XAYABURI HYDROELECTRIC POWER PROJECT

Fish Migration Facilities

Vientiane, 15 July 2015

Dr Tobias Coe

CONTENT OF PRESENTATION

- General issues at Xayaburi
- Data collection used to inform fish pass design
  - Fish biomass and sampling
  - Fish swimming ability tests
- Principles of upstream fish pass design
  - General Principles
  - Designs at other dams
- Design principles for Xayaburi
- Facilities for monitoring and proposed future monitoring

GENERAL ISSUES AT XAYABURI

Maximum water to water head loss across the dam is 29 m

Maximum turbine flow 5000 m^3/s. Eight turbine units

Dam has navigation lock, spillway, central intermediate block, powerhouse, fish pass

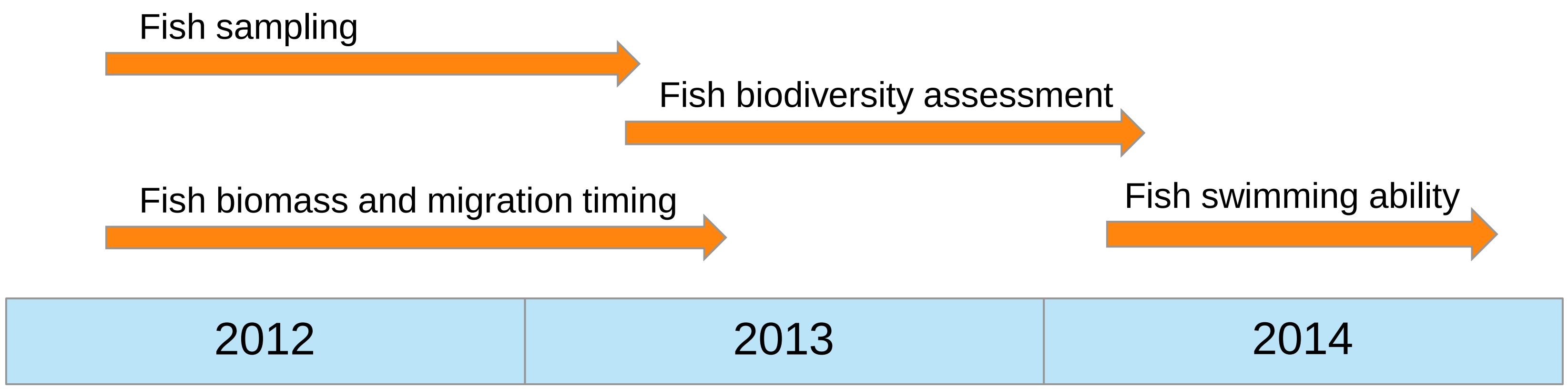
Large number of ‘artisanal’ fishermen

GENERAL ISSUES AT XAYABURI

- Fish population very diverse
  - Multiple species from many familes
  - Total species assemblage not necessarily known
  - Range of body forms
- Huge range in fish size (30 – 3000 mm)
- Downstream water levels highly variable
- Different migration seasons for different species
- WHAT ELSE?!

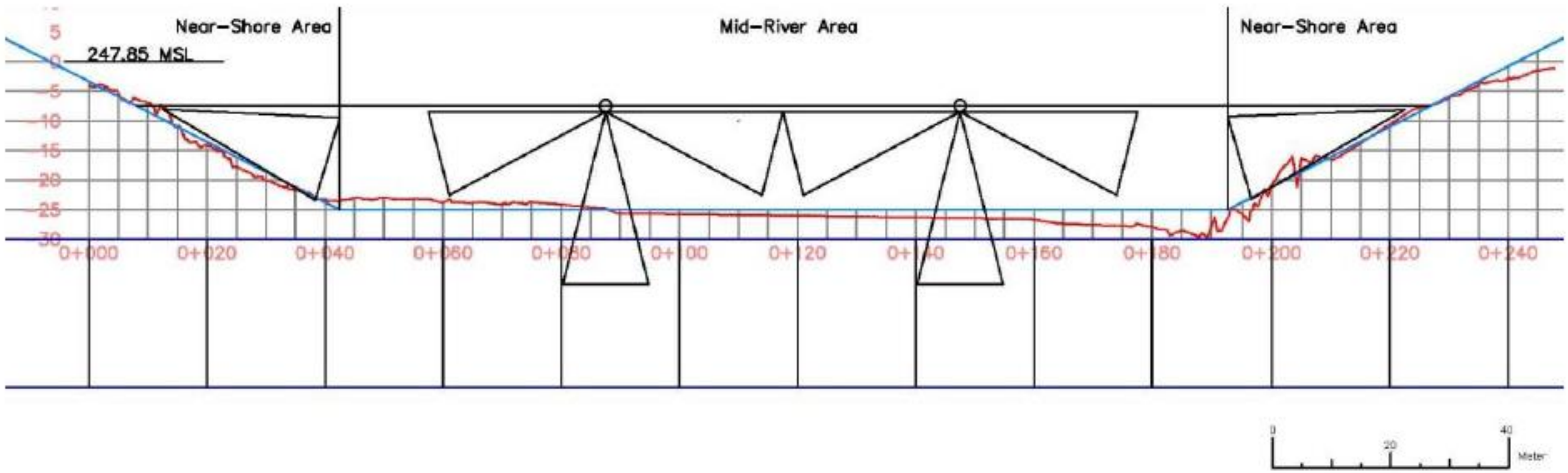
DATA COLLECTION USED TO INFORM FISH PASS DESIGN

- Fish biomass and migration timing
- Fish sampling
- Fish swimming ability



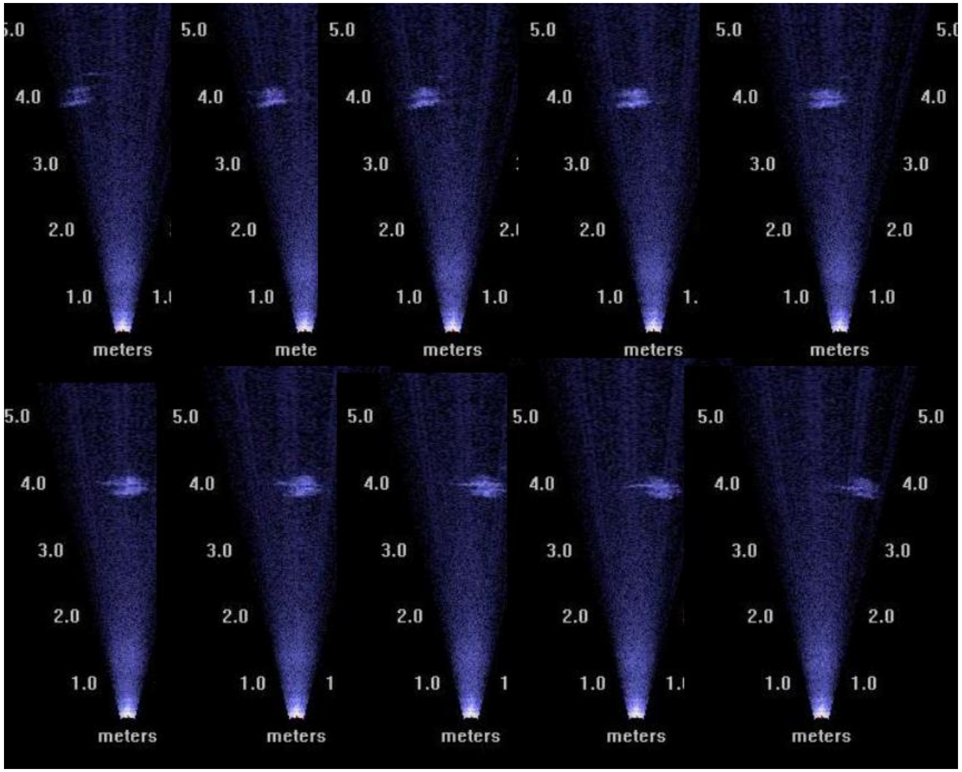
DATA COLLECTION – FISH BIOMASS AND MIGRATION

- Sonar acoustic ‘DIDSON’ camera used
- Ten field investigations
  - Spread over an entire year
  - Each field investigation 2 weeks



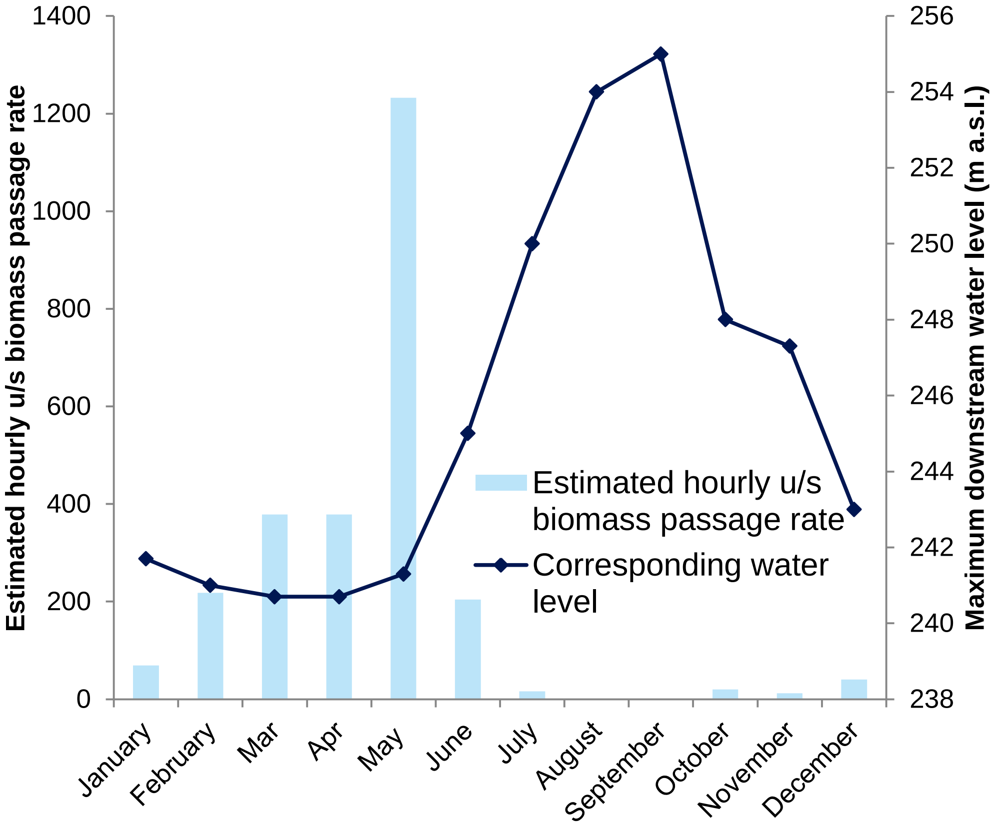
DATA COLLECTION – FISH BIOMASS AND MIGRATION

- Sonar acoustic ‘DIDSON’ camera used
- Ten field investigations
  - Spread over an entire year
  - Each field investigation 2 weeks
- Abundance and biomass quantified
- Primarily investigated upstream migration
- Conducted by Terraplant Ltd



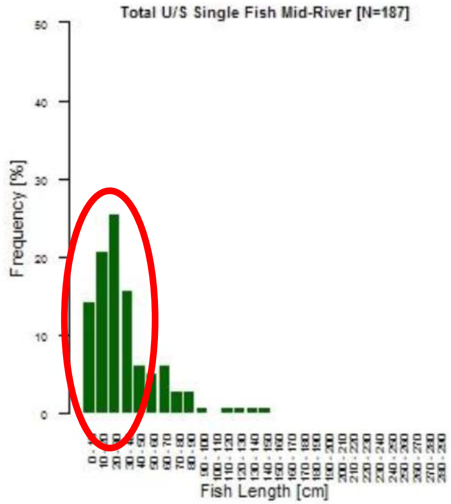
DATA COLLECTION – FISH BIOMASS AND MIGRATION

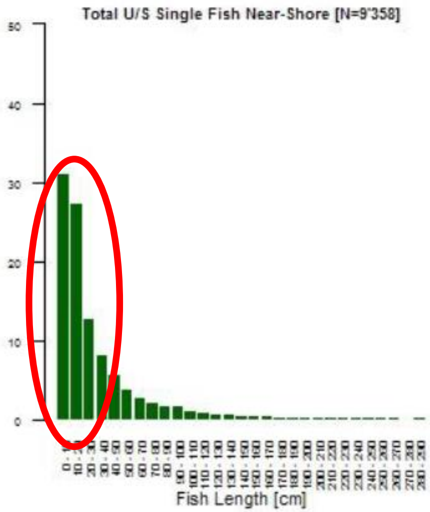
- Primary migration timings determined
- Biomass passage rates a maximum of 1,200 kg/hr in May. Peaked at 5,000 kg/hr in one survey
- Very large numbers and biomass of fish migrating



DATA COLLECTION – FISH BIOMASS AND MIGRATION

- Primary migration timings determined
- Biomass passage rates a maximum of 1,200 kg/hr in May. Peaked at 5,000 kg/hr in one survey
- Wide range of fish observed
- 71% in near shore and 60% in mid-river <30 cm





DATA COLLECTION – FISH SAMPLING

- Fish sampled using gill-netting. Also collected from local fishermen
- Conducted at same time as sonar camera work
- Species identified, measured and examined for maturation stage
- Carried out by TEAM Consulting

Henicorhynchus lobatus (female, stage 4)

Puntioplites falcifer (male, stage 2)

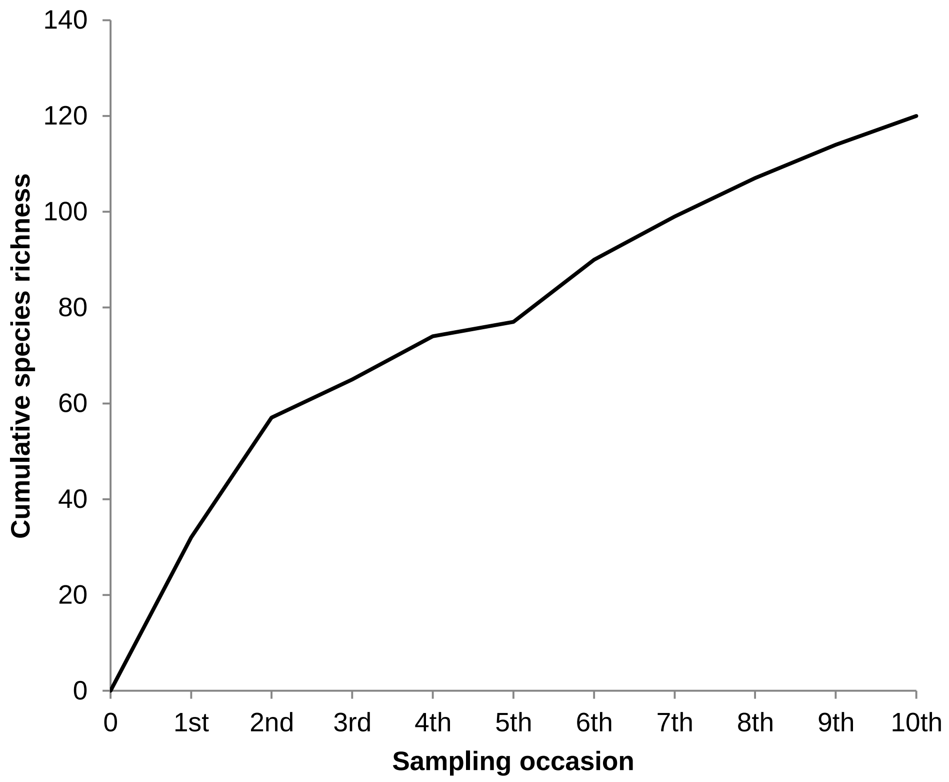
Belodontichthys truncatus (female, stage 2)

Hemisilurus mekongensis (female, stage 5)

DATA COLLECTION – FISH SAMPLING

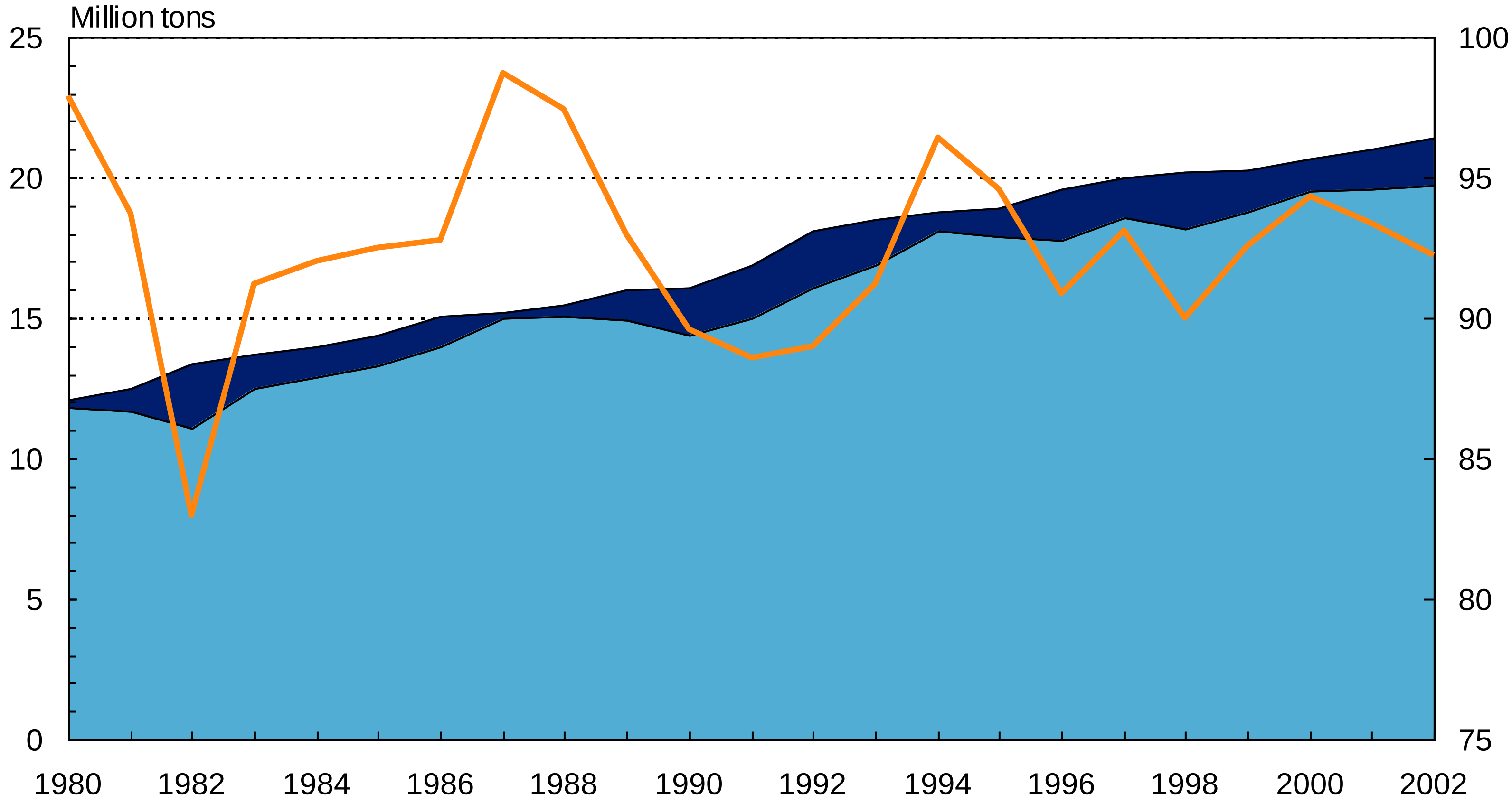
- Total of 120 species from 26 families found over the sampling period
- Highly likely more present
- Fish Biodiversity Assessment considered 308 species present

- Mekong is the third most species rich river system in the world
- Almost all species found at Xayaburi widely found throughout middle Mekong
- Many fish species highly migratory



COMBINED AREA LINE CHART

INSERT GRAPH OF SPECIES NUMBERS WITH PICS OF COMMON FISH



DATA COLLECTION – DESIGN GUIDANCE LIST

- Information from fish biomass and sampling used, as well as ‘Fish Biodiversity Assessment’
- IUCN RedList and Fish Base
- Focussed on species classified as vulnerable to hydropower development on the Mekong mainstream (Halls and Kshatriya 2009; ICEM 2010)
- 139 (45.1%) fish species were considered as Present at the Xayaburi HPP Site, 84 (27.3%) as Probably Present and 85 (27.6%) with Presence Questionable

- Design Guidance Species list identified
- 28 species belonging to 7 families

DATA COLLECTION – DESIGN GUIDANCE LIST

Family	Scientific Name	Design Guidance Category	Presence Xayaburi HPP	Origin Lao PDR	Red List Category
Target Species					
Clupeidae	*Tenualosa thibaudeaui*	A	Present	Native	VU
Cyprinidae	*Aaptosyax grypus*	A	Probably Present	Native	CR
	Bangana behri	A	Probably Present	Native	VU
	Hypsibarbus lagleri	A	Present	Native	VU
	Probarbus jullieni	A	Probably Present	Native	EN
Dasyatidae	*Dasyatis laosensis*	A	Present	Native	EN
Pangasiidae	*Pangasianodon gigas*	A	Probably Present	Native	CR
	Pangasianodon hypophthalmus	A	Present	Native	EN
	Pangasius krempfi	A	Probably Present	Native	VU
Lead Species					
Cobitidae	*Syncrossus helodes*	A	Present	Native	LC
	Yasuhikotakia modesta	A	Present	Native	LC
Cyprinidae	*Amblyrhynchichthys truncatus*	A	Present	Native	NE
	Cirrhinus molitorella	A	Present	Native	NT
	Cyclocheilichthys enoplos	A	Present	Native	LC
	Cyclocheilichthys furcatus	A	Present	Native	LC
	Henicorhynchus lobatus	A	Present	Native	LC
	Henicorhynchus siamensis	A	Present	Native	LC
	Hypsibarbus malcolmi	A	Present	Native	LC
	Hypsibarbus wetmorei	A	Present	Native	LC
	Mekongina erythrospila	A	Present	Native	NT
	Paralaubuca typus	A	Present	Native	LC
	Puntioplites proctozystron	A	Present	Native	LC
Gyrinocheilidae	*Gyrinocheilus pennocki*	A	Present	Native	LC
Pangasiidae	*Helicophagus waandersii*	A	Present	Native	NE
	Pangasius larnaudii	A	Present	Native	LC
	Pangasius macronema	A	Present	Native	LC
	Pseudolais pleurotaenia	A	Present	Native	LC
Schilbeidae	*Clupisoma sinense*	A	Present	Native	LC

DATA COLLECTION – FISHING SWIMMING ABILITY

An understanding of the swimming ability of fish species is critical for the effective design of a fish pass and is the first question that should be asked when designing a fish pass facility (Armstrong *et al.*, 2010).

Fish have different swimming ‘gaits’ and behaviours

Large background of studies into fish swimming

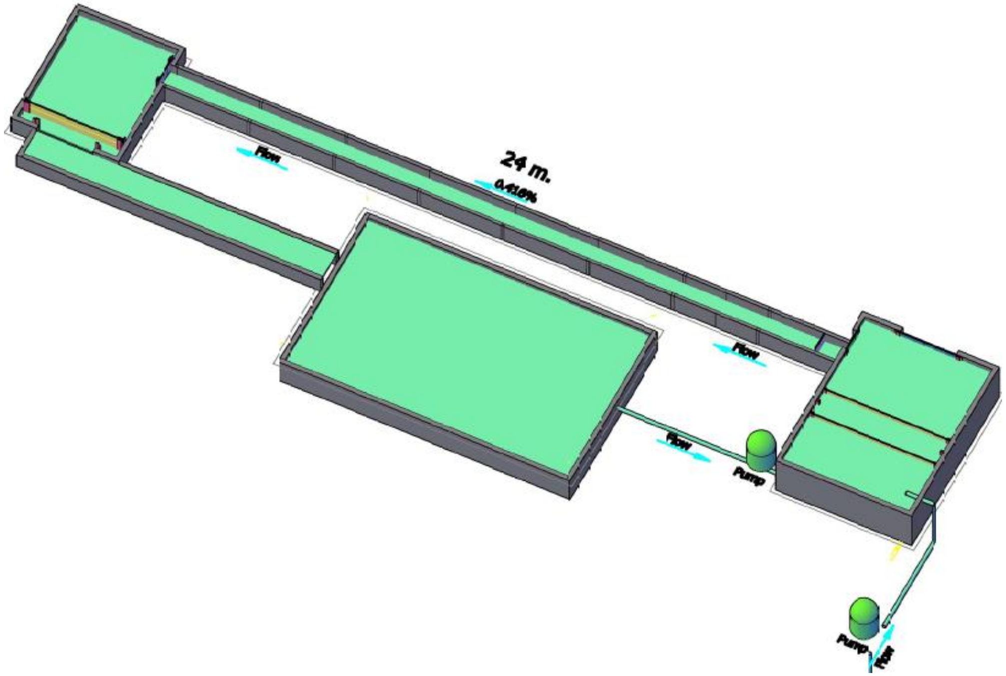
Literature consulted extensively. Collaborated with Prof. Paul Kemp

DATA COLLECTION - FISH SWIMMING ABILITY

- Little known about swimming ability of Mekong fish species
- Historically, tests have used small flumes with rectilinear flows
- For a given species, inter-individual differences in swimming ability exist → don't design for Usain Bolt!
- Environmental factors influence swimming ability / speed. Temperature, pH, dissolved oxygen

DATA COLLECTION – FISH SWIMMING ABILITY

- Large flume constructed on site
- Turbulent flow conditions
- Water pumped from river. Some recirculation, but most water through-flow
- Tanks at either end of flume with sluices – fine tune water levels and velocities



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- Water pumped from river. Some recirculation, but most water through-flow
- Tanks at either end of flume with sluices – fine tune water levels and velocities
- Flume design is based on work at the Conte lab by Alex Haro *et al*

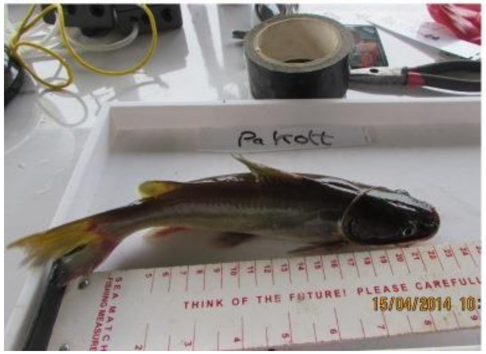
DATA COLLECTION – FISH SWIMMING ABILITY

- Fish captured using help from local fishermen
- Fish brought for testing daily
- Captured using range of techniques
- Three different tests performed
  - Burst swimming speed tests (5 species)
  - ‘Velocity barrier’
  - Ucrit tests

DATA COLLECTION – FISH SWIMMING ABILITY

- **Burst swimming speed**
- Wide range of velocities
- Five different species tested
  - Pa Sakang
  - Pa Soi
  - Pa Pak
  - Pa Kott
  - Pa Ort



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- **Burst swimming speed**
- Wide range of velocities
- Five different species tested
  - Pa Sakang
  - Pa Soi
  - Pa Pak
  - Pa Kott
  - Pa Ort
- Tested in section of flume (standard method)
- Introduced and swum until failure

DATA COLLECTION – FISH SWIMMING ABILITY

- **Velocity barrier**
- Three velocities tested (0.8, 1.2 and 1.6 m/s)
- >20 species tested
- Tagged externally using PIT tag

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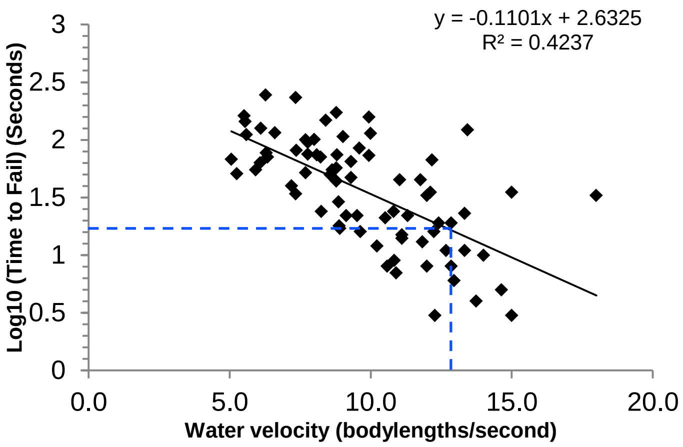
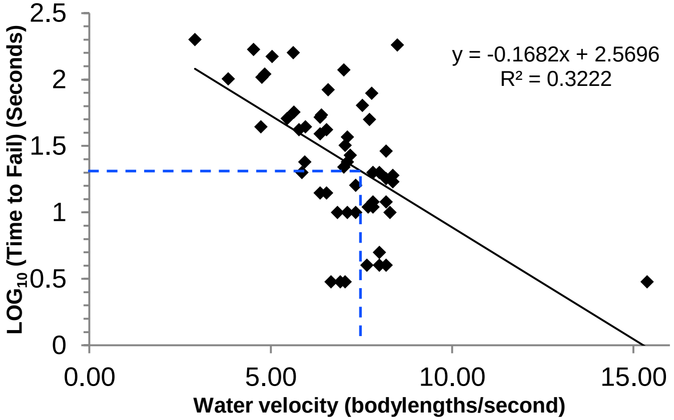
- **Velocity barrier**
- Three velocities tested (0.8, 1.2 and 1.6 m/s)
- >20 species test
- Tagged externally using PIT tag
- Fish introduced in groups into pen at downstream end
- Left for one hour and movements recorded

DATA COLLECTION – FISH SWIMMING ABILITY

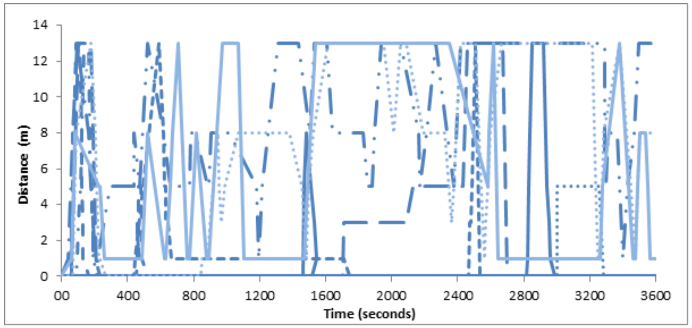
- **Burst swimming speed results**
- Swimming speeds high, between 8 – 20 bodylengths/second
- Graph the results, calculate where time to fail = 20 seconds = burst speed
- High proportion of fish didn't fail at the tested velocity
- Critically important parameter in fish pass design

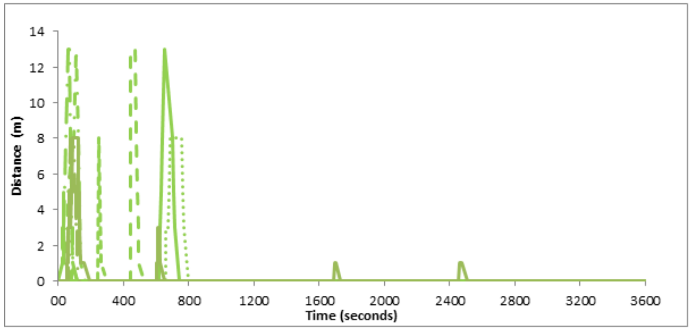


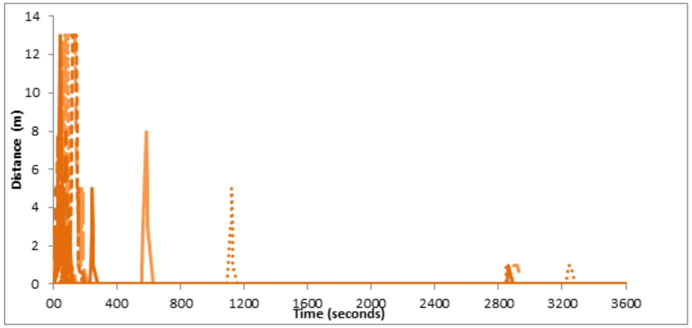


DATA COLLECTION – FISH SWIMMING ABILITY

- **Velocity barrier results**
- For most species, much more movement up and down flume at lower velocities
- Movements at 1.6 m/s were infrequent for most species
- For 70% of fish species test, water velocity significantly impacted maximum distance moved up flume
- However, some species (Pa Kott, Pa Khae) still moved at 1.6 m/s







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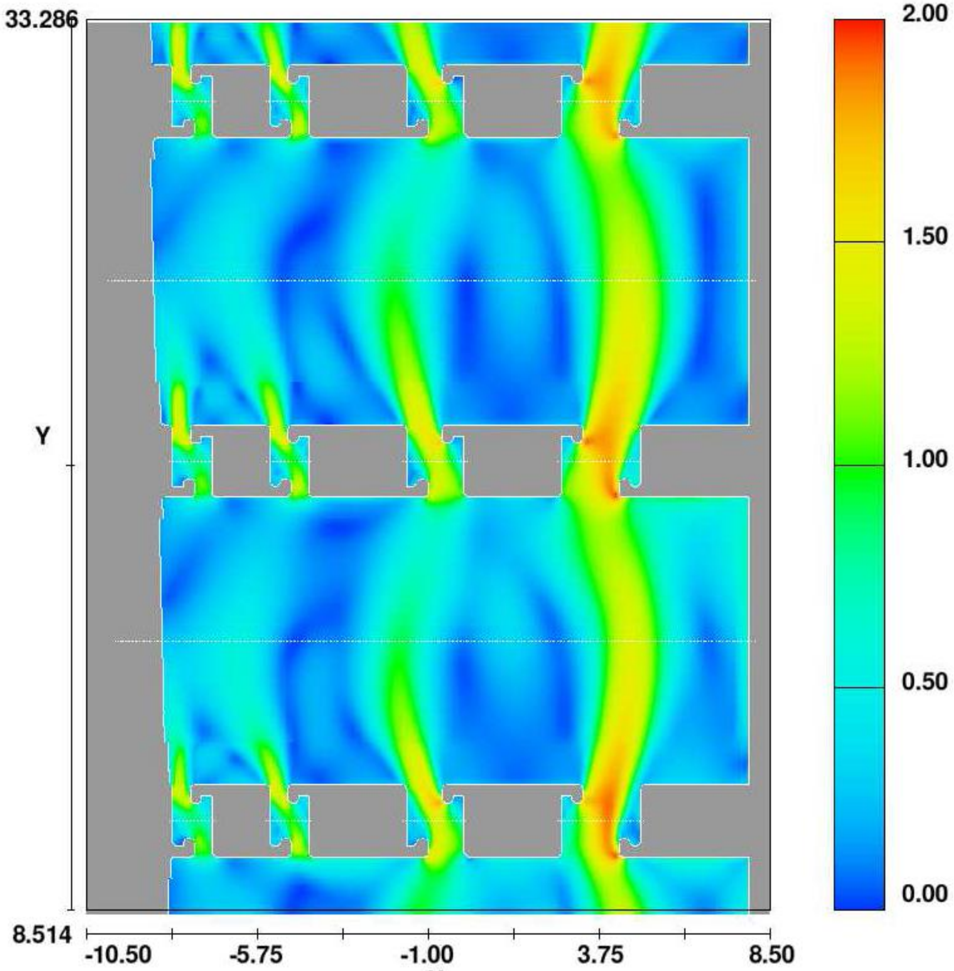
APPLICATION OF RESULTS TO DESIGN

- Swimming capabilities / preferences identified
- Range of velocities required in the fish passing facilities → heterogeneity
- Low velocities generally result in increased movement



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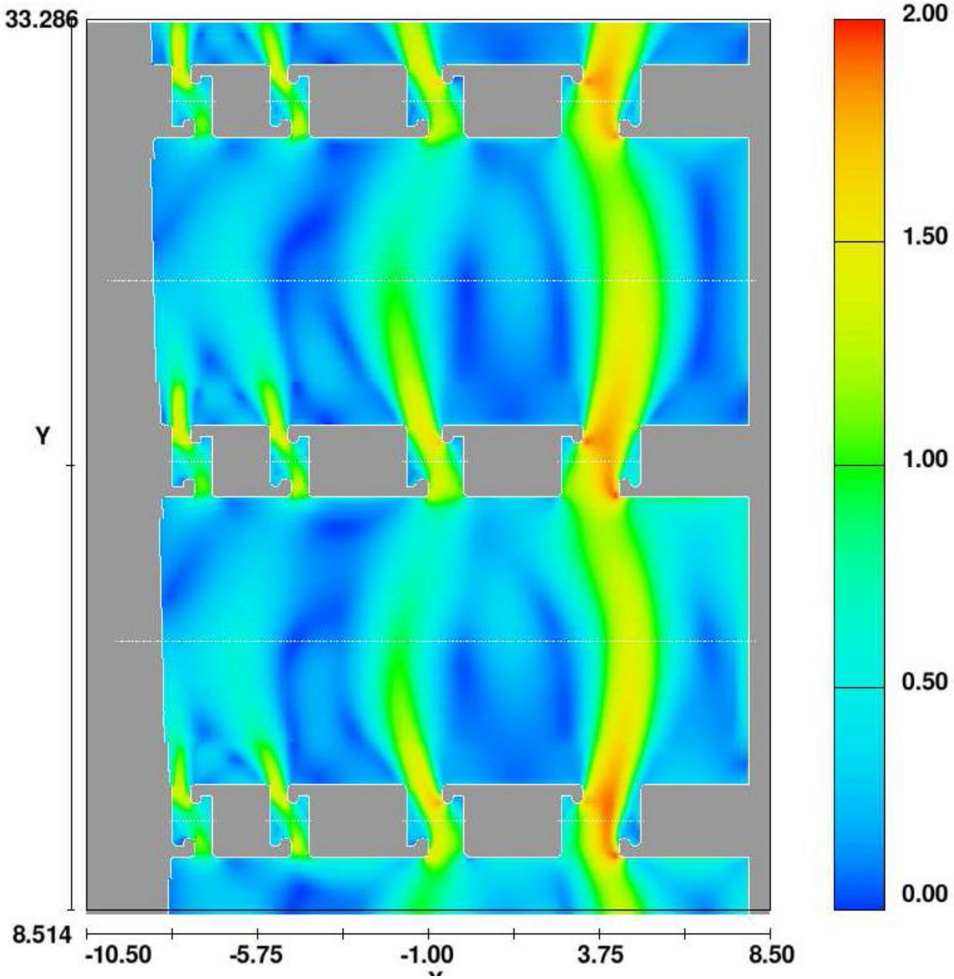
- Range of velocities required in the fish passing facilities → heterogeneity
- Low velocities generally result in increased movement
- Multiple slots reduces predation risk. Can be issue in tropical fish passes.



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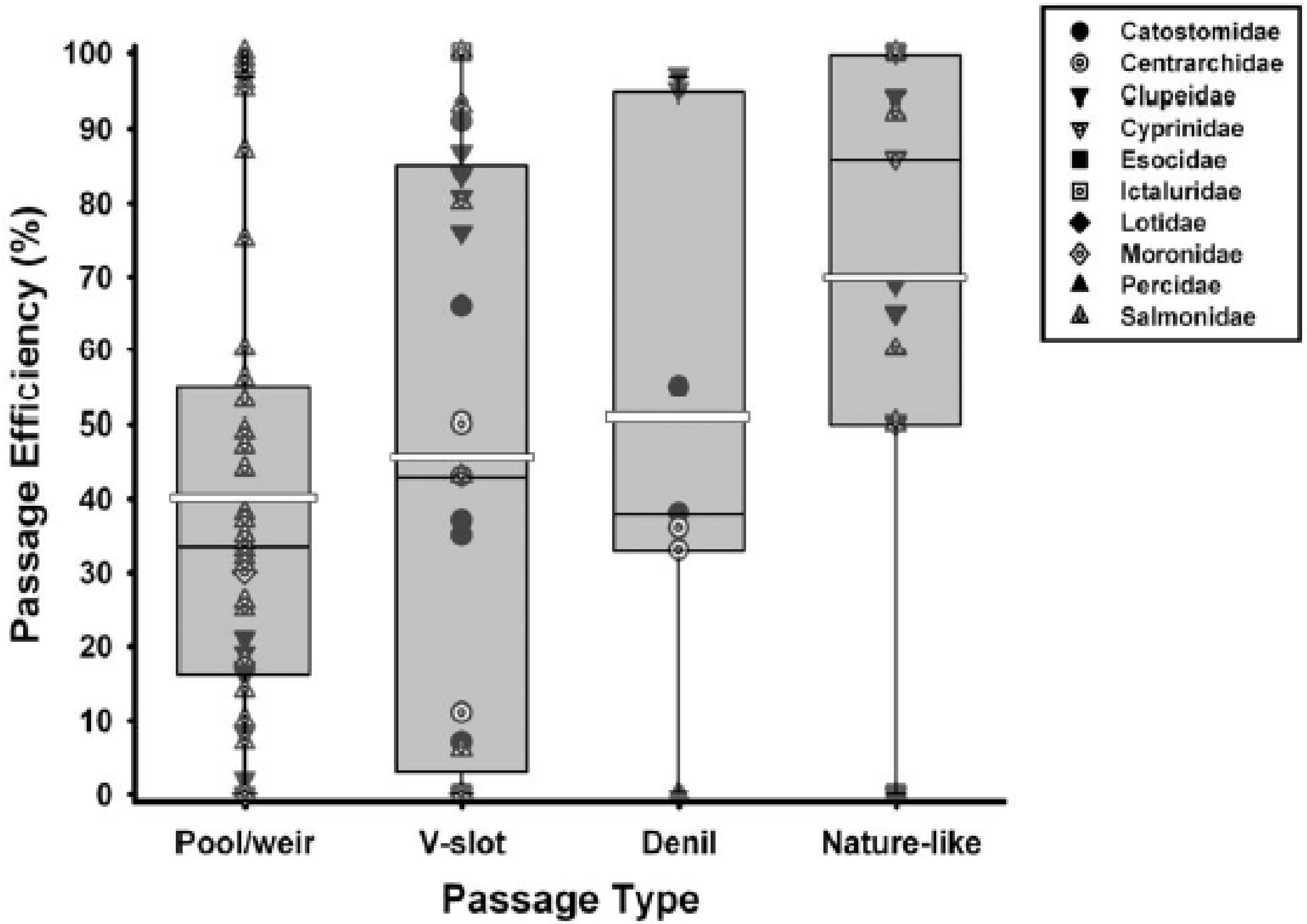


GENERAL PRINCIPLES FOR THE DESIGN

- Heterogeneous flow conditions in the pass. Uses vertical slot hydraulics
- Fish pass the whole height of the dam?
  - → Evidence is that this does not work in the tropics
  - → Sequential loss of fish during passage up long fish passes has been previously found (Agostinho *et al.*, 2007; Makrakis *et al.*, 2007; Wagner *et al.*, 2012)
- Shorter length of pass = larger pass, multiple slots, range of velocities
- Use man-power, rather than fish energy to move bulk of height of dam

GENERAL PRINCIPLES FOR THE DESIGN

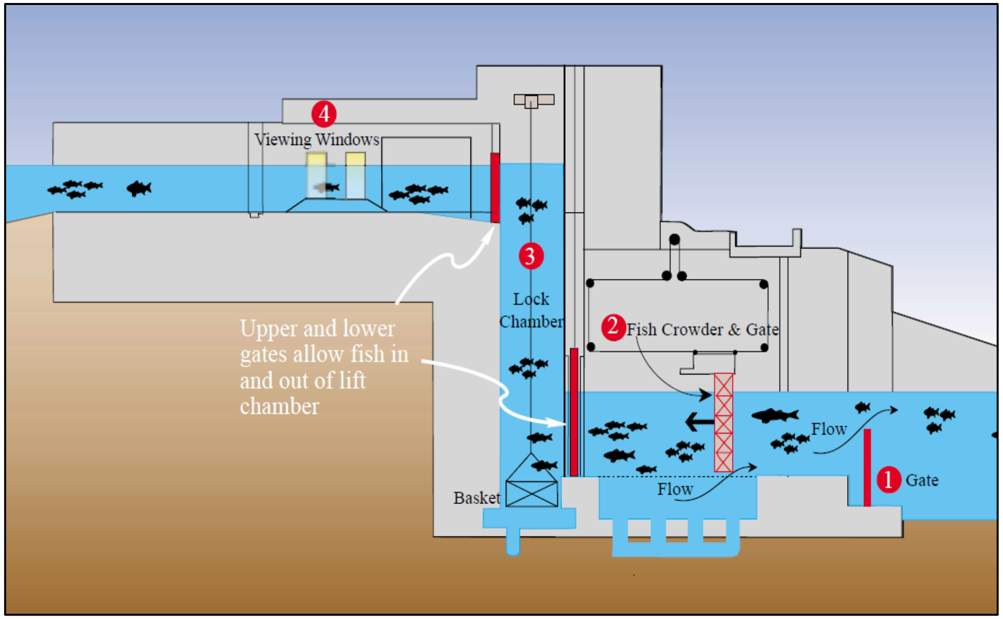
- **Fish pass section**
- Low slope (1%). Head drop 0.12 m between pools
- Velocity is low and variable between slots. Maximum is < 1.4 m/s in small slots

GENERAL PRINCIPLES FOR THE DESIGN

- **Fish pass section**
- Low slope (1%). Head drop 0.12 m between pools
- Velocity is low and variable between slots. Maximum is < 1.4 m/s in small slots
- Pools very large (18 m wide and 10 m long). Energy density < 45 W/m3. Very low

GENERAL PRINCIPLES FOR THE DESIGN

- **Fish locks**
- At upstream end of fish pass
- Double lock (redundancy, more efficient, no waiting)
- Technically, a combination between fish lift and fish lock



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- Double lock (redundancy, more efficient, no waiting)
- Technically, a combination between fish lift and fish lock
- Each fish lock 5 m x 5 m. Minimum depth ????

GENERAL PRINCIPLES FOR THE DESIGN

- Fish swim up fish pass, through ‘in-scales’ into lock
- Crowders close, move forward and move fish into lock

Crowder Video 1 here

GENERAL PRINCIPLES FOR THE DESIGN

- Fish swim up fish pass, through 'in-scales' into lock
- Crowders close, move forward and move fish into lock
- Lock floods and screen at bottom moves up lock, moving the fish up to upper level
- Gate opens and fish swim out at level of reservoir
- System is *flexible and adjustable*

Crowder Video 2 here

GENERAL PRINCIPLES FOR THE DESIGN - MONITORING

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THANK YOU!

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