman 3	Nam Khong 2	Nam Kong 3	A Luoi	total length of type	% of reach type converted to reservoir
							Bolevan			Xe Kaman			Nam Khong		Vietnam		
Hydropower project status							Op.	Op.	Cons.	Cons.	Cons	Op.	Cons.	Cons.	Op.		
River reach type						kms	kms	kms	kms	kms	kms	kms	kms	kms	kms		
Large	moist broadleaf forest region	low	low		Rare	39.39										0	-
Large	dry broadleaf forest region		low		Common	324.01				14.32	53.9					68.22	21.05
Large	dry broadleaf forest region			floodplains	Rare	18.51										0	-
Medium	moist broadleaf forest region	low	low		Rare	145.52									11.3	11.3	7.77
Medium	moist broadleaf forest region	low	high		Rare	31.69										0	-
Medium	moist broadleaf forest region	high	low		Rare	43.25						11.15				11.15	25.78
Medium	moist broadleaf forest region	high	high		Rare	14.22		0		0		0		0	0	0	-
Medium	dry broadleaf forest region		low		Common	499.43			5.36		7.95		22.69	31.81		67.81	13.58
Medium	dry broadleaf forest region			floodplains	Rare	161.00										0	-
Small	moist broadleaf forest region	low	low		Rare	173.64									14.03	14.03	8.08
Small	moist broadleaf forest region	low	high		Rare	256.39										0	-
Small	moist broadleaf forest region	high	low		Rare	404.61	10.7	20.71	30.33							61.74	15.26
Small	moist broadleaf forest region	high	high		Rare	500.50	4.23	0	3.28	0		6.19		0	0	13.7	2.74
Small	dry broadleaf forest region		low		Common	1,822.02			30.66	1.11	27.68		10.39	35.02		104.86	5.76
Small	dry broadleaf forest region		high		Rare	329.47					14.69			1.99		16.68	5.06
Headwater	moist broadleaf forest region	low			Rare	701.02		0			2.43				15.74	18.17	2.59
Headwater	moist broadleaf forest region	high			Common	2,313.33	21.68	31.61	40.64	0		8.13		0	0	102.06	4.41
Headwater	dry broadleaf forest region	low			Common	4,135.52			10.15	3.34	90.71		11.46	43.1		158.76	3.84
Headwater	karst	low			Rare	5.66										0	-
		Total Length Rare					14.93	20.71	33.61	0	17.12	17.34	0	1.99	41.07		
		Total Length Common					21.68	31.61	86.81	18.77	180.24	8.13	44.54	109.93	0		
		Total Length					**36.61**	**52.32**	**120.42**	**18.77**	**197.36**	**25.47**	**44.54**	**111.92**	**41.07**		
		% of rare reaches					40.78	39.58	27.91	-	8.67	68.08	-	1.78	100.00		
		Length of high gradient reaches					4.23	0	3.28	0	14.69	6.19	0	1.99	0		
		% of high gradient					11.55	-	2.72	-	7.44	24.30	-	1.78	-		
		Length of headwaters					21.68	31.61	50.79	3.34	93.14	8.13	11.46	43.1	15.74		
		% of Headwaters					59.22	60.42	42.18	17.79	47.19	31.92	25.73	38.51	38.32		
		Length of high elevation					36.61	52.32	74.25	0	0	25.47	0	0	0		
		% of high elevation reaches					100.00	100.00	61.66	-	-	100.00	-	-	-		
		Length of high elevation and high gradient					25.91	31.61	43.92	0	0	14.32	0	0	0		
		% of high elevationb and high gradient					70.77	60.42	36.47	-	-	56.22	-	-	-		

Table 4-2: Distribution of river reaches expected to be inundated by planned reservoirs in the Sekong basin

River size	Ecoregion	Elevation	Gradient	Geomorphology	Rare Class	al length of type in Seko	Xe Kong 3d	Xe Kong 3up	Xe kong 4A	Xe kong 4B	Xe Kong 5	Xe Kaman 2A	Xe Kaman 2B	Xe Kaman 4A	Xe Kaman 4B	Dak E Mule	Nam Kong 1	Xe Katam	Xe Nam Noy 5	Xe Xou	total length of reach type	% of reach type converted to reservoir
							Mainstem dams					**Xe Kaman**				**Tributaries**						
Large	moist broadleaf forest region	low	low		Rare	39.39	14.39				14.12										28.51	72.38
Large	dry broadleaf forest region		low		Common	324.01	19.85	34.92	8.31	6.95											70.03	21.61
Large	dry broadleaf forest region			floodplains	Rare	18.51		3.97													3.97	21.45
Medium	moist broadleaf forest region	low	low		Rare	145.52	14.26				19.49										33.75	23.19
Medium	moist broadleaf forest region	low	high		Rare	31.69															0	-
Medium	moist broadleaf forest region	high	low		Rare	43.25															0	-
Medium	moist broadleaf forest region	high	high		Rare	14.22									2.18			2.78			4.96	34.88
Medium	dry broadleaf forest region		low		Common	499.43	16.64		3.47			10.21	16.03				19.28			33.93	99.56	19.93
Medium	dry broadleaf forest region			floodplains	Rare	161.00														4.43	4.43	2.75
Small	moist broadleaf forest region	low	low		Rare	173.64	0.64														0.64	0.37
Small	moist broadleaf forest region	low	high		Rare	256.39					10.59		3.29								13.88	5.41
Small	moist broadleaf forest region	high	low		Rare	404.61									5.62	14.49			3.6		23.71	5.86
Small	moist broadleaf forest region	high	high		Rare	500.50								4.58	15.87	13.27		6.58	4.48		44.78	8.95
Small	dry broadleaf forest region		low		Common	1,822.02	12.31	25.87									4.71			35.96	78.85	4.33
Small	dry broadleaf forest region		high		Rare	329.47		2.21				1.11	3.11								6.43	1.95
Headwater	moist broadleaf forest region	low			Rare	701.02	46.16				17.34		3.14								66.64	9.51
Headwater	moist broadleaf forest region	high			Common	2,313.33					9.56		5.75		11.22	23.57			2.06		52.16	2.25
Headwater	dry broadleaf forest region	low			Common	4,135.52	6.05	25.58	20.88	8.23		2.91	3.81				21.4			63.72	152.58	3.69
Headwater	karst	low			Rare	5.66															0	-
		Total Length Rare					**75.45**	**6.18**	**0**	**0**	**61.54**	**1.11**	**9.54**	**4.58**	**23.67**	**27.76**	**0**	**9.36**	**8.08**	**4.43**		
		Total Length Common					**54.85**	**86.37**	**32.66**	**15.18**	**9.56**	**13.12**	**25.59**	**0**	**11.22**	**23.57**	**45.39**	**0**	**2.06**	**133.61**		
		Total Length					**130.3**	**92.55**	**32.66**	**15.18**	**71.1**	**14.23**	**35.13**	**4.58**	**34.89**	**51.33**	**45.39**	**9.36**	**10.14**	**138.04**		
		% of rare					57.90	6.68	-	-	86.55	7.80	27.16	100.00	67.84	54.08	-	100.00	79.68	3.21		
		length of high					0	2.21	0	0	10.59	1.11	6.4	4.58	18.05	13.27	0	9.36	4.48	0		
		% of high gradient					-	2.39	-	-	14.89	7.80	18.22	100.00	51.73	25.85	-	100.00	44.18	-		
		Length of headwaters					52.21	25.58	20.88	8.23	26.9	2.91	12.7	0	11.22	23.57	21.4	0	2.06	63.72		
		% of HW					40.07	27.64	63.93	54.22	37.83	20.45	36.15	-	32.16	45.92	47.15	-	20.32	46.16		
		length of high elevation					0	0	0	0	9.56	0	5.75	4.58	34.89	51.33	0	9.36	10.14	0		
		% of high elevation					-	-	-	-	13.45	-	16.37	100.00	100.00	100.00	-	100.00	100.00	-		
		Length of high elevation and high gradient					0	0	0	0	9.56	0	5.75	4.58	29.27	36.84	0	9.36	6.54	0		
		% of high elevation and high gradient					-	-	-	-	13.45	-	16.37	100.00	83.89	71.77	-	100.00	64.50	-		

Table 4-3: Distribution of river reaches expected to be inundated by the additional proposed hydropower projects

River size	Ecoregion	Elevation	Gradient	Geomorphology	Rare Class	total length of type in Sekong	A_2	A_3	A_4	A_5	A_7	A_8	A_9	Xe Kong_US1	Xe Kong_US2	Xe Kong_US3	Xe Kong_US6	total length of type	% of reach type converted to reservoir	Houay Axam Circle	Upper Xe Kaman Circle
Large	moist broadleaf forest region	low	low		Rare	39.39											8.67	**8.67**	**22.01**		
Large	dry broadleaf forest region		low		Common	324.01											53.68	**53.68**	**16.57**		
Large	dry broadleaf forest region			floodplains	Rare	18.51												**0**	**-**		
Medium	moist broadleaf forest region	low	low		Rare	145.52					7.6	4.23		14.92	21.85	17.8		**66.4**	**45.63**	22.33	
Medium	moist broadleaf forest region	low	high		Rare	31.69						6.92				3.14		**10.06**	**31.75**	3.14	2.03
Medium	moist broadleaf forest region	high	low		Rare	43.25	3.07	3.73										**6.8**	**15.72**	0	9.65
Medium	moist broadleaf forest region	high	high		Rare	14.22			1.54									**1.54**	**10.83**	0	1.54
Medium	dry broadleaf forest region		low		Common	499.43												**0**	**-**		
Medium	dry broadleaf forest region			floodplains	Rare	161.00												**0**	**-**		
Small	moist broadleaf forest region	low	low		Rare	173.64						1.53			0.64		3.93	**6.1**	**3.51**	1.11	
Small	moist broadleaf forest region	low	high		Rare	256.39				3.04		5.88		5.17	6.72	16.96		**37.77**	**14.73**	16.96	0
Small	moist broadleaf forest region	high	low		Rare	404.61				7.62								**7.62**	**1.88**	2.21	0.64
Small	moist broadleaf forest region	high	high		Rare	500.50				5.07					6.64			**11.71**	**2.34**	4.57	9.43
Small	dry broadleaf forest region		low		Common	1,822.02							14.49				21.62	**36.11**	**1.98**		
Small	dry broadleaf forest region		high		Rare	329.47											34.98	**34.98**	**10.62**	0	0
Headwater	moist broadleaf forest region	low			Rare	701.02				0.67		1.39	3.3	0.69	1.61	11.04	8.93	**27.63**	**3.94**	22.23	
Headwater	moist broadleaf forest region	high			Common	2,313.33					3.53	5.84		12.2	17.91	7.4		**46.88**	**2.03**	36.74	22.77
Headwater	dry broadleaf forest region	low			Common	4,135.52							1.99				67.13	**69.12**	**1.67**		
Headwater	karst	low			Rare	5.66											2.2	**2.2**	**38.87**		
		Total Length Rare					**3.07**	**3.73**	**1.54**	**16.4**	**7.6**	**19.95**	**3.3**	**20.78**	**37.46**	**48.94**	**58.71**			**72.55**	**23.29**
		Total Length Common					**0**	**0**	**0**	**0**	**3.53**	**5.84**	**16.48**	**12.2**	**17.91**	**7.4**	**142.43**			**36.74**	**22.77**
		Total Length					**3.07**	**3.73**	**1.54**	**16.4**	**11.13**	**25.79**	**19.78**	**32.98**	**55.37**	**56.34**	**201.14**			**109.29**	**46.06**
		% of rare					100.00	100.00	100.00	100.00	68.28	77.36	16.68	63.01	67.65	86.87	29.19			66.38	50.56
		length of high					0	0	1.54	8.11	0	12.8	0	5.17	13.36	20.1	34.98			24.67	13
		% of high gradient					-	-	100.00	49.45	-	49.63	-	15.68	24.13	35.68	17.39			22.57	28.22
		Length of headwaters					0	0	0	0.67	3.53	7.23	5.29	12.89	19.52	18.44	78.26			58.97	22.77
		% of HW					-	-	-	4.09	31.72	28.03	26.74	39.08	35.25	32.73	38.91			53.96	49.44
		length of high elevation					3.07	3.73	1.54	12.69	3.53	5.84	0	12.2	24.55	7.4	0			43.52	44.03
		% of high elevation					100.00	100.00	100.00	77.38	31.72	22.64	-	36.99	44.34	13.13	-			39.82	95.59
		Length of high elevation and high gradient					0	0	1.54	5.07	3.53	5.84	0	12.2	24.55	7.4	0			41.31	33.74
		% of high elevation and high gradient					-	-	100.00	30.91	31.72	22.64	-	36.99	44.34	13.13	-			37.80	73.25

Table 4-3 shows the distribution of river reach types in the additional proposed projects. All the relatively small reservoirs of the A group projects have quite high proportion rare river reach types, especially – A_2, A_3, A_4 and A_5 all have 100%, with A_2 and A_3 covering *Medium river, in moist broadleaf forest region at high elevation, with low gradient,* but together only covering 15% of this river reach type. Similarly, A_4 covers 10% of the rare river reach *Medium river, in moist broadleaf forest region at high elevation, with high gradient.* A_5 has several rare river reaches mostly in the *Small river, in moist broadleaf forest region at low and high elevation and high gradients,* but none of these make a significant impact upon the total coverage of these rare river reaches.

A_7 has a 68% coverage of the rare river reach *Medium river, in moist broadleaf forest region at low elevation, with low gradient.* A_8 has about 77% coverage of several rare river reaches, including *Medium and small rivers, in moist broadleaf forest region at high elevation, with low and high gradients,* and *Headwaters at low elevation.* A_9 has a low proportion (17%) of Small headwater streams in moist broadleaf regions at low elevation.

The additional suggestions for the Upper Sekong – US1, US2, US3 basically split up the original proposed Sekong 5 into three sections and US6 is an upper variation of Sekong 4 reservoir. US1, US2, US3 all have quite high proportions of rare river reaches (63, 67 and 87% respectively of the river reaches covered are rare), while 29% of US6 reaches are rare. The three US1 – 3 options all have similar characters with the rare *Medium river, in moist broadleaf forest region at low elevation, with low gradient, Small river, in moist broadleaf forest region at low elevation, with high gradient, and Headwater in moist broadleaf at low elevation.* The most significant of these is the first, and together these three cover 35% of this type of rare river reach.

US6 has a different character, covering 22% of the rare river reach, *Large river in moist broadleaf forest region at low elevation and low gradient.* There are also some small lengths of rare river reaches covered including *Small rivers in moist broadleaf forest regions with low elevation and low gradient* and *Small rivers in dry broadleaf forest region with high gradient.*

In terms of rivers with high gradient, A_4 has 100 % of its river reaches with high gradient, and A_5 and A_9 have about 50% of the river reaches with high gradient. The US options have generally lower proportions of river reaches with high gradients, though US3 has the highest with about 35% of high gradient.

The combination of high elevation and high gradient, A_4 stands out with 100% coverage, A_5 and A_7 have about 31% and A_8 has 22% of river reaches in these categories. US1 and US2 have 37 and 44% of high elevation and high gradient reaches, and US3 has 13%. The rest do not have such categories, making them less likely to host endemic fish species which prefer these conditions.

The NHI options also consider two "circles" – those around Houay Axam, and those in the Upper Xe Kaman. These are also found in Table 4-3. The Houay Axam circle contains 66% of rare river reaches, of which 22% have high gradient and 38% have both high elevation and high gradient. The Upper Xe Kaman circle has about 50% of rare river reaches, with 28% with high gradient and 73% with high elevation and high gradient. Both "circles" would be likely to host endemic species of fish.

4.3 Extension of hydropower projects into Protected areas and Key Biodiversity areas

Protected Areas and Key Biodiversity Areas (KBAs) represent areas that have high biodiversity importance for different reasons. Protected Areas have been designated within the Sekong river basin at both national and district level. There are also several watershed and border protection forest areas that have been established in the Sekong basin. These include:

- Xe Sap NBCA
- Dong Amphan NBCA
- Dong Hua Sao NBCA
- Xe Pian NBCA

Key Biodiversity Areas are areas that have been identified as having known presence of threatened species or endemic species, often bird and mammal species. Annex 2 has the listing of KBAs and the reasons for their designation. In some cases, they overlap with NBCAs, but they may be wider than this. They have no official designation or protection, but are indicative of important biodiversity. There are no KBAs in the Sekong which are specific for fish or aquatic species, though some are important for water birds. There are two KBAs which cover part of the lower Sekong river and the Upper Xe Kaman. Table 4-4 shows the listing of KBAs in the Sekong river basin, and Figure 4-3 provides a map of the protected areas and KBAs in the basin. The hydropower reservoirs that intersect with both Protected Areas and Key Biodiversity Areas are shown in Table 4-6.

Table 4-4: Listing of Key Biodiversity Areas in the Sekong river basin

Name of KBA	**Area (ha)**	**Country**
Western Siem Pang	138,137	Cambodia
Virachey	432,415	Cambodia
Sekong River	14,116	Cambodia
Nam Ghong	160,000	Laos
Xe Pian	243,100	Laos
Nong Khe Wetlands	3,900	Laos
Xe Khampho / Xe Pian	197,280	Laos
Xe Khampho	120,000	Laos
Attapu Plain	71,400	Laos
Dong Ampham	180,220	Laos
Phou Kathong	94,000	Laos
Bolaven North-east	73,000	Laos
Upper Xe Kaman	34,780	Laos
Dakchung Plateau	5,140	Laos
Phou Ahyon	148,900	Laos
Xe Sap	137,120	Laos
A Luoi - Nam Dong	112,200	Vietnam
Northern Hien	24,700	Vietnam
Lo Xo Pass	15,000	Vietnam
Song Thanh	95,000	Vietnam

Figure 4-3 also shows the locations of deep pools and rapids and recognised Fish Conservation Zones (FCZs) that were mapped by WWF in 2009 and 2010. The extent of this mapping was limited to mainstem of the Sekong and Lower Xe Kaman. These would be covered by the mainstem Sekong reservoirs, Xe Kong 3 up and down, and Xe Kong 4 up and down.

Figure 4-3: Map of Protected Areas and Key Biodiversity Areas in the Sekong

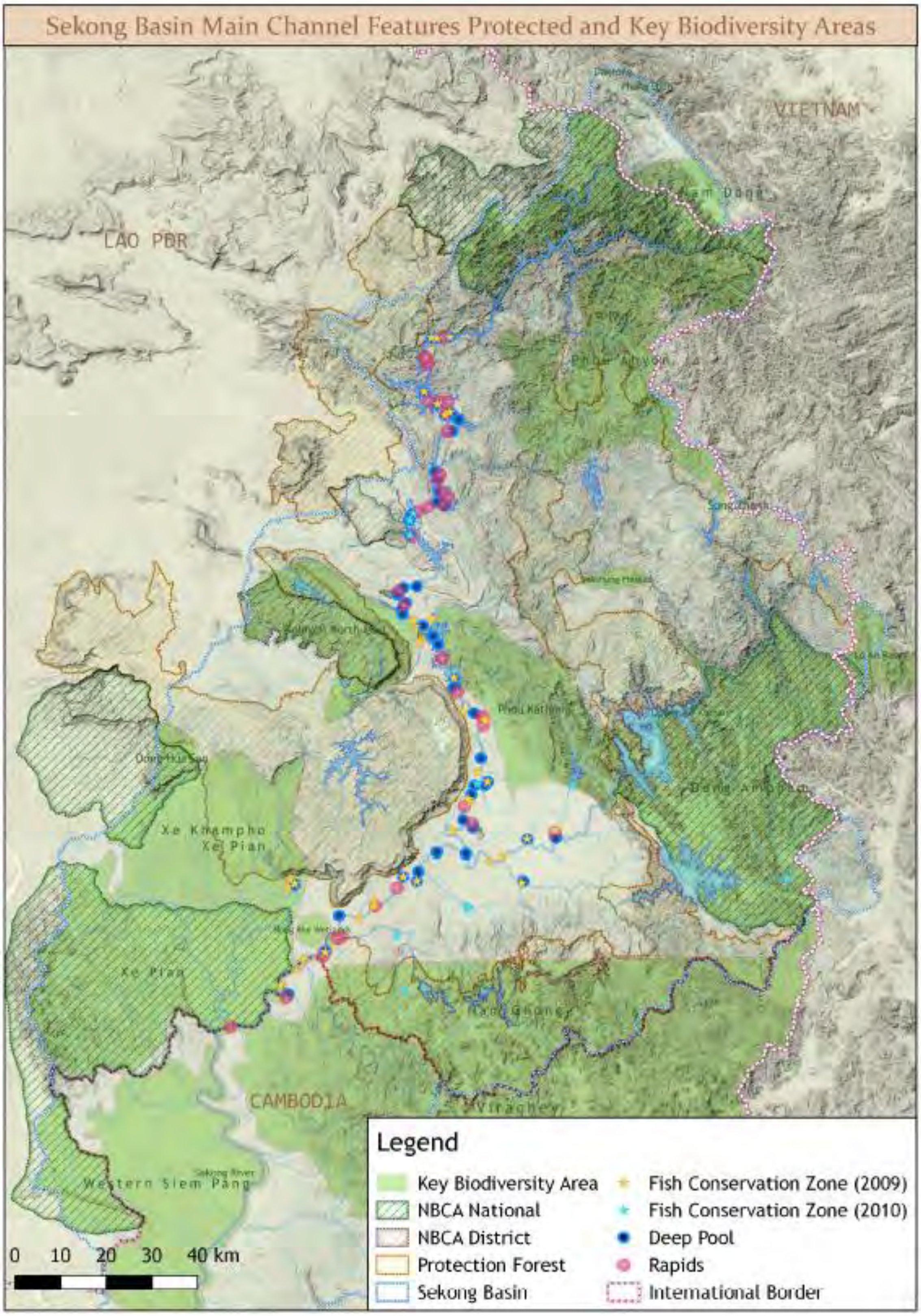


Table 4-5: Hydropower projects that intersect with Protected Areas and Key Biodiversity Areas

Dam Name	PA	KBA
Sekong mainstem	**Name**	**Name**
A Luoi		A Luoi/Nam Dong
Xe Kong 5	Xe Sap	Xe Sap
Xe Kong_US1	Xe Sap	Xe Sap
Xe Kong_US2	Xe Sap	Xe Sap
Xe Kong 3d		Phou Kathong
Xe Kaman		
Xe Kaman 2B	Dong Ampham	Dong Ampham, Upper Xe Kaman
Xe Kaman 2A	Dong Ampham	Dong Ampham, Upper Xe Kaman
Xekaman 1	Dong Ampham	Dong Ampham, Upper Xe Kaman
Xekaman-Sanxay		Upper Xe Kaman
Tributaries		
Houay Lamphan		Bolevan North east
Xe Katam		Bolevan North east
Xe Nam Noy 5		Bolevan North east
Xe Xou	Dong Ampham	Dong Ampham
Nam Kong 1		Nam Ghong
Nam Kong 2		Nam Ghong
Nam Kong 3		Nam Ghong

4.4 Identifying hydropower locations with presence of endemic species

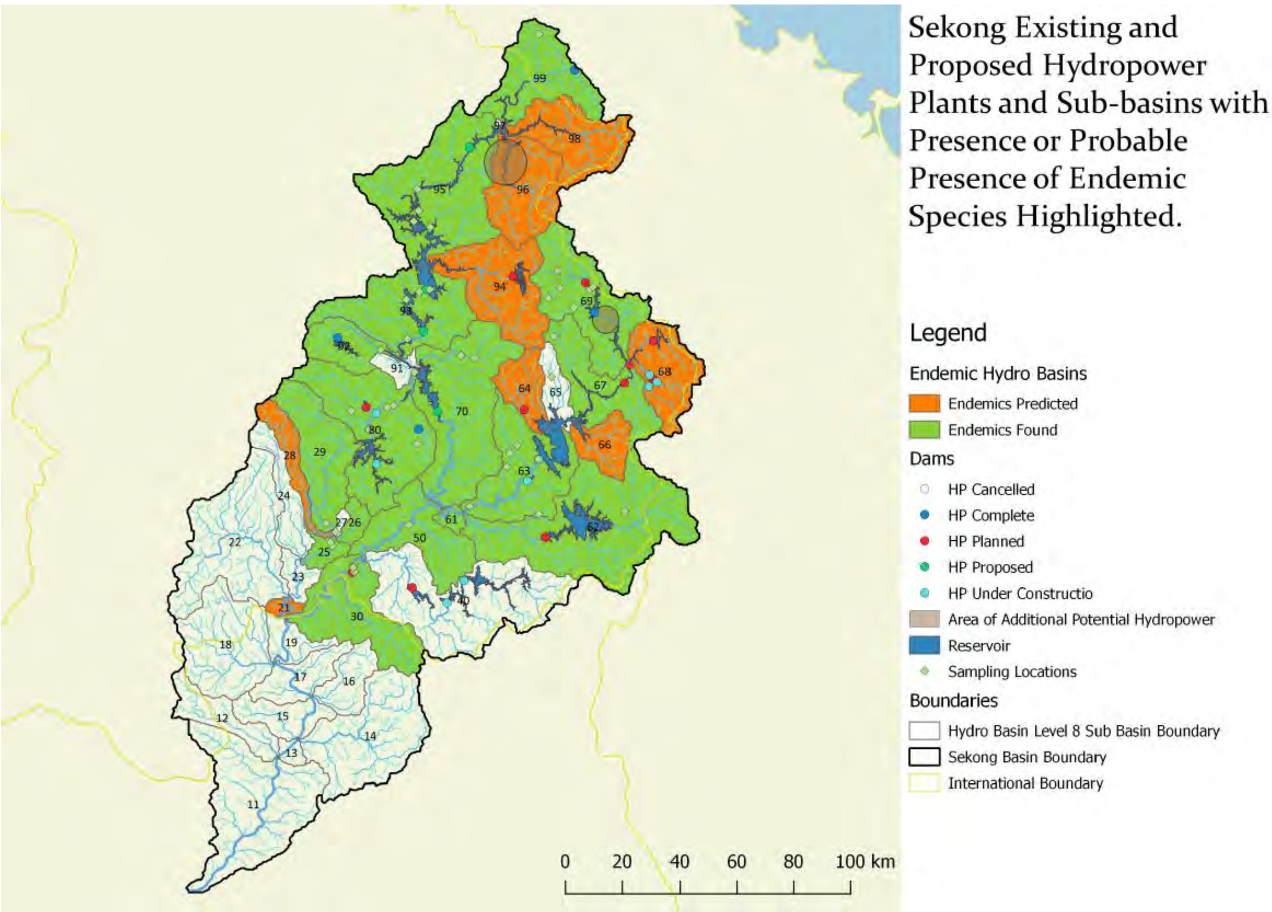
The final step in this process is to map the locations of existing and proposed hydropower dams and reservoirs with the sub-basins that have a higher probability of containing endemic fish species.

From the above analysis, the following sub-basins have either a proven or projected presence of endemic species:

- 95 and 70 – Sekong mainstem with high proportion of “Large river, in moist broadleaf forest region at low elevation, with low gradient”
- 98 – upper Sekong with high proportion of karst
- 93, 94, 95, 96, 98, 99, 69 and 68, i.e. the upper Sekong and upper Xe Kaman
- 70, 62, 63, 64, 66, and 67, (i.e. Lower Xe Kaman)
- 80, 28 and 29 – Eastern & central Bolevan Plateau
- 61 – confluence between Sekong and Xe Kaman
- 21 – confluence between Xe Pian and Sekong

These are mapped with the locations of the existing and proposed hydropower plants in Figure 4-4. There is a clear overlap between the areas that are most suited for hydropower development and the sub-basins where endemic species of fish are found. Some of these species are new to science and have not been fully described. The areas where additional hydropower potential has been identified also fall into the sub-basins where endemic species are located.

Figure 4-4: Map of the Sekong sub-basins with existing and proposed hydropower plants – sub-basins with probable presence of endemic species highlighted.



4.5 Assessing the risk to endemic species from hydropower projects

Table 4-6 combines the above analyses for each of the hydropower projects and their reservoirs. It provides information for each project on the overall length of river reaches inundated, the % of rare river reaches, and %s of high gradient and high gradient and elevation reaches, which have been identified as favoured by most endemic species. It also includes the presence of the reservoirs in Protected Areas and Key Biodiversity Areas, and the numbers of endemic species and threatened species found in each of the sub-basins where the reservoirs are located. Apart from the three Nam Kong reservoirs, where no endemic species were recorded or predicted, all the other reservoirs lie in sub-basins that contain endemic species. The Xe Kong mainstem sub-basins has the highest numbers of threatened species, while the reservoirs in the Xe Kaman have very few threatened species. The Bolevan reservoirs are also located in sub-basin that have higher numbers of threatened species.

An assessment is then done of the risks to endemic species by each reservoir. This takes into account the length of river reach inundated (the shorter the length, the less risk), the river reach rarity (the higher the % of rare river reaches, the greater the risk) and the proportion of high gradients and high elevation reaches (the higher % of these river reach types, the greater the risk). Each criterion is scored on a scale 1 – 3 and then multiplied together to give relative risk assessments. The highest risk reservoirs include A_4, Xe Kaman 4A and 4B, Xe Pian-Xe Namnoy and Xe Katam.

The reservoirs of medium risk to endemic species include A Luoi, Xe Kong 5, Xe Kong US1, US2, US3 and US6 and Xe Kong 3d, on the mainstem, Xe Kaman 2B, Dak E Mule, Houay Ho, Houay Lamphan, and Xe Nam Noy 5 and A_5.

The reservoirs of low risk to endemic species include A-7 (because of its relatively short reservoir), Xe Kong 4A and B and Xe Kong 3 up, A_2, A_3, Xe Kaman 2A and 2B, Xe Kaman 1 and Xe Kaman - Sanxay. In the tributaries the Xe Xou Hpp (Xe Xou and US-9 and US 10 appear to have low risk to endemics, as does A_9 and the Nam Khong HPPs. US-9 appears to be at the top end of the Xe Xou reservoir and may require adjustment of the Xe Xou HPP, and is located within the Dong Ampham NBCA. US-10 lies above the Xe Xou reservoir and is not located within the Dong Ampham NBCA, though the potentially dewatered reach downstream may flow through the NBCA.

Table 4-6: Combined data on river reaches, presence of endemic and threatened species, PAs and KBAs for existing and proposed dams

Dam Name	Basin_ID	Length of river reaches	% of rare river reaches	% of high gradient reaches	% of high elevation and high gradient reaches	Risk to endemic species	PA	KBA	Endemic species	Number of threatened species predicted		
Sekong mainstem		km					Name	Name	No.	CR	EN	VU
A Luoi	99	41.07	100.0	0.0	0.0	M		A Luoi/Nam Dong	10	0	5	3
Xe Kong 5	96, 95,97,98	71.1	86.5	14.9	13.5	M	Xe Sap	Xe Sap	10	0	5	3
Xe Kong_US1	99	33.0	63.0	15.7	37.0	M	Xe Sap	Xe Sap	10	0	5	3
Xe Kong_US2	98	55.4	67.7	24.1	44.3	M	Xe Sap	Xe Sap	Predicted	0	0	3
Xe Kong_US3	96	56.3	86.9	35.7	13.1	M			Predicted	0	0	3
A_7 (*)	96	11.1	68.3	0	31.7	L			10	0	0	3
Xe Kong_US6	95	201.1	29.2	17.4	0.0	M			10	0	5	3
Xe Kong 4B	95	15.18	0	0	0	L			10	0	5	3
Xe Kong 4A	93, 94,95	32.66	0	0	0	L			10	0	5	3
Xe Kong 3up	93	92.55	6.7	2.4	0	L			10	0	5	3
Xe Kong 3d	70, 80, 91, 92, 93	130.3	57.9	0	0	M		Phou Kathong	10	1	5	6
Xe Kaman												
A_2	69	3.07	100	0	0	L			4	0	0	0
A_3	69	3.73	100	0	0	L			4	0	0	0
A_4	69	1.54	100	100	100	H			4	0	0	0
Xe Kaman 4A	68	4.58	100	100	100	H			Predicted	0	0	1
Xe Kaman 4B	68	34.89	67.8	51.7	83.9	H			Predicted	0	0	1
Xe Kaman 3	69	25.47	68.1	24.3	56.2	M			4	0	0	0
Xe Kaman 2B	67, 68, 69	35.13	27.2	18.2	16.4	L	Dong Ampham	Dong Ampham, Upper Xe Kaman	4	0	0	1
Xe Kaman 2A	67	14.23	7.8	7.8	0	L	Dong Ampham	Dong Ampham, Upper Xe Kaman	4	0	0	1
Xekaman 1	63, 64, 65, 66	197.36	8.7	7.4	0.0	L	Dong Ampham	Dong Ampham, Upper Xe Kaman	4	0	0	1
Xekaman-Sanxay	63	18.77	0.0	0.0	0.0	L		Upper Xe Kaman	4	0	0	1
Tributaries												
Dak E Mule	94	51.33	54.1	25.9	71.8	M			Predicted	0	0	3
Houay Ho	80	52.32	39.6	0.0	60.4	M			8	0	0	6
Xepian-Xenamnoy	80	120.42	27.9	2.7	36.5	H			8	0	0	6
Houay Lamphan	92	36.61	40.8	11.6	70.8	M		Bolevan North east	10	0	0	3
Xe Katam	80	9.36	100	100	100	H		Bolevan North east	8	0	0	6
Xe Nam Noy 5	80	10.14	79.7	44.2	64.5	M		Bolevan North east	8	0	0	6
Xe Xou	62	138.04	3.2	0	0	L	Dong Ampham	Dong Ampham	2	0	0	1
US_9	62	10	0.0	0	0	L	Dong Ampham	Dong Ampham	2	0	0	1
US_10	62	10	0.0	0	0	L			2	0	0	1
A_5	63	16.4	100	49.5	30.9	M			4	0	0	1
A_9	63	19.78	16.7	0	0	L			4	0	0	1
Nam Kong 1	40	45.39	0	0	0	L		Nam Ghong	0	1	0	3
Nam Kong 2	40	44.54	0.0	0.0	0.0	L		Nam Ghong	0	1	0	3
Nam Kong 3	40	111.92	1.8	1.8	0.0	L		Nam Ghong	0	1	0	3

* Note that A-7 is in a similar location as US-3. The difference in the risk to endemics is in the length of the reservoir

Scoring:

Length class (km)	Rarity class (%)	Gradient/ elevation class (%)	Score	Combined Score	Risk to endemics
0 - 25	0 - 25	0 - 25	1	1-4	Low risk
25 - 75	25 - 75	25 - 75	2	5-8	Medium risk
>75	75 -100	75 -100	3	>9	High risk

5 Conclusion

This paper has considered the potential for identifying river reach types in the Sekong that may provide suitable habitats for species of fish that are endemic to the Sekong basin. There are at least 13 confirmed endemic species of fish with possibly another 12 species to be described scientifically in this river basin. The study combines two separate lines of assessment i) the identification of the distribution of different types of river reach in the sub-basins of the Sekong with a focus on assessing the rare river reach types and ii) distribution of endemic species in these sub-basins. The distribution of migratory fish and threatened fish species and other aquatic species has also been described to complement, the endemic species, many of which have been designated as Endangered or Vulnerable because of their restricted ranges. The preferred habitats of many of these endemic species has been used to identify the river reach types where endemics are most likely to be found. There is a working hypothesis that endemics may be associated with rare river reach types though it is difficult to confirm an exact relationship.

The second part of the paper considers the existing and planned hydropower reservoirs and assesses the likelihood of them covering the habitats of endemic species, thereby posing an additional threat to these species. This assessment is based upon, the presence of rare river reaches in the reservoir footprint, and the presence of preferred habitat types – small streams with high gradient and high elevation, together with the known presence of endemics in the sub-basins where the reservoirs are located.

The paper identifies several the existing and planned hydropower projects which have a higher risk of inundation of habitats of endemic species. These tend to be in the upper reaches of the basin both on the Xe Kong mainstem and on the Xe Kaman and Bolevan Plateau.

It is perhaps not surprising that endemic fish species share the same sub-basins where conditions ae most suitable for hydropower. Endemic and new to science species of fish tend to be found in the relatively small, fast flowing, often steep and rocky rivers that characterise the rivers in the tops of the catchments, e.g. top of Sekong and Xe Kaman rivers. These areas are more isolated, sometimes by very steep drops in elevation, e.g. in the Bolevan Plateau, and are further away from the main rivers where the more widely distributed species exist.

Suitable locations for hydropower development are characterised by having a reliable source of water with a steep slope or large drop in elevation to create a good head of water for generation. The headwaters of the Sekong and the Bolevan have amongst the highest rainfall in the region, with the headwaters of the Xe Kaman only slightly lower, and the slopes and drop in elevation is high.

It is unlikely that the presence of endemic species of fish alone will be sufficient reason for creating no-go areas for hydropower development. Rather it may be one of the reasons why a specific proposed hydropower plant may be not developed, for example together with a protected area and Key Biodiversity Area.

It is however, important to assess the distribution of a particular endemic species that may be affected by a hydropower development. If the endemics are found elsewhere within the basin, then it may be assumed they will not be driven to extinction, if their preferred habitats are to be inundated by a reservoir or affected by downstream flows. The issue is that with widespread development of hydropower in every available location possible, many, if not all, of the locations where endemic species live will be impacted and the chances of species extinction will be much higher.

Part of the problem is that the distribution of many fish and other aquatic species, including the endemics, is not well understood for the rivers of Laos. This paper provides an attempt at identifying where endemic species may be found, based upon the different classes of river. It shows a correlation between the sub-basins where rare river reach classes occur and those where endemics have been found. The prediction that endemics will be found in other sub-basins where surveys have not been carried out, is based upon the presence of similar proportions of rare river reach classes. However, each major tributary and its sub-basins have a different set of endemic fish species, although these are often of similar families to those found in the Sekong, e.g. Schistura, Sewellia and Poropuntius. If the approach were to be extended to other tributaries, e.g. Xe Bang Hieng and Xe Bang Fai, a similar analysis of rare river reaches would have to be carried out, a comparison with the rare river reaches of the Sekong and an association with endemic species that have already been found in the river being studied. The difficulty is that the Sekong is one of the most studied of the Mekong tributaries, and not all of the other tributaries will have had endemics identified. Nevertheless, the process could be used to identify the river reaches where endemic species, if they exist, are most likely to be found, and to confirm whether those reaches are likely to be inundated by proposed reservoirs.

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Annex 1 Species lists by sub-basin from IBAT data base

Crustacea

			Presence	Sub-basin Code																																							
Species Binomial		**Red List Code**	**in sub-basins**	**99**	**98**	**97**	**96**	**95**	**94**	**93**	**92**	**69**	**68**	**91**	**80**	**67**	**66**	**65**	**64**	**61**	**63**	**62**	**29**	**28**	**27**	**26**	**24**	**50**	**25**	**40**	**22**	**23**	**21**	**30**	**19**	**18**	**17**	**16**	**15**	**14**	**12**	**13**	**11**
Caridina lanceifrons	Atyid shrimp	LC	2	1																		1																					
Esanthelphusa dugasti	Rice field crab	LC	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Leptocarpus potamiscus	Bombay prawn	LC	2	1																		1																					
Macrobrachium dienbienphuense	Prawn	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Macrobrachium mieni	Prawn	LC	2	1																		1																					
Macrobrachium niphanae	Prawn	LC	34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1					1		1
Macrobrachium nipponense	Prawn	LC	3	1	1																	1																					
Macrobrachium rosenbergii	Prawn	LC	10																															1	1	1	1	1	1	1	1	1	1
Pupamon pealianoides	Crab, endemic to Laos	DD	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Sayamia germaini	Crab	LC	10																														1	1	1		1	1	1	1	1	1	1
Vietopotamon aluoiense	Crab, endemic to Sekong in Vietnam	DD	9	1	1	1	1	1	1	1	1			1																													
Total				**9**	**6**	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**4**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**8**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**3**	**4**

Odonata

Species Binomial	Red List Code	Presence in sub-basins	Sub-basin Code																																							
			99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11
Aciagrion azureum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aciagrion hisopa	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Aciagrion occidentale	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Acisoma panorpoides	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aethriamanta brevipennis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aethriamanta gracilis	LC	35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1					1	1	1
Agriocnemis femina	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Agriocnemis minima	LC	11																														1	1	1	1	1	1	1	1	1	1	1
Agriocnemis nana	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Agriocnemis pygmaea	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Agrionoptera insignis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphithemis curvistyla	DD	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Amphithemis kerri	DD	9	1	1	1	1	1	1	1	1			1																													
Anaciaeschna jaspidea	LC	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Anax guttatus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Anax immaculifrons	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Anax panybeus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Archibasis oscillans	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Archibasis viola	LC	11	1	1	1	1	1	1	1	1			1						1		1																					
Argiocnemis rubescens	LC	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Brachydiplax chalybea	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brachydiplax farinosa	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Brachythemis contaminata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Burmagomphus divaricatus	LC	35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1					1	1	1
Camacinia gigantea	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion auranticum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion azureum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion cerinorubellum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion fallax	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion indochinense	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion olivaceum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceriagrion praetermissum	LC	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Coeliccia montana	DD	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1							
Copera ciliata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Copera marginipes	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Copera vittata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cratilla lineata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Crocothemis servilia	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Davidius fruhstorferi	LC	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																						
Diplacodes trivialis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dysphaea gloriosa	LC	21	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1		1	1	1										
Epophthalmia vittigera	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Euphaea guerini	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Euphaea masoni	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Euphaea ochracea	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Gomphidia abbotti	LC	35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1					1	1	1
Gomphidictinus perakensis	LC	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1							
Gynacantha subinterrupta	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Heliaeschna uninervulata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Idionyx thailandica	LC	10												1								1	1	1	1	1		1		1	1	1										
Indocnemis orang	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Ischnura senegalensis	LC	39	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leptogomphus baolocensis	DD	10												1								1	1	1	1	1		1		1	1	1										
Leptogomphus divaricatus	LC	9	1	1	1	1	1	1	1	1			1																													
Lestes concinnus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Libellago hyalina	LC	12																											1			1	1	1	1	1	1	1	1	1	1	1
Libellago lineata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Macrogomphus borikhanensis	DD	32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1							
Macrogomphus matsukii	DD	2																												1		1										
Macromia flavocolorata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Macromia septima	DD	29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1										
Merogomphus parvus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mortonagrion falcatum	LC	9	1	1	1	1	1	1	1	1			1																													
Neurobasis chinensis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neurothemis fluctuans	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Onychargia atrocyana	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Onychothemis culminicola	LC	12												1					1			1	1	1	1	1		1		1	1	1			1							
Orchithemis pulcherrima	LC	21	1	1	1	1	1	1	1	1			1						1		1											1	1		1	1	1	1	1	1	1	1
Orolestes octomaculatus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orolestes selysi	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Orthetrum chrysis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orthetrum japonicum	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Orthetrum luzonicum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orthetrum sabina	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orthetrum testaceum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pantala flavescens	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Paragomphus capricornis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Prodasineura laidlawii	LC	11																														1	1	1	1	1	1	1	1	1	1	1
Protosticta robusta	DD	9	1	1	1	1	1	1	1	1			1																													
Pseudagrion pruinosum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pseudothemis jorina	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rhinagrion hainanense	LC	26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1			1	1										
Rhinocypha biforata	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Rhinocypha fulgipennis	DD	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1			
Rhinocypha perforata	LC	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Rhyothemis phyllis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rhyothemis variegata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tetrathemis irregularis	LC	11	1	1	1	1	1	1	1	1			1						1		1																					
Tholymis tillarga	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tramea basilaris	LC	5	1	1							1	1									1																					
Trithemis aurora	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trithemis festiva	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trithemis pallidinervis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Urothemis signata	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vestalaria smaragdina	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Vestalis gracilis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Zygonyx iris	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Zyxomma petiolatum	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total			90	90	89	89	89	89	89	89	82	82	89	80	81	81	81	81	87	81	83	80	80	80	80	80	76	80	77	80	80	86	74	69	76	64	64	64	64	72	72	72
Total DD			7	7	7	7	7	7	7	7	5	5	7	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	6	2	1	2	1	1	1	1	0	0	0
Total LC			83	83	82	82	82	82	82	82	77	77	82	75	76	76	76	76	82	76	78	75	75	75	75	75	72	75	73	75	75	80	72	68	74	63	63	63	63	72	72	72

Molluscs

Species Binomial	Class	Red List Code	Presence in sub-basins	Sub-basin Code																																							
				99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11
Anulotaia mekongensis	GASTROPODA	DD	6																												1		1			1					1	1	1
Assiminea brevicula	GASTROPODA	LC	9	1	1	1	1	1	1	1	1			1																													
Bithynia morleti	GASTROPODA	DD	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Brotia costula	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Clea spinosa	GASTROPODA	DD	12																				1	1	1	1	1		1		1	1				1					1	1	1
Clenchiella microscopica	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corbicula baudoni	BIVALVIA	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corbicula blandiana	BIVALVIA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corbicula castanea	BIVALVIA	DD	35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1				1	1	1	1		1	1	1
Corbicula lamarckiana	BIVALVIA	LC	12																			1								1				1	1	1	1	1	1	1	1	1	1
Corbicula leviuscula	BIVALVIA	DD	31									1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corbicula lydigiana	BIVALVIA	DD	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corbicula messageri	BIVALVIA	DD	9	1	1	1	1	1	1	1	1			1																													
Corbicula moreletiana	BIVALVIA	LC	17	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1																					
Corbicula siamensis	BIVALVIA	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corbicula tenuis	BIVALVIA	DD	7																																		1	1	1	1	1	1	1
Cristaria plicata	BIVALVIA	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ensidens ingallsianus	BIVALVIA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Gyraulus convexiusculus	GASTROPODA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Gyraulus siamensis	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Halewisia expansa	GASTROPODA	LC	5																												1					1					1	1	1
Hubendickia polita	GASTROPODA	NT	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1							
Hubendickia velimirovichi	GASTROPODA	DD	1																												1												
Hyriopsis delaportei	BIVALVIA	LC	8																												1					1	1	1	1		1	1	1
Hyriopsis myersiana	BIVALVIA	DD	9																																1	1	1	1	1	1	1	1	1
Idiopoma doliaris	GASTROPODA	LC	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Idiopoma ingallsiana	GASTROPODA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Idiopoma javanica	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Idiopoma simonis	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Indoplanorbis exustus	GASTROPODA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Intha umbilicalis	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jullienia harmandi	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jullienia microsculpta	GASTROPODA	DD	3																																						1	1	1
Lacunopsis monodonta	GASTROPODA	DD	3																																						1	1	1
Lacunopsis sphaerica	GASTROPODA	DD	1																												1												
Lecythoconcha lecythis	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnoperna fortunei	BIVALVIA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mekongia lamarcki	GASTROPODA	DD	5																												1					1					1	1	1
Mekongia rattei	GASTROPODA	DD	5																												1					1					1	1	1
Melanoides tuberculata	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neritina violacea	GASTROPODA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Pachydrobia dubiosa	GASTROPODA	DD	1																												1												
Pachydrobia incerta	GASTROPODA	NT	21	1	1	1	1	1	1	1	1			1	1								1	1	1	1	1	1	1	1	1	1				1							
Pachydrobia paradoxa	GASTROPODA	LC	3																																						1	1	1
Paludomus siamensis	GASTROPODA	DD	6																															1	1		1	1	1	1			
Paraprososthenia brandti	GASTROPODA	NT	4																												1										1	1	1
Parreysia humilis	BIVALVIA	DD	3																																						1	1	1
Physunio eximius	BIVALVIA	LC	3																																						1	1	1
Physunio inornatus	BIVALVIA	LC	3																																						1	1	1
Physunio micropterus	BIVALVIA	LC	3																																						1	1	1
Physunio superbus	BIVALVIA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pila pesmei	GASTROPODA	LC	2																												1		1										
Pila polita	GASTROPODA	LC	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1							
Pilsbryoconcha lemeslei	BIVALVIA	LC	3																																						1	1	1
Pisidium clarkeanum	BIVALVIA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pisidium javanum	BIVALVIA	LC	10																				1	1	1	1	1		1		1	1	1			1							
Pisidium sumatranum	BIVALVIA	LC	10																				1	1	1	1	1		1		1	1	1	1									
Polypylis hemisphaerula	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pseudodon inoscularis	BIVALVIA	LC	2																												1					1							
Pseudodon vondembuschia	BIVALVIA	LC	3																																						1	1	1
Radiatula pilata	BIVALVIA	LC	15																				1	1	1	1	1		1		1	1				1	1	1	1		1	1	1
Radix auricularia	GASTROPODA	LC	22												1					1			1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Scabies crispata	BIVALVIA	LC	23																	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Segmentina trochoidea	GASTROPODA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sinanodonta woodiana	BIVALVIA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sinomytilus harmandi	BIVALVIA	LC	22												1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Stenothyra mcmulleni	GASTROPODA	DD	4																												1										1	1	1
Sulcospira dakrongensis	GASTROPODA	LC	9	1	1	1	1	1	1	1	1			1																													
Tarebia granifera	GASTROPODA	LC	22	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																		1	1	1	1
Thiara rudis	GASTROPODA	LC	15																	1		1								1	1		1	1	1	1	1	1	1	1	1	1	1
Trapezoideus exolescens	BIVALVIA	LC	6																												1		1			1					1	1	1
Trapezoideus misellus	BIVALVIA	DD	5																												1					1					1	1	1
Uniandra contradens	BIVALVIA	LC	11																														1	1	1	1	1	1	1	1	1	1	1
Unionetta fabagina	BIVALVIA	LC	31									1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total				36	36	36	36	36	36	36	36	33	33	36	32	33	33	33	33	36	33	35	37	37	37	37	37	33	37	35	54	37	39	34	35	48	37	37	37	35	56	56	56
Total Bivalve				13	13	13	13	13	13	13	13	13	13	13	14	13	13	13	13	14	13	15	18	18	18	18	18	15	18	15	22	18	18	17	17	24	21	21	21	18	29	29	29
Total Gastopods				23	23	23	23	23	23	23	23	20	20	23	18	20	20	20	20	22	20	20	19	19	19	19	19	18	19	20	32	19	21	17	18	24	16	16	16	17	27	27	27

Aquatic plants

				Sub-basin Code																																							
Species Binomial		Red List Code	Presence in sub-basins	99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11
Acanthus ilicifolius	MAGNOLIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Adenosma indianum	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aeschynomene aspera	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aeschynomene indica	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Aglaonema simplex	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Alisma plantago-aquatica	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Alocasia odora	LILIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Alternanthera sessilis	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Bacopa monnieri	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Blyxa aubertii	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Blyxa octandra	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Blyxa quadricostata	LILIOPSIDA	DD	3																												1		1			1							
Caldesia oligococca	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Caldesia parnassifolia	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Centella asiatica	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Centrostachys aquatica	MAGNOLIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Ceratophyllum demersum	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ceratophyllum muricatum	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladopus fallax	MAGNOLIOPSIDA	DD	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Cladopus pierrei	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Colocasia esculenta	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Colocasia fallax	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Cryptocoryne ciliata	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Cryptocoryne crispatula	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cryptocoryne mekongensis	LILIOPSIDA	DD	3																												1		1			1							
Cryptocoryne retrospiralis	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Curanga amara	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Cussetia carinata	MAGNOLIOPSIDA	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cussetia diversifolia	MAGNOLIOPSIDA	DD	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1							
Cyanotis axillaris	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cyclosorus interruptus	POLYPODIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Cynometra iripa	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dopatrium junceum	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Drosera burmanni	MAGNOLIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Drosera indica	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Drosera peltata	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Eclipta angustata	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Enydra fluctuans	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ethulia conyzoides	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Grangea maderaspatana	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Hemisteptia lyrata	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Hydrilla verticillata	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hydrobryum griffithii	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Hydrobryum japonicum	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Hydrobryum tardhuangense	MAGNOLIOPSIDA	DD	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Hydrocharis dubia	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Hydrodiscus koyamae	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Hydrolea zeylanica	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Hygrophila auriculata	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Hygrophila pinnatifida	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hygrophila polysperma	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hygrophila salicifolia	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Isachne globosa	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Juncus articulatus	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Juncus bufonius	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Juncus decipiens	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Juncus prismatocarpus	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Juncus wallichianus	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Landoltia punctata	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Lasia spinosa	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lemna aequinoctialis	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Lemna perpusilla	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnophila erecta	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnophila geoffrayi	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnophila glabra	MAGNOLIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Limnophila heterophylla	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnophila indica	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnophila laxa	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Limnophila micrantha	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Limnophila polyantha	MAGNOLIOPSIDA	DD	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Limnophila rugosa	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Limnophila sessiliflora	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Limnophila villifera	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Limnophyton obtusifolium	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Lindernia antipoda	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lindernia crustacea	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lindernia micrantha	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lindernia mollis	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lindernia procumbens	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Lindernia viatica	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Marsilea crenata	POLYPODIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Marsilea minuta	POLYPODIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Marsilea quadrifolia	POLYPODIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Monochoria cyanea	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Monochoria hastata	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Monochoria korsakowii	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Monochoria vaginalis	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Najas graminea	LILIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Najas indica	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Najas marina	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Najas minor	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Nechamandra alternifolia	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Neptunia oleracea	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nymphaea nouchali	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nymphaea pubescens	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nymphaea rubra	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nymphaea tetragona	MAGNOLIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Oenanthe javanica	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ottelia alismoides	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Ottelia cordata	LILIOPSIDA	LC	15																	1		1								1	1		1	1	1	1	1	1	1	1	1	1	1
Potamogeton nodosus	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Potamogeton octandrus	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Potamogeton wrightii	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Ranalisma rostrata	LILIOPSIDA	DD	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Sagittaria guayanensis	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Sagittaria pygmaea	LILIOPSIDA	LC	2																	1		1																					
Sagittaria trifolia	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salvinia cucullata	POLYPODIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salvinia natans	POLYPODIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sesbania bispinosa	MAGNOLIOPSIDA	LC	31	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1								1	1		1	1	1	1	1	1	1	1	1	1	1
Sesbania javanica	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trapa incisa	MAGNOLIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Typha angustifolia	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Typha orientalis	LILIOPSIDA	LC	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1
Typhonium flagelliforme	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vallisneria natans	LILIOPSIDA	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Vallisneria spiralis	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wedelia chinensis	MAGNOLIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wolffia globosa	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Xyris wallichii	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Zannichellia palustris	LILIOPSIDA	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total				117	117	117	117	117	117	117	117	117	117	117	78	117	117	117	117	119	117	119	78	78	78	78	78	78	78	86	88	78	88	85	85	88	60	60	60	60	85	85	85
Total Liliopsida				50	50	50	50	50	50	50	50	50	50	50	28	50	50	50	50	52	50	52	28	28	28	28	28	28	28	31	33	28	33	31	31	33	23	23	23	23	31	31	31
Total Magnoliopsida				61	61	61	61	61	61	61	61	61	61	61	45	61	61	61	61	61	61	61	45	45	45	45	45	45	45	50	50	45	50	49	49	50	33	33	33	33	49	49	49
Total Polypodiopsida				6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	5	5	5

Fish

			Sub-basin Code																																							
Species Binomial	Red List Code	Presence in sub-basins	99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11
Acanthopsoides delphax	LC	25					1		1	1				1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Acanthopsoides gracilentus	LC	19					1		1	1				1								1	1			1			1	1			1	1	1	1	1	1	1	1	1	1
Acanthopsoides gracilis	LC	16					1		1	1				1								1	1			1			1	1			1		1			1	1	1	1	1
Acanthopsoides hapalias	LC	26					1		1	1				1					1		1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Acantopsis choirorhynchos	LC	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Achiroides melanorhijnchus	LC	3																																						1	1	1
Akysis bilustris	DD	9																				1	1	1	1	1		1			1	1	1									
Amblyceps serratum	DD	8																														1		1		1	1	1		1	1	1
Amblypharyngodon chulabhornae	LC	10																														1		1	1	1	1	1	1	1	1	1
Annamia normani	LC	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																					
Auriglobus modestus	LC	3																																						1	1	1
Auriglobus nefastus	LC	2																												1		1										
Bagarius suchus	NT	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bagarius yarrelli	NT	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bagrichthys obscurus	LC	10																														1	1	1		1	1	1	1	1	1	1
Balitora annamitica	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bangana behri	VU	20	1	1	1	1	1	1	1	1			1						1								1					1	1	1		1	1	1		1	1	1
Bangana yunnanensis	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbichthys laevis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbonymus altus	LC	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbonymus gonionotus	LC	19																				1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Barbonymus schwanenfeldii	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Belodontichthys truncatus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Betta prima	LC	3																																						1	1	1
Betta smaragdina	DD	3																																						1	1	1
Boesemania microlepis	NT	8																														1		1		1	1	1		1	1	1
Boleophthalmus boddarti	LC	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brachirus harmandi	LC	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brachirus panoides	LC	3																																						1	1	1
Brachygobius mekongensis	LC	11																	1								1					1	1	1		1	1	1		1	1	1
Catlocarpio siamensis	CR	10																												1		1			1	1	1	1	1	1	1	1
Channa gachua	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Channa lucius	LC	3																																						1	1	1
Channa marulius	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chaudhuria caudata	DD	18																				1	1	1	1	1		1		1	1	1		1	1	1	1	1	1	1	1	1
Chitala blanci	NT	11																	1								1					1	1	1		1	1	1		1	1	1
Chitala lopis	LC	3																																						1	1	1
Chitala ornata	LC	3																																						1	1	1
Cirrhinus jullieni	DD	3																																						1	1	1
Cirrhinus microlepis	VU	3																																						1	1	1
Cirrhinus molitorella	NT	15	1	1	1	1	1	1	1	1			1																1	1		1								1	1	1
Clarias macrocephalus	NT	3																																						1	1	1
Clupeichthys aesarnensis	LC	3																																						1	1	1
Clupisoma sinensis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Coilia lindmani	LC	3																																						1	1	1
Cosmochilus harmandi	LC	31	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Crossocheilus atrilimes	LC	9																												1		1			1	1	1	1		1	1	1
Crossocheilus reticulatus	LC	10																												1		1		1	1	1	1	1		1	1	1
Cyclocheilichthys apogon	LC	3																																						1	1	1
Cyclocheilichthys armatus	LC	22																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cyclocheilichthys enoplos	LC	11																	1								1					1	1	1		1	1	1		1	1	1
Cyclocheilichthys furcatus	LC	9																														1	1	1		1	1	1		1	1	1
Cyclocheilichthys heteronema	LC	3																																						1	1	1
Cyclocheilichthys lagleri	LC	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cyclocheilichthys repasson	LC	3																																						1	1	1
Cynoglossus feldmanni	LC	3																																						1	1	1
Cynoglossus microlepis	LC	3																																						1	1	1
Datnioides undecimradiatus	VU	20												1								1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Dermogenys siamensis	LC	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Devario gibber	LC	13	1	1	1	1	1	1	1	1			1						1								1					1	1									
Devario salmonatus	DD	10	1	1	1	1	1	1	1	1			1						1																							
Doryichthys boaja	LC	3																																						1	1	1
Doryichthys contiguus	LC	10																														1	1	1		1	1	1	1	1	1	1
Elops machnata	LC	2	1	1																																						
Epalzeorhynchos frenatum	LC	3																																						1	1	1
Epalzeorhynchos munense	VU	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Esomus longimanus	DD	10																												1		1			1	1	1	1	1	1	1	1
Esomus metallicus	LC	3																																						1	1	1
Eugnathogobius siamensis	LC	3																																						1	1	1
Garra cambodgiensis	LC	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Garra cyrano	DD	20	1	1	1	1	1	1	1	1			1						1								1					1	1	1		1	1	1		1	1	1
Garra fasciacauda	LC	13																	1								1		1			1	1	1		1	1	1	1	1	1	1
Glossogobius giuris	LC	9	1	1	1	1	1	1	1	1			1																													
Glyptothorax filicatus	DD	11	1	1	1	1	1	1	1	1			1						1								1															
Glyptothorax lampris	LC	21																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
Glyptothorax laosensis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Glyptothorax trilineatus	LC	10																				1	1	1	1	1		1		1	1	1		1								
Gymnostomus caudimaculatus	LC	11																														1	1	1	1	1	1	1	1	1	1	1
Gymnostomus lineatus	LC	8																														1		1		1	1	1		1	1	1
Gymnostomus lobatus	LC	8																														1		1		1	1	1		1	1	1
Gymnostomus ornatipinnis	LC	20												1								1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Gymnostomus siamensis	LC	10																												1		1		1	1	1	1	1		1	1	1
Gyrinocheilus pennocki	LC	9																														1	1	1		1	1	1		1	1	1
Hampala dispar	LC	8																														1		1		1	1	1		1	1	1
Hampala macrolepidota	LC	3																																						1	1	1
Helicophagus leptorhynchus	DD	3																																						1	1	1
Helostoma temminkii	LC	3																																						1	1	1
Hemibagrus filamentus	DD	3																												1		1			1							
Hemibagrus nemurus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hemibagrus wyckii	LC	12																												1		1	1	1	1	1	1	1	1	1	1	1
Hemibagrus wyckioides	LC	12																												1		1	1	1	1	1	1	1	1	1	1	1
Hemimyzon ecdyonuroides	DD	11	1	1	1	1	1	1	1	1			1	1					1																							
Hemimyzon papilio	LC	18	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1																					
Heteropneustes fossilis	LC	18	1	1	1	1	1	1	1	1			1	1								1	1	1	1	1		1		1	1											
Homaloptera confuzona	DD	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homaloptera leonardi	LC	3																																						1	1	1
Homaloptera smithi	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homaloptera tweediei	DD	11																														1	1	1	1	1	1	1	1	1	1	1

	Red List	Presence in	Sub-basin Code																																					
Species Binomial	Code	sub-basins	99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11
Homaloptera yunnanensis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homaloptera zollingeri	LC	7																																		1	1	1	1	1	1	1
Hypsibarbus lagleri	VU	12																	1								1					1	1	1		1	1	1	1	1	1	1
Hypsibarbus malcolmi	LC	6																																		1	1	1		1	1	1
Hypsibarbus pierrei	DD	30									1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hypsibarbus vernayi	LC	3																																						1	1	1
Hypsibarbus wetmorei	LC	13																	1								1					1	1	1	1	1	1	1	1	1	1	1
Kryptopterus bicirrhis	LC	22																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kryptopterus geminus	LC	3																																						1	1	1
Labeo barbatulus	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Labeo chrysophekadion	LC	31	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Labeo pierrei	VU	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Labiobarbus leptocheila	LC	22	1	1	1	1	1	1	1	1			1						1								1		1			1	1	1		1	1	1	1	1	1	1
Labiobarbus siamensis	LC	6																																		1	1	1		1	1	1
Laides longibarbis	LC	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Laubuca caeruleostigmata	EN	10																												1		1			1	1	1	1	1	1	1	1
Lepidocephalichthys furcatus	LC	15					1		1	1				1								1	1			1				1	1	1		1	1	1		1		1		
Lepidocephalichthys hasselti	LC	12																			1		1			1			1	1			1		1			1	1	1	1	1
Leptobarbus rubripinna	DD	3																																						1	1	1
Lobocheilos melanotaenia	LC	3																																						1	1	1
Lobocheilos rhabdoura	LC	3																																						1	1	1
Luciosoma bleekeri	LC	3																																						1	1	1
Luciosoma setigerum	DD	3																																						1	1	1
Lycothrissa crocodilus	LC	3																																						1	1	1
Macrochirichthys macrochirus	NT	11																	1								1					1	1	1		1	1	1		1	1	1
Macrognathus circumcinctus	LC	6																																		1	1	1		1	1	1
Macrognathus maculatus	LC	18																				1	1	1	1	1		1		1	1	1	1	1	1	1	1	1		1	1	1
Macrognathus semiocellatus	LC	6																												1		1			1					1	1	1
Macropodus opercularis	LC	8									1	1			1	1	1	1	1	1																						
Mastacembelus favus	LC	3																																						1	1	1
Mekongina erythrospila	NT	20	1	1	1	1	1	1	1	1			1						1								1					1	1	1		1	1	1		1	1	1
Monopterus albus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Monotrete baileyi	LC	9																														1	1	1		1	1	1		1	1	1
Monotrete cambodgiensis	LC	20												1								1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Monotrete cochinchinensis	LC	3																																						1	1	1
Monotrete ocellaris	LC	3																																						1	1	1
Mystacoleucus atridorsalis	LC	14																	1								1			1		1	1	1	1	1	1	1	1	1	1	1
Mystacoleucus marginatus	LC	33	1	1	1	1	1	1	1	1			1	1					1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mystus atrifasciatus	LC	5																												1		1								1	1	1
Mystus multiradiatus	LC	32	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mystus mysticetus	LC	5																												1		1								1	1	1
Mystus rhegma	DD	3																																						1	1	1
Mystus singaringan	LC	20												1								1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Nandus oxyrhynchus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nemacheilus longistriatus	LC	28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1			1	1	1									
Nemacheilus platiceps	DD	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neodontobutis aurarmus	LC	3																																						1	1	1
Neolissochilus blanci	NT	38	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1
Notopterus notopterus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ompok urbaini	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Onychostoma meridionale	LC	12																	1								1					1	1	1		1	1	1	1	1	1	1
Opsarius koratensis	LC	5																												1		1								1	1	1
Opsarius ornatus	LC	5																												1		1								1	1	1
Opsarius pulchellus	LC	22	1	1	1	1	1	1	1	1			1	1					1								1			1		1	1		1	1	1	1		1	1	1
Osphronemus exodon	VU	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Osteochilus lini	LC	3																																						1	1	1
Osteochilus melanopleura	LC	6																																		1	1	1		1	1	1
Osteochilus microcephalus	LC	6																																		1	1	1		1	1	1
Osteochilus vittatus	LC	6																																		1	1	1		1	1	1
Osteochilus waandersii	LC	8																														1		1		1	1	1		1	1	1
Oxyeleotris marmorata	LC	6																												1		1			1					1	1	1
Oxygaster anomalura	LC	8																														1		1		1	1	1		1	1	1
Oxygaster pointoni	VU	20												1								1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Pangasianodon hypophthalmus	EN	10																												1		1			1	1	1	1	1	1	1	1
Pangasius bocourti	LC	9																														1		1	1	1	1	1		1	1	1
Pangasius conchophilus	LC	9																														1		1	1	1	1	1		1	1	1
Pangasius elongatus	DD	9																														1		1	1	1	1	1		1	1	1
Pangasius krempfi	VU	19																				1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Pangasius larnaudii	LC	22																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pangasius macronema	LC	22												1					1			1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Pangasius mekongensis	LC	22																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pangasius sanitwongsei	CR	23												1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pangio myersi	LC	11																	1								1					1	1	1		1	1	1		1	1	1
Papuligobius ocellatus	LC	12																	1								1		1			1	1	1		1	1	1		1	1	1
Parachela maculicauda	LC	3																																						1	1	1
Parachela oxygastroides	LC	31									1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Parachela siamensis	LC	3																																						1	1	1
Parachela williaminae	LC	3																																						1	1	1
Paralaubuca barroni	LC	3																																						1	1	1
Paralaubuca harmandi	LC	6																																		1	1	1		1	1	1
Paralaubuca riveroi	LC	15																	1								1		1	1		1	1	1	1	1	1	1	1	1	1	1
Paralaubuca typus	LC	6																																		1	1	1		1	1	1
Parambassis apogonoides	LC	3																																						1	1	1
Parambassis siamensis	LC	6																																		1	1	1		1	1	1
Parambassis wolffii	LC	3																																						1	1	1
Parasikukia maculata	LC	3																																						1	1	1
Phalacronotus apogon	LC	3																																						1	1	1
Phalacronotus bleekeri	LC	3																																						1	1	1
Physoschistura pseudobrunneana	LC	12																	1								1					1	1	1		1	1	1	1	1	1	1
Polynemus aquilonaris	LC	6																												1		1			1					1	1	1
Poropuntius aluoiensis	DD	9	1	1	1	1	1	1	1	1			1																													
Poropuntius bolovenensis	EN	18	1	1	1	1	1	1	1	1			1	1								1	1	1	1	1		1			1	1										
Poropuntius consternans	EN	18	1	1	1	1	1	1	1	1			1	1								1	1	1	1	1		1			1	1										
Poropuntius laoensis	LC	13												1					1								1		1			1	1	1		1	1	1		1	1	1
Poropuntius lobocheiloides	EN	18	1	1	1	1	1	1	1	1			1	1								1	1	1	1	1		1			1	1										
Poropuntius normani	LC	20	1	1	1	1	1	1	1	1			1						1								1					1	1	1		1	1	1		1	1	1
Poropuntius solitus	EN	18	1	1	1	1	1	1	1	1			1	1								1	1	1	1	1		1			1	1										
Pristolepis fasciata	LC	6																																		1	1	1		1	1	1

			Sub-basin Code																																						
Species Binomial	Red List Code	Presence in sub-basins	99	98	97	96	95	94	93	92	69	68	91	80	67	66	65	64	61	63	62	29	28	27	26	24	50	25	40	22	23	21	30	19	18	17	16	15	14	12	13	11
Probarbus labeamajor	EN	11																	1								1					1	1	1		1	1	1		1	1	1
Pseudobagarius inermis	DD	31	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
Pseudolais micronemus	DD	6																												1		1			1					1	1	1
Pseudomystus siamensis	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Puntioplites falcifer	LC	3																																						1	1	1
Puntioplites waandersi	LC	3																																						1	1	1
Puntius brevis	LC	6																												1		1			1					1	1	1
Raiamas guttatus	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rasbora amplistriga	LC	6																																	1			1	1	1	1	1
Rasbora aurotaenia	LC	3																																						1	1	1
Rasbora borapetensis	LC	3																																						1	1	1
Rasbora daniconius	LC	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rasbora spilocerca	LC	3																																						1	1	1
Rasbora tornieri	LC	30									1	1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rasbora trilineata	LC	3																																						1	1	1
Rhinogobius taenigena	LC	4																	1								1					1	1									
Scaphognathops bandanensis	VU	17																				1	1	1	1	1		1		1	1	1			1	1	1	1	1	1	1	1
Scaphognathops stejnegeri	LC	3																																						1	1	1
Schistura bairdi	EN	3																																						1	1	1
Schistura bolavenensis	EN	10	1	1	1	1	1	1	1	1			1	1																												
Schistura carbonaria	LC	9	1	1	1	1	1	1	1	1			1																													
Schistura clatrata	LC	17	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1																						
Schistura dorsizona	LC	1												1																												
Schistura fusinotata	LC	11									1	1			1	1	1	1	1	1							1					1	1									
Schistura imitator	LC	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																						
Schistura isostigma	LC	26	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1												1	1	1		1	1	1		1	1	1
Schistura kengtungensis	LC	3																																						1	1	1
Schistura khamtanhi	DD	27	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1							1					1	1	1		1	1	1		1	1	1
Schistura kontumensis	VU	3										1			1						1																					
Schistura magnifluvis	LC	6																												1		1			1					1	1	1
Schistura nicholsi	LC	39	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Schistura nomi	LC	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1															
Schistura rikiki	DD	2																	1								1															
Schistura tizardi	DD	2																	1								1															
Scomberomorus sinensis	DD	3																																						1	1	1
Serpenticobitis octozona	DD	12	1	1	1	1	1	1	1	1			1						1		1						1															
Sewellia diardi	DD	10												1								1	1	1	1	1		1		1	1	1										
Sewellia elongata	NT	11												1					1			1	1	1	1	1		1		1	1	1										
Sewellia speciosa	LC	29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1										
Sikukia gudgeri	DD	21	1	1	1	1	1	1	1	1			1						1								1					1	1	1		1	1	1	1	1	1	1
Sikukia stejnegeri	LC	3																																						1	1	1
Sundasalanx mekongensis	LC	20					1		1	1				1								1	1			1			1	1		1	1	1	1	1	1	1	1	1	1	1
Sundasalanx praecox	LC	6																																		1	1	1		1	1	1
Syncrossus helodes	LC	22																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tetraodon abei	LC	31	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
Thryssocypris tonlesapensis	LC	6																												1		1			1					1	1	1
Thynnichthys thynnoides	LC	10																												1		1			1	1	1	1	1	1	1	1
Tor laterivittatus	DD	17	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1																						
Tor tambra	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tor tambroides	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Toxotes microlepis	LC	22																	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trichopodus microlepis	LC	3																																						1	1	1
Trichopodus pectoralis	LC	3																																						1	1	1
Trichopodus trichopterus	LC	3																																						1	1	1
Trichopsis pumila	LC	3																																						1	1	1
Trichopsis schalleri	LC	3																																						1	1	1
Trichopsis vittata	LC	3																																						1	1	1
Wallago attu	NT	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wallago micropogon	DD	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Xenentodon canciloides	LC	14																					1			1			1	1			1	1	1	1	1	1	1	1	1	1
Yasuhikotakia eos	LC	16					1		1	1				1								1	1			1			1	1			1		1			1	1	1	1	1
Yasuhikotakia longidorsalis	DD	8					1		1	1				1								1	1			1				1												
Yasuhikotakia nigrolineata	VU	20	1	1	1	1	1	1	1	1			1	1					1			1	1	1	1	1	1	1			1	1										
Total			**74**	**74**	**73**	**73**	**81**	**73**	**81**	**81**	**43**	**44**	**73**	**82**	**44**	**43**	**43**	**43**	**104**	**43**	**37**	**89**	**91**	**82**	**83**	**91**	**95**	**83**	**71**	**109**	**84**	**153**	**113**	**119**	**107**	**139**	**138**	**143**	**96**	**221**	**220**	**220**
Total CR			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Total EN			**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**0**	**0**	**5**	**5**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**4**	**4**	**4**	**4**	**4**	**1**	**4**	**0**	**2**	**4**	**7**	**1**	**1**	**2**	**3**	**3**	**3**	**2**	**4**	**4**	**4**
Total VU			**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**0**	**1**	**3**	**6**	**1**	**0**	**0**	**0**	**6**	**0**	**1**	**8**	**8**	**8**	**8**	**8**	**6**	**8**	**3**	**7**	**8**	**10**	**8**	**8**	**7**	**9**	**9**	**9**	**8**	**10**	**10**	**10**
Total NT			**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**4**	**4**	**6**	**5**	**4**	**4**	**4**	**4**	**8**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**7**	**5**	**5**	**5**	**5**	**10**	**7**	**7**	**4**	**8**	**8**	**8**	**4**	**10**	**10**	**10**
Total LC			**45**	**45**	**44**	**44**	**51**	**44**	**51**	**51**	**31**	**31**	**44**	**54**	**31**	**31**	**31**	**31**	**69**	**31**	**25**	**58**	**60**	**52**	**53**	**60**	**64**	**53**	**53**	**78**	**54**	**103**	**82**	**86**	**77**	**100**	**99**	**104**	**68**	**170**	**169**	**169**
Total DD			**15**	**15**	**15**	**15**	**16**	**15**	**16**	**16**	**8**	**8**	**15**	**11**	**8**	**8**	**8**	**8**	**19**	**8**	**7**	**13**	**13**	**12**	**12**	**13**	**16**	**12**	**9**	**15**	**12**	**21**	**14**	**16**	**15**	**17**	**17**	**17**	**12**	**25**	**25**	**25**

Annex 2: Listing of Key Biodiversity Areas (KBAs) in the Sekong Basin

Name of KBA	Area (ha)	Country	Significant populations of globally threatened species	Significant populations of endemic species known only to be found in a limited area	Significant congregations of one or more bird species at certain times in their lifecycle or seasonal migration	Significant populations of species known only to be found in a particular biome and/or significant regional/sub-regional populations of trigger species	Amphibians	Large water birds	Ducks	Vultures	Birds of Prey	Forest birds	Forest mammals	Plants	Tortoise/Turtles	Crocodile
Western Siem Pang	138,137	Cambodia	1		1	1		1		1	1					
Virachey	432,415	Cambodia	1	1		1						1	1	1	1	
Sekong River	14,116	Cambodia	1	1	1			1		1					1	
Nam Ghong	160,000	Laos	1										1		1	
Xe Pian	243,100	Laos	1					1		1		1	1	1	1	
Nong Khe Wetlands	3,900	Laos	1													1
Xe Khampho / Xe Pian	197,280	Laos	1	1	1	1		1		1		1				
Xe Khampho	120,000	Laos	1						1							
Attapu Plain	71,400	Laos	1			1				1	1	1				
Dong Ampham	180,220	Laos	1	1		1						1	1	1		
Phou Kathong	94,000	Laos	1										1			
Bolaven North-east	73,000	Laos	1										1			
Upper Xe Kaman	34,780	Laos	1	1		1		1				1				
Dakchung Plateau	5,140	Laos	1	1								1	1		1	
Phou Ahyon	148,900	Laos	1	1								1	1			
Xe Sap	137,120	Laos	1	1			1					1	1	1	1	
A Luoi - Nam Dong	112,200	Vietnam	1										1		1	
Northern Hien	24,700	Vietnam	1										1			
Lo Xo Pass	15,000	Vietnam	1	1								1	1	1		
Song Thanh	95,000	Vietnam	1									1	1	1	1	

Appendix 7.2:
Descriptions of Dam Sites in Tier 5

Annex 7.2: Tier Five: Small-scale Hydropower Sites for Local Consumption

As noted in Section 7, the Sustainable Site Suitability Survey, projects below 25MW are regarded as too small to be practical for power exports, therefore we assign them a separate tier for development. These would replace output from the mainstream dams that is intended for sale to EDL for local consumption. These aggregate to 67 MW and a total of 295 GWh/y new power (Table 7-3 in Section 7), which would be sufficient for likely growth in demand in the local grid that serves Sekong and Attapeu Provinces for well into the future. However, because they are small, they may also have a relatively high impact on migratory fish per unit of power produced. Therefore, these should only be invited by the Government of Lao as necessary for local development requirements.

Project Descriptions and Estimated Power Output

Houay Pache

Houay Pache is estimated to have a mean annual energy output of 49 GWh (11 MW of capacity) with the design head of 172 m and the design discharge of 16 m^3/s. Table 7.2-1 lists the salient features of this site, while the layout and profile of the project are shown in Figure 7.2-1 and 7.2-2, respectively.

Table 7.2-1. Salient Features of Houay Pache Site.

Item	Houay Pache
Location (Province)	Sekong
Location (Lat. /Long.)	15º56.70'N 106º52.51'E
River	Xe Kong
Installed Capacity (MW)	11
Annual energy (GWh)	49
Catchment Area (km^2)	186
Average annual flow (m^3/s)	9
Rated head (m)	172
Design discharge (m^3/s)	16
Full supply level (m)	450
Headrace tunnel (km)	4.3
Penstock (km)	1
Dam height (m)	65

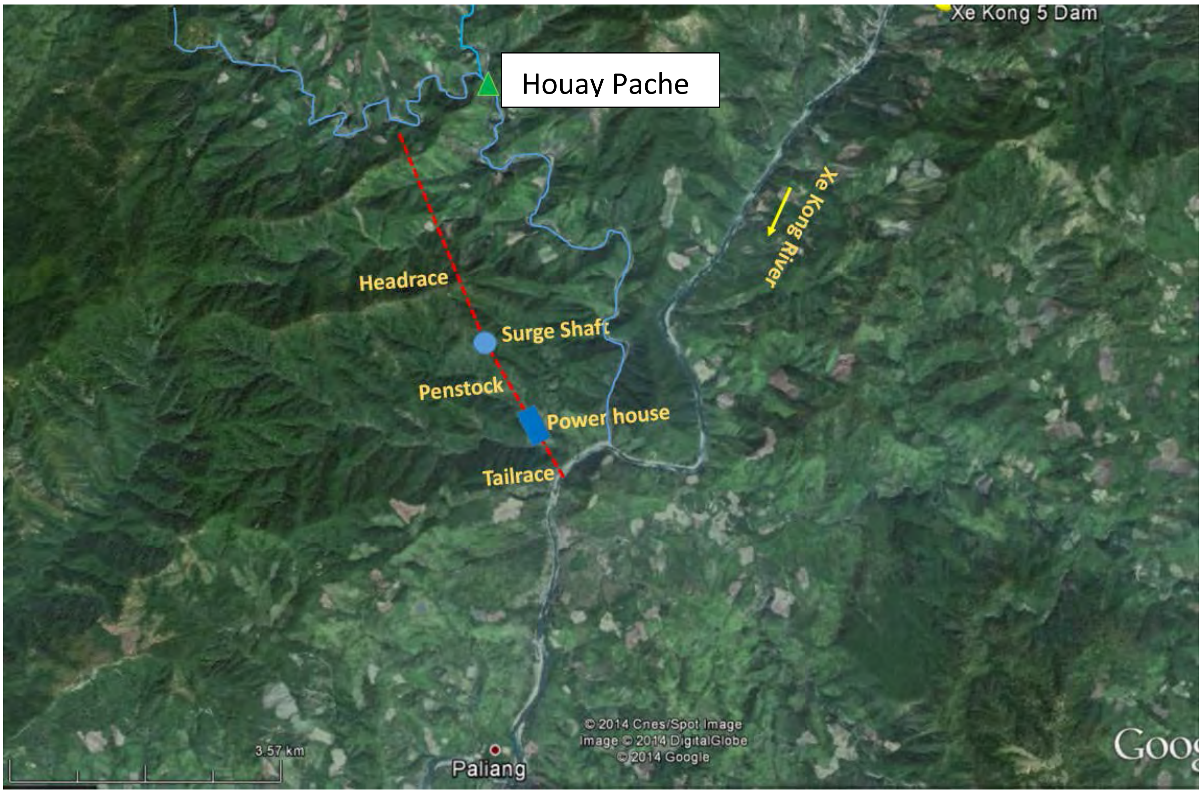

Figure 7.2-1. Layout of Houay Pache Hydropower Project.

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Figure 7.2-2. Profile of Houay Pache Hydropower Project.

Phak Houay

The main features of Phak Houay are presented in Table 7.2-2. The mean annual energy output of the project is 57 GWh (13 MW of capacity) with the design discharge of 14 m^3/s and 240 m the head. The 90 m head out of 240 m design head is gained from the dam. The profile and location of Phak Houay are shown in Figure 7.2-3 and 7.2-4, respectively.

Table 7.2-2. Salient Features of Phak Houay.

Item	Phak Houay
Location (Province)	Sekong
Location (Lat. /Long.)	15º54.11'N 106º55.94'E
River	Xe Kong
Installed Capacity (MW)	13
Annual energy (GWh)	57
Rated head (m)	240
Design discharge (m^3/s)	14
Full supply level (m)	420
Catchment Area (km^2)	141
Average annual flow (m^3/s)	6
Headrace tunnel (km)	3.4
Penstock (km)	2.3
Dam height (m)	90

Figure 7.2-3. Profile of Phak Houay Hydropower Project.

Figure 7.2-4. Layout of Phak Houay.

Nam Pouang Hydropower Site

Nam Pouang Hydropower Site is designed for 69 GWh of mean annual energy output (16 MW of capacity) with design flow of 19 m^3/s and design head of 145 m. The salient features of the project are provided Table 7.2-3. The general layout of Nam Pouang Hydropower Site is shown in Figure 7.2-5 and the approximate profile in Figure 7.2-6.

Table 7.2-3. Salient Features of Nam Pouang Hydropower Site.

Item	Nam Pouang
Location (Province)	Attepeu
Location (Lat. /Long.)	15º41.50’N 107º18.84’E
River	Xe Xou
Installed capacity (MW)	16
Annual energy (GWh)	69
Rated head (m)	145
Design discharge (m^3/s)	19
Full supply level (m)	330
Catchment Area (km^2)	298
Average annual flow (m^3/s)	11
Headrace tunnel (km)	1.5
Penstock (km)	4
Dam height (m)	20

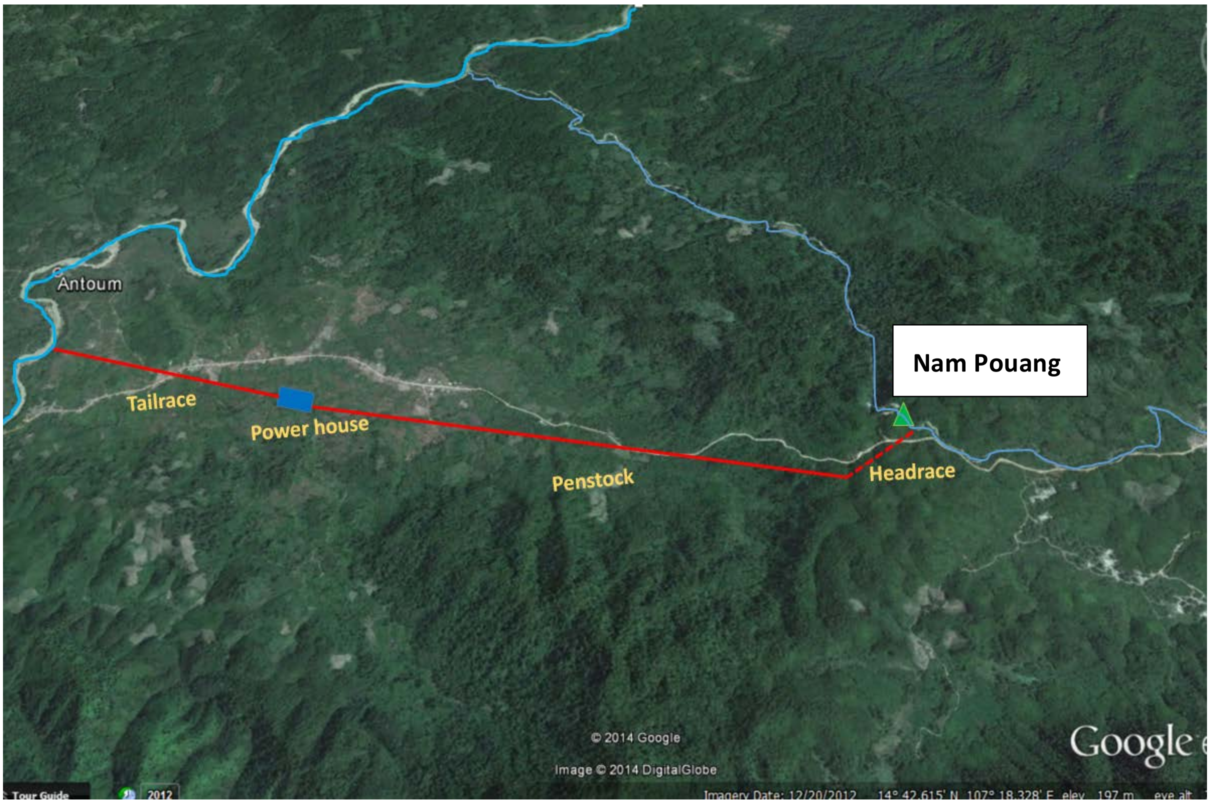

Figure 7.2-5. Layout of Nam Pouang Hydropower Site.

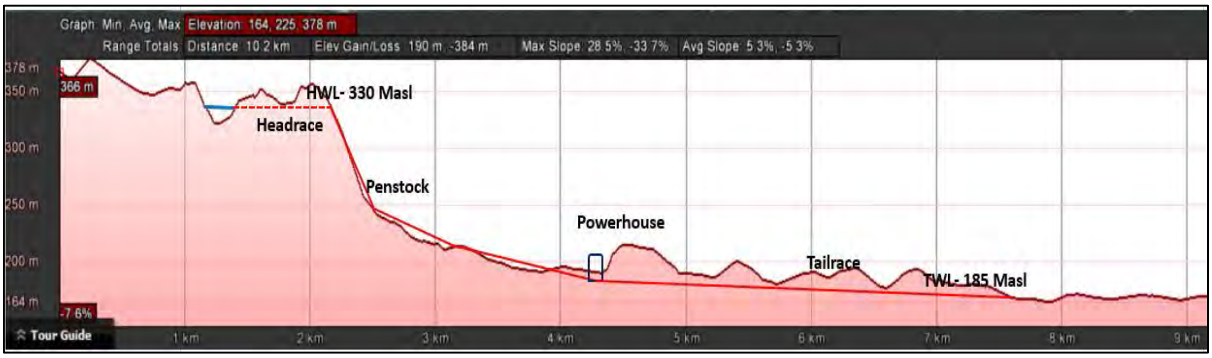

Figure 7.2-6. Profile of Nam Pouang Hydropower Project.

NHI Site_C

NHI Site_C would have a mean annual energy output of 43 GWh (10 MW of capacity) with the design head of 134 m and the design flow of 15 m^3/s. The salient features of this project are presented in Table 7.2-4. Figure 7.2-7 shows the layout and Figure 7.2-8 shows the profile of NHI Site_C project. The dam height is 70 m, which can be can possibly reduced by changing the location of the dam (moving upstream) to achieve the same design head. For that, better topographic information and site inspection is needed.

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Table 7.2-4. Salient Features of NHI Site_C Hydropower Project.

Item	NHI Site_C
Location (Province)	Sekong
Location (Lat. /Long.)	15º58.64'N 106º42.60'E
River	Xe Kong
Installed capacity (MW)	10
Annual energy	43
Rated head (m)	134
Design discharge (m^3/s)	15
Full supply level (m)	350
Catchment Area (km^2)	186
Average annual flow (m^3/s)	7.7
Headrace tunnel (km)	4.0
Penstock (km)	1.2
Dam height (m)	70

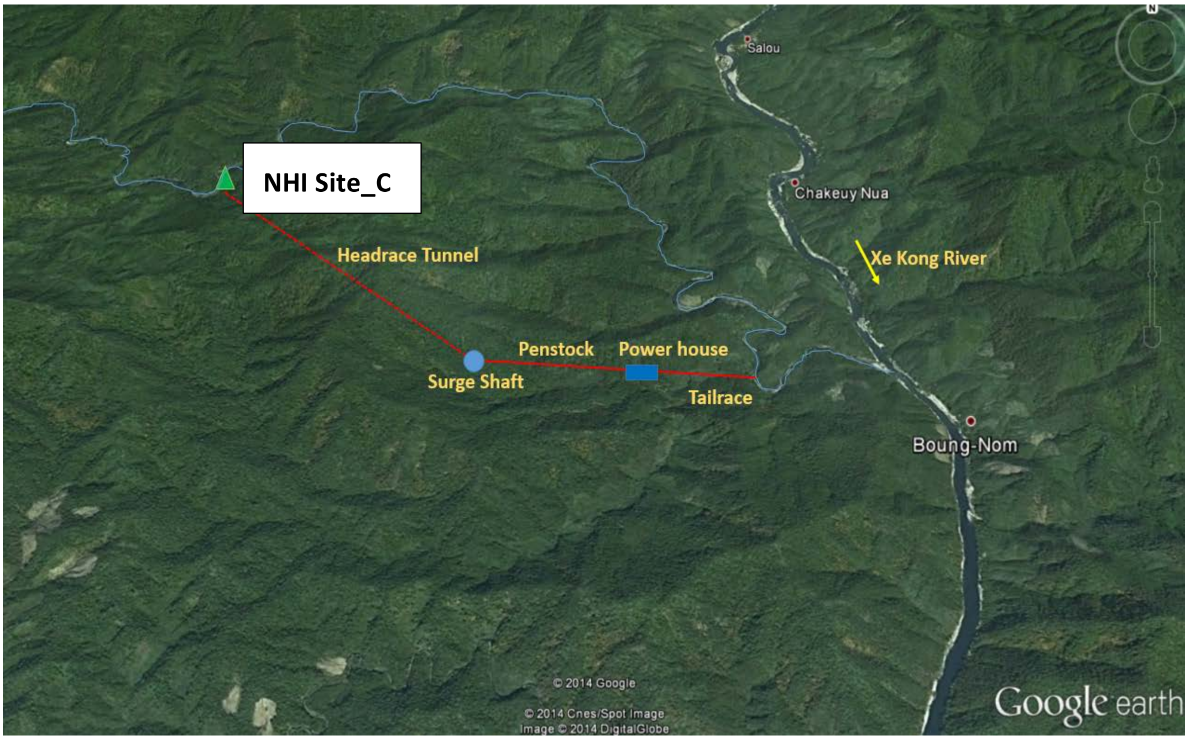


Figure 7.2-7. Layout of NHI Site_C Hydropower Project.

Figure 7.2-8. Profile of NHI Site_C Hydropower Project.

NHI Site_D

NHI Site_D is designed for 42 GWh mean annual energy output (9 MW of capacity) with the design head of 190 m and the design discharge of 9 m³/s. Table 7.2-5 presents the salient features of this site. Figure 7.2-9 and Figure 7.2-10 show the layout and profile of this site, respectively.

Table 7.2- 5. Salient Features of NHI Site D Hydropower Project.

Item	NHI Site_D
Location (Province)	Sekong
Location (Lat. /Long.)	15º30.80'N 106º50.84'E
River	Xe Kong
Installed capacity (MW)	9
Annual energy (GWh)	42
Rated head (m)	190
Design discharge (m^3/s)	9
Full supply level (m)	350
Catchment Area (km^2)	110.6
Average annual flow (m^3/s)	4.7
Headrace tunnel (km)	6.7
Penstock (km)	3.0
Dam height (m)	50

Figure 7.2-9. Layout of NHI Site_D Hydropower Project.

Figure 7.2-10. Profile of NHI Site_D Hydropower Project.

Houay Chalelu Site

The Houay Chalelu 1 site is placed on a small tributary to the Xe Kaman between the Xe Kaman #3 reservoir and the Xe Kaman #3 powerhouse. The mean annual energy output is 25 GWh (6 MW of capacity) (see Tables 7-1 and 7-3 in Section 7).

Nam Pa Site

The Nam Pa site is placed on a small tributary to the Xe Kaman with confluence to the Xe Kaman below the Xe Kaman #3 hydropower plant. The mean annual energy output is 10 GWh (2 MW of capacity) (see Tables 7-1 and 7-3 in Section 7).

Annex 9.1:

Illustrative Study of Design Improvements and Operation Policies

Annex 9.1: Illustrative Study of Design Improvements and Operation Policies

Introduction

This Section presents the results of a study of illustrative design improvements and operational policies for four of the hydropower dams proposed for the mainstream Xe Kong River to maximize sediment discharge. The selected dams are highlighted in Figure 9.1-1:

1. Xe Kong 5
2. Xe Kong 4B
3. Xe Kong 3B
4. Xe Kong 3A

The same considerations could also be applied the other three proposed dams. Sections 2 and 5 of this Master Plan have shown that sediment passage through these dams is very important for the continued health and biological productivity of the Xe Kong River within Lao PDR, within Cambodia, and for the downstream Mekong River, Mekong Delta, and Tonle Sap. The purpose of this work is not to suggest that these dams be built—indeed, Section 5 of this Master Plan shows that the impacts they would impose on the migratory fishery calls into question their sustainability—but to demonstrate that if they were to be built, there are design and operational strategies that would vastly improve their ability to pass sediment through them. The other purpose is to show that the more sustainable dams at the alternative sites identified in this Master Plan could also be designed and operated to pass sediments.

This Section identifies reservoir sedimentation management methods that can be used to increase the amount of sediment passed to the river reach downstream of these proposed dams. Seven alternative designs were also considered, in addition to the proposed dams identified above. The assessment included analyzing sediment removal from four alternative designs that may be used instead of the currently proposed Xe Kong 5 Dam. Three alternative designs for the currently proposed Xe Kong 4 Dam were also considered.

The study results indicate that it is possible to increase significantly the amount of sediment that may be passed downstream of the cascade of dams when implementing reservoir sedimentation management technology. Concurrent implementation of drawdown flushing along the cascade of dams is likely to increase the availability of sediment in the downstream river reaches from 20% (without sediment management) to at least 72% of current conditions with the alternative designs the currently proposed Xe Kong 5 and Xe Kong 4 Dams. The Xe Kong 3B and Xe Kong 3A Dams, correctly designed and operated, would perform satisfactorily to pass sediment (but not migratory fish). The study has been executed at pre-feasibility level, i.e., at the conceptual stage of design.

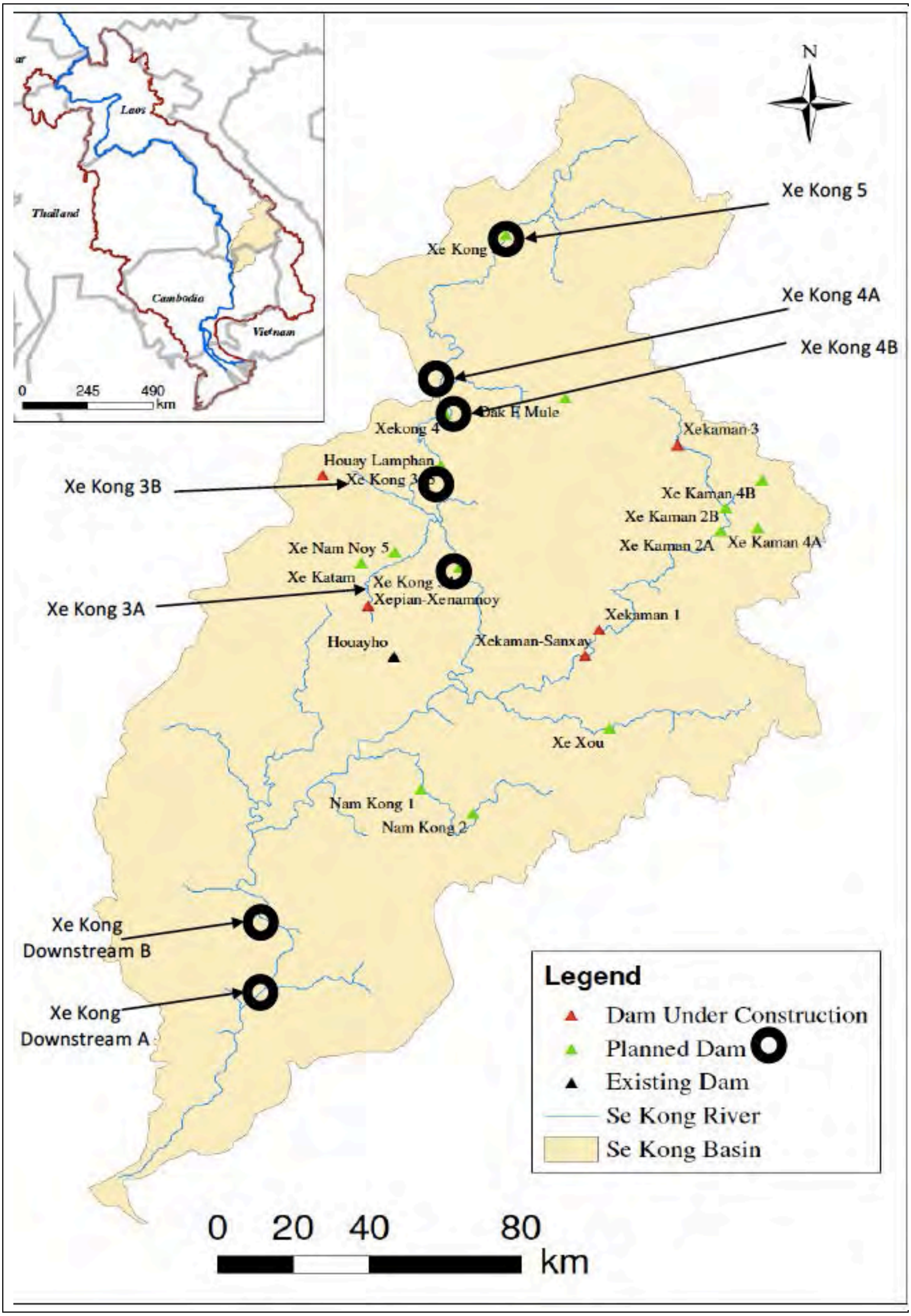


Figure 9.1-1. Location map of hydropower projects on the Xe Kong River, Lao PDR.

Approach

The study evaluated the potential to pass sediment through the four proposed dams and their reservoirs by making use of established reservoir sedimentation management techniques. This was done by first considering the potential to pass sediment through the currently proposed dams. If it was found that the sediment passage ability of the currently proposed dams can be improved, alternative designs were conceived and analyzed. The designs with the greatest potential to pass sediment to the downstream river were identified.

Data

Flow and sediment data and the information on reservoir type and size were obtained from various sources (such as ICEM, 2010; Meynell, 2014 and the Hydropower Database http://www.3sbasin.org/iucn/). Google Earth also provided additional, approximate topographic information.

Sediment management alternatives

At least eleven different techniques exist to manage sediment in reservoirs (see, e.g., Annandale, 2011). Not all of these techniques are viable for increasing sediment passage through the dams along the Xe Kong River. After consideration of the problem, it was decided that the reservoir sedimentation management techniques with the greatest potential for passing sediment through the four dams along the Xe Kong River are drawdown flushing, sluicing, and density current venting.

Drawdown flushing - description

The objective of drawdown flushing is to erode and remove previously deposited sediment from a reservoir and discharge it downstream. This is accomplished by first emptying the reservoir and allowing the river flowing through the reservoir to erode and transport the previously deposited sediment. During drawdown, flushing a reservoir is brought to the original river-like condition by releasing reservoir flows through bottom outlets. This is usually executed during a low-flow period, preferably just prior to the monsoon. By implementing drawdown flushing just prior to the monsoon allows the reservoir to be refilled with water once drawdown flushing is complete.

It is important for flushing flows to freely discharge through the low-level outlets without damming; therefore the need to implement drawdown flushing during low-flow periods. Sediment is eroded by water flowing in single or multiple channels through the sediment that previously deposited in the reservoir. The success of sediment removal by flushing depends on the reservoir size, geometry (such as width of the reservoir, the valley side slopes and longitudinal river-slope), location of the low-level outlets, the type of sediment deposited in the reservoir, and the magnitude of the flushing flows.

A distinguishing feature of drawdown flushing is that it requires emptying a reservoir and allowing the formation of river-like flow conditions over the previously deposited sediment. This requires the use of low-level gates to discharge freely the eroded sediment downstream. The creation of river-like conditions requires that drawdown flushing be implemented during low-flow periods, i.e., during the non-monsoon season. Once drawdown flushing is complete, the outlets are closed and the reservoir filled with water for continued power generation.

Assessment criteria

White (2001) provided criteria to assess the potential for successful drawdown flushing. In general, drawdown flushing is successful in narrow, steep reservoirs where the sediment transport capacity of the water used to execute drawdown flushing is large enough to remove the amount of sediment that has deposited within a reservoir between flushing events. In order to implement drawdown flushing it is obviously also necessary to have available low-level outlets that are large enough to drain the reservoir and to freely discharge re-entrained sediment downstream.

To assist dam designers in decision-making, White (2001) devised six parameters that may be used to determine the potential success of drawdown flushing. The proposed parameters were validated by using data from 14 dams where drawdown flushing has been implemented in the past. Drawdown flushing was deemed successful at six of those dams and unsuccessful at the remaining eight. This recorded experience provides a good basis for predicting potential drawdown flushing success at other projects. The six criteria are conceptually presented in what follows. More detail may be found in White (2001).

Sediment balance ratios (SBR and SBR_d)

The sediment balance ratio (SBR) quantifies the ability to re-entrain and transport previously deposited sediment during drawdown flushing. The SBR is the ratio between the amount of sediment that may be removed by the water flowing through the reservoir during drawdown flushing and the amount of sediment that has deposited in the reservoir between drawdown flushing events. Conceptually, the SBR is defined as follows:

$$SBR = \frac{Sediment\ volume\ that\ may\ be\ removed\ during\ flushing}{Sediment\ volume\ deposited\ between\ flushing\ events}$$

Due to the fact that the sediment transport capacity of the water used during drawdown flushing is determined by the amount by which the water surface in the reservoir is drawn down, White (2001) also proposed to use an additional criterion, which is the SBR if the reservoir is drawn down to the maximum extent possible. He named that parameter SBR_d.

The SBR represents the sediment balance ratio if the water level at the dam is drawn down to the elevation of the low-level outlet. Such an outlet may not be located right at the bottom of the dam, due to design constraints. The SBR_d parameter provides an indication of the potential to successfully flush the sediment from the reservoir should one be able to draw down the water surface to the lowest level possible, i.e., to the level of the riverbed at the dam. For flushing to be successful both SBR and SBR_d must be greater than one, i.e., the potential to flush sediment out of the reservoir must be greater than the amount of sediment that deposited in it during the period between flushing events. SBR_d will always be greater than SBR, making it, in essence, a superfluous parameter.

Drawdown ratio (DDR)

Another parameter devised by White (2001) is known as the drawdown ratio (DDR). This parameter quantifies how far the water surface elevation can be drawn down using a low-level outlet (LLO). The parameter is defined as:

$$DDR = 1 - \frac{H_f}{H_{max}}$$

The meaning of the variables H_f and H_{max} are shown in Figure 9.1-2.

By making use of the fourteen projects where drawdown flushing has been implemented, White (2001) found that if DDR > 0.7, then flushing may be successfully implemented (see further on).

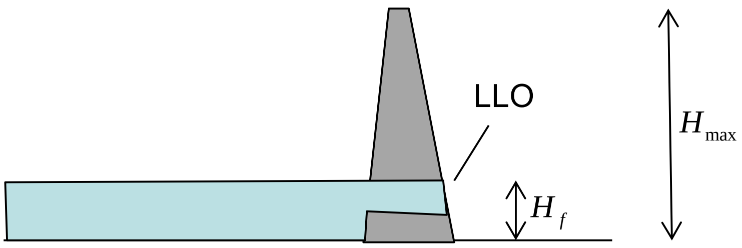


Figure 9.1-2. Variables defining the DDR.

Flushing width ratio (FWR) and top width ratio (TWR)

The two ratios known as the flushing width ratio (FWR) and the top width ratio (TWR) provide some idea of the ability to remove substantial amounts of deposited sediment from a reservoir by means of drawdown flushing. Figure 9.1-3 represents an average cross section of a reservoir valley. Suppose that sediment has filled the entire valley and that an attempt to remove sediment through drawdown flushing is made. When using drawdown flushing a channel is eroded into the deposited sediment. The dimensions of that channel are defined by W_f and W_{ftop}, i.e., the bottom width and the top width of the channel that is eroded into the deposited sediment during the flushing event. The dimensions of the original reservoir valley are defined by W_{bot} and W_{top}, i.e., the bottom and top widths of the reservoir valley.

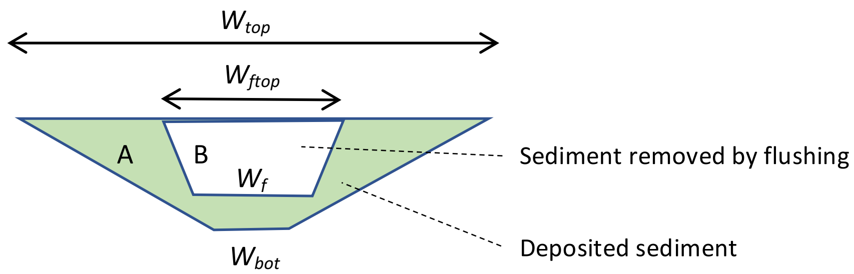


Figure 9.1-3. Cross section of reservoir valley and variables used to quantify FWR and TWR.

The FWR is defined as:

$$FWR = \frac{W_f}{W_{bot}}$$

And the TWR is defined as:

$$TWR = \frac{W_{ftop}}{W_{top}}$$

From Figure 9.1-3 it can be seen that if drawdown flushing results in both the top and bottom widths of the eroded channel exceeding the top and bottom widths of the reservoir valley, then all the sediment would have been removed. Therefore, in the ideal case drawdown flushing would be successful if both the FWR and TWR parameters are greater than one. In cases where they are slightly less than one, it may mean that only part of the sediment may be removed. It means that some but not all of the reservoir storage space may be preserved in the long term.

Long-term capacity ratio (LTCR)

From a practical point of view, it may not be possible to remove all deposited sediment from reservoirs by making use of drawdown flushing, as indicated in the previous section. Therefore, what one wishes to know is how much of the original reservoir volume can be preserved in the long term if drawdown flushing is regularly implemented. The long-term capacity ratio (LTCR) provides a measure of how much of the reservoir volume might be preserved in the long term when regularly implementing drawdown flushing. It is defined as the ratio between the cross-sectional area of the channel eroded into the deposited sediment (the area B in Figure 9.1-3) and the total cross sectional area of the reservoir valley prior to sedimentation (the sum of area A and area B in Figure 9.1-3), that is:

$$LTCR = \frac{Area\ B}{Area\ A\ + Area\ B}$$

Validation of criteria

The criteria defined in the previous sections are used in the RESCON model (Palmieri et al. 2003) to assess the potential success to use drawdown flushing to remove deposited sediment from reservoirs. That model, i.e., the RESCON model, has been used to assess the dams and reservoirs investigated in this study. The criteria used in the RESCON model are shown in Table 9.1-1.

Table 9.1-1. Drawdown flushing criteria used in the RESCON Model.

Parameter Name	Criterion
SBR	> 1
LTCR	> 0.35
DDR	> 0.7
FWR	> 1
TWR	~ 1
SBR_d	> 1

The viability of these criteria to predict the potential success of implementing drawdown flushing to remove adequate amounts of deposited sediment from reservoirs were reviewed by White (2001). He used information obtained from fourteen projects to perform the assessment. Drawdown flushing was deemed successful at six of those projects, and unsuccessful at the other eight.

Figure 9.1-4 and Figure 9.1-5 compare the calculated values of SBR, FWR, LTCR and TWR to the criteria set in Table 9.1-1. The comparison of the DDR values is shown in Figure 9.1-6. It is observed that the criteria are substantially satisfied. These criteria were therefore used to assess the potential for drawdown flushing at the four dams and reservoirs reviewed during this study.

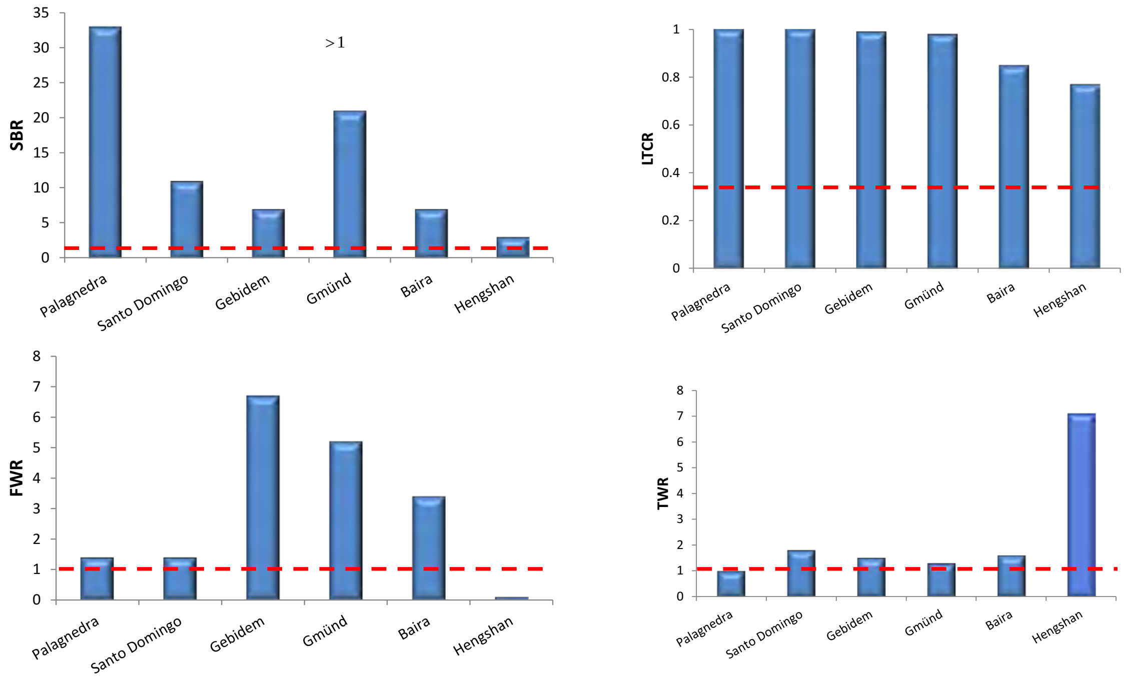


Figure 9.1-4. Comparison of flushing criteria parameter values at reservoirs that have been successfully flushed (White, 2001).

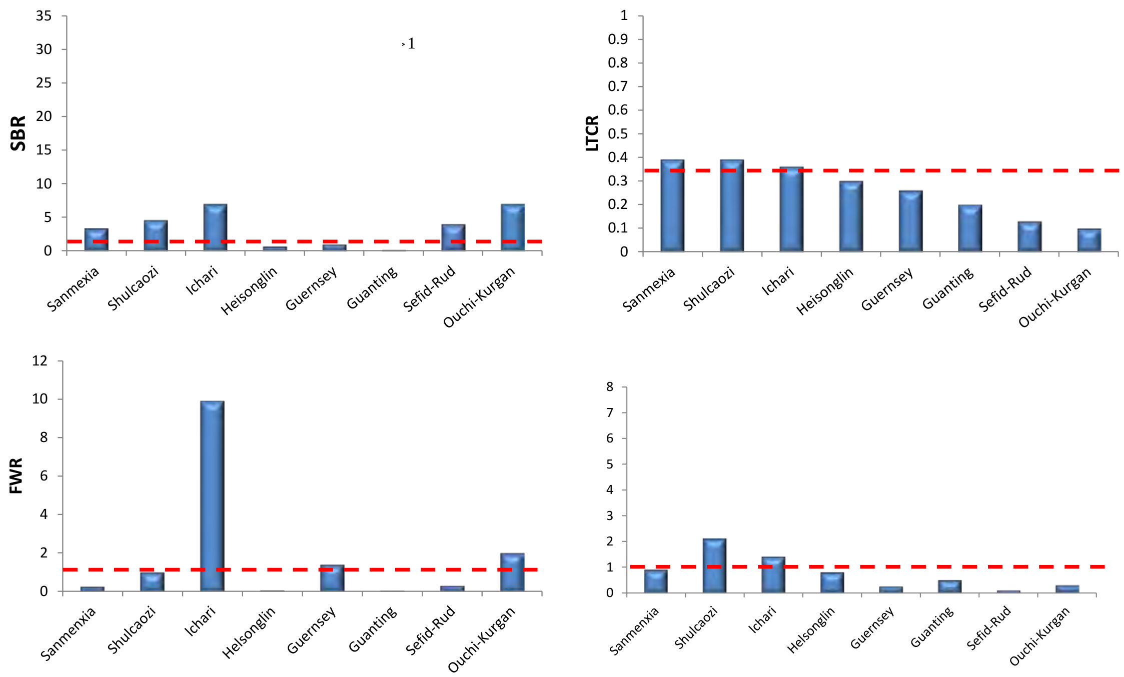


Figure 9.1-5. Comparison of flushing criteria parameter Values at Reservoirs that have not been Successfully Flushed (White, 2001).

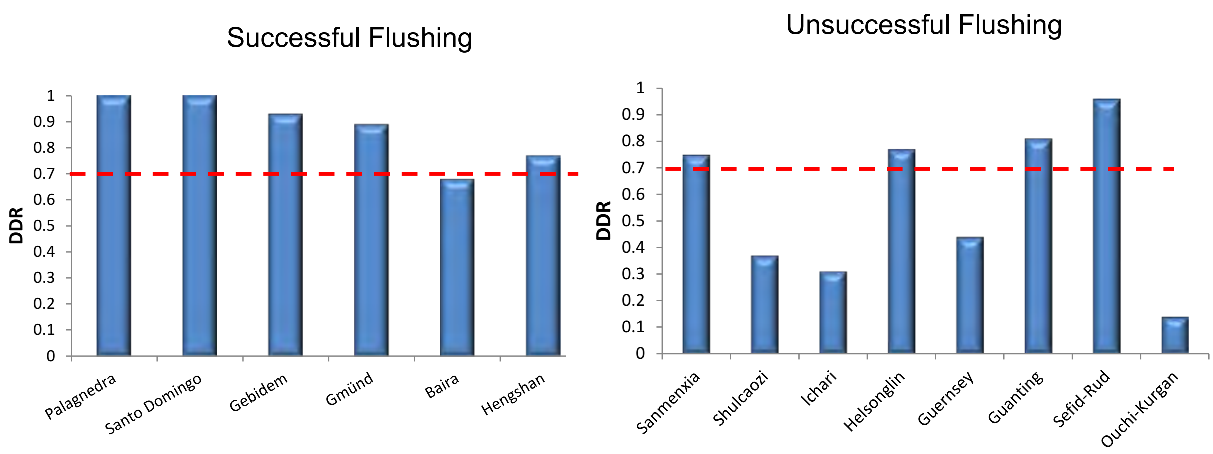


Figure 9.1-6. Comparison DDR Parameter Values and Criteria for Reservoirs that are Known to have and have not been Successfully Flushed (White, 2001).

Sluicing - description

Sluicing is a sediment management technique implemented during floods, i.e., during the monsoon. The objective of sluicing is to minimize the amount of sediment that will deposit in a reservoir. This is done by creating flow conditions in a reservoir that are characterized by high sediment carrying capacity. In the ideal case, which is seldom accomplished, the sediment transport capacity in the reservoir will be equal to the sediment transport capacity of the river carrying sediment into the reservoir. Should it be possible to accomplish this goal the amount of sediment carried into a reservoir from upstream (S_1) will equal the amount of sediment discharged downstream (S_2), with no net amount of sediment depositing in the reservoir (Figure 9.1-7).

The sediment transport capacity in the reservoir is maintained at a high level by drawing down the water surface elevation at the dam as much as possible while floodwaters flow through the reservoir. By doing so, the energy slope of the water flowing through the reservoir is increased, thereby maximizing the sediment transport capacity of those flows. The water surface elevation at the dam is drawn down by using low- and / or mid-level gates at the dam. It is obviously not possible to draw down the flows in a reservoir to the same extent required by drawdown flushing. The reason for this is that sluicing is implemented during high flows (the monsoon) during which time the rate of flow into the reservoir is normally larger than the free-flow discharge capability of low-level outlets.

Sluicing is best implemented in narrow reservoirs, located in relatively steep rivers where monsoon flow volumes are large relative to the reservoir volume. Successful flushing also requires provision of enough large mid- and low-level outlets in the dam that will allow the water surface elevation at the dam to be drawn down significantly during flood flows characteristic of the monsoon. Dams that are designed with the ability to significantly draw down the water surface elevation at the dam during the monsoon have a much greater potential to successfully transport large amounts of sediment through the reservoir without deposition; thus fulfilling the purpose of sluicing.

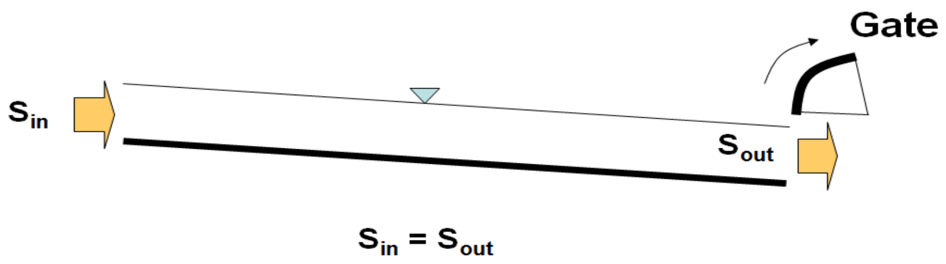


Figure 9.1-7. Concept of Sediment Pass-through by Making Use of Sluicing.

Assessment criteria

The engineering profession has not developed simple criteria for assessing the potential success of sluicing at pre-feasibility level investigations. The potential for implementing sluicing has therefore not been assessed during this study. It is left for more detailed assessment during the feasibility and design phases of the projects.

Density current venting - description

When water with very high sediment concentrations flow into a reservoir it is possible that the density of the sediment-laden water is higher than the water contained in the reservoir. Depending on local conditions very little mixing might occur between the density current and the reservoir water. This means that a dense, sediment-laden current flows along the bottom of the reservoir towards the dam.

Deposition of this sediment can be prevented by releasing the density current downstream of the dam. This is accomplished by installing low-level gates at the dam. When these gates are opened as the density current approaches the dam, the high sediment concentration water may be released downstream of the dam. This means that the heavy sediment loads contained in the density current is discharged downstream of the reservoir, without depositing in the reservoir. The process is known as density current venting (Figure 9.1-8).

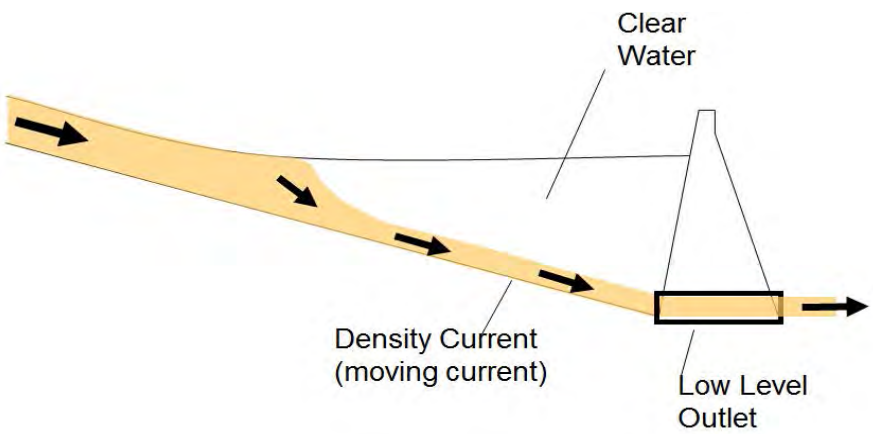


Figure 9.1-8. Concept of Sediment Pass-through by Density Current Venting.

Assessment criteria

In order to assess the potential for density current formation and to determine the level of efficiency by which density currents may be used to release sediment through low-level outlets at a dam require sediment rating curves, sediment particle size distributions and water discharge data for the river in question. None of this information has been available for assessment during this pre-feasibility study. The approach that was therefore followed was to conduct a sensitivity analysis to determine under what conditions density currents might form in the four reservoirs and how efficient such currents would be at passing sediment through the reservoirs when using low-level outlets. For this purpose, a method developed by Fan, as described in Morris and Fan (1998), has been used. Once the required sediment and water discharge data becomes available in the future, studies that are more detailed can be performed to assess the effectiveness of density current venting. The results of such studies will be used to determine whether the assessments made during this project are viable.

Essential design elements

Implementation of drawdown flushing, sluicing, and density current venting requires incorporation of low- and mid-level outlets in dams. Without the availability of such outlets, it is not possible to implement any of the three reservoir sedimentation management techniques considered in this study. It may also be necessary to install a lining in the low-level outlets to resist the effects of abrasion.

Outlets

Dam design elements required to facilitate successful implementation of drawdown flushing, sluicing, and density current venting include low- and mid-level outlets (Figure 9.1-9). The outlets are used differently in each case.

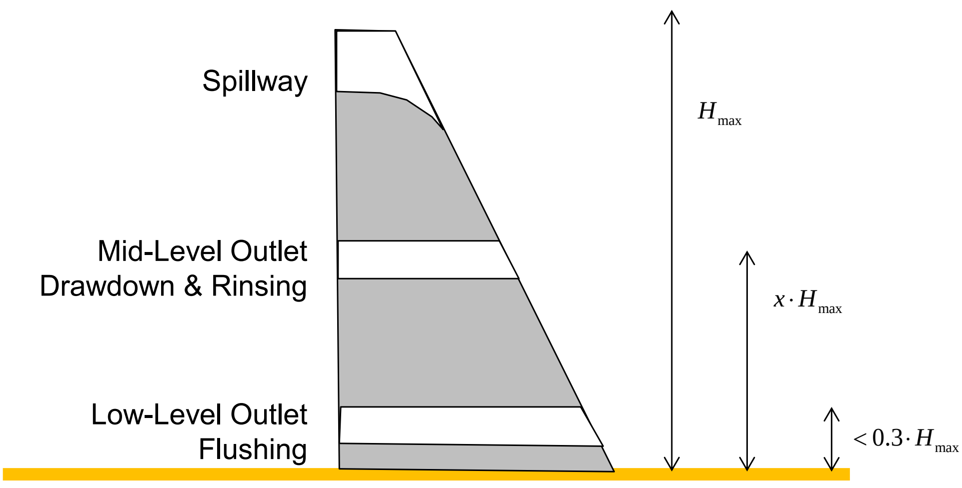


Figure 9.1-9. Essential Dam Design Elements Required to Facilitate Drawdown Flushing, Sluicing, and Density Current Venting.

Drawdown flushing

To implement drawdown flushing, executed during the non-monsoon season, it is necessary to first empty the reservoir. This is accomplished by opening both the mid- and low-level outlets. Using both outlets allows rapid emptying of the reservoir. Once the reservoir is empty, the low-level outlets are used to discharge the water containing re-entrained sediment to the downstream river. After drawdown flushing has been completed, the low-level outlets are closed to refill the reservoir. When the water level reaches the mid-level outlets, they are opened to allow discharge of clean water to the downstream river. Release of this clean water is necessary to rinse the fine sediments that may have deposited along the riverbanks and on the riverbed of the downstream river reach. Rinsing the fine sediment with clean water enhances environmental conditions and appearance. After rinsing is complete, the mid-level outlets are also closed to continue filling the reservoir.

Sluicing

Sluicing is executed during flood (monsoon) conditions, which means that it will not be possible to empty the reservoir. The objective during sluicing, i.e., to maximize the sediment transport capacity of the water flowing through the reservoir, is accomplished by opening both mid- and low-level outlets. By modulating the openings of the low- and mid-level gates it is also possible to regulate the sediment concentration in the water released downstream of the dam. Once sluicing is complete, the low-level outlets are closed and the mid-level outlets may be used to rinse fine sediments that may have deposited along the downstream river reach, if necessary. Upon completion of the rinsing process, the mid-level outlets are also closed and the reservoir refilled with water.

Density current venting

Density currents are released through the low-level outlets. This means that these outlets are opened to facilitate venting once the density current reaches the dam face. The mid-level outlets may be used to control the sediment concentration of the sediment-laden water released through the low-level outlet. This is done by releasing clean water from the mid-level outlets by opening them to the desired degree. When density current venting is complete, the low-level outlets are closed. At this time, the mid-level outlets may be opened to release clean water to rinse the downstream river from fine sediments, if necessary. Once completed, all outlets are closed to maintain a full reservoir.

Lining

It may be necessary to line the low-level outlets to prevent damage by abrasion. This may be accomplished by using high-strength concrete, steel or other abrasion resistant materials like basalt tiles.

Sediment management in dam cascades

When passing sediment through cascades of dams, as in the case under consideration along the Xe Kong River, it is usually preferred to concurrently release sediments from all dams in the cascade. This may be performed by first opening outlets at the upstream dams, followed by sequential opening of outlets at the downstream dams. Detailed specification of how this should be accomplished is project specific. The procedure is determined by more detailed study and refined through experience gained during implementation.

Hydropower Projects Considered

Four hydropower projects were studied along the main stream of Xe Kong River in Lao PDR. The salient features of these four projects are given in Table 9.1-2.

Table 9.1-2. Salient Features of the proposed Xe Kong Hydropower Projects.

Item	Xe Kong 5	Xe Kong 4	Xe Kong 3B	Xe Kong 3A
Status	F.S. completed	F.S. approved	F.S. completed	F.S. completed
Location	Lat. 15˚58.5'/ Long 106˚55.8'	Lat. 15˚30.8'/ Long 106˚47.3'	Lat. 15˚22.6'/ Long 106˚46.8'	Lat. 14˚34.2'/ Long 106˚54.9'
River	Xe Kong	Xe Kong	Xe Kong	Xe Kong
Installed capacity (MW)	330	300	146	140
Rated head (m)	188	140	34	17
Design discharge (m^3/s)	146	240	460	568
Full supply level (m)	500	290	160	117
Catchment area (km^2)	2,615	5,400	5,882	9,700
Mean annual flow (m^3/s)	137	205	240	316
Total reservoir volume (mill m^3)	1,356	3,100	425	486
Reservoir length (km)	41	92	15	21
CIR (Capacity Inflow Ratio)	0.31	0.48	0.01	0.02
Trap efficiency (%)	95	99	48	55
Sediment yield ($t/km^2/yr$)	280	280	280	290

Note: F.S. completed/ F.S. approved = Feasibility Study completed or approved

Sediment Management

Proposed facilities – sediment balance

At this time, little information is available about sediment management plans at the four proposed dams and their reservoirs along the Xe Kong River. By assuming that sediment management would not be implemented at any of these dams, it is estimated that about 80% of the sediment will be trapped by these reservoirs. This was estimated by using Brune Curve (Brune, 1953) based on the inflow, reservoir size, and the incoming sediment load. Table 9.1-3 shows the sediment balance through the cascade of four reservoirs, in the absence of sediment management. This simple calculation shows the need of sediment management plans for sediment transport continuity.

Table 9.1-3. Sediment Balance through Cascade of Dams.

Dam	Catchment Area (km^2)	Incremental Area (km^2)	Sediment Yield (t/km^2/yr)	Sediment Load (t/yr)	Cum. Sediment Passed, No Dam Case (t/yr)	Cumulative Sediment Load (t/yr) with Dams	Trap Efficiency (%)	Sediment Trapped (t/yr)	Sediment Passed (t/yr)	Cum. Decrease in Sediment Load (t/yr)	Cum. Decrease in Sediment Load (%)
Xe Kong 5	2,615	2,615	280	732,200	732,200	732,200	95	695,590	36,610	695,590	95
Xe Kong 4	5,400	2,785	280	816,410	1,548,610	853,020	99	844,490	8,530	1,540,080	99
Xe Kong 3B	5,882	482	280	143,124	1,691,734	151,654	48	72,794	78,860	1,612,874	95
Xe Kong 3A	9,700	3,818	290	1,181,645	2,873,379	1,260,505	55	693,278	567,227	2,306,152	80

Sediment management alternatives

Xe Kong 5

The Xe Kong 5 hydropower project is planned at the top of a cascade of dams in the mainstream Xe Kong River. This dam and four other alternative designs, which might replace the proposed design, were considered to optimize the potential to pass sediment through this facility. Principle features of the five alternative hydropower projects are shown in Table 9.1-4.

Table 9.1-4. Comparison of Characteristics of Xe Kong 5 Dam and its Alternatives.

Item	Xe Kong 5 Current Design	Xe Kong 5 Alternative 1	Xe Kong 5 Alternative 2	Xe Kong 5 Alternative 3	Xe Kong 5 Alternative 4
Location	Lat. 15˚58.5' Long 106˚55.8'	Lat. 5˚52.90' Long 106˚53.37'	Lat.15˚52.90' Long 106˚53.37'	Lat. 15˚52.90' Long 106˚53.37'	Lat. 15˚58.5' Long 106˚55.8'
Installed capacity (MW)	330	248	198	141	248
Rated head (m)	188	188	150	107	188
Design discharge (m^3/s)	146	146	146	146	146
Full supply level (m)	500	431	393	350	468
Reservoir length (km)	41	32	20	18	35
Dam height (m)	188	156	118	75	156
Reservoir volume (Mill m^3)	1,356	1,356	851	541	1,158
CIR (Capacity Inflow Ratio)	0.31	0.31	0.20	0.13	0.27
Trap efficiency	95%	95%	92%	88%	94%

Xe Kong 5 reservoir

The proposed Xe Kong 5 reservoir has a capacity inflow ratio (CIR) of 0.31, which corresponds to a sediment trapping efficiency of 95%. The current design does not have a bottom outlet and the NHI team has no other information about the sediment management plans. Figure 9.1-10 shows the approximate coverage of the proposed Xe Kong 5 reservoir. It is noted the reservoir is narrow and long (41.3km). The narrow-ness of the reservoir is a positive indicator of the potential for flushing, but the length and large volume of the reservoir may limit successful implementation of drawdown flushing.

The RESCON program was used to assess the potential for drawdown flushing, assuming adequately sized low-level gates were available in the current design. Calculations to determine the potential to implement density current venting were also performed. The results of these analyses are presented below.

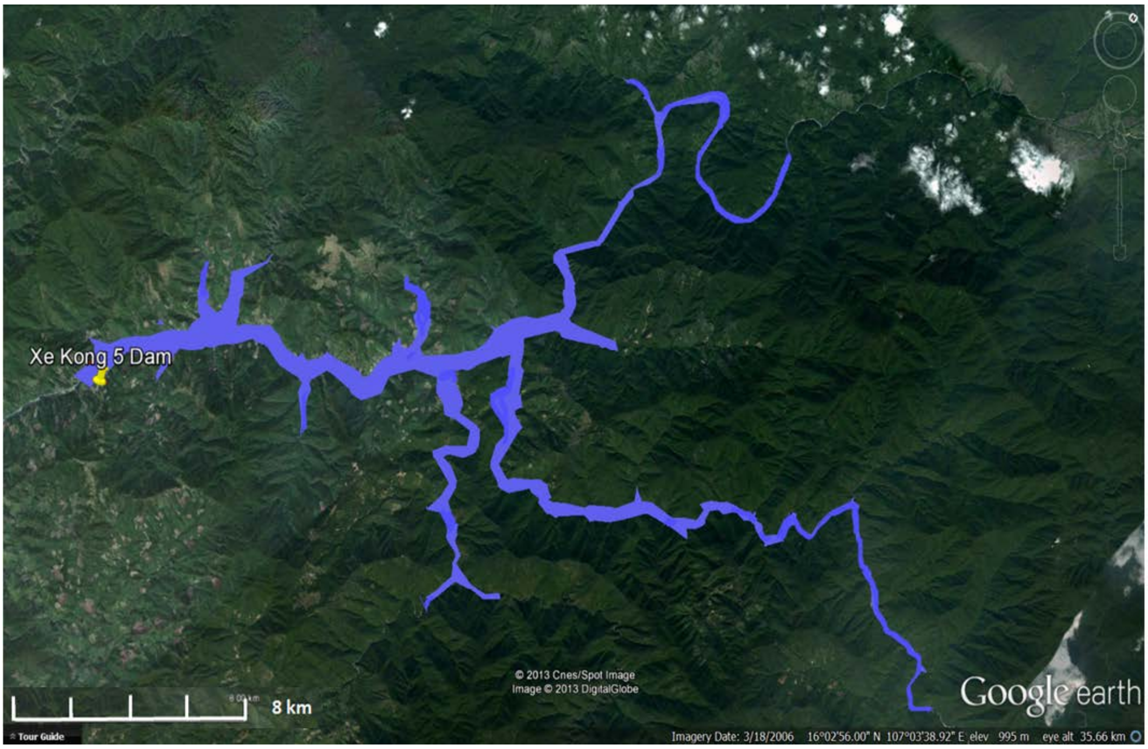


Figure 9.1-10. Approximate Inundation Area of the Xe Kong 5 Reservoir**.**

Xe Kong 5 alternative designs

An alternative dam site was identified approximately 11 km downstream of the proposed Xe Kong 5 dam site. Three different alternatives were studied by varying the dam height at this location. Figure 9.1-11 shows the schematic layout(s) of the alternative(s). These alternative options include headrace and tailrace tunnels, and an underground powerhouse. The total length of underground work is approximately 9 km. The tunnel arrangement provides an additional head of 32m compared to the head available at the dam. It is assumed that the geologic conditions are good enough for underground construction. This assumption requires validation to proceed further on these alternatives. Alternative-1 maintains the same design head (i.e., 188 m) as in the original design. Alternative-2 creates a design head of 150m and Alternative-3 creates a design head of 107m. Other features of these three alternatives are given in Table 9.1-4.

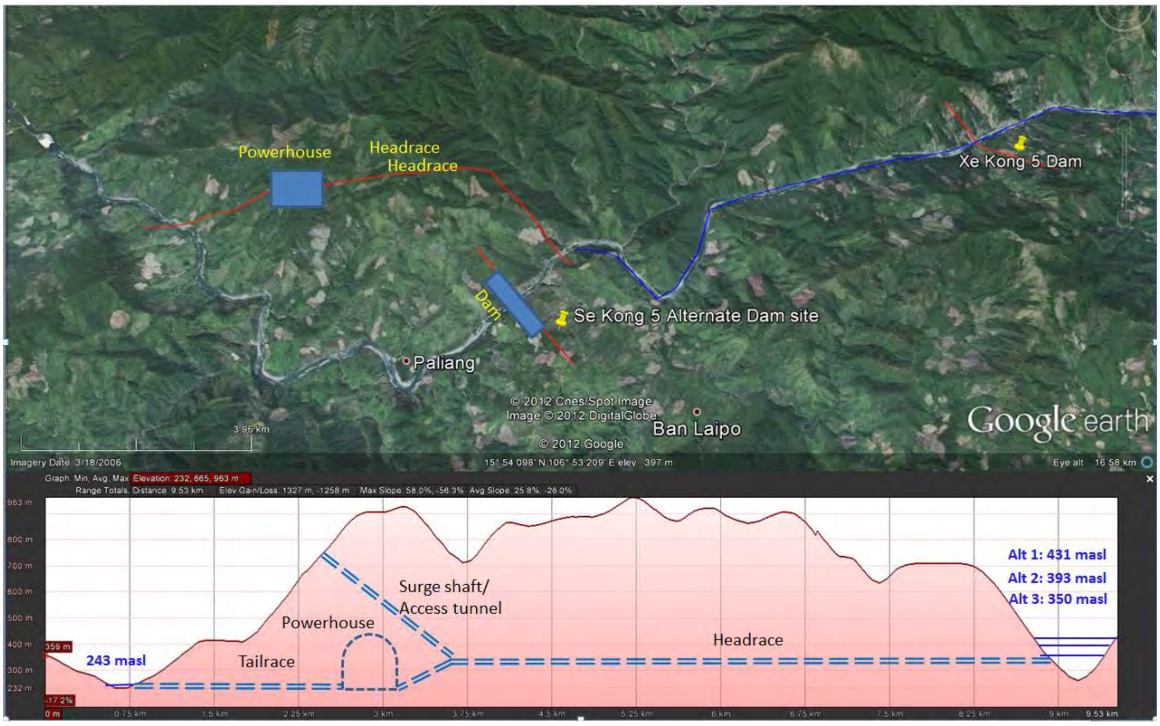


Figure 9.1-11. Schematic of Xe Kong 5 Alternatives 1 to 3.

The reservoir lengths in all alternatives are shorter and the reservoir volumes of two of the alternatives are smaller than the proposed design. These geometric features provide somewhat more favorable conditions for drawdown flushing. It is also noted that the shorter reservoir lengths and smaller reservoir volumes also require lesser amounts of resettlement and lesser amounts of environmental impact due to inundation, should these issues be of concern. The shorter reservoir lengths and changes in inundated area can be observed in Figure 9.1-12 through Figure 9.1-13, which are on the same scale. An attempt has also been made to maintain the installed capacity of the alternative designs as close to the original as possible by making use of a tunnel and a downstream powerhouse to generate power.

The additional head provided by the tunnel arrangement is 32m, which corresponds to approximately 42 MW of power for the given design discharge. If the powerhouse is built at the dam of the alternative site (i.e., tunnel arrangement is discarded), then each alternative will produce 42 MW less power than with the tunnel. In lieu of a tunnel arrangement a powerhouse could be constructed at the dam; this may be decided based on financial/economic optimization, which is beyond the scope of this study.

In addition to Alternatives 1-3, another alternative, Alternative 4 of Xe Kong 5, was considered at the originally proposed Xe Kong 5 dam site. In this alternative (i.e., Figure 9.1-15), the top level of the dam is reduced to 468 masl (compared to the current design level of 500 masl), but a tunnel arrangement—including headrace, powerhouse and tailrace facilities – has been added to achieve the same head as before (i.e., 188m). Figure 9.1-15 through Figure 9.1-17 illustrate the layout, tunnel alignment, and reservoir area of this alternative. The additional head provided by the tunnel arrangement is 32m.

Figure 9.1-12. Reservoir Inundation Area of Xe Kong 5 Alternative-1.

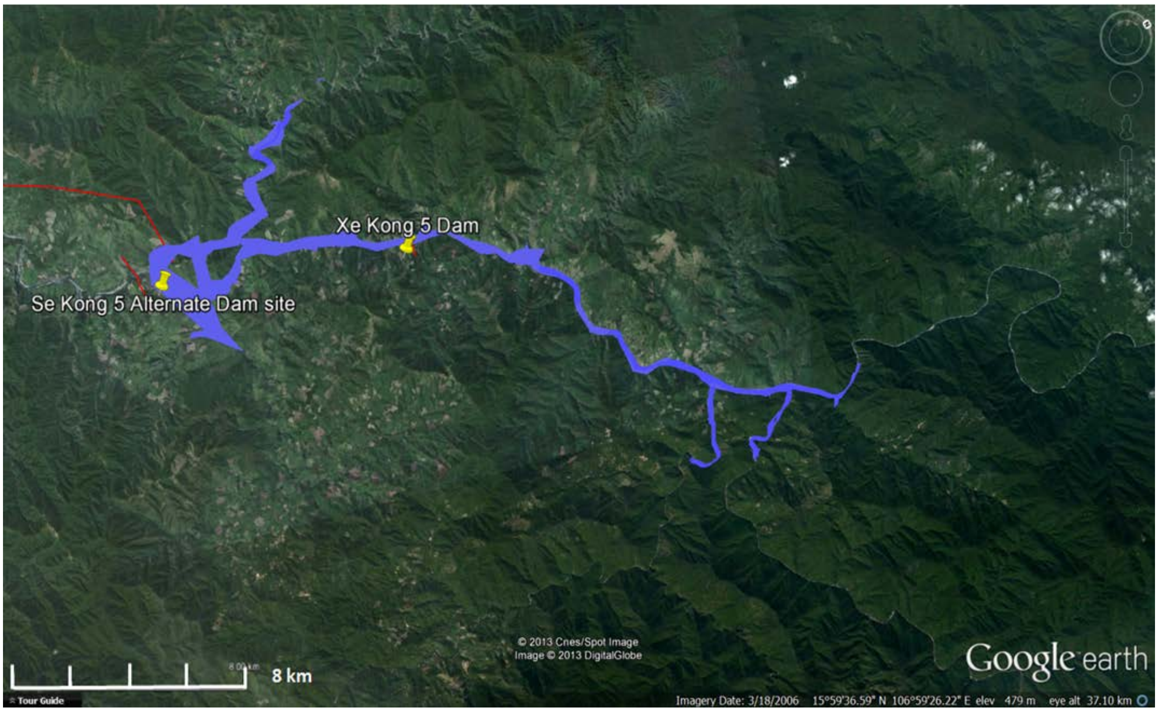


Figure 9.1-13. Reservoir Inundation Area of Xe Kong 5 Alternative-2.

Figure 9.1-14. Reservoir Inundation Area of Xe Kong 5 Alternative-3.

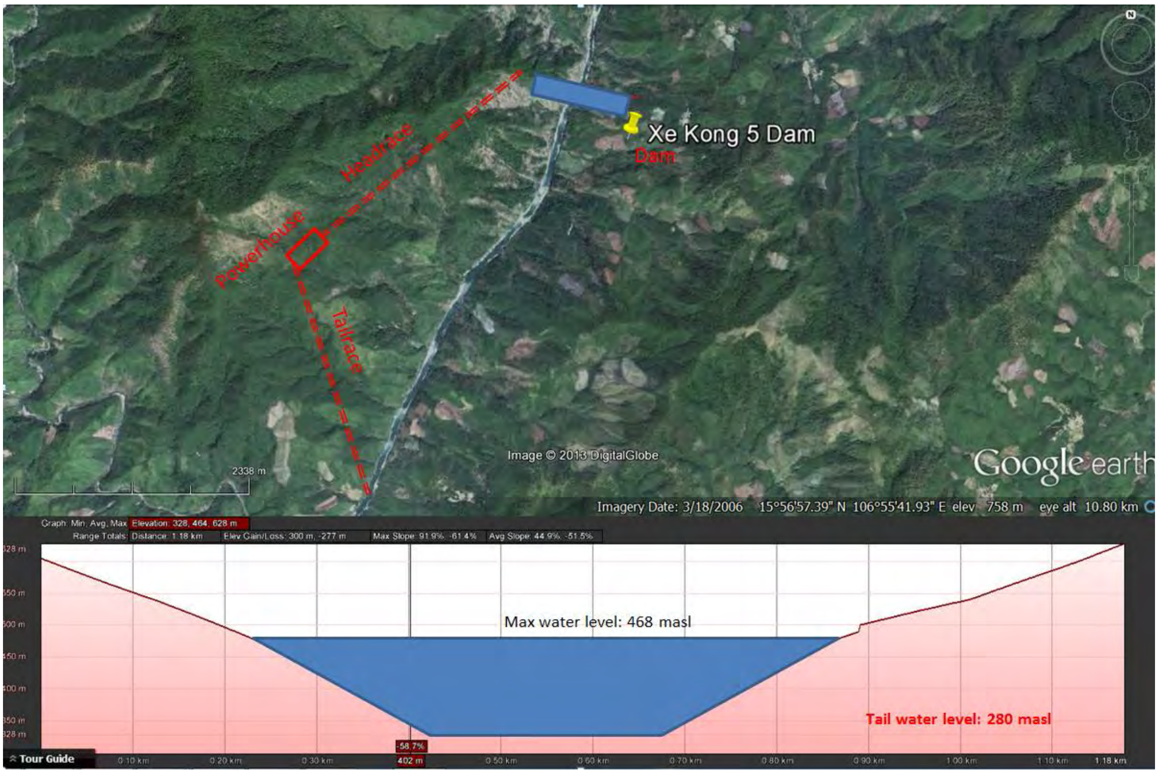


Figure 9.1-15. Schematics of Xe Kong 5 Alternative-4.

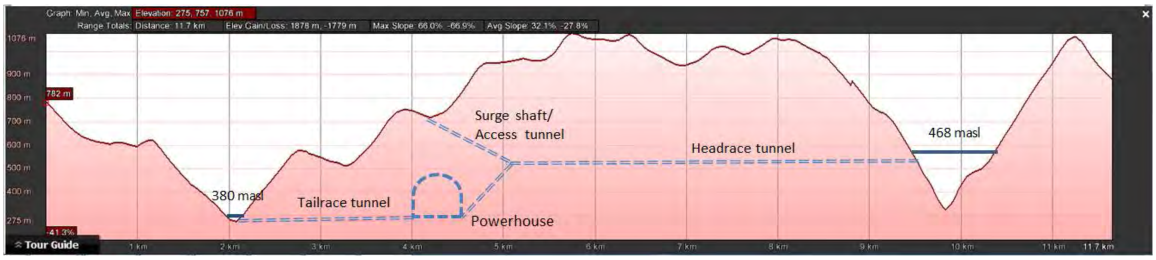


Figure 9.1-16. Tunnel Alignment of Xe Kong 5 Alternative-4.

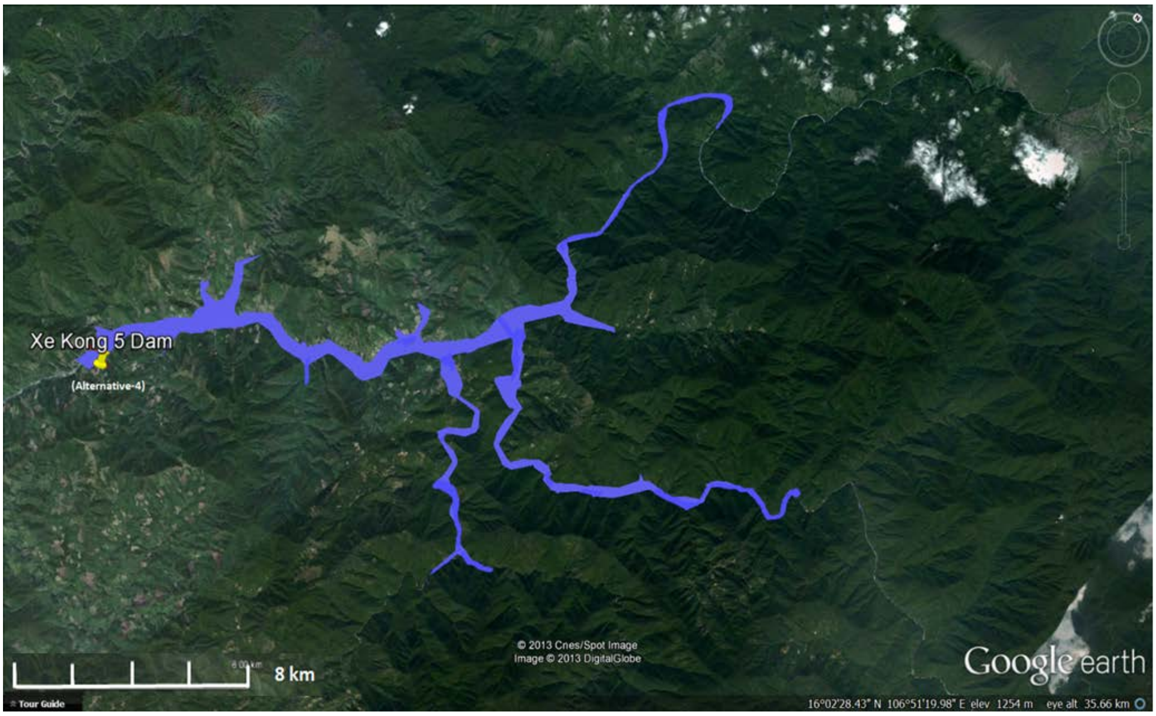


Figure 9.1-17. Reservoir Inundation Area of Xe Kong 5 Alternative-4**.**

All four of these alternatives present better sediment flushing potential through the reservoir than the current design. The RESCON program was used to assess the potential for drawdown flushing of each. Calculations to determine the potential to implement density current venting were also performed. The results of these analyses are presented in the next section.

Xe Kong 5 potential to pass sediment

Drawdown flushing

The graphs on Figure 9.1-18 summarize the drawdown flushing analysis results for the Xe Kong 5 Dam and its proposed alternatives. On the graph showing the flushing criteria, results indicating most of the parameters having values greater than one mean that implementation of drawdown flushing would likely be successful. Similarly, the values of LTCR > 0.35 and DDR > 0.70 indicate that the proposed design as well as the alternatives may all successfully remove deposited sediment by drawdown flushing. However, it is noted that the criterion indicating DDR > 0.7 implies that the dam designs will contain adequately sized low-level outlets allowing the flushing discharge to freely flow through the dam, without damming.

TWR < 1.0 is not a great concern. The LTCR parameter compensates for its effect. If TWR were greater than one, it would have resulted in a LTCR value approximating 1.0, which means that drawdown flushing may remove all deposited sediment. The fact that none of the LTCR values approaches one indicates that the assessment acknowledges that not all sediment can be removed by drawdown flushing, which is what could be expected for TWR < 1.0.

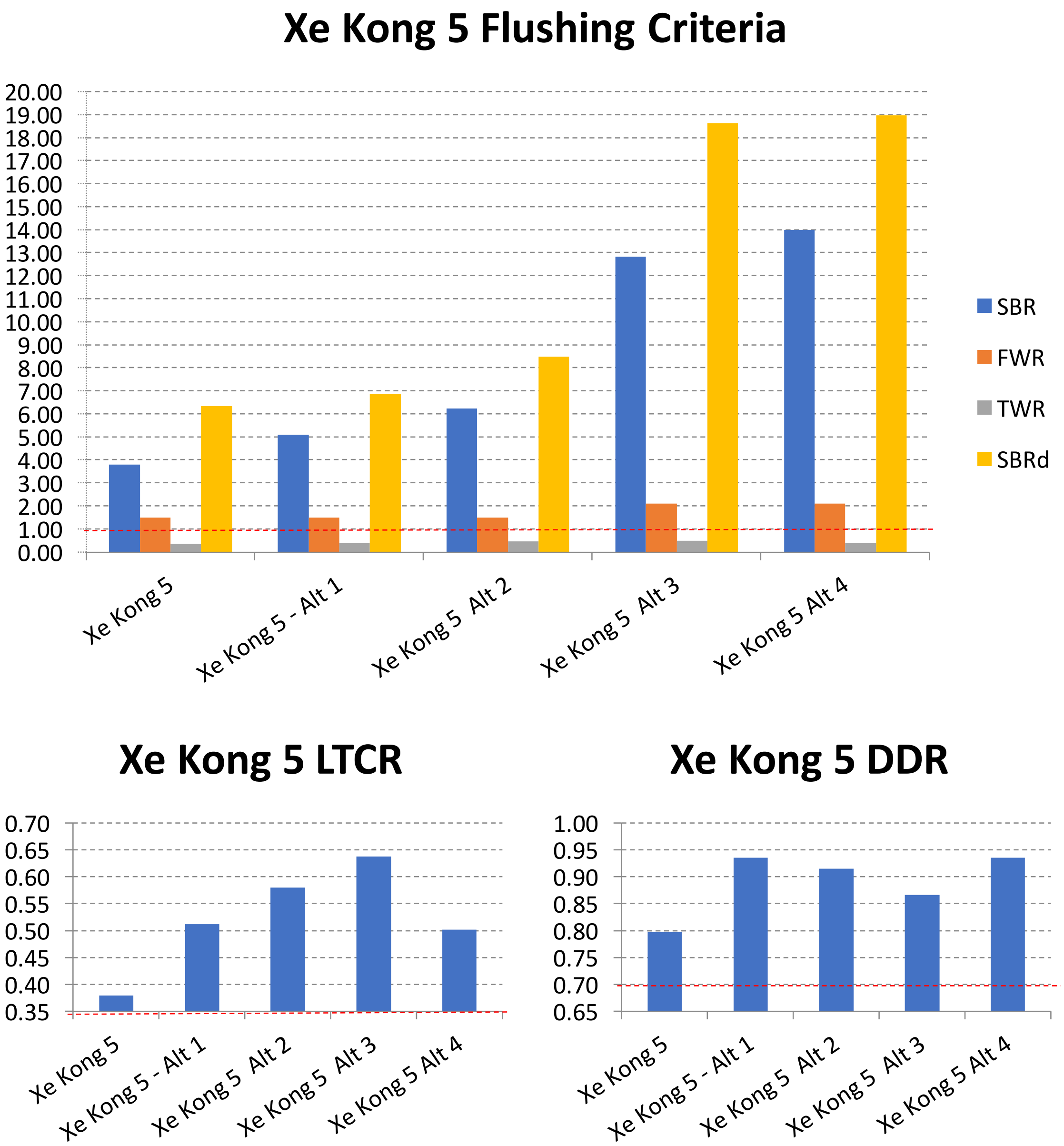


Figure 9.1-18. Comparison of Quantified Values of SBR, FWR, TWR, SBRd, LTCR, and DDR and Criteria for Xe Kong-5 Dam and Alternative Designs.

Note that the Xe Kong 5 Alternative 3 has the greatest potential to remove deposited sediment by making use of drawdown flushing. That alternative has the highest LTCR value, meaning that it has the potential to remove the greatest amount of deposited sediment and retain close to 65% of the reservoir volume in the long term. From an operational point of view, Alternative 3 is also favored because its reservoir volume is much smaller than any of the other options. It is estimated at only 541 million m^3, whereas the currently proposed Xe Kong 5 Dam has an estimated reservoir volume equaling 1,356 million m^3. For purposes of drawdown flushing the smaller reservoir volume will require less time for emptying the reservoir, and therefore less time lost for generating power.

Based on the results it is important to note that drawdown flushing requires dam designs containing low-level and mid-level outlets of adequate size. Correct design of the dam is therefore very important. The two sets of outlets are required to draw down the reservoir water surface rapidly when preparing the reservoir for drawdown flushing. Once the reservoir is empty, the low-level gates discharge flushed sediment downstream. When refilling the reservoir, once drawdown flushing is complete, clean water released from the mid-level outlets rinses fine sediment in the downstream river reach. An indication of the required size of the gates may be found on page 33, which considers requirements for flushing the entire cascade of dams using the preferred alternatives.

Table 9.1-5. Venting Efficiency (%) for Xe Kong 5 and its Alternatives.

Flow (m^3/s)	Sediment Concentration (mg/l)					
	100	**500**	**1,000**	**2,000**	**5,000**	**10,000**
137[1]	0	0	12	19	24	28
274	0	0	17	23	28	32
685	0	0	23	28	32	37
1,370	0	21	27	31	36	40

Density current venting

The density current venting analysis results are presented in Table 9.1-5, which contains estimates of venting efficiency for various possible combinations of flow magnitudes and sediment concentrations, flowing into the reservoir. This approach was followed because of the absence of a rating curve providing a relationship between river discharge and sediment concentration. For example, the table indicates that it would be highly unlikely for a density current to form if a flood with a magnitude of 685 m^3/s discharging into the reservoir would be associated with a sediment concentration of 500mg/l. This is concluded by observing that the venting efficiency of such an event is zero, i.e., a density current would not form.

On the other hand, if that same flood (685m^3/s) would carry sediment at a concentration of 2,000 mg/l then it is likely that a density current would form. This conclusion is made by observing from the table that the venting efficiency of such an event would be 28%. What this means is that about 28% of the sediment flowing into the reservoir would be contained in a density current. By passing this current through a low-level outlet at the dam, it may be possible to release that percentage of the incoming sediment downstream of the dam.

The conclusion made from Table 9.1-5 is that density currents might form in the reservoir of the Xe Kong 5 Dam if the sediment concentrations in the inflowing water are high enough. It also indicates that the venting efficiency would likely be approximately 30%. This means that if density currents would form then they would have the ability to discharge about 30% of the incoming sediment to downstream reaches of the reservoir if vented through a low-level outlet at the dam.

[1] Average annual flow.

Additional work that should be completed is to collect sediment concentration and water discharge data, as well as particle size distributions of suspended sediment flowing into the reservoir during high flow conditions. This information will be useful to provide more confidence about the possible formation of density currents.

Xe Kong 4

The potential to pass sediment through the Xe Kong 4 Dam and its reservoir was considered by analyzing the currently proposed design as well as three other alternative designs. The salient features of these four alternative designs are presented in Table 9.1-6.

Table 9.1-6. Comparison of Characteristics of Xe Kong 4 and its Alternatives.

Item	Xe Kong-4 Current Design	Xe Kong-4 Alternative 1	Xe Kong-4 Alternative 2	Xe Kong-4 Alternative 3
Location	Lat. 15˚30.8’ Long 106˚47.3’	Lat. 15˚30.8’ Long 106˚47.3’	Lat. 15˚43’ Long 106˚47’	Lat. 15˚39’ Long 106˚48’
Installed capacity (MW)	300	173	130	152
Rated head (m)	140	80	60	70
Design discharge (m^3/s)	240	240	240	240
Full supply level (m)	290	230	230	230
Dam height (m)	140	80	40	50
Reservoir length (km)	92	71	31	47
Reservoir volume (Mill m^3)	3,100	1,771	768	1,167
CIR (Capacity Inflow Ratio)	0.48	0.27	0.12	0.18
Trap efficiency	99%	94%	88%	91%

Xe Kong 4 reservoir

The reservoir volume of the proposed Xe Kong 4 Dam is very large compared to the inflow, corresponding to a sediment trapping efficiency of 99%. Figure 9.1-19 shows the approximate reservoir area, indicating substantial inundation.

Xe Kong 4 alternatives – overview

Three alternatives were studied for Xe Kong 4 Dam. The locations of these alternative designs relative to the location of the currently proposed Xe Kong 4 Dam and relative to the location of Xe Kong 5 Dam and Xe Kong 5 Alternative-1 Dam are shown in Figure 9.1-20.

Figure 9.1-19. Reservoir Inundation Area of Xe Kong 4.

Figure 9.1-20. Xe Kong 4 Alternatives**.**

Xe Kong 4 Alternative-1 is at the same location as the currently proposed Xe Kong 4 Dam, but has a reduced dam height. The reason for reducing the dam height is that it facilitates implementation of Xe Kong-5 Alternative-1. If the dam height is not lowered, the head at Xe Kong 5 Alternative-1 design will be reduced due to inundation. The backwater of the currently proposed Xe Kong-4 Dam reaches the toe of the currently proposed Xe Kong 5 Dam. With Xe Kong 5 Alternative-1 located downstream of the currently proposed Xe Kong 5 Dam, it is necessary to lower the water surface elevation at the outlet of its tailrace tunnel. The dam heights of all the Xe Kong 4 Dam alternatives have been set such that their tail water does not exceed the location of the tailrace tunnel exit of Xe Kong 5 Alternative-1 (see Figure 9.1-20). The shorter reservoir lengths and lower reservoir volumes also make drawdown flushing more feasible. Additional head for power generation at Xe Kong 4 Alternatives-2 and -3 is created by making use of tunnels, illustrated by the red dashed lines in Figure 9.1-20.

Xe Kong 4 Alternative 1

The Xe Kong 4 Alternative-1 design incorporates a reduced 80 m high dam at the same location as the currently proposed Xe Kong 4 Dam. Figure 9.1-21 shows the approximate outline of its reservoir.

Figure 9.1-21. Reservoir Cover Area of Xe Kong 4 Alternative-1.

Xe Kong 4 Alternative 2

The Xe Kong 4 Alternative-2 design incorporates a reduced dam height of 40m, which is located approximately 40 km upstream of the currently proposed dam site. This alternative includes headrace and tailrace tunnels, approximately 7 km in length, and a powerhouse cavern (Figure 9.1-22). Figure 9.1-23 shows the approximate reservoir area.

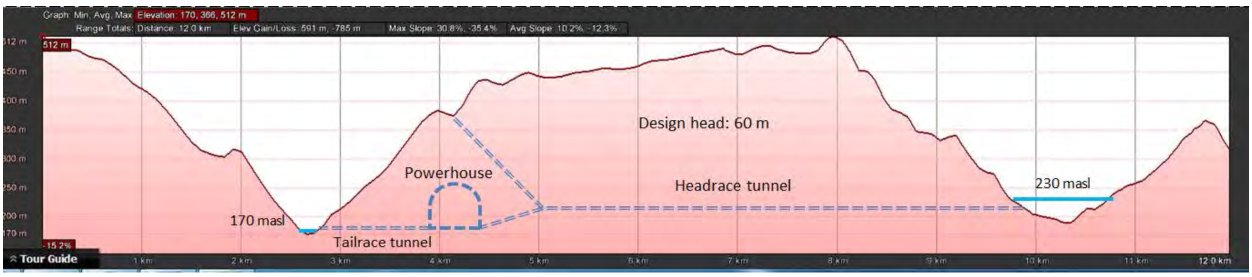


Figure 9.1-22. Schematics of Alternative 2 of Xe Kong 4.

Figure 9.1-23. Reservoir Inundation Area of Xe Kong 4 Alternative-2.

Xe Kong 4 Alternative 3

The Xe Kong-4 Alternative-3 design incorporates a reduced dam height of 50 m, which is located approximately 24 km upstream of the currently proposed Xe Kong-4 Dam site. This alternative also includes approximately 7 km of tunnel/underground work including headrace and tailrace tunnels and a powerhouse cavern (Figure 9.1-24). Figure 9.1-25 shows the reservoir inundation area.

Figure 9.1-24. Schematics of Xe Kong 4 Alternative-3.

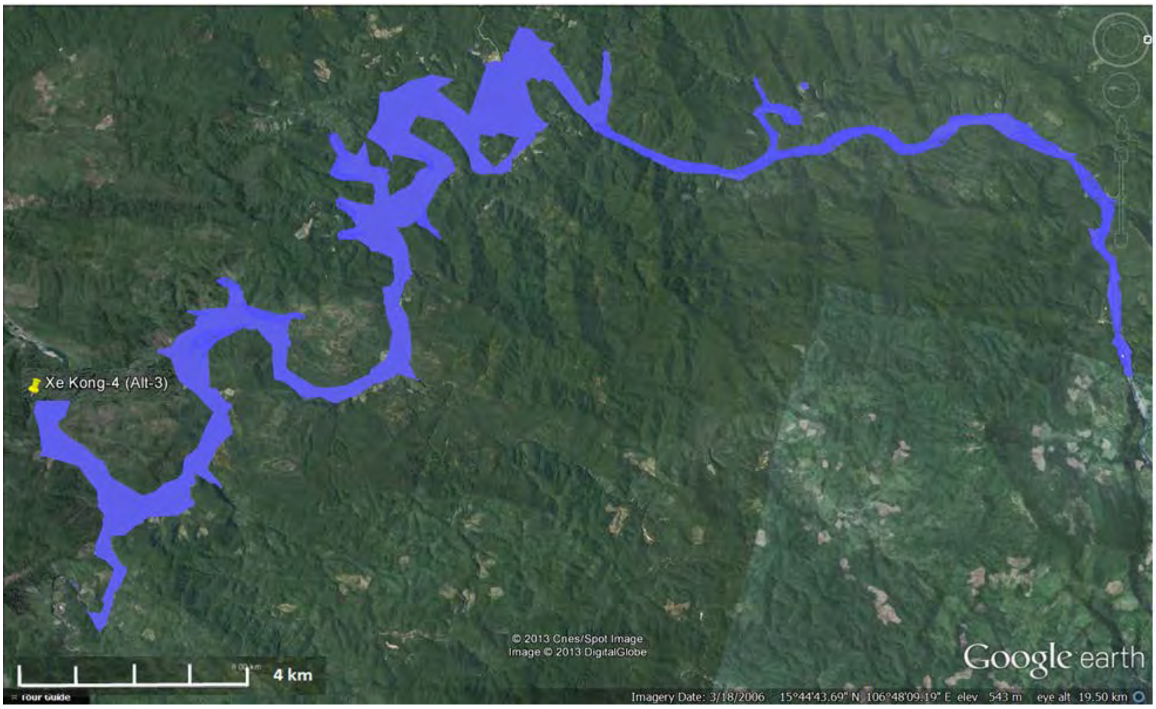


Figure 9.1-25. Reservoir Inundation Area of Xe Kong-4 Alternative-3.

Xe Kong 4 potential to pass sediment

Drawdown flushing

From Figure 9.1-26 it is noted that the flushing criteria are substantially met at all four designs (except for TWR), which implies that drawdown flushing may be successfully implemented. From a sediment passage point of view it is likely that Xe Kong 4 Alternative-2 will be the preferred design because its high LTCR value implies that it will pass the greatest amount of deposited sediment. From an operational point of view, it is also favored because its reservoir volume is much smaller than any of the other options. It is estimated at only 768 million m^3, whereas the currently proposed Xe Kong 4 Dam has an estimated reservoir volume equaling 3,100 million m^3. For purposes of drawdown flushing the smaller reservoir volume will require less time for emptying the reservoir, and therefore less time lost for generating power. It is therefore concluded that it will likely be possible to implement drawdown flushing at the Xe Kong 4 Dam and its alternatives, provided that adequately sized mid- and low-level outlets are installed to facilitate its implementation.

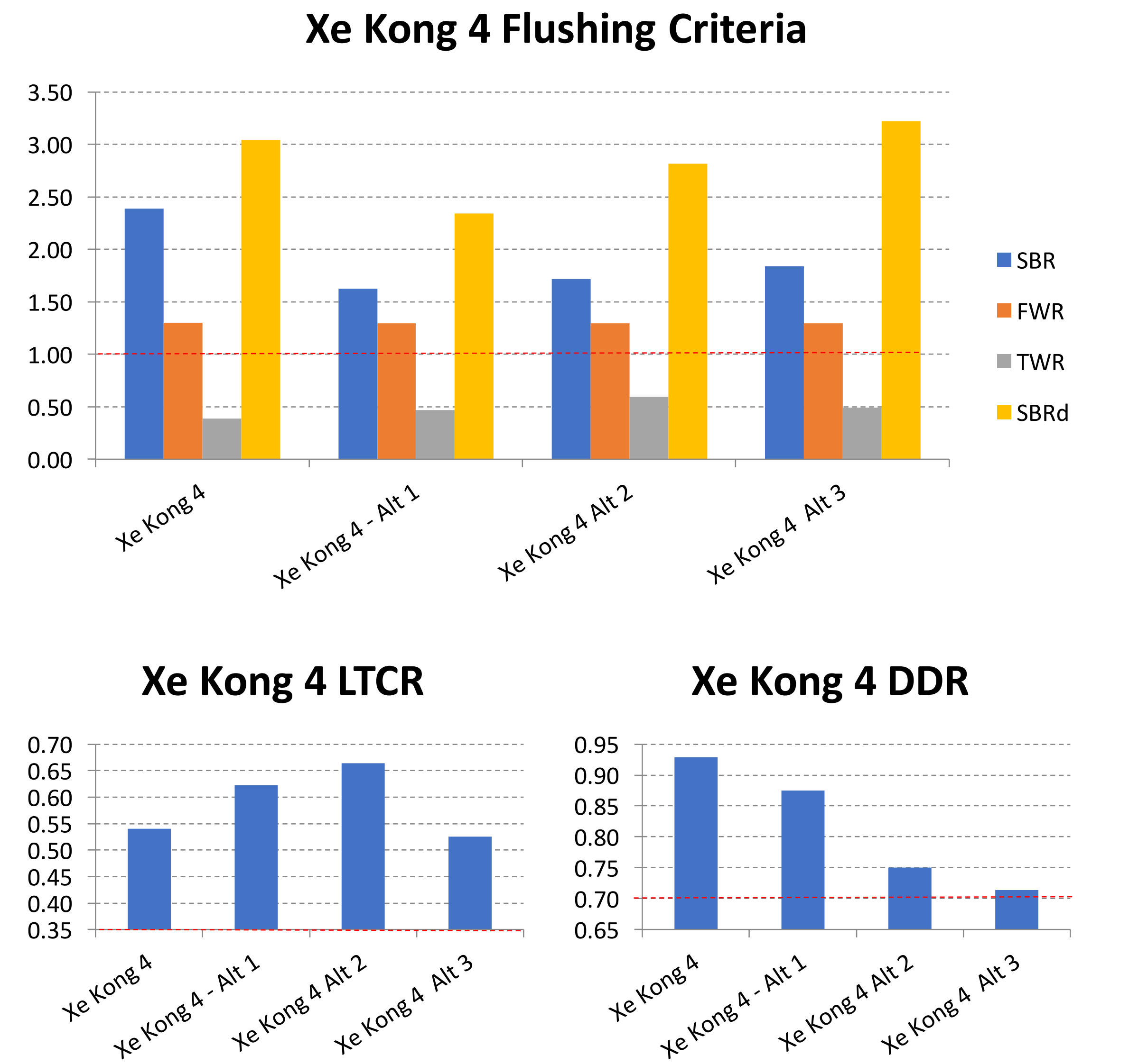


Figure 9.1-26. Comparison of Quantified Values of SBR, FWR, TWR, SBRd, LTCR, and DDR and Criteria for Xe Kong-4 Dam and Alternative Designs**.**

Density current venting

The lack of a rating curve providing a relationship between river discharge and sediment concentration necessitated using the approach implement for the Xe Kong 5 analysis for determining the potential viability of density current venting. The density current venting analysis results are presented in Table 9.1-7, which contains estimates of venting efficiency for various possible combinations of flow magnitudes and sediment concentrations.

The conclusion made from Table 9.1-7 is that density currents might form in the reservoir of the Xe Kong 4 Dam if the sediment concentrations in the inflowing water are high enough. It also indicates that the venting efficiency would likely be on the order of about, say, 25%. This means that if density currents would form then they would have the ability to discharge about 25% of the incoming sediment to downstream reaches of the reservoir if vented through a low-level outlet at the dam.

Additional work that should be completed is to collect sediment concentration and water discharge data, as well as particle size distributions of suspended sediment flowing into the reservoir during high flow conditions. This information will be useful to provide more confidence about the possible formation of density currents.

Table 9.1-7. Venting Efficiency (%) for Xe Kong 4 and its Alternatives.

Flow (m^3/s)	**Sediment Concentration (mg/l)**					
	100	**500**	**1,000**	**2,000**	**5,000**	**10,000**
205[2]	0	0	0	9	16	21
410	0	0	0	14	20	24
1,025	0	0	14	20	26	29
2,050	0	0	19	24	29	33

Xe Kong 3B and Xe Kong 3A

Xe Kong 3B

Xe Kong 3B hydropower project is planned to be downstream of proposed Xe Kong 4 hydropower project. The main features of this project are listed in Table 9.1-8. Figure 19.1-27 shows the approximate inundation area reservoir. No alternative designs were found viable to replace the Xe Kong 3B Dam.

Table 9.1-8. Main Features of Xe Kong-3B Hydropower Project.

Item	**Xe Kong-3B**
Location	Lat. 15˚22.6'/ Long 106˚46.8'
River	Xe Kong
Installed capacity (MW)	146
Rated head (m)	34
Design discharge (m^3/s)	460
Full supply level (m)	160
Catchment area (km^2)	5,882
Mean annual flow (m^3/s)	240
Total reservoir volume (mill m^3)	425
Reservoir length (km)	15
Bottom width of the dam (m)	200
CIR (Capacity Inflow Ratio)	0.01
Trap efficiency (%)	48
Sediment yield (t/km^2/yr)	280

[2] Average annual flow.

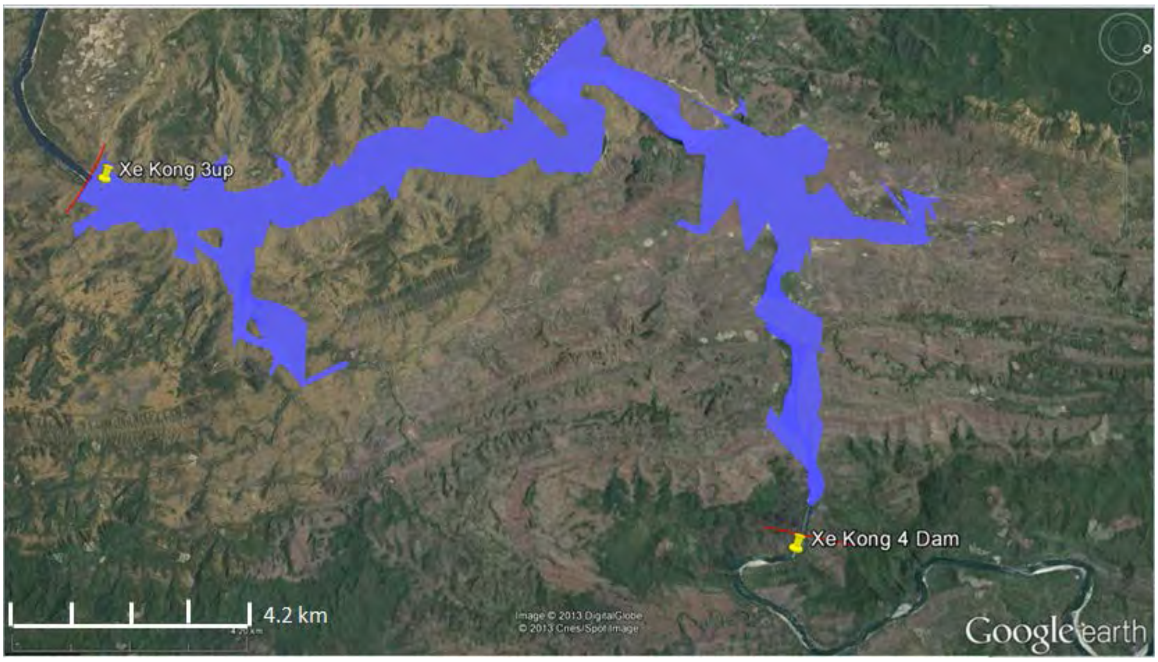


Figure 9.1-27. Reservoir Inundation Area of Xe Kong 3B. (Note: Xe Kong 3up is the same as Xe Kong 3B.)

Xe Kong 3A

The Xe Kong 3A hydropower project is proposed at the most downstream reach of the cascade formed by the four proposed dams. Its dam site is located near the powerhouse of the existing 152 MW Houay Ho hydropower project. Table 9.1-9 lists the main features of the Xe Kong 3A project. Figure 9.1-28 shows the approximate reservoir inundation area. Investigations indicated no feasible alternatives for replacing the Xe Kong 3A Dam.

Table 9.1-9. Main Features of Xe Kong 3A Hydropower Project.

Item	**Xe Kong 3A**
Location	Lat. 14˚34.2'/ Long 106˚54.9'
River	Xe Kong
Installed capacity (MW)	140
Rated head (m)	17
Design discharge (m^3/s)	568
Full supply level (m)	117
Catchment area (km^2)	9,700
Mean annual flow (m^3/s)	316
Total reservoir volume (mill m^3)	486
Bottom width of the dam (m)	200
Reservoir length (km)	21
CIR (Capacity Inflow Ratio)	0.02
Trap efficiency (%)	55
Sediment yield (t/km^2/yr)	290

Figure 9.1-28. Reservoir Cover Area of Xe Kong 3A. (Note: Xe Kong 3d is the same as Xe Kong 3A, and Xe Kong 3up is the same as Xe Kong 3B.)

Xe Kong 3B and Xe Kong 3A – potential to pass sediment

Drawdown flushing

The RESCON analysis performed on Xe Kong 3B and Xe Kong 3A Dams and their reservoirs indicates that it will likely be feasible to implement successfully drawdown flushing at both facilities. This can be seen in Figure 9.1-29, which compares the drawdown flushing parameter values to the criteria deemed to make drawdown flushing successful. Only one of the criteria, i.e., TWR, is not satisfied; which is not a great concern. It is noted that it will likely be possible to implement drawdown flushing at these two dams provided that adequately sized mid- and low-level outlets are installed to facilitate its implementation.

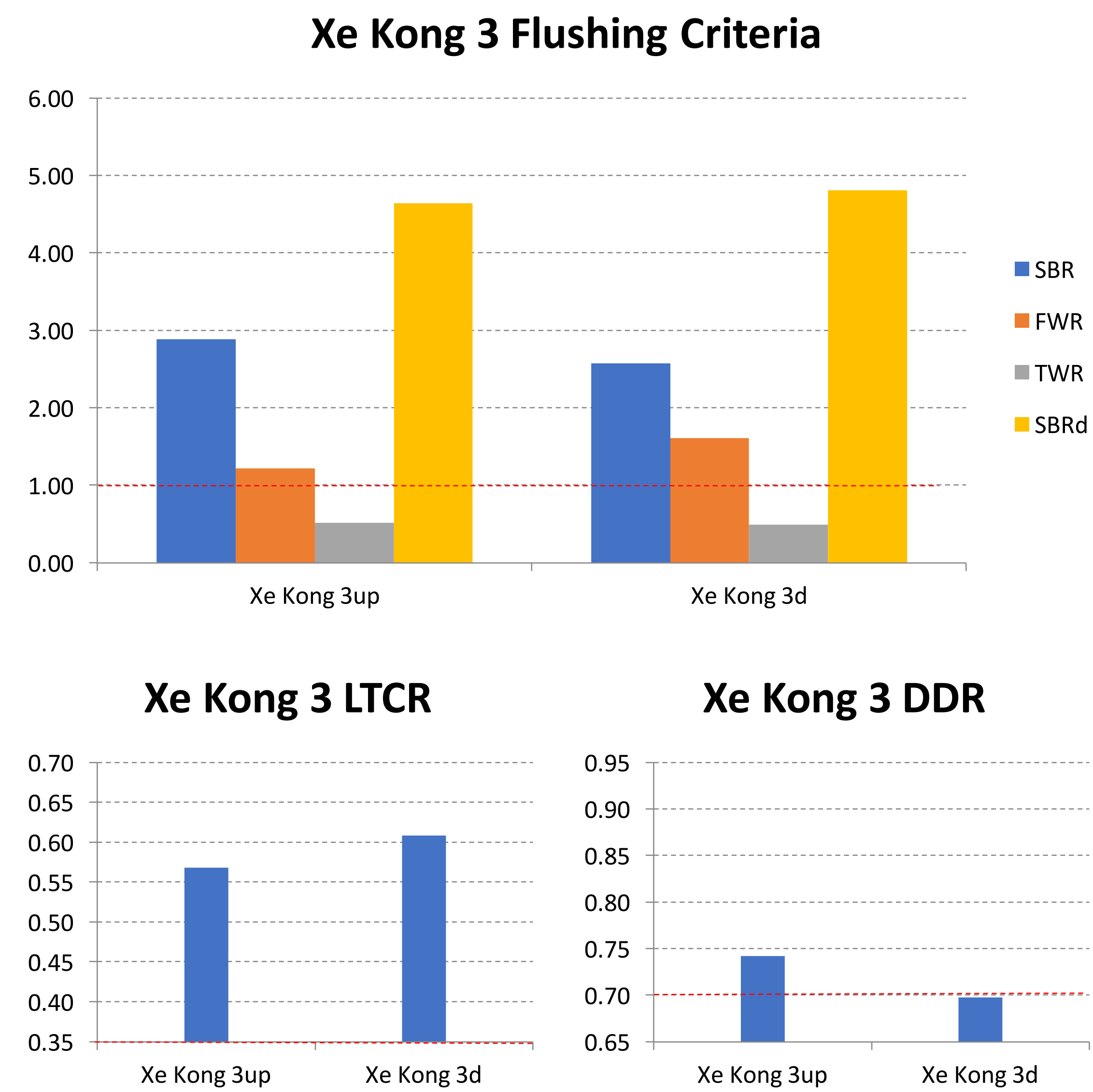


Figure 9.1-29. Comparison of Quantified Values of SBR, FWR, TWR, SBRd, LTCR, and DDR and Criteria for Xe Kong-3B and 3A Dams. (Note: Xe Kong 3d is the same as Xe Kong 3A, and Xe Kong 3up is the same as Xe Kong 3B.)

Density current venting

The density current venting analysis, performed using the same basis as for the other dams, indicates that such formation may be possible at high flows that concurrently occur with high sediment concentrations (Table 9.1-10 and Table 9.1-11). The venting efficiency appears to be slightly less effective at Xe Kong 3A. However, it is likely reasonable to assume a density current venting efficiency of about 20% to 25%.

Table 9.1-10. Venting Efficiency (%) for Xe Kong 3B.

Flow (m³/s)	Sediment Concentration (mg/l)					
	100	500	1,000	2,000	5,000	10,000
240[3]	0	0	0	13	20	24
480	0	0	9	18	24	27
1,200	0	0	18	23	29	32
2,400	0	0	22	27	32	36

Table 9.1-11. Venting Efficiency (%) for Xe Kong 3A.

Flow (m³/s)	Sediment Concentration (mg/l)					
	100	500	1,000	2,000	5,000	10,000
316[4]	0	0	0	0	15	19
632	0	0	0	13	19	23
1,580	0	0	12	19	24	28
3,160	0	0	18	23	28	32

Cascade of Dams – flushing

Flushing discharges

All the dams in the cascade have been found to be amenable to drawdown flushing. However, each of the facilities was considered independently in the foregoing sections. Because the dams are in a cascade it is necessary to perform an assessment of the effectiveness of drawdown flushing when executed in a cascade. When flushing dams in a cascade it is preferred to implement concurrently the procedure at all dams. The exact timing of gate openings, from the most upstream dam to the most downstream dam, is determined by more detailed studies to be conducted at a later stage, and will normally be refined during practical implementation.

Table 9.1-12 presents the flushing discharges that may be considered at each of the dams. The second column indicates the discharges (Q_f) that are expected to result in viable flushing should the procedure be implemented independently at each dam (as determined in the previous sections). However, the fact that these dams are in a cascade requires modification of those flushing discharges. The discharges that will be used when flushing the cascade ($Q_{f\_Cascade}$) are shown in the third column in Table 9.1-12.

[3] Average annual flow.
[4] Average annual flow.

Table 9.1-12. Flushing Discharges in Cascade.

Dam	Q_f (m^3/s)	$Q_{f\_Cascade}$ (m^3/s)
Xe Kong 5 Alt-3	274	410
Xe Kong 4 Alt-2	410	410
Xe Kong 3B	360	410
Xe Kong 3A	632	632

For example, Xe Kong 4 Alternative-2 is located immediately downstream of Xe Kong 5 Alternative-3. This means that it will be necessary to increase the flushing discharge at Xe Kong 5 Alternative-3 to 410 m^3/s to ensure that the flushing discharge at Xe Kong 4 Alternative-2 is high enough. The higher discharge released from Xe Kong 4 Alternative-2 implies that the flushing discharge available at Xe Kong 3B will also be greater than originally used to assess its flushing feasibility. For purposes of this assessment, it is therefore assumed that the flushing discharge at Xe Kong 3B is 410 m^3/s. It is also assumed that the additional catchment area between Xe Kong 3B and Xe Kong 3A is large enough to ensure that the flushing discharge at the latter facility is 632 m^3/s.

Potential of cascade to pass sediment

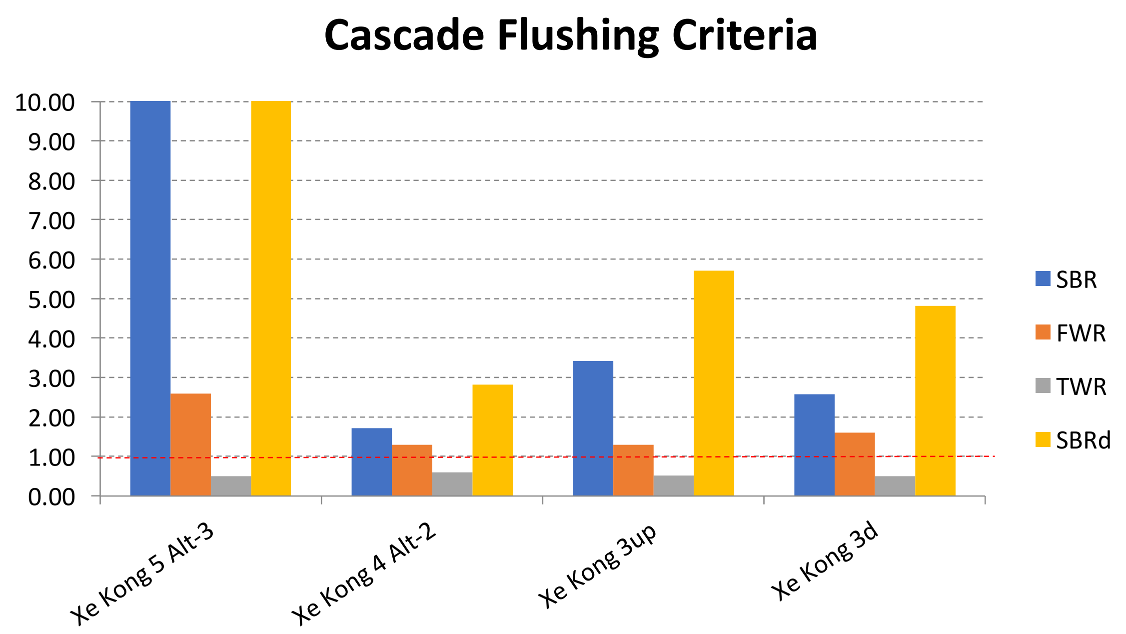
The effectiveness of flushing the cascade of dams has been determined by calculating the flushing criteria when using the flushing flows required for flushing the cascade. Figure 9.1-30 presents the analysis results, indicating that flushing through the cascade should be effective. The majority of criteria, except for TWR, are satisfied.

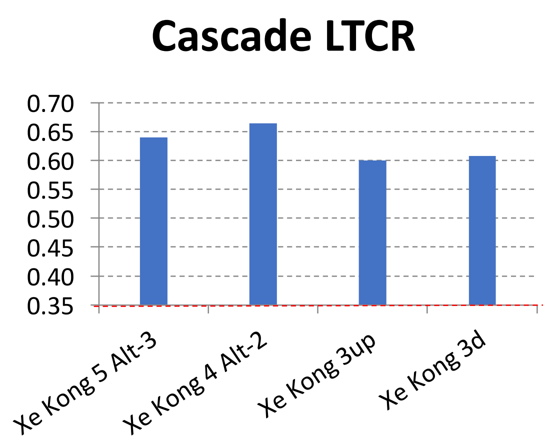
Sediment management combinations

The preferred approach to managing sediment in this cascade of dams is to implement sediment management technology at all dams. This means that it is desirable to incorporate adequately sized mid- and low-level outlets at all dams and to implement a sediment management strategy requiring concurrent drawdown flushing at all reservoirs on a regular basis; either annually or at least every two or three years.

Drawdown flushing effectiveness

The effectiveness of passing sediment to the downstream river increases when implementing sediment management at all dams along the cascade. Table 9.1-13 presents estimates of the reduction in sediment load in the river downstream of Xe Kong 3A when implementing various combinations of sediment management in the upstream reservoir. For example, if sediment is not passed through any of the reservoirs along the cascade, the reduction in the sediment load in the downstream river will be 80%. It means that only 20% of the original sediment load will be present in the river if the cascade of dams is built without any sediment management.





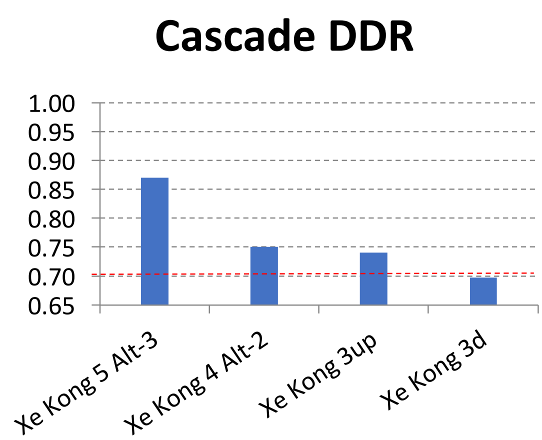


Figure 9.1-30. Comparison of Quantified Values of SBR, FWR, TWR, SBRd, LTCR, and DDR and Criteria for Flushing through the Cascade of Dams along the Xe Kong River. (Note: Xe Kong 3d is the same as Xe Kong 3A, and Xe Kong 3up is the same as Xe Kong 3B.)

Table 9.1-13. Reduction in sediment load for various sediment management combinations.

Management Alternative	Reduction in Sediment Load
No Passage	80%
Passage through 3B and 3A only	62%
Passage through 3B, 3A & 4	43%
Passage through all dams	28%

On the other hand, if sediment passage is successfully implemented at all four reservoirs by making use of drawdown flushing it is estimated that the reduction in the sediment load in the downstream river will only amount to about 28%. It means that the amount of sediment in the river will equal about 72% of the current sediment load when successfully implementing drawdown flushing in the cascade of dams. The selected projects to accomplish this goal are Xe Kong 5 Alternative-3, Xe Kong 4 Alternative-2, Xe Kong 3B, and Xe Kong 3A.

The estimated reduction in sediment load when implementing sediment management at Xe Kong 4 Alternative-2, Xe Kong 3B, and Xe Kong 3A is 43%. If sediment management is only implemented at Xe Kong 3B and Xe Kong 3A, the reduction is estimated at 62%. It is therefore concluded that concurrently implementing sediment management at all four dams along the cascade will significantly increase the sediment load in the downstream river.

Density current venting

In addition to the analysis results previously presented in this report, a rough estimate of venting efficiency was also made as a check calculation by using a relationship presented by Morris and Fan (1998). That empirical relationship between the reservoir length and venting efficiency is expressed as:

$$Eff = -0.122.\ln(L) + 0.6907$$

Where, "*Eff*" is the flushing efficiency and "*L*" is the reservoir length in km. Table 9.1-14 presents the sediment venting efficiency with respect to reservoir length for different cases.

It is noted that the average venting efficiency is approximately 30% for the most desirable projects, i.e., Xe Kong 5 Alternative-3, Xe Kong 4 Alternative-2, Xe Kong 3B, and Xe Kong 3A. Based on this information and the information previously presented in the report it may be concluded that it might be likely to pass about 30% of the incoming sediment loads associated with density currents, should they exist. Additional studies to determine the potential existence of density currents, based on measured sediment and water discharge data, are required to confirm this result. If it is found that density currents will likely occur, it will also be necessary to determine whether they could be passed through a cascade of dams. This might be a challenge because the upstream ends of reservoirs are generally very close to each of the dams. However, it is noted that installation of mid- and low-level outlets, adequately sized, will facilitate density current venting should they occur once the dams are constructed.

Sluicing

It is noted that sluicing effectiveness was not studied because general criteria for determining its success are not generally available. The potential to use sluicing as a sediment management techniques requires more detailed investigations. However, it is noted that installation of adequately sized mid- and low-level outlets will facilitate its implementation, as it will implementation of drawdown flushing and density current venting.

Table 9.1-14. Density Current Venting Efficiency using Empirical Relationship.

Reservoir	Length (km)	Efficiency (%)
Xe Kong 5	41	24
Xe Kong 4	92	14
Xe Kong 3B	15	36
Xe Kong 3A	21	32

Alternatives		
Xe Kong 5 Alt-1	32	27
Xe Kong 5 Alt-2	20	33
Xe Kong 5 Alt-3	18	34
Xe Kong 5 Alt-4	35	26
Xe Kong 4 Alt-1	71	17
Xe Kong 4 Alt-2	31	27
Xe Kong 4 Alt-3	47	22

Conclusions

Sediment management techniques to facilitate passage of sediment through the cascade of dams consisting of the Xe Kong 5, Xe Kong 4, Xe Kong 3B and Xe Kong 3A Dams were considered. The methods that were studied include sluicing, drawdown flushing and density current venting. Design criteria compatible with the pre-feasibility level of assessment performed during this study have been used to determine the relative level of success that can be accomplished when using these sediment management techniques.

Simple design criteria for establishing the relative success of implementing sluicing have not been established in the profession at this time. It was therefore not possible to determine its potential success as a sediment management technique during this pre-feasibility study. It means that the potential use of sluicing as a sediment management technique should be determined through more detailed studies during the feasibility and design stages of these projects.

Drawdown flushing was found to be potentially feasible for the proposed designs of all considered projects. By considering alternatives for Xe Kong 5 and Xe Kong 4 Dams, it was found that the effectiveness of flushing can be considerably increased. The preferred projects are the Xe Kong 5 Alternative-3 and Xe Kong 4 Alternative-2. These alternatives have reservoirs of lesser lengths and lesser volumes that currently proposed. This means that sediment removal would be more effective because drawdown will occur more rapidly, thereby reducing power production downtime.

It was found that the reduction in sediment load in the river downstream of the cascade may be reduced from 80% when sediment management is not implemented to only 28% should drawdown flushing be concurrently implemented at all dams along the cascade. The estimate, therefore, indicates that the sediment load in the downstream river will increase from 20% of what it currently is (with no sediment management) to about 72% of what it currently is (when concurrently implementing drawdown flushing along the entire cascade). To accomplish this improvement in the availability of sediment after construction of the cascade it is necessary to use Xe Kong 5 Alternative-3 and Xe Kong 4 Alternative-2 modified designs (or other designs that may be devised, which perform at those levels or better) and the currently proposed Xe Kong 3B and Xe Kong 3A designs.

The use of density current venting in addition to drawdown flushing may further increase the amount of sediment that is released downstream of the cascade. The preliminary estimates performed during this study indicate that it may be possible to release about 30% of the amount of sediment entering a reservoir during the occurrence of a density current. It is noted that the analysis conducted during this study did not have available sediment data (i.e., particle size distributions, sediment concentrations and sediment rating curves), which are required for defensible analysis. However, sensitivity analyses of the potential of density current formation presented in this report indicate the combinations of water discharge and sediment concentrations that may result in such occurrences. Once sediment data have been collected, it may be possible to predict the potential for density current formation with more confidence.

The preliminary estimates of density current efficiency indicate that it is approximately 30% for Xe Kong 5 Alternative-3, Xe Kong 4 Alternative-2, Xe Kong 3B, and Xe Kong 3A. This means that it might be possible to concurrently vent density currents through the cascade of dams, should they occur. However, this opinion requires further investigation during more detailed feasibility and design studies.

It is therefore concluded that the availability of sediment in the downstream river, after construction of the cascade of dams, may be considerably increased through implementation of reservoir sedimentation management technology. The analysis results indicate that the use of alternative dam designs combined with drawdown flushing may increase the availability of sediment in the river downstream of the cascade by about three times, i.e., it is expected to increase from 20% to about 72% of what it currently is. The provision of low- and mid-level outlets required for drawdown flushing may also provide additional sediment management benefits if it is found that density currents occur in the reservoirs. In such cases, the low-level outlets may be used to vent those density currents. Similarly, the availability of low- and mid-level outlets will also facilitate implementation of sluicing, should it be found during further studies to be a viable sediment passage technique. Importantly, it is emphasized that adequately sized low-level and mid-level outlets should be provided at all dams. Provision of such outlets will not only facilitate drawdown flushing, but will also make possible density current venting and sluicing should those management techniques be found to be viable.

Recommendations

Based on the findings of this study the following recommendations are made:

1. Consider implementing Xe Kong 5 Alternative-3 and Xe Kong 4 Alternative-2 design modifications proposed in this report. These alternative designs significantly improve the ability to pass sediment by means of drawdown flushing. The proposed alternative designs should be refined during the feasibility and design stages of the project.
2. Implement technology facilitating sediment management at all dams along the cascade, i.e., at Xe Kong 5 Alternative-3, Xe Kong 4 Alternative-2, Xe Kong 3B and Xe Kong 3A.
3. Install adequately sized low- and mid-level outlets in each of the dams. The outlets must be adequately sized to facilitate drawdown flushing, sluicing, and density current venting.
4. During the feasibility and design phases of the project, conduct studies to establish how the cascade will be operated to pass sediment. This means that each dam should not be independently designed, but that a comprehensive design incorporating all four dams should be performed. During such studies, it is

necessary to carefully study the management and movement of sediment through and downstream of the entire cascade of dams. The configuration of the cascade of dams indicates that it will be necessary to concurrently implement sediment management techniques at each of the dams. When implementing drawdown flushing and sluicing, it is necessary to commence opening gates at the most upstream dam. The gates at the other dams are then opened in succession, from upstream to downstream. Refinement and optimization of such an operating procedure is necessary as part of the feasibility studies and design of the cascade of dams. Operating procedures for density current venting in the cascade of dams should be established during the feasibility and design stages of the cascade of dams.

5. Collect field data at each dam site, including particle size distributions of suspended sediment and bed load, and concurrent measurements of suspended sediment concentrations and water discharge data. This information is required to develop sediment rating curves and to assess in more detail the characteristics of drawdown flushing, sluicing, and density current venting.

6. Perform additional, more detailed studies during the feasibility and design stages of the cascade of dams to:

   A. Refine the drawdown flushing design and the operating procedures

   B. Establish the viability of using sluicing to pass additional amounts of sediment and establish the required operating procedure.

   C. Determine whether density currents are likely to occur within the reservoirs upstream of the dams, thereby allowing implementation of density current venting as an additional sediment management technique to pass sediment downstream.

   D. Study and refine the operating procedures to successfully pass sediment through the cascade of dams when using drawdown flushing, sluicing, and density current venting.

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