Shan Gaing Fish Passage

Shang Gaing Fish Pass Design Report
Funding provided by Australian Centre for International Agricultural Research

John Conallin, Lee Baumgartner, Martin Mallen-Cooper, Tim Marsden, Aye Myint Swe, Zau Lunn, Nyi Nyi Tun, Maung Maung Moe Nyunt

Cataloguing in Publication provided by the Institute for Land, Water and Society (ILWS) Charles Sturt University, Albury, NSW, 2640.

To be cited as:
Conallin et al. (2020). Shan Gaing Sluice Fishway: proposed design criteria and concept. Charles Sturt University; 41p.

For further information contact:
Principal Contacts
Lee Baumgartner       John Conallin
Professor             Senior Research Fellow
Charles Sturt University       Charles Sturt University
Institute for Land Water and Society       Institute for Land Water and Society
lbaumgartner@csu.edu.au  jconallin@csuedu.au

Disclaimer: Information contained in this report has been formulated with all due care, CSU does not warrant or represent that the report is free from errors or omission, or that it is exhaustive. CSU disclaims, to the extent permitted by law, all warranties, representations or endorsements, express or implied, with regard to the report including but not limited to, all implied warranties of merchantability, fitness for a particular purpose, or non-infringement. CSU further does not warrant or accept any liability in relation to the quality, operability or accuracy of the report. The report is made available on the understanding that CSU and its employees and agents shall have no liability (including but not limited to liability by reason of negligence) to the users of the report for any loss, damage, cost or expense whether direct, indirect, consequential or special, incurred by, or arising by reason of, any person using or relying on the report and whether caused by reason of any error, omission or misrepresentation in the report or otherwise. Users of the report will be responsible for making their own assessment of the information contained within and should verify all relevant representations, statements and information. Furthermore, whilst the report is considered to be true and correct at the date of publication, changes in circumstances after the time of publication may impact upon the accuracy of the presented information.
Contents

1. Introduction .................................................................................................................. 3
2. Background on Fishway Design .................................................................................... 4
   2.1 Attraction ............................................................................................................ 4
   2.2 Passage ................................................................................................................ 5
3. Operation of Shan Gaing Sluice .................................................................................. 7
4. Biology and Hydrology ................................................................................................. 8
   4.2 Fish size .............................................................................................................. 11
   4.3 Migration and flow ............................................................................................. 12
   4.4 Migration and Water Levels ............................................................................. 13
5. Reverse Head ................................................................................................................. 19
6. Fish Passage Objectives ............................................................................................... 19
   6.1 Downstream ....................................................................................................... 19
   6.2 Upstream ............................................................................................................ 20
7. Fishway Design ........................................................................................................... 20
   7.1 Attraction (fishway entrance) ........................................................................... 20
   7.2 Passage - Fishway Options .............................................................................. 25
   7.3 Application of Preferred Fishway Design ...................................................... 28
8. Fishway Layout ........................................................................................................... 30
9. Potential Construction Techniques ............................................................................ 30
10. Operation of the Shan Gaing Sluice to optimise fish passage .................................. 36
11. Fish Monitoring ......................................................................................................... 36
12. Safety and Operations ............................................................................................... 37
13. Conclusion .................................................................................................................. 37
14. References .................................................................................................................. 38
15. Appendices ................................................................................................................ 39
1. Executive Summary

**Background**
- In Myanmar freshwater fish are a major source of food security and livelihoods.
- Most fish in Myanmar migrate upstream and downstream to complete life cycles.
- Sluice gates and dams block or restrict migrations so that fish cannot complete life cycles and fish/shrimp populations decline.

**Fishways - restoring fish migration**
- Fishways are a passage of water – usually a low-gradient channel – around a sluice gate, that migratory fish can easily migrate upstream and downstream.

**First Fishway for Myanmar**
- A Fish Passage Masterclass was held at Bago with Charles Sturt University, Australia, and MOALI. The Masterclass provide an overview of all aspects of designing fishways, and identified Shan Gaing Sluice as the most suitable site for the first fishway in Myanmar.

**Development of Fishway Concept Design**
- Engineers, biologists, river operators and fishers have worked together to produce a concept design that will: pass fish, be cost-effective, and be easy to operate and maintain.
- There are 2 key aspects to fishway design: i) attracting fish into the fishway and ii) passing fish through the fishway. The first requires a high discharge relative to the river and an entrance that is easy for fish to locate. The second aspect requires understanding the water depths, velocities and turbulence that suits the migrating fish at the site.
- To achieve these design objectives background data is needed on:
  - Hydrology and water levels upstream and downstream
  - Biology (e.g. fish size) and migration season
- Several fishway designs were assessed and the **dual vertical slot fishway design** was considered the most suitable for Shan Gaing Sluice because it has highly variable upstream and downstream water levels.
- The fishway would be a 6 m wide, 5 m deep, 70m long channel divided into 11 pools by baffles. It would likely be constructed as a sheet pile channel with pre-cast baffle units (Figure A).

**Next Steps**
- CSU and MOALI have developed a fishway concept design.
- The next steps are:
  1. Further engineering work by MOALI to examine materials, structure and construction options.
  2. Final concept
  3. Review of engineering specifications by a hydraulic engineer
  4. Detailed design
  5. Review of final drawings by an irrigation engineer
  6. Tender and construction
- An operations manual needs to be developed with the design.
- On completion of the fishway a workshop with operators is needed to so that all staff are familiar with the fishway.
- Finally there needs to be monitoring of the fishway to evaluate that is it passing fish and to provide recommendations for any improvements.
1. Introduction

A design of a fishway for Shan Gaing Sluice is an outcome of the collaborative project “Quantifying biophysical and community impacts of improved fish passage in Lao PDR and Myanmar”, between the Myanmar Ministry of Agriculture, Livestock and Irrigation (MOALI) and the Australian Centre for International Agricultural Research (ACIAR). The main implementing partners on the project in Myanmar are Myanmar Irrigation and Water Utilisation Management Department, the Myanmar Department of Fisheries, and Fauna and Flora International in collaboration with Charles Sturt University, Australia.

The Shan Gaing Sluice has been selected by the partners as the site where a demonstration fishway will be built, after an extensive consultation and field-based appraisal of all significant barriers within the Bago catchment. All authors have been on site at the Shan Gaing sluice and assessed the sluice as part of the design process.

The opinions in this report are a collective view based on experience in numerous countries and particularly in the Mekong Basin, including experimental research on fishways in Laos PDR (Baumgartner et al. 2012; Baumgartner et al. 2018).

The present report is the second draft. The first draft report was issued in December 2019. Feedback on various sections of that draft has refined the text and design criteria, which are now more targeted at specific water levels while the length and width of the proposed fishway has been reduced to simplify constructability. Following comments on this draft, the report will be finalised.

2. Background on Fishway Design

As background to the project we summarise two fundamental components to fishway design:

i) Attraction: which concerns attracting fish to the fishway entrance, and

ii) Passage: which concerns passing fish through the fishway.

2.1 Attraction

Attraction involves: fishway discharge, entrance location and design. Providing sufficient discharge (flow) in the fishway to attract fish is a primary design consideration, and a starting point for fishway design. Using more than 10% of river flow in the fishway is a common target in design. At very low flows often all flow can pass through a fishway, while in high flows in the rainy season it would likely be less than 10%.

The entrance location needs to be designed so that fish can locate it easily and this involves two key design principles:

i) locating the entrance at the upstream limit of migration, and

ii) ensuring that the fishway flow is easily detectable by fish and not masked by turbulence and crossflows.

Achieving these conditions involves design and operation of the whole structure or sluice gate. If the structure is a new design, most aspects of the structure need to be
considered (e.g. abutment, gates, stilling basin, dissipators) to meet these two criteria. For both new and existing structures, operation of sluice gates is important to provide attraction. The objective in design and operation is to provide flow patterns that guide fish to the fishway entrance, under the different streamflow conditions that fish are migrating.

2.2 Passage

Passage involves all aspects or fish passing through the fishway channel itself. It is essential to know, or provide the best estimate, of:

1) the minimum and maximum size of fish that are migrating.
2) season and flows when fish are migrating.
3) the water levels at the structure, to link with 1) and 2).

To develop these three aspects into fishway design criteria, a conceptual model of fish migration and flows for the site is used and was developed during a Masterclass held in Bago in 2019. This is a simple explanation (text, table or diagram) of what fish are migrating (species and sizes) at what flows. Often data is incomplete, so the model represents the best understanding of fish migration and is likely to include opinions of professionals and fishers, as well as scientific data. A simple conceptual model of migration, fish size, abundance, season and flow is shown in Figure 1; this example was developed in the Masterclass.

The conceptual model of flows and fish migration determines: the flow patterns downstream of the structure to examine for entrance location and design (e.g. low flows and low turbulence, or high flows and high turbulence); and the optimum upstream and downstream water levels for the fishway.

Knowing the size of fish, and the flows at which they are migrating, determines the hydraulics of the fishway channel (e.g. smaller fish have lesser swimming ability and larger fish require greater depth).
Figure 1. Example of a simple conceptual model for a fish passage project showing migration, fish size, abundance, season and flow.
3. Operation of Shan Gaing Sluice

Understanding the operation of a structure is fundamental to fishway design. The Shan Gaing Sluice was built to prevent saltwater intrusion upstream into the rice paddy fields, as well as provide storage of freshwater for dry season irrigation. A significant management issue is sediment accumulating downstream of the sluice in the dry season. When downstream water levels are higher than upstream water levels the sluice is closed to prevent saltwater intrusion and sediment moving upstream. The sluice is completely closed in dry conditions when there is very little flow.

Over a year, the sluice is generally closed in March and April; partially open from December through to February; and totally open during the wet season from May through to November (Figure 2). This overlaps with the fish migration season of April to November (Figure 2). These operations affect fish migrating up to the sluice and through the fishway, so the operations plan for the sluice will have to be updated to incorporate operating the fishway for maximum efficiency, whilst still maintaining the functioning of the sluice.

Siltation below the sluice is a major challenge from January to May when, to open the sluice, machinery is used to remove the silt and start the flow of water out of the sluice. This will also be an important consideration in the design and the operation of the fishway. To aid in operation, sluice operators should be trained on operating the fishway for maximum efficiency and a small operation manual in Myanmar language would help as operators will most likely change. This will need to be updated as more is learned after wet commissioning. The fishway should be left open for as long as possible and should never be left partially open; that is, it should be either fully open or fully closed. At the start of the wet season the first water should be released down the fishway and entering the main tributary channel to the Sittaung before opening other gates. As gates are sequentially closed as the dry season approaches, the fishway should remain fully open and gates closed in a sequence to maintain attraction flow to the fishway. This can be done by closing gates at the opposite bank to the fishway first, and gate by gate toward the fishway.

Operation of the sluice is critical to enable the fishway to function.

<table>
<thead>
<tr>
<th>Fish Migration</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gates Totally Open*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gates Partially Open*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gates Closed*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siltation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The opening and closing of the gates at the sluice is seasonally dependent upon the wet season and water demand

Figure 2. A calendar showing fish migration patterns in relation to the operations of Shan Gaing Sluice. Siltation and reverse head are a major challenge and need to be considered within the fishway design. The calendar was developed in the Fish Passage Design Workshop at Bago in July 2019.
4. **Biology and Hydrology**

4.1 **Fish Community**

The Shan Gaing Sluice is located on the Abyar-Shangaing tributary, a tributary of the Sittaung River which discharges into the Gulf of Mottama (Figure 3). The river has several migratory fish species of varying economic, livelihood and conservation importance. The Abyar-Shangaing tributary enters the Sittaung River approximately 50 kms upstream of the mouth of the Sittaung, and the hydrology of the system is influenced by upstream monsoonal weather patterns and downstream tidal movement from the Sittaung. An estimated 44 freshwater native freshwater fish species and one freshwater shrimp species (*Macrobrachium* sp.) have been recorded from the Abyar-Shangaing tributary prior to the placement of the Shan Gaing Sluice. The Shan Gaing Sluice is situated approximately 5 kms upstream of the confluence of the Abyar-Shangaing tributary and Sittaung River. After the installation of the sluice the number of species has reduced from approximately 44 species to approximately 36 species since the sluice was built (Table 1, data provided by DOF/FFI 2019; Appendix A). As fish cannot pass easily through the sluice it is likely some fish that originally migrated up the Abyar-Shangaing tributary no longer do, and remain in the Sittaung and move into other systems.

Interviews with fisherman and Department of Fisheries leasable fisheries data suggest overall fish production was high before the placement of the sluice, and that post sluice an overall reduction in production has occurred. Species that appear to be most negatively impacted by the sluice are species: i) moving from the sea to the freshwater to spawn (anadromous) such as Hilsa-Ngathalauk (*Tenualosa* spp.) and Pangas catfish-Ngadan (*Pangasius* spp.); and ii) species moving from freshwater to the estuary/sea to spawn (catadromous) such as Barramundi-Kakadit (*Lates calcarifer*) and Giant Freshwater Prawn-Yaychopuzunhtokegyi (*Macrobrachium rosenbergii*) (Table 1).

Hilsa, Pangas catfish and Barramundi adults and juveniles were originally caught in the upstream reaches of the Abyar tributary, but this has not occurred since the sluice was built. Giant Freshwater Prawn (*M. rosenbergii*) are still caught upstream but reported to be declining in catch rates each year. Fishers report catches of several sizes of *Tenualosa* sp., *Pangasius* sp., *Lates calcarifer*, *Cirrhinus* sp., *Gibelion* sp., *Morulius* sp., *Rohita* sp., *Hemibagrus* sp., *Sperata* sp., etc. aggregating below the sluice early in the wet season as water levels start to rise, and water begins to be released from the sluice. However, these aggregating fish don’t appear in fish catches upstream so are unlikely to pass even when sluice is fully open (May-November) during the wet season. However, *Tenualosa* sp., *Pangasius* sp., and *Lates calcarifer* juveniles can be sometimes caught upstream, so some fish may be able to pass through the sluice at certain times – probably during unintended reverse flow - although passage would be very limited. There is also a strong presence of smallbodied freshwater species upstream such as *Puntius sophore* (Barbs), *Esomus* spp; (flying barbs), *Trichogaster* spp: (Gourami), *Mystus* spp: (Catfish), *Channa* spp; (Snake head), *Wallago attu* (Boal) (Table 1).
Figure 3. The Shan Gaing Sluice located on the Abyar tributary, a tributary of the Sittaung River which discharges into the Gulf of Mottama.

Table 1. Fish species in the Abyar-Shangaing tributary and their expected minimum and maximum size migrating (Data provided by DOF/FFI 2019).

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Local name</th>
<th>Before Sluice</th>
<th>After Sluice</th>
<th>Average Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Notopteridae</td>
<td>Notopterus</td>
<td>n. notopterus</td>
<td>Nga Lar</td>
<td>*</td>
<td>*</td>
<td>100-360</td>
</tr>
<tr>
<td>2</td>
<td>Ophichthidae</td>
<td>Pisodonophis</td>
<td>boro</td>
<td>Nga Thanione</td>
<td>*</td>
<td>*</td>
<td>NI-NI</td>
</tr>
<tr>
<td>3</td>
<td>Clupeidae</td>
<td>Corica</td>
<td>soborna</td>
<td></td>
<td>*</td>
<td>*</td>
<td>20-40</td>
</tr>
<tr>
<td>4</td>
<td>Tenualosa</td>
<td>ilisha</td>
<td>Nga Tha Lauk</td>
<td></td>
<td>*</td>
<td>R</td>
<td>NI-NI</td>
</tr>
<tr>
<td>5</td>
<td>Cyprinidae</td>
<td>Amblyphysogodon</td>
<td>mola</td>
<td>Nga Bal Phyu</td>
<td>*</td>
<td>*</td>
<td>40-110</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>danica</td>
<td>Nga Daung Shay</td>
<td>*</td>
<td>*</td>
<td>40-140</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>cirrhousus</td>
<td>Nga Kyin Pyu</td>
<td>*</td>
<td>No</td>
<td>NI-400</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>catla</td>
<td>Nga Thaing Gaung Pwa</td>
<td>*</td>
<td>No</td>
<td>NI-NI</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>calbasu</td>
<td>Nga Net Pyar</td>
<td>*</td>
<td>No</td>
<td>160-230</td>
</tr>
<tr>
<td>10</td>
<td>Osteobrama</td>
<td>belangeri</td>
<td>Nga Phan Ma</td>
<td></td>
<td>*</td>
<td>*</td>
<td>50-285</td>
</tr>
<tr>
<td>11</td>
<td>Puntius</td>
<td>sophore</td>
<td>Nga Khone Ma</td>
<td></td>
<td>*</td>
<td>*</td>
<td>35-90</td>
</tr>
<tr>
<td>Sr.</td>
<td>Family</td>
<td>Genus</td>
<td>Species</td>
<td>Local name</td>
<td>Before Sluice</td>
<td>After Sluice</td>
<td>Average Range (mm)</td>
</tr>
<tr>
<td>-----</td>
<td>------------</td>
<td>---------</td>
<td>---------</td>
<td>------------</td>
<td>---------------</td>
<td>--------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>12</td>
<td>Rasbora</td>
<td>daniconius</td>
<td>Nga Khone Ma</td>
<td>*</td>
<td>*</td>
<td>50 95</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Rohita</td>
<td>rohita</td>
<td>Nga Myit Chin</td>
<td>*</td>
<td>*</td>
<td>NI 450</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Cobitidae</td>
<td>Lepidocephali-chthys</td>
<td>berdmorei</td>
<td>Nga Tha Lae Htoe</td>
<td>*</td>
<td>*</td>
<td>50 70</td>
</tr>
<tr>
<td>15</td>
<td>Bagridae</td>
<td>Hemibagrus</td>
<td>microphthalmus</td>
<td>Nga Elke</td>
<td>*</td>
<td>*</td>
<td>120 380</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td>peguensis</td>
<td>Nga Elke</td>
<td>*</td>
<td>*</td>
<td>NI NI</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td>spiopterus</td>
<td>Nga Elke</td>
<td>*</td>
<td>*</td>
<td>23 29</td>
</tr>
<tr>
<td>18</td>
<td>Mystus</td>
<td>falcarius</td>
<td>Nga Ye Cho</td>
<td>*</td>
<td>*</td>
<td>115 185</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>pulcher</td>
<td>Nga Zin Yine Kywe</td>
<td>*</td>
<td>*</td>
<td>70 72.3</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>gulo</td>
<td>Nga Zin Yine Kywe</td>
<td>*</td>
<td>*</td>
<td>45 170</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>vittatus</td>
<td>Nga Zin Yine</td>
<td>*</td>
<td>*</td>
<td>30 170</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Sperata</td>
<td>acicularis</td>
<td>Nga Gyaung</td>
<td>*</td>
<td>No</td>
<td>NI NI</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Siluridae</td>
<td>Ompok</td>
<td>bimaculatus</td>
<td>Nga Nu Than</td>
<td>*</td>
<td>*</td>
<td>90 250</td>
</tr>
<tr>
<td>24</td>
<td>Wallago</td>
<td>attu</td>
<td>Nga Batt</td>
<td>*</td>
<td>*</td>
<td>270 1000</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Pangasiidae</td>
<td>Pangasius</td>
<td>pangasius</td>
<td>Nga Dan</td>
<td>*</td>
<td>R</td>
<td>270 920</td>
</tr>
<tr>
<td>26</td>
<td>Sisoridae</td>
<td>Bagarius</td>
<td>bagarius</td>
<td></td>
<td></td>
<td>250 270</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>Gagata</td>
<td>sp.</td>
<td>*</td>
<td>*</td>
<td>NI NI</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Claridae</td>
<td>Clarias</td>
<td>batrachus</td>
<td>Nga Khu</td>
<td>*</td>
<td>*</td>
<td>160 250</td>
</tr>
<tr>
<td>29</td>
<td>Heteropneustidae</td>
<td>Heteropneustes</td>
<td>fossils</td>
<td>Nga Kyee</td>
<td>*</td>
<td>*</td>
<td>120 200</td>
</tr>
<tr>
<td>30</td>
<td>Schilbeidae</td>
<td>Pachypterus</td>
<td>acutirostris</td>
<td>Nga Than Gyalik</td>
<td>*</td>
<td>*</td>
<td>37 110</td>
</tr>
<tr>
<td>31</td>
<td>Mugilidae</td>
<td>Sicanugil</td>
<td>hamiltonii</td>
<td>Ka Bi Lu</td>
<td>*</td>
<td>*</td>
<td>61 113</td>
</tr>
<tr>
<td>32</td>
<td>Belonidae</td>
<td>Xenentodon</td>
<td>cancila</td>
<td>Nga Pyaung Yoe</td>
<td>*</td>
<td>*</td>
<td>110 295</td>
</tr>
<tr>
<td>33</td>
<td>Mastacembelidae</td>
<td>Macrognathus</td>
<td>zebrinus</td>
<td>Nga Maw Htoe</td>
<td>*</td>
<td>*</td>
<td>70 270</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>Macrognthus</td>
<td>sp.</td>
<td>Nga Maw Htoe</td>
<td>*</td>
<td>*</td>
<td>NI NI</td>
</tr>
<tr>
<td>35</td>
<td>Ambassidae</td>
<td>Parambasis</td>
<td>ranga</td>
<td>Nga Zin Zat</td>
<td>*</td>
<td>*</td>
<td>20 95</td>
</tr>
<tr>
<td>36</td>
<td>Latidae</td>
<td>Lates</td>
<td>calcarifer</td>
<td>Ka Ka Dit</td>
<td>*</td>
<td>R</td>
<td>400 510</td>
</tr>
<tr>
<td>37</td>
<td>Polynemidae</td>
<td>Eleutheronema</td>
<td>tetradactylum</td>
<td>Kakuyan/Nga Kyaung Tpyae</td>
<td>*</td>
<td>*</td>
<td>NI 133</td>
</tr>
<tr>
<td>38</td>
<td>Gobiidae</td>
<td>Glossogobius</td>
<td>giuris</td>
<td>Ka Tha Boe</td>
<td>*</td>
<td>*</td>
<td>45 250</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td>Parapycrites</td>
<td>sp.</td>
<td>Nga Pyan Phyu</td>
<td>*</td>
<td>*</td>
<td>NI NI</td>
</tr>
<tr>
<td>40</td>
<td>Amblyopidae</td>
<td>Odontamblyopus</td>
<td>rubicundus</td>
<td>Nga Pyan Ni</td>
<td>*</td>
<td>*</td>
<td>75 125</td>
</tr>
<tr>
<td>41</td>
<td>Badidae</td>
<td>Badis</td>
<td>sp.</td>
<td>*</td>
<td>*</td>
<td>22 38</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Anabantidae</td>
<td>Anabas</td>
<td>festudineus</td>
<td>Nga Pyay Ma</td>
<td>*</td>
<td>*</td>
<td>85 140</td>
</tr>
<tr>
<td>43</td>
<td>Osphronemidae</td>
<td>Trichogaster</td>
<td>labiosa</td>
<td>Nga Phin Than Latt</td>
<td>*</td>
<td>*</td>
<td>20 150</td>
</tr>
<tr>
<td>44</td>
<td>Channidae</td>
<td>Channa</td>
<td>panaw</td>
<td>Nga Pa Naw</td>
<td>*</td>
<td>*</td>
<td>100 230</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>striata</td>
<td>Nga Yant</td>
<td>*</td>
<td>*</td>
<td>85 540</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Cynoglossidae</td>
<td>Cynoglossus</td>
<td>sp.</td>
<td>Nga Khway Shar</td>
<td>*</td>
<td>*</td>
<td>64 100</td>
</tr>
<tr>
<td>Sr.</td>
<td>Family</td>
<td>Genus</td>
<td>Species</td>
<td>Local name</td>
<td>Before Sluice</td>
<td>After Sluice</td>
<td>Average Range (mm)</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>---------------</td>
<td>---------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>47</td>
<td>Tetraodontidae</td>
<td>Leiodon</td>
<td>cutcutia</td>
<td>Nga Pu Si</td>
<td>*</td>
<td>*</td>
<td>NI  NI</td>
</tr>
<tr>
<td>48</td>
<td>Plaemonidae</td>
<td>Macrobachium</td>
<td>rosenbergii</td>
<td>Yaycho- puzun-hiokgeyi</td>
<td>*</td>
<td>*</td>
<td>70  435</td>
</tr>
<tr>
<td>49</td>
<td></td>
<td>ruse</td>
<td></td>
<td>Puzun Thay Myar</td>
<td>*</td>
<td>*</td>
<td>NI  NI</td>
</tr>
</tbody>
</table>

**Prawns**

For the majority of the species recorded at the sluice, unimpeded movement between different habitats (freshwater, estuary, wetland) is important to complete key life-history aspects, such as spawning and juvenile dispersal. In addition to the migration patterns described above between freshwater and the estuary/sea, there are fish migrating wholly among freshwater habitats (potamodromous). There are many of these fish species moving between different riverine and wetland habitats for spawning, feeding or to access refuge habitats; these migrations are cyclic, moving upstream, downstream and laterally onto floodplains or wetlands. The extent of spawning upstream is unknown but it is likely that many riverine species will have larvae that drift downstream with the current, and that juveniles will move at different times (upstream and downstream) compared to adult life stages. Locals have reported that many of these fish disappeared from upstream reaches after the sluice was constructed.

### 4.2 Fish size

The fish species present at the Shan Gaing sluice will migrate upstream and downstream at a variety of life stages, including juveniles and adults. Large adult fish migrate upstream to spawn and feed. Adult fish at the Shan Gaing sluice could vary in size from 100 mm long to >1200mm long, but are most likely to be 150-750mm long on average, although being an estuary system, many small-bodied fish are likely to migrate up into the freshwater environments, therefore, juvenile and small fish species (20-100 mm long) also migrate upstream and downstream and need to use the fishway at various times. These small fish form the basis of the food chain for larger fish species, and also make up an important component of the subsistence livelihood-based species essential for food and nutritional security for local communities. All sizes of fish, therefore, will need to be considered in the design.
4.3 Migration and flow

Peak migration upstream in the Abyar River tributary is reported to occur at the onset and first half of the rainy (wet) season (data provided by DOF/FFI 2019); which is typically from June to October. Upstream migration is reported from April to October. However, it is likely that there is some migration throughout the year, whenever there is flow in the river and the sluice gates are open, or on the incoming tide encouraging fish to move up. There is also likely to be downstream migration of certain species at different times; therefore, the total closure of the sluice would affect these species (e.g. *Lates, Macrobrachium*). At the Shan Gaing sluice it has been reported that *Macrobrachium* can accumulate upstream of the sluice in March/April when it is closed and therefore cannot migrate downstream to the estuary. This should be taken into account when designing the fishway operations guidelines.

We have plotted the approximate river discharge with the expected periods of peak upstream fish migration for 2018 (Figure 4). Initial flows at the onset of the rainy season are approximately 75 m$^3$/s and increase in the early wet season to over 200 m$^3$/s; this represents the flow range to optimise the fishway design. Mean flow is approximately 120 m$^3$/s and 10% of this – 12 m$^3$/s - is a target for fishway flow. In the absence of information on migration at low flows we have chosen to design the fishway to operate at the minimum flow of 25 m$^3$/s.

![Figure 4](image)

**Figure 4.** Calculated flow at Shan Gaing Sluice. The expected period of peak fish migration is shown in red. Note that migration may occur at all flows but there is insufficient data at present to refine this. The regular fluctuation in Aug-Dec is caused by tidal backwater influencing flow through the sluice.
4.4 Migration and Water Levels

*Head differential*

The difference in upstream and downstream water levels (head differential) is a key design criterion, as this determines the length of the fishway. A sluice with a large head differential would require a longer fishway than a sluice with a small head differential. At Shan Gaing Sluice, the minimum daily head differential from 2017 to 2019 is plotted in Figure 5. It shows that approximately half the time there are reverse heads (water level downstream is higher than upstream), which are shown as green bars in Figure 5. Fish passage could potentially occur at these times, but the sluice is closed to prevent intrusion of saltwater and sediment.

Positive head differentials (upstream water level higher than downstream) are shown as blue and grey bars in Figure 5; 95% of the positive head data is less than 0.6 m (Figure 5), which are the blue bars. This has been selected as the preliminary design criterion for the fishway (Figure 5). A subset of data from the main upstream migration season of June to October inclusive was analysed and the results were very similar with a minimum head differential of 0.6 m occurring 93% of the time. More detailed data was also collected in October 2019 which shows similar patterns. The maximum positive head difference can be up to 1.8 m and it should be noted that a fishway designed for 0.6 m head differential would be sub-optimal – passing less fish - when the head differential increases to 0.8 or 1.0 m, and would likely pass very few fish when the head differential is between 1.0 and 1.8 m.

![Figure 5](image_url)

*Figure 5.* Frequency distribution of minimum daily head differential (difference in upstream and downstream water levels) at Shan Gaing Sluice from 2017 to 2019 (N= 820 days). Green bar is when upstream is higher than downstream. The blue bar is reverse head when downstream levels are higher than upstream levels. The data includes individual combined readings from AM, Noon, and PM.
Headwater and Tailwater Levels

Headwater (upstream) levels vary from an elevation of 4.0m to 7.5m, while tailwater levels vary from an elevation of 4.0m to 7.7m. These levels are important to determine the minimum depth in the fishway and hence the fishway invert or floor level, which then determines the total fishway channel depth. More recent data on tailwater (tide) levels from August to October 2019 remain within the range of 4.0m to 7.7m.

From the analysis of biology, the largest fish migrating is approximately 750 mm long. Fish of this size generally need 1.5 m depth to freely ascend fishways, which are a more confined space compared to the river. To provide this minimum depth the floor level (invert) of the fishway exit would need to be at EL 2.5 m. However, we have set the invert at EL 3.0 m to reduce the depth of the channel by 0.5 m to reduce cost and make construction slightly easier. A fishway exit invert of EL 3.0 m provides 1.0 m depth for 100% of the time and 1.5 m depth for 90% of the time.

Given a head differential of 0.6 m and a fishway exit invert of EL 3.0 m, the entrance invert is then EL 2.4 m.

Operation of fishway with nominated water levels

Headwater and tailwater levels for the Shan Gaing Sluice Fishway Design are shown in Figures 5, 6 and 7, and summarised in Figure 9.

Summary of Design Criteria

- Design target flow for fishway, 10% of mean flow = 12 m³/s
- Maximum head differential for fishway design = 0.6 m
- Exit invert = EL 3.0 m
- Entrance invert (downstream) = EL 2.4 m
Figure 6. Frequency distribution of headwater and tailwater levels at Shan Gaing Sluice from 2017 to 2019 (N= 2462, 820 days by AM, Noon, PM).
Figure 7. Headwater, tailwater and differential head a Shan Gaing Sluice (AM, Noon, and PM data 2017-19), shown with key migration season and operational range of fishway (blue shaded area).
Figure 8. Headwater and tailwater plotted against head differential head (difference in upstream and downstream water level), using AM, Noon and PM levels for 2017-19.
Figure 9. Summary of design levels for the Shan Gaing Sluice fishway. Note fishway channel is 0.3 m higher than EL 7.7m to provide freeboard and prevent flood debris blocking the fishway.
5. Reverse Head

Reverse head is when water levels on the downstream side are higher than the upstream side. It will be a significant factor in the flows through the sluice (Figure 5, Figure 7) and will positively and negatively (if fishways is closed during reverse head times) affect fish migration. Fish observations at other sluice/barrages show that fish can accumulate at the bottom of estuary-based fishways and when reverse head occurs, they can utilise the fishway to migrate upstream.

Reverse head provides challenges for sluice and fishway operations if saltwater intrudes into the freshwater storage upstream of the sluice. Reverse head is most significant at the end of the rainy season. During the wet season months (May-October), freshwater discharge from the Sittaung is large and maintains the water mostly in a freshwater state that moves up the Abyar River to the sluice through tidal influences. This provides less saltwater intrusion challenges upstream of the sluice and the fishway can operate without affecting the freshwater storage upstream.

Flap gates or the provision to add flap gates or stop logs can be utilised to prevent reverse head within the fishway but also completely stops fish migration. Therefore, flap gates or stop logs should not be employed unless saltwater intrusion is at unacceptable levels. To determine this, reverse head salinity levels need to be measured and trigger points for closure established. In addition, even if saltwater impedes, when reverse head subsides as the tide reverses, saltwater that has intruded may be flushed directly back out through the sluice gates and fishway, but this will be dependent on the months of the year and if water saving in the upstream storage is a key priority. March is noted as a high salinity month and both the sluice and fishway could be closed at this time. An operations plan and monitoring program within the plan will help to inform better operations altered through an adaptive management approach of learning-by-doing.

6. Fish Passage Objectives

6.1 Downstream

As migration is cyclic, fish passage objectives include upstream and downstream aspects. For the present review and proposed concept, the sluice is already in place and been operating for a number of years. Downstream migration will occur through both the sluice gates when fully open and the fishway (generally in proportion to the flow passing either through the sluice or down the fishway).

Safe downstream passage of fish through the sluice gates should occur if these are fully open in high flows, but the use of undershot gates can cause fish mortalities when partially open at lower flows (Baumgartner et al. 2006). For future projects it should be noted that overshot gates with a deep tailwater (40% of the differential head) provide safe downstream fish passage, and fish screens are needed on irrigation channel intakes to keep fish in the river and prevent their loss in irrigation systems.
6.2 Upstream

Attraction

The objective for attraction is to provide the upstream limit of migration at a single area - by creating a zone of low turbulence and water velocity – over the typical range of flows from 25 m$^3$/s to 280 m$^3$/s. At Shan Gaing this will mostly be done by operating the sluice gates to achieve conditions that guide fish to the fishway.

Passage

The objective for upstream passage is to pass sufficient numbers of all life stages of fish so they can complete their life cycle and restore populations that have declined. This objective applies to the target flow range, from low flows of 25 m$^3$/s through to moderate flows of 280 m$^3$/s; with a particular focus on providing passage from the onset of the wet season and early wet season.

7. Fishway Design

7.1 Attraction (fishway entrance)

When sluice gates and weirs are passing a low discharge (e.g. 1 to 2 m$^3$/s), the upstream limit of migration and downstream flow patterns are relatively easy to predict, so locating the fishway entrance is clear. At high discharge sites, such as Shan Gaing Sluice, it is more difficult to predict the upstream limit of migration and downstream flow patterns, especially as conditions change in low and high flows. At these sites the main method to understand the complex flow patterns is physical modelling (1:10 to 1:20 scale), which enables fish attraction to the fishway entrance to be optimised. 3D computer modelling (Computational Fluid Dynamics [CFD]) can be used but is limited in the number of variations that can tested.

After physical or computer modelling wet commissioning is required to confirm flow patterns. If physical or computer modelling is not used then wet commissioning is much more extensive and time-consuming. Modifications, such as adding rock or wingwalls to an abutment, may be needed to modify flow patterns and prevent excessive recirculation. Wet commissioning involves testing combination of gates to ensure fish are guided to the fishway entrance, which is not masked by turbulence.

The present Shan Gaing Sluice uses undershot sluice gates. Depending on the flows and operation of the sluice gates there would be different zones of fish attraction at different flows (Figure 10, Figure 11, Figure 12, Figure 13). Fish are attracted to the edge of high flows. When there is high discharge in the river, fish are likely to be attracted to the banks (Figure 10), while at other flows they are attracted to the low turbulence zones adjacent to the open sluice gate. These features can be used to operate the gates to enhance fish attraction to the fishway. In general, gates can be operated to guide fish to one bank, so the fishway entrance can be on one bank. As noted earlier, wet commissioning with different open gates is an important part of optimising the final fishway installation.
Figure 10. Predicted zones of fish attraction at **high flows** with uniform flow through all sluice gates.
Figure 11. Predicted zones of fish attraction at moderate flows with flow through half the sluice gates.
Figure 12. Predicted zones of fish attraction at low flows with flow through one or two sluice gates.
Figure 13. Detail of predicted zones of fish attraction with low flow through one sluice gate.
7.2 Passage - Fishway Options

The water levels and fish community strongly influence the Shan Gaing fishway design. Shan Gaing Sluice has highly variable water levels but low differential heads (difference in upstream and downstream water levels). The fishway design that most suits these conditions is the vertical-slot (Figure 14). At sites with high discharge like the Shan Gaing Sluice the dual vertical-slot design is commonly used to pass more discharge and attract more fish (Figure 15).

![Figure 14. Vertical-slot fishway design.](image)

Two other fishway designs with potential are the cone design (Figure 16) and dragon’s teeth design (Figure 17). However, these have not been used at sites with highly variable headwater. There is potential to provide a tiered baffle in a cone or dragon’s teeth fishway (Figure 18) but this would need to be considered experimental and would need intensive monitoring with the capacity to modify the baffles if they were not suitable.

It is important for the demonstration fishway at Shan Gaing Sluice, to have a fishway that is a low risk design, with very high certainty of passing the majority of fish. Hence, for Shan Gaing Sluice we recommend a dual vertical-slot design to accommodate the variable water levels and provide a high discharge.
Figure 15. Example of a dual-slot fishway (top figure) using sheet pile and a single-slot vertical-slot fishway (bottom figure).
Figure 16. Example of a cone fishway.

Figure 17. Example of a dragon’s teeth fishway.
Figure 18. Potential baffle arrangement for a cone or dragon’s teeth fishway to accommodate variable water levels.

7.3 Application of Preferred Fishway Design

Design specifications for a dual vertical-slot fishway for Shan Gaing Sluice are summarised in Table 3. An unusual characteristic of the site are the highly variable water levels; these result in a fishway channel that is at least 4.5 m deep, and will likely be 5.0 m deep or more to match the surrounding landscape and prevent reverse flows of saline water. The fishway baffles will need to be 4.5 m tall. These accommodate the minimum depth of 1.5 m for large fish for 90% of the time.

Because the site is tidal there are very small fish (approx. 30 mm long) that are migrating upstream from spawning grounds, and these require passage. For these fish very low water velocities and turbulence are needed, which are two key design criteria. For Shan Gaing we consider that for the small fish (e.g. 30-60 mm long), where a high certainty of passage is required, 1.0 m/s is the maximum water velocity (equivalent to 50 mm head loss per pool) and 20 Watts per cubic metre (W/m³) is the maximum turbulence (assuming a Cd of 0.99). These may represent conservative values, but it is unknown until monitoring is done. If monitoring results show that only larger fish (e.g. >300 mm) are migrating, then a higher velocity of 1.4 m/s and turbulence of 55-70 W/m³ can be used in the next fishway.

Integrating target fishway discharge, water velocity and turbulence to determine pool size and fishway length

To meet the maximum water velocity and turbulence criteria, while achieving the target flow of 12 m³/s, would require a fishway with pools that are 11 m wide by 9 m long, which would result in a fishway channel that is 145.7 m long. We considered the length would be too costly for the project, and the width was complex for the bridge span that is required. We concluded that a pool size of 6 m by 6 m that would result in a 69.3 m long fishway was more practical, with a readily achievable bridge span.
Table 3. Design specifications for the Shan Gaing Sluice fishway.

<table>
<thead>
<tr>
<th>Functional Objective</th>
<th>Hydraulic/Physical Design Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATTRACTION DESIGN</strong></td>
<td></td>
</tr>
</tbody>
</table>
| High discharge required in rainy season | Rainy Season Discharge | Target is 12 m$^3$/s (10% of mean flow)  
6.6 m$^3$/s achieved  
Note: fishway channel is reduced in size for cost and practicality, so discharge is reduced. |
| Low discharge required in dry season | Dry Season Discharge | Approx. 0.25 m$^3$/s |
| **PASSAGE DESIGN – WATER LEVELS** |                                          |
| Fishway operational range | Headwater | EL 4.0 m to 7.5 m |
|                         | Tailwater  | EL 4.0 m to 6.0 m |
|                         | Head differential | 0.6 m max. |
| Fishway Channel Height (also fishway entrance and exit height) | | EL 8.0 m min. (to prevent reverse flow and overtopping) |
| Fishway floor levels | Invert of upstream exit | EL 3.0 m |
|                         | Invert of downstream entrance | EL 2.4 m |
| **PASSAGE DESIGN - BIOLOGY** |                                          |
| Smallest fish: approx. 30mm | Pool Head Loss:  
(determines max. water velocity) | 50 mm (max. velocity 1.0 m/s) |
|                       | Turbulence:  
(determines min. pool size) | 20 Watts per cubic metre (W/m$^3$) (assuming a Cd of 0.99) |
| Largest fish: 1.5 m  
(Wallago attu) | Minimum Depth:  
(90% of the time) | 1.5 m for 90% of the time  
(more depth is more effective) |
|                       | Pool size:  
(4 m by 4 m is the minimum for fish behaviour) | 6 m by 6 m selected for design to achieve high discharge and low turbulence  
(4 m by 4 m is the minimum suggested but research needed to quantify this aspect) |
| Biomass: unknown but expected to be high | Pool size:  
(4 m by 4 m is the minimum suggested but research needed to quantify this aspect) | 6 m by 6 m selected for design to achieve high discharge and low turbulence  
(4 m by 4 m is the minimum suggested but research needed to quantify this aspect) |
| Fishway Length | 69.3 m (assuming a baffle thickness of 0.3 m) |
| Fish behaviour | Pass species requiring light  
(Hilsa) | Open to light  
Open channel |
| Pass benthic species catfish  
(Wallago) | Benthic (floor) passage in channel | Vertical-slot to floor of channel, or submerged orifice provided in baffle |
| **OTHER LIKELY REQUIREMENTS** |                                          |
| Flap gates to prevent saline or sediment intrusion | Essential – design to be determined |
| Trap for monitoring | Essential – design to be determined |
| Upstream concrete pad for trap | Essential – design to be determined |
8. **Fishway Layout**

The preferred location for the fishway is the left-hand bank abutment, facing downstream, so that access and viewing of the fishway is optimised. The layout is determined by: i) the entrance location at the base of the sluice, which is where migrating fish will be attracted to, and ii) the exit located away from the sluice gates, to ensure that fish migrating upstream are not swept back through the sluice. Once these two criteria are met the fishway layout is flexible. In the following figures (Figure 19, Figure 20, Figure 21) are three possible layouts, but others could be used. A baffle designed for Shan Gaing is shown in Figure 22.

There is also the option of including a vertical-slot fishway within a sluice bay; this would be done by inserting four or five baffles within the existing concrete sluice bay. It would only operate at low differential heads (e.g. 300mm) but could be inexpensive and be a useful second fishway. We have not discussed this option in the present report.

9. **Potential Construction Techniques**

Fishways are often poured *in-situ* concrete. An alternative and effective construction technique is to use sheet pile walls and pre-cast concrete baffles (Figure 23). The channel can have a concrete base or, alternatively, a prepared soil and gravel base with geotextile layers and pre-cast floor units to support the baffles.
Figure 19. Potential layout of a vertical-slot fishway aligned with the sluice and bank.
Figure 20. Potential layout of a vertical-slot fishway that avoids the sluice.
Figure 21. Potential layout of a vertical-slot fishway as a straight channel for construction simplicity.
Figure 22. Detail of baffle of dual vertical-slot fishway for Shan Gaing Sluice.
Figure 23. Longitudinal section of concept design for a vertical-slot fishway for Shan Gaing Sluice, showing key levels. Not to scale.

Figure 24. An example of a sheet pile dual vertical-slot fishway with a fence that enables viewing (red circle), but also provides safety for visitors.
10. Operation of the Shan Gaing Sluice to optimise fish passage

Once the fishway is completed, operation of the Shan Gaing Sluice in harmony with the fishway will be essential to ensure attraction of fish to the fishway entrance and to optimise fish passage. A small operating manual in Myanmar language needs to be developed and a “handover workshop” needs to be done with sluice operators and managers at the completion of construction, and start of operation. The aim of the workshop would be to explain the value and purpose of the fishway, and to show the critical role these staff play in optimising the function of the fishway.

The workshop would explain that the fishway effectiveness is very dependent on operation and would outline: the objectives for fish attraction and passage, and the different configurations of gates needed to optimise these aspects. Sluice operators would also be trained in when to open, close and maintain the fishway.

The operating manual will need to be updated after wet commissioning and as more is learned.

Some initial principles for the operating manual include:

- the fishway should be left open for as long as possible
- the fishway should be left either fully open or fully closed, never partially open
- at the start of the wet season the first water should be released down the fishway and entry and exit to the main river channel established before opening other gates.
- as gates are closed as the dry season approaches, the fishway should remain fully open and gates closed in a sequence of closing gates at the opposite bank to the fishway first, and gate by gate towards the fishway.

11. Fish Monitoring

Monitoring of the fishway is important to assess the fishway effectiveness, improve the operations of the fishway after wet commissioning, and inform future designs. The Shan Gaing Sluice fishway will act as a demonstration fishway so monitoring forms an essential component of the project. Monitoring should be considered in the design of the fishway from the beginning. Monitoring of fish in the river should occur before and after the fishway is built, to provide a baseline of species downstream and upstream. The data would provide size and relative abundances of different species, from which the population structure and age classes can be determined. Once the fishway is built, monitoring should also occur directly within the fishway at the bottom and at the top, and sampling should be stratified to take into account different times of the day and tide. Fisherman could be utilised in the monitoring of the fishway, so they feel ownership of the fishway and are less likely to illegally fish at the entrance and within the fishway. A separate monitoring plan will be prepared in collaboration with MOALI staff.
12. **Safety and Operations**

Community engagement is an important part of maintaining both the operations and effectiveness of the structure, and safety within and around the fishway. As the site is a demonstration fishway, it should be designed for easy viewing and for safety so that people won’t easily fall into the structure. Figure 23. An example of a sheet pile dual vertical-slot fishway with a fence that enables viewing (red circle), but also provides safety for visitors. provides an example of how this has been achieved with a sheet pile dual vertical-slot fishway, where a fence has been provided. Fisherman also need to be engaged in the project and informed not to fish near the entrance, exit and directly in the fishway.

An essential consideration is safety near and in the fishway. The lower third of the fishway functions as an open channel that fish swim into and baffles are submerged in rising tailwater. It is likely that people will also enter the channel, so provision for people to climb out of each fishway pool will likely be necessary. Please note that the engineer who prepares the plans is responsible for ensuring the safety of people near and in the fishway.

13. **Conclusion**

Fish passage in Myanmar and more specifically the Bago/Sittaung catchment is important to sustain fish populations that provide nutritious food and important livelihoods and industry for Myanmar people. We have provided fishway design criteria that we consider suit the ecology and biology of fish species in this river, based on our collective experience, including specific experience in Myanmar and the broader Lower Mekong Basin. Our assessment of the three possibly options is that a dual vertical-slot fishway is the preferred design.
14. References


DOF/FFI 2019. Table of fish species and sizes at migration provided by the Myanmar Department of Fisheries in collaboration with Fauna and Flora International.
15. Appendix – Draft fishway CAD designs
Shan Gaing Fishway

Notes:
1. Walls are shown as sheet pile but can be other materials.
2. If sheet piles are used, seepage analysis is required to determine depth of piles.
3. Baffles are shown as concrete but can be other materials.
4. Layout can vary but the entrance on the downstream side needs to be adjacent to the abutment.
5. Floor of the fishway can be concrete or geotextile and rocks (with sheet pile length to prevent seepage).
6. Trapping provisions shown are indicative and should be based on the trap used and lifting capacity expected.
7. No detail of the road crossing of the fishway shown, this should be designed as per local road specifications.
8. Development of the concept design will need to consider management of sediment.
9. These plans are to be used in conjunction with the 2020 concept design report: Shan Gaing Fishway proposed design criteria and concept John Conallin, Lee Baumgartner, Martin Mallen-Coope, Tim Marsden, Aye Myint Swe, Zau Lunn, Nyi Nyi Tun, Maung Maung Moe Nyunt.

Conceptual design by: Lee Baumgartner, Martin Mallen-Coope, Tim Marsden and John Conallin.
Contact: Lee Baumgartner

Institute for Fish, Water and Society
Charles Sturt University
Elizabeth Mitchell Drive, Albury, NSW 2640
Tel: +61 2 6025 9271
Email: baumgartner@csu.edu.au
CONCEPT - NOT FOR CONSTRUCTION

PLAN OF SHAN GAING SLUICE

CONCEPT - NOT FOR CONSTRUCTION