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FAO/TCF WORKSHOP ON FISH PASSAGE DESIGN AT CROSS-RIVER OBSTACLES – EXPERIENCES FROM DIFFERENT COUNTRIES, WITH POTENTIAL RELEVANCE TO MONGOLIA

Selenge Resort, Mongolia, 7–12 April 2014

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PREPARATION OF THIS DOCUMENT

The first draft of the report of the FAO/TCF workshop on "Fish passage design at cross-river obstacles – experiences from different countries, with potential relevance to Mongolia", held in the Selenge Resort, Mongolia, in April 2014, was prepared by Mr Eldev-Ochir Erdenebat, consultant of the Taimen Conservation Fund (TCF) of Mongolia. It formed the basis for the present version jointly finalized by the resource persons of the workshop, Mr Rolf-Jürgen Gebler, Mr Andreas Zitek and Mr Gerd Marmulla, Fishery Resources Officer of the FAO Fisheries and Aquaculture Department in Rome, as well as Mr E. Erdenebat. The two country reports are reproduced largely as submitted but have been lightly edited. All information contained in these country reports and the views and opinions expressed therein are the responsibility of the authors and not of FAO or the editors. The opening remarks and other presentations included in the appendixes are also reproduced as submitted.

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ABSTRACT

The workshop "Fish passage design at cross-river obstacles – experiences from different countries, with potential relevance to Mongolia" was jointly organized by FAO and the Taimen Conservation Fund (TCF) of Mongolia and held in Mongolia in April 2014. Workshop participants included representatives from the Ministry of Nature and Green Development of Mongolia, the Egiin Gol Hydro Power Plant Project Unit (EGHPPPU), the Dorgon hydropower station, the Mongolian Mining Corporation, the National Water Association, civil society and the TCF. Workshop participants presented two country reports on the status of fish passage development, research and construction in Mongolia, and on the biology and behaviour of the most important fish species to be considered in planning fish passage facilities in Mongolia, and in particular in the Eg River. The resource persons presented knowledge on different fish passage issues from both the biological and the engineering perspectives. Although the known facts are mainly derived from studies in North America and Europe, the basic aspects can serve as "food for thought" also in other regions, including Mongolia. Information provided and designs presented should, however, under no circumstances just be copied but have to be adapted to local conditions (taking into due consideration the species present) while respecting the important basic design criteria which are valid for all passes of the same type at all locations, whether in Europe, North America or Asia. As regards the planned Eg River hydropower plant, the workshop did not have a unanimous view concerning the need for, and the usefulness and the environmental impacts of, the planned dam construction. However, all workshop participants unanimously agreed that, should the dam on the Eg River be constructed, a fish passage system would be needed to mitigate the blocked upstream and downstream passage for maintaining genetic exchange between fish in the Eg and Selenge Rivers. The workshop agreed that trap-and-transport for both upstream and downstream fish passage, with the option of later modifications, would be the only viable solution for this Eg River power plant. However, the resource persons clearly held that based on their assessment during the field visit and the additional information provided during the classroom sessions – from a fish ecological, biodiversity and fisheries point of view – the dam must not be constructed at the planned location because it would inflict irreversible damage to the aquatic ecosystem. In fact, the excellent ecological status of the Eg River just upstream of the confluence with the Selenge River (and also further upstream in the watershed) calls for the preservation of the given morphological and hydrological characteristics. Alternatives should be sought as regards either the location of the dam (i.e. consider to construct one dam or several smaller dams on one or several other rivers that are less important for taimen) or the type of energy produced (solar or wind). Furthermore, the resource persons held that, most importantly, the workshop must not be seen as encouragement to construct new dams solely because the principles of the design and construction of fish passage facilities are known.

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Executive summary

The workshop "Fish passage design at cross-river obstacles – experiences from different countries, with potential relevance to Mongolia" was jointly organized by FAO and the Taimen Conservation Fund (TCF) of Mongolia and held in Selenga, Mongolia, on 7–12 April 2014. It was attended by 20 representatives from the Mongolian administration, including from the Ministry of Nature and Green Development of Mongolia, research institutions, the Eg River Hydro Power Plant Project Unit (EGHPPPU), the Dorgon hydropower station, the Mongolian Mining Corporation, the National Water Association, the civil society and the TCF. Workshop participants presented two country reports, i.e. one on the status of fish passage development, research and construction in Mongolia, and one on the biology and behaviour of the most important fish species to be considered in the planning of fish passage facilities in Mongolia, and in particular in the Eg River. FAO resource persons presented global knowledge on fish passages from both the biological and the engineering perspectives. This included basic aspects on fish biology and behaviour relevant to fish migration, different types of fish passage facilities, ecological and hydrological requirements for enhancing the effectiveness of fish passages, as well as the monitoring, evaluation and maintenance of fish passages. However, it was made clear that the information provided and designs presented should under no circumstances just be copied but have to be adapted to local conditions (taking into due consideration the species present), while respecting the important basic design criteria valid for all passes of the same type at all locations, whether in Europe, North America or Asia.

The field visit took workshop participants to the planned hydropower dam construction site on the Eg River. The Eg River is considered the most natural river catchment in Mongolia inhabited by a self-sustaining population of *Hucho taimen*. The planned dam construction site is located in the narrowest section of this part of the valley, with a steep slope adjacent to the left bank and a moderately steep slope on the right bank, about 2 km upstream of the confluence of the Eg River with the Selenge River, and about 2–3 km downstream of a river stretch extremely rich in habitat diversity. This part of the Eg River, as most of its catchment, is still completely natural and not modified by any anthropogenic interventions. The section just upstream of the planned dam is in such a natural status that it could perfectly serve as a model for the description of "the ideal river" on a global scale. The resource persons recommended that based on their assessment during the field visit and the additional information provided during the classroom sessions – from a fish ecological, biodiversity and fisheries point of view – the dam must not be constructed at the planned location because it would inflict irreversible damage to the aquatic ecosystem. Moreover, the dam should also not be constructed further upstream in the Eg River as it is the last largely unaffected river hosting a good population of *Hucho taimen* in Mongolia. In fact, the excellent ecological status of the Eg River just upstream of the confluence with the Selenge River (and also further upstream in the watershed) calls for the preservation of the given morphological and hydrological characteristics. Alternatives should be sought either as regards the location of the dam (i.e. consider construction of a dam or several smaller dams on one or several other rivers that are less important for taimen) or as regards the type of energy to be produced (solar or wind energy).

The workshop did not have a unanimous view on the need for, and on the usefulness and the environmental impacts of, the planned dam construction. However, all the participants unanimously agreed that, should the dam be constructed, there would be a need to implement a fish passage system for mitigating the blocked upstream and downstream passage in order to maintain genetic exchange between fish in the Eg and Selenge Rivers. Options for a potential

fish passage facility were discussed, should the dam be constructed. The great height of the planned dam and the long reservoir it would form were considered. The workshop finally agreed that for upstream passage a trap-and-transport system, with the option for later modifications, would be the only viable solution. Downstream migrating fish should be collected before reaching the reservoir and transported downstream. The potential negative impacts below the dam along the Eg and Selenga Rivers (icing, increased erosion owing to sediment storage in the reservoir, significant changes in the hydrology of the river owing to seasonal hydropeaking in winter during several hours a day, and significant reduction in the discharge in summer owing to filling of the reservoir) were discussed. The resource persons reminded the workshop that the construction of a fish passage facility did not remediate the other ecological impacts.

On several occasions during the workshop, the resource persons emphasized that, most importantly, the workshop must not be seen as an encouragement to construct new dams merely because the principles of the design and construction of fish passage facilities are known. The case of the Eg River in Mongolia is seen as an example from which other countries could learn.

The workshop participants much appreciated the information provided and judged the workshop very useful.

1. INTRODUCTION

1. The workshop on "Fish passage design at cross-river obstacles – experiences from different countries, with potential relevance to Mongolia" was organized by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the Taimen Conservation Fund (TCF) of Mongolia, and held in the Selenge Resort, Mongolia, from 7 to 12 April 2014. The workshop was divided in three parts, i.e. (i) a scientific field excursion to the planned construction site of the proposed Egiin Gol hydropower plant on the Eg River; (ii) presentations on fish passage issues in Mongolia and knowledge-sharing from global experiences; and (iii) discussions on and preliminary development of the potential solution (solutions) for fish passage at the planned hydropower station on the Eg River. The agenda of the workshop appears as Appendix 1 to this report.

2. The workshop was attended by a total of 21 representatives from the Ministry of Nature and Green Development of Mongolia, the Egiin Gol Hydro Power Plant Project Implementation Unit (EGHPPPU), the Dorgon hydropower station, the Mongolian Mining Corporation, the National Water Association, civil society and the Taimen Conservation Fund (TCF). Also present were Mr Gerd Marmulla (FAO/FI) as well as Mr Rolf-Jürgen Gebler and Mr Andreas Zitek (FAO consultants) as FAO resource persons. The list of participants appears as Appendix 2.

2. VISIT OF THE PLANNED DAM CONSTRUCTION SITE OF THE PROPOSED EGIIN GOL HYDROPOWER PLANT

3. On the first day of the workshop, the FAO resource persons and a group of participants consisting of members of the Taimen Conservation Fund and the Egiin Gol Hydro Power Plant Project Unit (EGHPPPU) visited the site on the Eg River where the dam construction is planned. The dam construction site is located in the narrowest section of this part of the valley, with a steep slope right adjacent to the orographic left bank and a moderately steep slope on the right bank, about 2 km upstream of the confluence of the Eg River with the Selenge River and about 2–3 km downstream of a river stretch extremely rich in habitat diversity. This part of the Eg River, as most of its catchment, is still completely natural and not modified by any anthropogenic interventions. The only human activity in this area is livestock raising, but this has not modified the structure of the river bed or the flow of the river. The section just upstream of the planned dam construction site is in such a natural status that it could perfectly serve as a model for the description of "the ideal river" (in Appendix 4 are reproduced a schematic presentation of a river course featuring a very high variety of different habitats along its continuum [from the FAO/Fishing News Books publication "Rehabilitation of rivers for fish", FAO 1998] and a photograph of the Eg River section just upstream of the site of the planned hydropower plant).

4. The Eg River is considered the most natural river catchment in Mongolia, inhabited by a self-sustaining population of the *Hucho taimen* which is safeguarded and to some extent "managed" by the TCF, e.g. fishing for *H. taimen* is only allowed as catch and release activity. The good status of the *H. taimen* population is maintained particularly through the TCF's fight against poaching by mobilizing organized patrols, while poaching has significantly reduced *H. taimen* populations in all other regions in Mongolia.

5. The resource persons were informed about details of the dam construction plans (beyond what was made available to them prior to the workshop and as far as already known or decided), and they used the field visit to gain a better understanding of the potential impacts of the dam on the environment, and in particular on fish. Their questions were answered as far as possible and to the best knowledge of the accompanying members of the TCF and EGHPPPU.

6. The field visit was extremely important for understanding the local environmental situation and for the further course of the workshop. Because of several extremely important factors (mentioned below), the resource persons came to the conclusion that, from a fish ecological, biodiversity and fisheries point of

view, this dam must not be constructed at the planned location as it would inflict irreversible damage to the aquatic ecosystem and, most probably, no dam at all should be constructed on the Eg River (owing to its very high importance for taimen and its overall good ecological condition due to very limited human influence in its catchment as compared with many other river systems in Mongolia and in the world).

7. The important factors in this respect are: (i) the absolutely natural status of the morphology of the river bed of the Eg River (at the planned dam construction site as well as below and above); (ii) the location of the planned dam (just upstream of the confluence with the Selenge River) and close to a tributary (to the Eg River) that was described as important for taimen; (iii) the problems for both the Eg and the Selenge Rivers that can be expected with regard to interrupted sediment transport and downstream erosion; (iv) the problems for both the Eg and the Selenge Rivers that can be expected with regard to ice formation and hydropeaking; (v) the change in the seasonal flow characteristics of the Eg and Selenge Rivers (with a complete modification of the discharge of the Eg River from high flow during summer to hydropeaking during winter and water storage and severely reduced discharge during summer); (vi) the extent and depth of the reservoir and the important water level fluctuations in the reservoir during the year; and last but not least (vii) the problems (or at least challenges) that can be expected with regard to the connection of any fish passage facility for upstream and downstream migration to the fluctuating water level in the reservoir.

8. Also the zone between the planned dam construction site and the confluence of the Eg River with the Selenge River was visited. Downstream of the planned dam construction site, the valley widens again and forms floodplains on the left bank just prior to the confluence. Taking into account the natural morphology of this zone and the migration behaviour of *H. taimen*, it is expected that the river stretch just upstream of the confluence of the two rivers is important for the reproduction of *H. taimen* coming from the Selenge River and should therefore not be modified.

9. All the above issues were intensively discussed during the field visit (and also later during the classroom session of the workshop, in particular on day 5). Moreover, the FAO resource persons mentioned several times that even the best possible fish passage facility would not be able to mitigate the loss of connectivity and that much more than just fish passage was at stake owing to the dam construction.

10. In view of above facts and conclusions, the FAO resource persons strongly suggested that the hydropower dam should not be built at the planned location and that alternatives should be sought either as regards the location of the dam (i.e. consider constructing one dam or several smaller dams on one or several other rivers that are less important for taimen) or as regards the type of energy to be produced (solar or wind energy). They also stressed that due consideration should be given to all the aforementioned factors, should a new environmental impact assessment (EIA) study, which would have to be comprehensive, be carried out for the planned construction site. In any case, a comprehensive study of the fish fauna and their habitat uses under different river discharges – not only in the Eg River but also in the Selenge River – was seen as indispensable and strongly recommended, together with the assessment of abiotic factors.

3. OFFICIAL OPENING OF THE WORKSHOP

11. Owing to the field visit on the first day of the workshop, the workshop was formally opened only on the second day. Mr Eldev-Ochir Erdenebat, TCF consultant, who very capably moderated or co-moderated all the workshop sessions, called the audience to order for the opening ceremony. The workshop was opened by Mr Shirendev Purevdorj, Executive Director of the Taimen Conservation Fund, who welcomed the participants to the workshop. On behalf of the TCF, he expressed thanks to FAO for providing the funding for organizing the workshop. He also expressed his special thanks to Mr Gerd Marmulla, Fishery Resources Officer, Marine and Inland Fisheries Branch, FAO Fisheries and Aquaculture Department, for his efforts, assistance and guidance in organizing the workshop.

12. Furthermore, Mr Purevdorj expressed thanks to the representatives of the Ministry of Nature and Green Development, the Egiin Gol Hydro Power Plant Project Implementation Unit, the fishery experts, the hydropower experts and scientists for accepting the invitation to attend this six-day workshop, despite their busy work schedule. He mentioned that on 16 November 2013 the Government of Mongolia had made the decision to establishing the Egiin Gol Hydro Power Plant Project Implementation Unit which is responsible for the overall management and building of a new hydropower plant on the Eg River. He briefly introduced TCF's activities on protecting the fish in the Eg River, involving the science team, which consists of biologists, hydrologists and specialists from the Mongolian Geo-Ecology Institute, the Institute of Biology, United States universities (i.e. University of Wisconsin, Madison; University of Nevada, Reno; University of California, Davis; and Rutgers, the State University of New Jersey), and other scientists from the Russian Federation, Canada and Mexico. He confirmed that the TCF would provide a full-scale research study of fish in the Eg and Selenge Rivers and provide recommendations to the decision-makers in relation to the construction of the Egiin Gol hydropower plant. He also expressed his hope that the workshop participants would exchange information, knowledge, opinions and thoughts in connection with the planned construction of the Egiin Gol hydropower plant and wished the workshop all possible success. His opening remarks appear as Appendix 3.

13. On behalf of FAO, Mr Gerd Marmulla also welcomed the participants. First, he conveyed to the plenary the greetings and best wishes for successful deliberations of Mr Ahaduzzaman, Deputy FAO Representative in Mongolia and Head of the FAO Office in Ulaanbaatar, who had been unable to attend the workshop owing to other urgent commitments scheduled earlier. Mr Marmulla then expressed appreciation to the TCF for the hosting arrangements made for the workshop.

14. Mr Marmulla noted that Mongolia was not particularly rich in fish species compared with other regions in the world, but that there existed species that are indigenous and therefore precious. One of these species is the taimen, which attracts many foreign visitors who bring foreign exchange to Mongolia. However, the number of taimen is declining in Mongolia and a further decline has to be prevented in order to avoid putting the survival of the species at risk. As the taimen is a migratory species, free upstream passage is a must in order to allow the adult fish to reach their spawning grounds, while free downstream passage is also needed for the dispersion of the juveniles so that taimen can colonize appropriate areas. Mr Marmulla further noted that the construction of cross-river obstacles, e.g. dams and weirs, could have negative impacts on fish by hampering or blocking migrations, and that stocking could not successfully replace natural reproduction in the long term and that, therefore, natural reproduction had to be fostered.

15. Mr Marmulla remarked that the workshop aimed at raising the general awareness of the usefulness, but also of the limitations, of fish passage facilities. The workshop was meant to show which fish passage facilities had been developed on a global scale and what conclusions might be drawn from this knowledge for the development of fish passage facilities in Mongolia. However, under no circumstances, this workshop must be seen as an encouragement to construct new dams solely because knowledge on how to design and construct fish passage facilities was available. He was confident that with the help of the workshop participants, the workshop would also try to discuss and develop potential scenarios for a fish passage facility at the Eg River. However, because of the importance of the taimen, and its vulnerability, all efforts should be made to re-evaluate the need for, and the overall usefulness of, a hydropower station on the Eg River. He stressed that fish passage facilities could certainly be constructed but that it had to be kept in mind that they could only mitigate the impacts of a dam to a certain extent, but never completely. Fish passage facilities may enable fish migration but they cannot compensate for lost river connectivity. His remarks appear as Appendix 3.

4. IMPORTANCE OF FISH PASSAGE

16. To set the scene for the workshop, Mr Marmulla gave a presentation on the importance of fish passage. He briefly introduced FAO's activities concerning fisheries and environmental aspects, the

importance of biodiversity, and FAO's work in the field of fish passage issues. He mentioned the five new "Strategic Objectives" of FAO, one of which focuses on increasing and improving provision of goods and services from agriculture, forestry and fisheries in a sustainable manner. He mentioned the multiuser impacts on aquatic resources, the threats to freshwater biodiversity by in-stream barriers, and the direct and indirect impacts of dam and weirs on the aquatic environment and the organisms induced by the change in physical and chemical conditions of the water. He noted that in case of dam construction there was a need to analyse thoroughly the requirements for free fish passage with a view to addressing the physiological needs of fish (and other aquatic animals) in terms of spawning, nursing and feeding, habitat preferences (summer/winter habitat), shelter, etc. He also mentioned several international instruments that had recognized the necessity for protection and conservation of the aquatic environment and its biodiversity. In particular, the FAO Code of Conduct for Responsible Fisheries (the Code) and the related technical guidelines also recognized the need for healthy ecosystems and biodiversity, and especially the need for the conservation of aquatic ecosystems, as well as the protection and restoration of fish movements across the obstacles constituting barriers to migration.

17. In concluding his presentation, Mr Marmulla warned that having the knowledge on how to design and construct fish passes must not be taken as a justification for constructing new dams and weirs.

5. COUNTRY REPORTS

5.1. The status of fish passage facilities development, research and construction in Mongolia

18. Mr T. Ganbold, General Manager for Site Infrastructure of the Mongolian Mining Corporation, made a presentation on "The status of fish passage facilities development, research and construction in Mongolia" (Appendix 5). He noted that the country's total hydropower potential had been estimated at more than 5 000 MW, about only 0.5 percent of which had so far been developed. He said that hydropower development was now a high priority for the country, in particular in view of the shortage of electricity in remote areas owing to the high cost of imported diesel fuel for the power generators under the control of the local district administrations ("soums"). Moreover, energy production in the central region of Mongolia depends entirely on coal-fired thermal powerplants, which cause severe air pollution. At present, the country's total electricity production comes from seven coal-fired thermal powerplants, which produce 3 billion kWh.

19. He mentioned that in Mongolia, to date, 13 mini and small hydropower plants (SHPs) had been constructed, of which two were SHPs with a dam that operated all year round, and one an SHP without a dam that worked only in summer. The other ten are equipped with mini-turbines and also operate only during summer. Out of the 13 hydropower plants, three are equipped with fish passage facilities, i.e. Dorgon hydropower plant, with a capacity of 12 MW constructed on the Chonokharaikh River in Khovd Province; Bogdiin hydropower plant, with a capacity of 2 MW constructed on the Bogdiin River in Zavkhan Province; and Tosontsengel hydropower plant, with a capacity of 0.38 MW constructed on the Ider River in Zavkhan Province. The Dorgon hydropower plant can operate all year around, but the Tosontsengel and Bogdiin plants operate only seasonally, i.e. in summer between 15 April and 15 October.

20. With regard to fish passage facilities, Mr Ganbold mentioned that environmental protection issues were increasingly being considered and that, therefore, in the case of dam construction, fish passage facilities should now be built when needed to save fish. Currently, the construction of fish passage facilities at the planned Egiin Gol hydropower plant was being considered, and Mongolian scientists were working to determine the best and most cost-effective options.

21. He noted that the Institute of Biology of the Mongolian Academy of Sciences, under which the "Fish Growing Research Centre" institute (headed by Ms Dulmaa) had been established in September 2009, was conducting fish studies. The main goal of this centre is to study the possibilities of growing fish.

The Hydrobiology and Fish Research Laboratory is also making joint investigations into aquatic species and the bioproductivity of fish in collaboration with an international team from Germany, the Russian Federation, the United States of America and the Czech Republic.

22. He has also noted that there was no specific law for fish pass construction in Mongolia and that only in clause 1.6 of the "Basic principles of designing works for hydraulic constructions" (published in 2003 by the Ministry of Infrastructure) was it stipulated that during the design phase fish protection measures should be planned.

23. He further mentioned that, according to the first design proposal elaborated by the Swiss company Electrowatt between 1992 and 1994, the Egiin Gol dam had been planned to be built without a fish passage facility, but that now Mongolian scientists were proposing to consider the following options: (i) fish trapping and transporting by truck for release upstream of the dam, so that fish can continue to migrate; or, (ii) construct a fish lift at the dam. However, as the feasibility study prepared by Electrowatt says that a fish lift requires heavy construction work, is not easy to operate and is expensive, the Mongolian scientists are now thinking of concentrating on the first option.

5.2 The biology and behaviour of the most important fish species to be considered in the planning of fish passage facilities in Mongolia, and in particular in the Eg River

24. Mr P. Tsogtsaikhan, Director of the Environment Impact Assessment and Auditing Division of the Ministry of Nature and Green Development of Mongolia, made a presentation on "The biology and behaviour of the most important fish species to be considered in the planning of fish passage facilities in Mongolia, and in particular in Eg River" (Appendix 6).

25. First, Mr Tsogtsaikhan provided a brief overview of the hydrogeographical characteristics of Mongolia, mentioning that there were more than 5 000 rivers in three drainage basins. The basins could be classified according to their directions of drainage, i.e. the Arctic Ocean drainage basin, the Pacific Ocean drainage basin, and the Central Asian closed basin. The Arctic Ocean basin, representing 20.6 percent of the territory of Mongolia, drains more than 50 percent of the surface water of Mongolia. It has two important river basins, i.e. the Selenge River basin and the Darkhad basin. Its main river is the Selenge River, which is transboundary, flowing from northern Mongolia down to Lake Baikal in southern Siberia in the Russian Federation. The Selenge River originates from the Mongolian mountains of Khangai and has two important tributaries, i.e. the Eg River and the Orkhon River. The Eg River, the main tributary of the Selenge River, originates from Lake Hovsgol, which is the largest freshwater lake in Mongolia, has a total length of 453 km and drains a catchment area of 41 799 km^2.

26. He noted that, according to the report of the Joint Soviet/Mongolian Biological Research Expedition of the USSR Academy of Sciences and the Mongolian Academy of Sciences in 1983, a total of 20 species of freshwater fish belonging to 11 genera had been recorded in the Selenge River and 19 species of 11 families in the Eg River. Only one species, i.e. the Baikal omul (*Coregonus migratorius*) was not recorded in the Eg River. As regards the fish composition of the Selenge River, 73.3 percent of the fish are native species, 20.1 percent are intentionally introduced, 3.3 percent are from unknown invasions, and 3.3 percent are accidentally introduced species.

27. The fish species of the Selenge River are classified into conservation status categories according to the guidelines for the application of the "Red list categories and criteria at a regional level". Thus, 5.2 percent are listed as Critically Endangered (CR), 15.7 percent as Endangered (EN), 5.2 percent as Vulnerable (VU), 5.2 percent as Near Threatened (NT), 21.1 percent as Data Deficient (DD) and 42.1 percent as Least Concern (LC). The largest fish of the Selenge River is the "river wolf" or "taimen" (*Hucho taimen*), which belongs to the family of the Salmonidae. The taimen is the world's largest salmonid fish and a charismatic fish known within Mongolia and abroad. Typically, adult taimen inhabit undisturbed

habitat types, the character of the habitat depending on the size of the fish. According to a Government resolution, the taimen is now listed as “Rare species”.

28. Mr Tsogtsaikhan then provided detailed information on the biology and the behaviour, including the spawning and feeding behaviour, of the taimen in Mongolia, mentioning that adult fish could reach 2 m in length and weigh more than 100 kg. The taimen populations in Mongolia can either be strictly riverine, where fish live and feed all year round in mainstream rivers and tributaries, or anadromous, living in or near areas of lakes and then ascending rivers in spring to spawn. In spring, taimen move to upstream reaches of rivers to reproduce and feed. The extent of movement varies among rivers. Some immature and resting fish, i.e. those that have spawned in previous years but have not yet again produced gametes, remain in downstream areas to feed.

29. In the Selenge River and its tributaries, spawning migration begin in early May, coinciding with ice melting. In general, taimen reach sexual maturity at the age of 5–6 years. They can reach an age of 15 years but do not spawn each year. Observations of high taimen density in deep pools during the summer suggest that taimen may also use behavioural thermoregulation, but the extent to which such pools provide a thermal refuge and the extent to which taimen use this refuge is currently unknown.

30. Since the demise of the Mongolian People’s Republic in 1990, the taimen population has decreased by about 60 percent. Reasons for this decline lie in the degradation of the quality of habitat due to mining and in the loss of mature individuals due to poaching.

31. Mr Tsogtsaikhan ended his presentation by touching upon fisheries management issues, saying that the current recreational fishery aiming at implementing a 100 percent catch-and-release strategy had little impact on the taimen population, but that recreational catches without release that also occur could affect survival, abundance and size structure. Studies of taimen movements suggest that spatial management should occur at larger scales and, as a result of climate change, intentional introductions, changes in river-channel morphology and other kinds of human activities, the Selenge River has become an important invasion corridor.

6. GENERAL ECOLOGICAL CONSIDERATIONS FOR BUILDING FISH PASSES

32. Mr Andreas Zitek informed the workshop about the general ecological considerations for building fish passes. At the start of his presentation, he stressed that the freshwater ecosystems were the most changed ecosystems in the world, and that it was now largely recognized that inland aquatic species were threatened by various factors, e.g. pollution, damming, river regulation, unsustainable fisheries and the introduction of alien species. He mentioned that damming threatened more than 900 fish species globally. Therefore, it was necessary to recognize the requirements of different species, particularly their specific needs to complete their life cycle successfully, in order to ensure sustainable planning and fisheries management. It was noted that, while there were species that need to undertake migrations from the sea towards inland areas for spawning and larval rearing (and vice versa), also most other freshwater fishes require open migration corridors in upstream and downstream directions, as well as in the lateral dimension, in order to complete their life cycle. Habitat connectivity (both laterally and longitudinally) is therefore necessary to satisfy the migratory requirements of freshwater fish species and ensure their existence in the habitats. He also reported on dam removal, which in North America is practised also to avoid sediment flushing from reservoirs.

33. Examples from the Danube River and other rivers in Europe were cited where several impassable migration barriers exist that create strong impacts on the existence of species, particularly on those dependent on long-distance and medium-distance migrations. Across Europe about 37 percent of the 550 existing freshwater fish species are threatened, with about half of them suffering from the loss of river continuity. It was noted that, therefore, in Europe the building of fish passes had become a priority and was

embedded in the legislation of the European Union (Member Organization) (EU), i.e. in the Water Framework Directive. The long-term viability of fish populations is nowadays seen as dependent on river connectivity (lateral, longitudinal, vertical and seasonal). In this connection, Mr Zitek also stressed the importance of the vertical connectivity that is threatened by the deposition of fine sediments that can jeopardize successful redd digging.

34. In concluding, Mr Zitek emphasized that freshwater habitat destruction and loss of river connectivity were global problems but protection measures needed to be implemented, and actions taken, locally. Especially important was the connectivity between habitats as migrations of fish are life-cycle adaptations that needed to be maintained. If hydropower development was unavoidable, fish biologists and ecologists would have to be consulted in order to help ensure the least impact on fish. Questions for deepening the understanding were raised by the participants and answered by the resource persons.

7. OVERVIEW: COMMON TYPES OF FISHWAYS – EXAMPLES OF WELL-FUNCTIONING FISH PASSES

35. Mr Rolf-Jürgen Gebler gave a presentation entitled "Overview: common types of fishways – examples of well-functioning fish passes". He noted that, in general terms, fishways were facilities that provided free passage for fish at cross-river obstacles (for both upstream and downstream migration), and the selection of appropriate types of fishways would depend mainly on the size of the weir (e.g. the head) and the availability of space for the construction of the fishway. The workshop was then informed about the different types of fishways for low-head weirs (e.g. rock ramp, fish ramp, pool pass, bypassing water course) and their design features (i.e. pool structure, pool-riffle structure, pool pass structure, vertical slot, pool pass with notches and orifices [an outdated design in most cases replaced by the more modern vertical-slot design]). Advantages and disadvantages of different types and structures of fishways were presented. The advantages of the rock ramps are: (i) no problems for fish to find the entrance because the pass stretches over the entire width of the river; (ii) suitable for upstream and downstream passage; and (iv) low maintenance costs. A disadvantage is that the weir in its entire width has to be modified. The advantages of fish ramps are: (i) they do not require additional space at the river bank because the passage corridor is constructed; (ii) their construction cost is low even for large weirs; and (iii) they are suitable for upstream and downstream passage and even provide a living habitat for fish. However, they require greater maintenance efforts. Fish passes, which are characterized by a separate chute, require little space at the river bank or no space at the river bank (if constructed in the river channel); a disadvantage is that they require considerable maintenance. The advantages of a bypassing water course are: (i) no interference with the existing weir structure; (ii) easy to build because the construction site is on the bank and not in the river; (iii) very good integration into the landscape; and (iv) provision of valuable living habitat for many species; the greatest disadvantage is that it needs a lot of space on the bank.

36. Also presented were methods/facilities to provide fish passage at high obstacles, and their advantages and disadvantages, e.g. fish locks (fish enter the lock, the entrance is closed, and the fish have to wait until the upper sluice gate opens so that they can leave in the upstream direction); fish lifts; and the "trap and transport" method. However, these methods/facilities do not allow continuous migration, can be selective (i.e. might work well only for certain species and sizes, depending on the chosen dimensions), and usually have high operating costs. Some of them can have a high efficiency, depending on the target species and the mode of operation. It was noted that many fish locks were constructed in France but were found to provide unsatisfactory results and were now rarely used.

37. Interesting questions concerning various issues were asked. In replying, the resource persons mentioned that the reasons for the non-functioning of the vertical slot pass in western Mongolia could be manifold, and one of them could be a problem with the entrance of the pass (in terms of flow velocity and/or position). As regards a question about the velocity of the attraction flow for European species, it was said that in general the velocity should be about 1.5 m/s (and in any case not exceed 2.0 m/s), and that

for the Danube salmon (*Hucho hucho*) the velocity should be around 0.8–1.5 m/s. It was also clarified that a fish lift would only work for upstream migration; downstream passage would have to be provided through different systems. A great height to be overcome by a fish lift (such as the 90 m at the planned Eg River dam) was not seen as a major problem, but the connection to the reservoir, especially under varying water-level conditions, could be a challenge. Furthermore, the functioning of a fish lift in harsh climate conditions could be problematic.

8. SWIMMING AND ORIENTATION BEHAVIOUR OF FISHES IN UPSTREAM DIRECTION

38. Mr Zitek, while making a presentation on "Swimming and orientation behaviour of fishes in upstream direction", stressed that the behaviour of the fish was one of the very important criteria in designing appropriate fish passage facilities as different species of fish (with different body shapes, swimming behaviour and swimming performances) have different abilities to move/migrate across habitats. Fish rheoreaction (i.e. orientation and swimming against the water current) is influenced by the flow velocity, temperature, level of illumination, degree of turbulence, and the physiological condition of the fish. Therefore, basic data, e.g. fish size (body length, body width), the critical burst speed of the fish (i.e. swimming speed that can be maintained for 20 seconds), the threshold (minimum) velocity for rheoreaction and flow velocity preferences during upstream and downstream migration as well as other behaviour, should be collected and considered in designing and constructing appropriate passes. In addition, the requirements of different life stages of fish (particularly those of the small juveniles) should also be considered when designing fish passage facilities to allow a wide range of age classes to pass through the facility.

39. It was also noted that other factors affect the effectiveness of fish passes, including *inter alia* water turbulence (i.e. too high a turbulence reduces the swimming capacity of fish, leads to disorientation, exhaustion and injuries of fish); position of the entrance of the fish pass (the appropriate position depends on the fish behaviour, e.g. whether the fish are swimming along the shoreline, in the main current, or at the surface/bottom, etc.); size of the fish pass and the volume and flow characteristics of the attraction flow compared with the size of the river (the flow volume should be large enough to attract fish); and specific behaviour of fish, e.g. in relation to orientation along the flow or (that might be still unknown for certain species). The appropriate period of operation of the fish pass should also be considered, i.e. whether the fish pass should function all year round, or only during specific times, e.g. during the migration period(s).

40. Considering the differences in swimming behaviour of the fish species, the vertical slot design was presented as a model for the hydraulic design of fish passes where fish can choose the vertical level at which to swim in the water column (between the bottom and the surface) when passing the slot, meaning that they can select from a variety of water velocities (decreasing from the surface to the bottom). Simply by a roughened bottom, the flow velocity within the roughness height of the stones can be reduced to one-third that of the maximum velocity occurring in a vertical slot as result of the drop height. The roughened bottom layer thus represents the migration corridor for species and size classes with limited swimming capacities. Nature-like fish passes probably provide the most diverse hydraulic possibilities for different species and age classes to migrate (later proved by the presentation of R. Gebler about the monitoring at the nature-like bypass channel at Rheinfelden).

9. LOCATION OF FISH PASSAGE FACILITIES AND ATTRACTION FLOW

41. Mr Gebler made a presentation on "Location and attraction of fishways". He stressed the importance of science as basis for the design and construction of fishways, emphasizing that biologists and engineers needed to work closely together in order to come up with the appropriate fish passage designs. He further pointed out that the location of the fish pass entrance was the most important factor in ensuring

the effectiveness of the passage as the entrance had to be easily detectable for the fish so that they could enter the fish pass.

42. Recommendations for good entrance conditions, including factors defining them, were given, e.g.: the entrance should be located at the bank side of the weir structure rather than in the middle of the weir; the mouth of the fish pass (fish pass entrance) should be close to the weir foot or turbine outlet; the location of the entrance at the pointed angle (between riverbank and weir) is better than at the obtuse angle; whenever possible, the entrance of a fishway should be positioned near the powerhouse (and not on the bank distant from the powerhouse) to make use of the turbine discharge to attract fish towards the fish pass entrance. In addition to the position of the entrance, the direction of discharge from the fish pass should also be considered, and this direction should be the same as that of the discharge from the powerhouse, while the water velocity and the ratio of the discharge from the fish pass outlet and the discharge from the turbine outlet should be sufficient to attract fish into the fish pass. In the case of highly turbulent water in the downstream section of the powerhouse (where the water is released from the draft tube or tubes), there is also the need to study the flow patterns in detail so as to detect those zones with adequate water flow in order to determine the right position of the entrance and direct the attraction flow in such a way that it can be detected by the fish. In this connection, it was mentioned that it was important to consider the turbine operation scheme, as different operation schemes create different flow conditions that could positively or negatively influence fish attraction. For example, one of the negative effects would be an eddy close to the fish pass entrance that would confuse fish and prevent them from finding the entrance. Such a situation has to be avoided and mitigated.

43. Furthermore, in the case where there are several active or potentially active water outlets in the same section of a weir (e.g. through the powerhouse, navigation channel, spilling over the weir), the area of the outlet through which most of the flow passes (and which therefore probably attracts most fish) should be chosen for the construction of fish passage facility. However, in many situations, owing to the different migratory behaviour of the fish, several fish passes and/or multiple fish pass entrances might be needed. This is particularly true for large or very large weirs and for weirs where the powerhouse and one or all other water outlets (i.e. spill gates and/or navigation locks) are distant or spatially separated (e.g. by an island or islands) from the powerhouse. In this connection, also the use (and usefulness) of a collection gallery with several entrances was explained.

44. The best entrance location for strong swimmers is close to the turbine outlet. However, for weaker swimmers and fish that move upstream near the shore (and that cannot reach the main entrance), an entrance is needed further downstream of the powerstation. A well-functioning example was shown and explained.

45. The workshop participants further took note of the fact that the effectiveness of attracting fish into a fish pass was the most critical aspect that should be considered in the construction of any fish passage facility. However, for judging the overall usefulness of a fish pass, attention must be given to the existence and the status of upstream habitats, and there must be an evaluation made of whether or not those are still suitable for fish.

46. In answering a question concerning the operating times of fish passes, it was clarified that in principle the fish passes should be open all year round and 24 hours a day (probably with the exception of the days with extremely high or low discharge conditions).

10. ANALYSIS OF FUNCTIONALITY OF DIFFERENT TYPES OF FISH PASSES AND MAJOR REASONS FOR DYSFUNCTION

47. Mr Zitek made a presentation entitled “Analysis of the functionality of different types of fish passes and major reasons for dysfunction”. When determining the functionality of a fish pass, this

functionality can be classified by rating the upstream migration (i) qualitatively (synonym with "effectiveness" – judgement of the number of species that pass), i.e. "fully operative" (all species and age classes can migrate), "operative" (all species except rare ones and nearly all age classes can migrate), "limitedly operative" (most abundant species and most age classes can migrate), "little operative" (only a few species and/or age classes can migrate), and "not operative" (no or only individual species and/or age classes can migrate); or (ii) quantitatively (synonym with "efficiency" – judgement of the ratio of the number of all individuals approaching the weir and the number of those able to pass), i.e. "fully operative" (all or nearly all individuals pass), "operative" (most individuals pass), "limitedly operative" (many individuals pass), "little operative" (few individuals pass), and "not operative" (only single individuals pass). The quantitative judgement of the total number of individuals passing is done separately for medium- and short-distance migrants. Finally, all three judgements done along a five-tiered scheme (species and age classes, proportion of the total number of individuals of medium distance migrants, proportion of the total number of individuals of short-distance migrants) are combined into an arithmetic mean value representing the overall functionality of the fish pass (rated from "1" – "fully operative", to "5" – "not operative"). The presented analysis of the functionality of a fish pass (whereby "functionality" here actually means "efficiency") was done by comparing the amount of fish downstream of the weir and the amount of fish caught in the trap at the upper end of the fish pass. The result of the analysis of fish passes in Austria indicated that 50 percent of fish passes had limited functionality.

48. The study of the fish pass efficiency in Austria also identified the major causes for the dysfunction of the fish passes. The major problems concerning the entrances were: (i) entrances positioned too far from the weir or not at the migration route of fish; (ii) entrances not reachable owing to insufficient minimum flow downstream of the weir (e.g. at water abstraction sites, fish were not able to reach the weir); and (iii) entrances not adapted to the prevailing water level (i.e. entrances "hanging in the air" so that fish cannot enter). Concerning the fish pass channels (chutes), the main problems were *inter alia*: (i) channels with too steep slopes or fed by too high a discharge, leading to too high flow velocities in the chute (i.e. beyond the swimming capacity of fish); (ii) pool drops too high for fish to go over; and (iii) discharge and water depth too low. In addition, the sill at the fish pass exit (water inlet) might be too high and the exit show too high flow velocities and high turbulence. The exit might also be too close to the weir.

49. In summary, the two major reasons limiting the efficiency of fish passes in Austria were the wrong position of the fish pass entrance (in combination with a lack of attraction) and too high flow velocities. It was found that "pool and weir passes" were less operative, while "vertical slot passes" and "nature-like passes" were more efficient. This could be mainly attributed to the inadequate construction of the steps between pools (too high, no bottom connection, etc.). Furthermore, maintenance also plays a crucial role.

50. As a conclusion, it was recalled that the functioning of the fish pass depends very much on: (i) entrance efficiency; (ii) passage efficiency; and (iii) maintenance.

51. In reply to the question concerning the height of an obstacle that a fish can negotiate by jumping, it was clarified that it was much better if fish did not have to jump at all as swimming was probably less energy-consuming than jumping.

11. FISH SPECIES AND BEHAVIOUR OF DIFFERENT SPECIES IN MONGOLIA

52. Mr Zitek started his presentation by pointing out that, most probably, from an ecological point of view, the Eg River at its confluence with the Selenge River had a very high relevance for the fish fauna of the Selenge River. Elaborating on this issue further, he formulated the "Eg–Selenge tributary hypothesis" that he built based on available international knowledge on the ecological importance of river confluences and the spawning behaviour of a similar species, the Sakhalin taimen, that prefers to spawn in river stretches with high sinuosity and riffles, exactly as found in the Eg River not far upstream of the confluence with the Selenge River, containing also larval and young fish habitats. Making reference to

studies of the importance of tributaries for the reproduction of *Hucho hucho*, he pointed out that the Eg River might have special relevance for the Selenge fish as the Selenge River is highly affected by mining activities in its catchment, whereas the Eg River is the most natural river in Mongolia containing the largest remaining population of the taimen in Mongolia. The finally derived hypothesis suggests that the braided section of the Eg River represents a preferred spawning place for *Hucho taimen* and other species moving in from the Selenge River (also because of impaired ecological quality there) and constitutes an important habitat for larvae and juveniles and for overwintering.

53. Mr Zitek then made reference to a monitoring study of the Tosontsengel fish pass, Zavkhan Aimag, where the target species for passage was *Hucho taimen*. The predominant fish species in the region were small-sized species such as *Phoxinus phoxinus*, *Barbatula toni* and *Cobitus melanoleuca*. Other larger species living in the area of the weir were *Brachymystax lenok* and *Thymallus arcticus*. At the Tosontsengel weir, a fish lock had been built but was only monitored to check whether fish would enter; passage through the lock was not studied. Only lenok spawners (55–68 cm) were found entering the fish lock, migrating from afternoon to evening (15:00–21:00), depending on the water temperature. In summer (when the fish lock was not operating), lenok were found jumping at the weir, which triggered poaching activity (i.e. about 500 fish captured) below the weir. Mr Zitek pointed out that this clearly showed that fish were accumulating downstream of the weir, which made poaching easier, and in this connection then emphasized again the importance of free fish passage and the need for well-functioning passes. Also, heavy problems occurred at the weir owing to icing and, eventually, the weir had to be blown up. The conclusions of the monitoring were that the fish lock had to be changed into a fish pass by adding traverse walls to create 5 chambers, each with a drop height of 65 cm (which is considered far too high by the resource persons). Further problems expected for future operation were late thawing of the fish pass, which was thought to represent a major reason for not functioning during the main migration period.

54. Mr Zitek then elaborated on the fish species of Mongolia, with special reference to the *Hucho taimen*, and noted that northern Mongolia's rivers were among the most unaffected river systems in the world. The Selenge River, forming the country's largest river system, flows north into Lake Baikal and holds a fish fauna consisting of at least 22 species, including *Hucho taimen* which is one of the world's largest salmonid species. Mr Zitek stressed that the *H. taimen* populations had globally declined across their range owing to anthropogenic impacts, primarily dam-building, pollution, deforestation, mining and overfishing. He then presented information on what was known and what remained still unknown with regard to the migration behaviour of *H. taimen.* Thereby, he laid a special focus on the home range and the migration distance of taimen. He expressed his doubt that the movement of taimen would only be so limited as suggested by the study in the upper Eg River. Based on the number of individuals (n=7, corresponding to 37 percent) that had moved out of the study area during the study (with their migration distances hence remaining unknown), he expressed the view that *Hucho taimen* might cover distances of more than 80 km more frequently than observed by the radio telemetry study in the Eg River. Consequently, he suggested that the migration distances were probably much underestimated and needed further studying. He therefore underlined the importance of the full home range not only for the dispersal and recolonization but also for the susceptibility to threats outside of the fishes' core range and stressed the need for considering the migrations of all life stages. He further emphasized that the sustainable management of taimen would need behaviour studies on a larger spatial scale and that poaching needed to be combated even more vigorously.

55. With regard to the behaviour and swimming capacities of the different fish species living in the project region, it was noted that similar species, such as Danube salmon (*Hucho hucho*), perch, pike or minnow, exist in Europe and that quite a lot of information about these species was available that could be used as starting point for designing fish passes in Mongolia. However, it was strongly recommended that also all information on migration, reproduction and habitat use of all the specific species living in the Selenge–Eg tributary system should be collected, as some of these species might show particular local adaptations of behaviour specific for this river system. In addition, highly relevant information will be

collected during the forthcoming monitoring programme. The data on behaviour will then have to be used in research pertaining to potential fish pass designs for Mongolia.

12. FISHWAYS AT SMALL WEIRS

56. Mr Gebler presented examples of fishways that could also be suitable for Mongolia (considering the weir/dam heights), e.g. rock ramps, fish ramps and bypassing water courses (all suitable for small/low-head weirs). Before explaining details of these structures, he made reference to the Tosontsengel weir that had already been mentioned by Mr Zitek in the preceding presentation. Mr Gebler expressed the view that the fish lock was not an appropriate solution for the Tosontsengel weir and made reference to the "best practice", which in this case would be the removal and reshaping of the cross-river structure or, even more appropriate, keeping the river free of any obstacle.

- ***Rock ramps:*** Rock ramps are often used when a weir is removed and the dissipation of the water energy has to be spread over a longer distance to avoid erosion. They can also be used when the upstream water level has to be fully maintained or to a certain extent (i.e. they function like a weir), and it is intended to spread the drop over some distance to provide gentle fish passage. This, however, needs space in the downstream area or in the upstream and downstream zone. Rock ramps can be created by placing rocks to reduce water flow, or by creating pool structures formed by rocks to allow fish to migrate upstream. There are several designs of rock ramps, e.g. irregular placement of the rocks, pool structure, rock cascade, etc. As mentioned, apart from providing fish passage, the rock ramps can also be used to dissipate the water energy over some distance.

- ***Fish ramps:*** A fish ramp is a sectional rock ramp (at a certain part or at one side of the weir). Fish ramps should be placed at the sharp angle of an oblique weir as fish are usually attracted to this point by the current; fish are thus guided towards the entrance of the ramp. Nowadays, it is recommended that the slope of the ramp should not be steeper than 1:30 (i.e. 3.34 percent) or 1:20 (i.e. 5 percent).

- ***Bypassing water courses:*** This type can be built in different ways, e.g. with pool and riffle structure (i.e. with a combination of deep/shallow sections, and variations in the steepness of the slopes) or as a rock cascade pass. Bypassing water courses can also be combined with other structures, e.g. a collection gallery, a vertical slot fish pass, etc., at the inlet and/or outlet area to regulate the water discharge, attract fish and facilitate their upstream migration. It should be noted that in Europe bypassing water courses are often designed to fulfil two objectives, i.e. first, to facilitate fish migration, and, second, to create instream habitats for fish breeding and nursing in order to mitigate hydropower impacts. However, note should be taken that the construction of bypassing water courses usually requires a very large space and that there is a limit as regards the height of weirs or dams at which they can be successfully used.

13. COMMON TYPES OF FISHWAYS AT LARGE HYDROPOWER PLANTS

57. Mr Gebler gave a presentation on "Common types of fishways at large hydropower plants" by showing and explaining various examples. He reported that, in principle, vertical slot passes or fish lifts were suitable solutions for high weirs or power stations, but that each case had to be studied individually in order to find the best solution. Up to a certain drop height, also bypassing water courses could be used if sufficient space were available. However, for very large and high dams that create high impacts on the ecosystem, it was noted that it was not easy to maintain or restore fish passage and that careful studies would have to be carried out at each site in order to come up with the best potential solutions. Mr Gebler further stressed that, in any case, fish passage facilities could only mitigate the impaired fish migration but not resolve all the environmental problems created by the dam.

58. In this presentation, he concentrated on vertical slot passes, saying that fish lifts would be the subject of a later presentation. However, he again briefly made reference to bypassing water courses, which had already been dealt with in the previous presentation. He thereby particularly reiterated here that there

was certainly a limitation as regards the height for which this type of pass could be selected (because of the space needed and the costs involved).

- ***Vertical slot passes:*** Construction of vertical concrete walls to create pools. Two consecutive pools are connected by one or two vertical slots. As for other fish pass types, the position of the entrance is the most important factor to allow fish to detect the fish pass and to enter it. The pool bottom should be covered by coarse material (i.e. gravel or small stones or rocks) to create a zone of low flow velocity. Vertical slot fish passes with multiple entrances to the chute at different levels could be considered in order to allow fish to enter at different downstream water levels. Mr Gebler reminded participants that often a vertical slot pass was used at the downstream and/or upstream part of a bypassing water course to balance fluctuation of water levels.

59. It was also noted that only the incorporation of fish passage facilities already at the initial planning phase of a dam construction project would allow the placing of the fish pass entrance (or entrances) in the right position (or positions) and allow the construction to be done with the most suitable structure for maximizing the effectiveness for fish migration.

60. Mr Gebler also made reference to two Mongolian dams, i.e. the Taishir hydropower plant on the Zavkhan River, and the Khovd hydropower station, and addressed some of the issues in relation to fish passage at these dams.

61. The audience asked questions about the solutions for varying water levels, e.g. flood events, and the possibilities for upstream and downstream passage at obstacles in the Rhine River. It was clarified that the former issue was extremely site-specific but there were obstacles where flood conditions were not a problem because of the gate management of the upstream and downstream weirs. It was further explained that the fish passage facilities were in the past mainly (if not exclusively) designed for upstream passage but that at some locations the fish could also migrate downstream because the fish pass exit was so wide (e.g. 60 m) that downstream migrating fish could use it more easily to enter the pass for downstream passage.

14. ECOLOGICAL REQUIREMENTS FOR THE CONSTRUCTION OF FISH PASSES

62. Mr Zitek gave a presentation outlining the ecological requirements for the construction of fish passes (i.e. how to establish/select the main parameters important for passage). He explained that in Europe the ecological requirements and the size of fish, particularly of the dominant and subdominant species, needed to be taken into consideration when discussing fish pass construction and the design of fish passes in order to ensure the provision of a migration corridor at the weir for the fish species concerned. In further describing this design approach, he introduced the concept of the “virtual hydraulic space for migration” whereby this space depends on the naturally existing and naturally expected species (i.e. including the species that are now absent but had been there originally), the species’ abundance and behaviour, the fish size, and the swimming capacity of the fish. Also, the river’s morphology and hydrology (i.e. its typology) have to be taken into consideration. All these aspects then lead to an overall idea of the potential fish pass design. The most important design considerations are thus: (i) the type of pass; (ii) the right entrance location (in respect of the natural migration routes); and (iii) the appropriate attraction flow (in terms of flow volume and velocity).

63. Decisions to be made include the

- ***Type of fish pass:*** this depends on the weir height, stream type, fish species/behaviours.

- ***Entrance situation:*** need to consider appropriate location, connection to the river bottom, attraction flow (amount of water, i.e. 1–5 percent of river or competing discharge; velocity of the water; flow patterns), fish species/behaviours, etc.

- ***Dimensions*** for
  - ***Technical pool passes:***
    - volume of discharge corresponding to river size or competing flow;
    - pool length/width/depth depend on the size of largest fish: minimum length = 3 times body length of fish, minimum width = 2 times body length, minimum pool depth = 5 times body height;
    - minimum slot width: 3 times body width (minimum 20 cm to avoid clogging).
  - ***Nature-like pool passes:***
    - minimum pool depth = 70–120 cm;
    - minimum depth at pool connection = 2.5 times body width (minimum 20 cm);
    - bottom roughness: to reduce water velocity.
- ***Slope:*** depending on swimming capacity of weakest fish.
- ***Minimum flow velocities:*** 0.3 m/s is the absolute minimum.
- ***Turbulence:*** in a river, turbulence naturally increases from downstream to upstream; depending on the species, drop heights in pass can be between 0.08 m and 0.2 m, with 80–160 W/m^3 of energy dissipation; for tropical lowland rivers, the energy dissipation should not be higher than 30–50 W/m^3.
- ***Periods of the year, when the fish pass should work:*** depends on the migration patterns of fish (all year, dry season, wet season, etc.).
- ***General features:*** protection of the entrance, changing water levels upstream and downstream; precaution measures for extreme events, etc.

64. It was further noted that, for ecosystems with fish communities where different species have different requirements, multiple entrances with different conditions, or even several and different passes, might be necessary to attract different fish species. Fishes could also be grouped and categorized based on their behaviour, and a compromise solution for the dominant and subdominant species could be sought and considered when designing a fish pass.

15. FISH LIFTS AND FISH SLUICES AT LARGE DAMS

65. Mr Gebler gave a presentation on "Fish lifts and fish sluices at large dams". He stressed that, at larger and higher dams, fish lifts and fish sluices were often the only type of fish pass that could be used. In the early years of fish pass construction, fish lifts and fish sluices were constructed on several dams in the then Soviet Union (i.e. on the Don, Volga and Kuban Rivers), Ireland, Scotland (the United Kingdom of Great Britain and Northern Ireland), and in South America (Salto Grande dam, Uruguay River; Parana River). In more recent times, such structures were built in France (e.g. at Golfech, Garonne River), the United States of America (Santee River, Susquehanna River) and Australia (Paradise dam).

66. The principle of a fish lift is similar to that of a passenger lift. The fish are attracted by a current to swim into a kind of tank. After a certain time, the entrance gate is closed and the whole fish tank is raised up, with the fish in it. In the upper position, the tank is tilted and the water, together with the fish, is drained via a chute or pipe into the headwater. Then, the tank is lowered in the initial position and the cycle starts again.

67. The operating principle of a fish lock is very similar to a navigation lock. Fish are attracted to swim in a downstream chamber. An open bypass creates a downstream flow to encourage fish to enter this chamber. The downstream chamber is connected by a vertical or sloping shaft to an upstream chamber. After a certain time the downstream gate is closed and the downstream chamber is filled up. When the

water level in the connecting shaft reaches the upstream water level, the fish can leave this shaft into the upstream chamber and the reservoir.

- The advantages of fish lifts and fish locks are: suitable for high obstacles; little space needed; relatively low cost (compared with other fish passes and in relation to the height of the obstacles); low sensitivity to variations of the headwater level.

- The disadvantages are: no continuous migration possible; in some situations, relatively low general efficiency; selective function, e.g. a low efficiency for small fish; higher operating costs than for other passes.

Their efficiency depends completely on the behaviour of the species. It is difficult to optimize the cycle when several species have to be taken into account.

68. As examples, Mr Gebler showed pictures and plans of several fish lifts and sluices on the Kuban River in the Russian Federation that had been designed for the migration of sturgeon. At the Krasnodar fish lift, the fish are attracted by a current to swim into a huge concrete chamber. After several hours, a movable screen forces the fish to swim to the upstream end of the chamber and into a container sunk in chamber bottom. Then the container holding water and fish is lifted and transported to the upstream reservoir where the fish are released. At the Fedorovskaya dam (downstream of the Krasnodar dam), a fish sluice was constructed instead of a fish lift. Both fish passage facilities, i.e. the Krasnodar fish lift and the Fedorovskaya fish sluice, were built in the 1980s and functioned very well. However, year after year, the number of migrating fish decreased, with a total breakdown of migration at the beginning of the 1990s. Most probably, the reasons were illegal fishing, loss of spawning grounds and/or the loss of access to them, and the interruption of the migration routes by impoundments.

69. Other examples are the fish lifts and sluices on the Volga River also designed for the migration of sturgeons. In these structures, the attraction flow is generated by small hydroelectric units. The attraction flow is charged through bottom outlets in the attraction chamber. Monitoring showed a very good functioning of these fishways, but also a rapidly decreasing number of sturgeons in the 1980s, with finally a complete collapse of the sturgeon migrations. Very significant is the difference in the number of fish counted at the first obstacle (first upstream of the mouth) and the second. The number of sturgeons at the second dam amounts to only 1 percent of the number of sturgeons counted at the first dam.

70. Newer fish lifts and sluices were constructed on the Santee River and on the Susquehanna River in the United States of America. As the four dams on the Susquehanna River blocked the migration run of the shad, the three most-downstream dams were equipped with fish lifts, whereas the upstream one received a fish ladder. Monitoring showed that the number of counted fish decreased rapidly with the distance from the mouth of river so that only a few fish were able to reach the spawning grounds upstream of the fourth dam. This led to the conclusion that the very expensive efforts of using lifts to restore fish migration in the Susquehanna River had failed, and, as a consequence, the removal of the first dam near the river mouth is now under discussion as the only sustainable solution to restore the shad population.

71. In conclusion, it can be said that fish lifts and fish sluices can be used at large dams. If well designed, such fish passage facilities may work successfully. However, they can never solve the problem of the high impacts of the dam construction on the ecosystem of the river. Questions for deepening their understanding were raised by the participants and answered by the resource persons.

16. FISH PASS DESIGN IN RELATION TO RIVER TYPES AND RELEVANT FISH FAUNA

72. Mr Zitek further presented the development of design criteria for different river types and their relevant fish fauna. He mentioned that 76 native fish species lived in Mongolia, showing a distinct distribution according to the major catchments (Amur watershed, Great Lakes watershed, Ob watershed,

Yenissei watershed). Mr Zitek then showed pictures of the fish fauna explaining what conclusions concerning the way of living of the fish could be drawn from their body form. When dealing with the design and construction of fish passes, river ecosystems could be simplified into different “biocoenotic stream types” that take into consideration the ecoregions (large areas with a distinct ecosystem and biodiversity) and abiotic settings as well as the typical longitudinal ecological zonations of rivers (with the assumption that the same zone should comprise species with the same bioecological characteristics and behaviours). Species compositions characteristic for different “biocoenotic stream types” could be used to develop design criteria for fish passage facilities that could then be applied to all rivers of a similar “biocoenotic stream type”.

73. It was noted that only limited information for species such as lenok and taimen is available, but information on biology and migratory behaviour of some other fish species, which also exist across Europe, could be collected as a starting point. However, it was recommended that research studies should be undertaken to gradually build up databases on the biology and migration behaviour of selected fish species important for the design of fish passes in Mongolia. The objective here should clearly be to meet the requirements of as many species as possible, with a focus on those species depending most on reproductive short-distance (< 30 km), medium-distance (30–300 km) and long-distance (> 300 km) migrations. In addition, as some species also need lateral connectivity to complete their life cycles, this aspect also needs to be considered. The historical distribution of fish species and the amount of habitat that can be made available for fish species should be also considered when prioritizing the sites for potential fish passes.

74. It was also reiterated that the construction of fish passage facilities should be incorporated right from the beginning of a dam construction project in order that appropriate design and the correct position of the pass (or passes) could be ensured. In summarizing, Mr Zitek stressed that the presented approach should help to simplify the decision of fish pass construction in different regions of Mongolia by defining different fish communities typical for “planning regions” where similar criteria apply, which would lead to the transferability of design criteria.

17. DESIGN OF VERTICAL SLOT PASSES

75. Mr Gebler gave a presentation on the design of vertical slot passes. He stressed that for the good functioning of a fish pass it was necessary to consider not only the biological and ecological requirements of fish but also the hydraulic requirements that need to be respected to achieve to good flow patterns. To emphasize this, he showed examples of acceptable and undesirable flow patterns, and how to achieve the former and avoid the latter. A particular role in achieving desired flow patterns in the vertical slot passes is played by the shape of the cross-walls and the hooks.

76. A good vertical slot design should aim to have no short circuit current in the pool, this in order to provide good energy distribution and dissipation. In addition, there should be no swelling current along the sidewall. There are different designs of vertical slot hooks that control the direction of water flow. The number of cross-walls, defining the number of slots and pools, depends on the height difference between the maximum upstream and the minimum downstream water levels (i.e. head) and the difference in drop chosen as a function of the swimming capacity of the fish at this location However, as the upstream and downstream water levels may vary during different periods of the year, the design should create conditions that are favourable for migration at least during the most important migration period (or periods) if not the whole year round. To emphasize this, Mr Gebler showed examples of the functioning of vertical slot passes for different flow situations with differences in headwater and/or tailwater levels. He reiterated that the discharge to attract fish had to be higher than the discharge needed in the pass, which necessitates the addition of discharge right at the entrance of the pass.

77. Following Mr Gebler's presentation, some general discussion centred on the questions of the usefulness of fish passes. In addition, questions were asked concerning the reasons for not constructing fish passage facilities (with particular reference to the Irkutsk hydropower plant in the Russian Federation, apparently constructed in 2013 without a fish pass) and the benefits of either fish lifts or trap-and-transport. The resource persons could not give any explanation as to why no fish pass had been constructed at the Irkutsk hydropower plant, but Mr Zitek mentioned that among the most common reasons for not constructing fish passes were: (i) no legal requirements for construction of fish passes; (ii) no Environmental Impact Assessment (EIA) required or carried out; (iii) no migratory species present; (iv) no suitable habitat upstream; (v) it had been forgotten to address fish passage issues; and, unfortunately, (vi) reasons of potential costs involved. It was, however, emphasized that the cost issue should never be a criterion to exclude fish pass construction. To underline the usefulness of trap-and-transport, the example of the Garonne River in France was mentioned, where a series of dams blocked the passage and where it was deemed inappropriate to construct fish passage facilities at each of these obstacles owing to the large number of obstacles and the delay fish might experience in passing all the obstacles. However, attention was drawn to the fact that there was only one migratory species (i.e. salmon) in limited numbers present, which eases the use of trap-and-transport. The passage of very high numbers of fish at single obstacles could probably be better managed by using a fish lift. In any case, the distance and the ecological conditions between the downstream location of collection and the upstream location of release play an important role in the choice of the method.

78. One workshop participant suggested that, should the Eg River dam be constructed, new spawning areas should be created just downstream of the dam (i.e. between the dam and the confluence of the Eg River with the Selenge River) in order to compensate for the loss of habitat that would occur by the submersion of one of the very important Eg River tributaries.

18. GENERAL HYDRAULIC DESIGN

79. Mr Gebler presented basic hydraulic calculations needed for the hydraulic design of fishways.

From the hydraulic design perspective, the following are the recommended dimensions of vertical slot passes:

- ***minimum slot width*** = 3 times the body width of the largest fish (which takes into consideration the ***ecological requirements***);

and

- ***pool length*** = 10 times slot width (minimum pool length = 3 times body length of largest fish);
- ***pool width*** = 7.5 times slot width (minimum pool width = 2 times body length of largest fish);
- ***pool width/length ratio*** = 0.75 (the latter three taking into consideration the ***hydraulic requirements***).

80. Taking into consideration the ecological requirements of different fish species and the hydraulic requirements, it was noted that the maximum flow velocity in the passes would have to depend on the swimming capacity of the weakest natural local fish species. Mr Gebler then provided information on how to calculate the flow conditions under a constant discharge, and made reference to the types of energy to be taken into consideration, i.e. position energy and kinetic energy, and the law of conservation of energy. He recapitulated that the velocity in the pass was influenced by the height of drop (water head) between two pools and the discharge controlled by the cross-section area of the openings (slots). Another factor influencing the velocity in the pass is for example the choice of the bottom substrate, i.e. a rough bottom surface reduces the velocity at the bottom layer. Mr Gebler further made reference to the energy dissipation

in the pools and how to calculate this energy dissipation, which stands as a surrogate for turbulence and, hence, for the ease with which fish can pass a pool. The Poleni equation was also explained.

81. Mr Gebler then informed the participants about further technical details of fish passes. In addition to hydraulic considerations, other issues that need to be considered in order to enhance the effectiveness of fish passes include:

- The ***location of the exit*** should be far enough from the weir/powerhouse.
- *A **beam (downflow baffle)*** could be installed at the fish pass exit (water intake) parallel to the main water current, with the lower edge 30 cm below the water level to keep floating debris out of the fishway.
- *A **bottom connection*** should be established between the river floor and the fish pass entrance.
- ***Auxiliary flow into a fishway*** to provide additional discharge to better attract fish; the water can be sent through a pipe, then passed through a pivoting screen to reach the entrance of fishway.
- If needed owing to the volume of the competing discharge, the ***discharge at the entrance*** could be much higher than the discharge in the pass itself in order to attract fish to enter.
- ***Lighting conditions*** need to be considered. Fishways should be exposed to natural light and should not be covered with material that plunges the pass into darkness. If cover is necessary, it should be translucent. If illumination is necessary, this should be done according to natural light conditions and/or the preferences of the species (if known).

Questions from the participants were then answered.

19. CASE STUDY: VERTICAL SLOT PASS AT A HYDROPOWER STATION

82. Mr Gebler presented the case study for defining the design of the new fish pass at the existing hydropower station in Koblenz on the Moselle River in Germany. This hydropower station, being located near the confluence of the Moselle with the Rhine River, to which the Moselle is a tributary, is the first obstacle for the upstream migrating fish coming from the Rhine River. The existing fish pass was largely impassable because of the pools that were too small and the entrance into the pass that was located too far downstream. The first step in designing the new fish pass was determining the right position of the fishway and its entrances at the right bank where the main current occurs (owing to the turbine outlets). The second step was the choice of the most appropriate type of pass. Owing to the little space available on the bank, a nature-like fish pass could not be considered and, therefore, a compact vertical-slot pass with multiple entrances was determined as the best choice. To find the right position for the entrances, an intensive examination of the local flow conditions downstream of the powerhouse at different discharges and operating conditions was carried out. These *in situ* investigations showed the existence of an area with low turbulence along the end of the draft tubes.

83. Three entrances were designed for fish to enter this fishway.

- **Entrance No. 1**: Directly below the powerhouse at the end of the draft tube, parallel to the powerhouse.

Purpose: Generate an attraction flow along the end of the draft tubes. Thus, also fish in the middle part or even at the opposite side of the fish pass entrance (i.e. at the distant end of the powerhouse) can be attracted.

- **Entrance No. 2:** Directly below the powerhouse at the end of the draft tube, parallel to the main flow.

Purpose: Generate an attraction flow along the river bank. Thus, fish approaching the dam in the expected main migration corridor are guided into the fishway.

- **Entrance No. 3:** At the bank about 50 m downstream of the powerhouse.

Purpose: Provide bottom connection and an additional way to enter the pass, especially for species with low swimming capability.

84. The next step in the design study was the identification of the relevant water levels upstream and downstream. To generate a readily perceptible attraction flow even during periods with high tailwater levels, a preferably constant opening area is needed. Owing to the fluctuations of the tailwater of about 3 m, sluices gates consisting of three movable parts each were designed at the entrances for the water level regulation as a function of the tailwater level. The pool dimensions were designed as a function of the largest local fish species (i.e. Atlantic salmon) and the special requirements of the fish species exhibiting schooling behaviour. The needed discharge in the fishway was calculated according to the slot dimensions and the drop between the pools. Based on these dimensions, the input of energy in the pools was to be calculated and checked that the maximum allowable amount was complied with.

85. The tailrace current at a powerhouse is dominated by the discharge of the power station. The attraction flow of the fishway has to compete with this main flow. According to Larinier, the recommended discharge at the entrance of the fishway is 1–5 percent of the competing flow. In this case, the discharge through the fish pass ($Q_{fishpass} = 0.78\ m^3/s$) does not create a sufficient attraction flow. Therefore, an additional discharge of about $4.0\ m^3/s$ is needed. The attraction flow $Q_{attraction} = Q_{fishpass} + Q_{bypass} = 0.78\ m^3/s + 4.0\ m^3/s = 4.78\ m^3/s$ equals approximately 1 percent of the maximum competing flow (i.e. maximum discharge of powerstation). To minimize financial losses for the hydropower company, a small turbine was installed to produce hydroelectric energy using the additional discharge of the bypass (i.e. the bypass discharge, Q_{bypass}) before adding it to the fish pass. The outlet of this turbine was placed at the bottom of the first large pool at the mouth of the fishway (fish entrance). In this way, the discharges of fishway and the small turbine join in this pool and the cumulated discharge is distributed to the three different entrances.

86. Because of the importance of this first obstacle and its location in the city of Koblenz, a large visitor centre and a monitoring facility were located beside the fishway to show and explain the importance and the function of such a fishway. The monitoring results indicate that the structure is functioning very well.

87. Mr Gebler took the opportunity to explain and stress the need for several entrances at certain power stations and under certain conditions.

88. The participants raised questions concerning, *inter alia*, the cost of construction of the Koblenz fish pass and its efficiency. It was reported that the construction cost had been about € 3.5 million (equivalent to about USD 4.8 million[1]). It was further mentioned that the fish passage facilities, i.e. one near-natural bypass and one vertical slot pass, built at the newly constructed powerstation at Rheinfelden on the Rhine River cost together € 6 million (equivalent to about USD 8 million[2]) (€ 5 million [or about USD 6.7 million] for the near-natural bypass and € 1 million [or about USD 1.3 million] for the vertical slot pass), which is only about 1.5 percent of the total construction cost of the new hydropower plant (about € 400 million; equivalent to about USD 530 million). Concerning the efficiency of the new Koblenz fish pass, it was said that monitoring was being carried out under the responsibility of the German Federal Institute of Hydrology (BfG; under the German Ministry of Transport) but that the resource persons did not yet have figures at hand. However, it could already be seen that the new fish pass was functioning better than the old one.

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[1] Based on the year 2011 Euro/USD average exchange rate of about 1.39 (2011 was the year when the fish pass was put into service)

[2] Based on the year 2010 Euro/USD average exchange rate of about 1.33 (2010 was the year when the fish pass was put into service)

20. MONITORING

89. Mr Zitek gave a presentation on “Monitoring of upstream migration”. While reiterating that ecological benefits can be obtained from the construction of fish passes, he emphasized that it was generally necessary to carry out appropriate monitoring in order to learn about the behaviour and migration of different species of fish as well as to evaluate the effectiveness of fish passes.

90. Mr Zitek stressed that monitoring needed to take into consideration two components, i.e. (i) the ***abiotic monitoring*** (e.g. temperature; flow velocities; discharges; drop height; turbulence; time of year/day; moon phase; etc.), which leads to an abiotic characterization; and (ii) the ***biotic monitoring***, i.e. the monitoring of fish (with the two subcomponents “capture-independent monitoring”, e.g. using visual observation, electric currents, hydro-acoustics, and “capture-dependent monitoring”, e.g. fish catches, marking/tagging experiments). The ***biotic data*** to be collected include *inter alia* species characteristics, number of species, number of fish, fish length, weight, age, developmental stage, position, and migration pathway. This leads to a biotic characterization.

91. Mr Zitek then recalled the definitions for “efficiency” and “effectiveness”. Monitoring can be done by using different methodologies, i.e. direct monitoring (e.g. with a fish counter; video monitoring; passive/active gears to collect fish; telemetry using radio transmitters) or indirect monitoring (e.g. by counting upstream spawning places). The monitoring and assessment of the functioning of fish passes should include two aspects, which are: (i) the monitoring of the entrance efficiency; and (ii) the monitoring of the passage efficiency. Monitoring and assessing the efficiency could *inter alia* provide information on the proportion of migrating fish at a specific fish pass (by using fish counts), the efficiency of multiple fish passes on a catchment level, and the effect of connectivity measures on fish populations. Should the results show that a fish pass is not efficient, the cause or causes have to be searched for and eliminated.

92. Below are listed examples of methods for the monitoring of upstream migration:

- ***Trap monitoring*** – By setting a trap at the entrance of fish passage (lower trap), it is possible to monitor whether or not fish enter the pass; by setting a trap at the end of fish pass[3] (upper trap), one can monitor whether or not fish can master the entire length of the fish pass. In using this method, the upstream outlet should be blocked in order to prevent fish entering from upstream through the fish pass outlet (i.e. the water intake). Fish in the pass could also be tagged to monitor up to which step in the passage they could migrate and where delays might occur. Where there are very large numbers of small fish, as is the case in many Southeast Asian countries, traps could be set for a certain period of time in order to obtain representative catches of fish. Samples could be taken to monitor the species composition and estimate the number of fish that pass during a specific period, and the results could be used together with factors such as the total volume of fish and swimming speed in order to estimate the total number of different fish species. The advantage of this method is that fish can be counted, measured, weighed and tagged. The challenges are the selectivity of traps, the risk of damage to fish and the heavy equipment needed in most cases.

- ***Video monitoring*** – A video camera could be installed above the water surface (bird’s-eye view), or at an underwater window (lateral view) to monitor fish that swim through the pass. In this way, the number of fish might be counted while some species may also be identified based on the body shape, the characteristics of their movement, etc. However, this might only be suitable for temperate areas with a small number of fish that can more easily be recognized, but it might not be appropriate for tropical countries with very large numbers of small fish and highly turbid water. Video monitoring has the advantage that the fish do not need to be touched, there is high precision as regards the time of fish passing and the labour needed is relatively little. A challenge is that light might prevent fish from passing, but there are ways to avoid this.

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[3] i.e. at the fish pass exit (water intake)

- ***Fish monitoring using a counter*** – The use of fish counters, e.g. the Vaki counter or Didson counter, is also a possibility for monitoring. The advantages are limited interference with the fish and the ease of counting and documenting when dealing with single-species situations. However, there can be problems when several species are present and passing at the same time. To judge the efficiency of a pass or to document habitat use, tagging can be used. Tags can be passive integrated transponders (PIT-tags) telemetry tags.

- ***Application of radio transmitters*** – Fish are equipped with transmitters that are placed, for example, in their abdomens and send out radio signals allowing for a determination of the position of a fish. By this method, information on fish movements over a specific period can be obtained and this could demonstrate whether fish are attracted to the fish pass entrance or to another location below the weir (e.g. the turbine outlet). Thus, using radio telemetry, in connection with other data, enables the expert to provide essential explanations on the reasons why fish are not able to negotiate the passage into the upstream water. In particular, incorrect entrance locations and inappropriate attraction flow conditions can be detected. Moreover, radio telemetry studies might be useful before planning a fish pass to learn about the spatial behaviour of fish below an existing weir, and to determine the most appropriate location of a fish pass entrance so as to avoid later problems or failure. The cost of radio telemetry studies and equipment can vary depending on the data to be collected and the specific technique used. The major problems when using radio transmitters are that (i) the antenna that protrudes from the body of the fish could cause an infection; and (ii) the battery life of transmitters could be short owing to the tag/battery size or if tags are not stored properly. The efficiency of the transmitter also depends on the water depth and conductivity. Acoustic 3-D telemetry can only be used where there is no noise (e.g. caused by air bubbles) or a low noise level.

93. Mr Zitek then explained the advantages and challenges of monitoring at the example of the Villach fish pass on the Drau River in Austria. He gave a description of the location and the design of the weir and the fish pass, explained the experimental set-up as well as the methodological approach, described the activities, presented the results and valued these results as a basis for needed modifications. He thereby clearly demonstrated the usefulness of such studies in determining the efficiency of fish passage facilities.

94. Various questions from the participants concerning monitoring issues, costs of monitoring equipment and spawning time of species were answered. It was pointed out that in the case of planned dams monitoring had to be done prior to dam construction in order to have reference values (baseline study). Monitoring has to continue during the construction phase to assess the impact of the construction works. Once the fish pass is constructed, the pass efficiency has to be monitored and evaluated.

95. Mr Zitek then presented the case study of habitat monitoring of the Lech River, which used the mesohabitat mapping method based on aerial photographs as well as electrofishing and visual observations. Mesohabitats are river units with similar characteristics, e.g. depth, flow velocity, substrate and pool/riffle sections. Mr Zitek also made reference to a micromapping of *Hucho hucho* by snorkelling. The microhabitat assessment led to the preparation of an “index of habitat use”, with the ultimate objective being to protect the species by re-creating habitat for all life stages of *Hucho*.

96. Mr Gebler then explained some other common methods for monitoring fish migration through the fishways at the examples of the Wyhlen fish pass (with a counting basin) and the Rheinfelden fish pass (with a fish weir and a counting basin). As Mr Zitek, he also drew attention to the challenges one is facing when using traps, e.g. that traps are selective gear (depending on mesh size). If a trap with a small mesh size is used, the trap could be clogged with fish and fish could be injured, while if a large mesh size is used, small fish will be able to pass through the meshes. An alternative is to use a “capture basin”, which is a specific construction feature next to the fish pass, allowing fish to be captured during their upstream migration. By closing the outlet of the fish pass (i.e. the water inlet), the water drains now through the capture basin where fish accumulate. As fish cannot leave this capture basin or the fish pass, they can be

collected from this basin. By using this method, which gives reliable monitoring results, all sizes of fish can be collected without injuries. The counting basin is easy to operate and fish can be easily removed for examination. One of the greatest advantages is that in particular small fish can be collected. However, a disadvantage could be that very large amounts of fish could accumulate in the capture basin; timely emptying of the basin is therefore a condition. Operation of the facility has high labour requirements.

97. Questions for clarifications, in particular concerning the counting basin and its design, were asked and answered. It was in particular clarified that when gathering the fish for removal fish do not risk remaining without water as the bottom of the counting basin has a special design (inclined bottom and a duct).

21. MAINTENANCE OF FISHWAYS

98. Mr Gebler gave a presentation on the maintenance of fishways. It was noted that regular maintenance was essential for the correct functioning of fish passes and that thorough initial planning of the maintenance measures and integration of devices into the fish pass could reduce maintenance (i.e. frequency and duration of interventions) in the long term (e.g. the installation of beams, i.e. downflow baffles, to reduce floating debris). It was also noted that different types of fish passes had different maintenance requirements. For example, “rock ramps” need low maintenance, only collection of waste and sludge removal once in a while; “fish ramps” need some more maintenance; “bypass water courses” need regular maintenance (inlet and outlet); and “vertical slot passes”, although having relatively low maintenance requirements in general, also need to be inspected after high water flows to remove debris that may have accumulated.

99. It was clarified that the maintenance was the responsibility of the owner of the weir or dam, and that at hydropower stations in most cases the staff of the power station took care of the maintenance activities.

22. ECOLOGICAL REQUIREMENTS OF DOWNSTREAM MIGRATION

100. Mr Zitek presented the ecological requirements of downstream migration. He informed the workshop about the known types of downstream migration, e.g. post-spawning migrations, larval drift, juvenile drift or migration, wintering migrations, catastrophic drift, and eel spawning migrations. The results of a study undertaken in Europe showed that several species of fish do migrate upstream to spawn and that these adults then perform post-spawning downstream migrations. Also larvae and subadults subsequently migrate downstream. There are various forms of downstream migration, i.e. passive migration (fish randomly move downstream); active migration (fish is heading straight downstream); and active–passive migration.

101. Mr Zitek made explicit reference to Russian studies that showed a zonation of downstream migrations in reservoirs. It is important to consider this downstream migration behaviour when defining the ecological zone of water intakes (e.g. turbines). It is important to understand the different types of downstream migration in order to design effective solutions for preventing fish entering the turbines and guiding fish towards a downstream fish passage facility. Fish of all age classes might suffer severe injuries during turbine passage by collision with parts of the turbine, rapid pressure changes, turbulence and shear as well as cavitation.

102. Studies to assess the efficiency of fish passes for downstream migration can be done at various scales, e.g. experimental studies (reduced scale), field monitoring. However, at present there are still not many study results available concerning the effectiveness of downstream fish passage facilities.

103. An example of a study, where drifting larvae were sampled (using automatic sampling over 24 hours), was given. Sampling stations were set at the upstream, middle-stream, and downstream section of a canal along the Danube River in Austria to collect larvae; the larvae were identified to species level and measured. The study showed that there were larvae of different species, sizes and developmental stages, hatched from eggs spawned at different times of the year, in the same drift sample. The result also showed that there were differences in migration patterns, based on species, season, time of day (day–night), temperature, distance from shorelines, etc. Therefore, the set-up of any monitoring of downstream migration of larvae and juveniles needs to take these factors into consideration.

104. The workshop also took note of equipment that could be used for monitoring downstream migrations, which includes *inter alia* larval traps; acoustic telemetry (for assessing the 3D position of fish); and Passive Integrated Transponder (PIT) tags. Pressure measurements can be carried out with dummies, i.e. “pressure fish”, to document rapid pressure changes that can cause problems to fish. Fish with swim bladders are even more vulnerable to barotrauma. It was also noted that, by assessing turbine passage characteristics and turbine mortality of fish, a model (simulation tool) could be developed to assess potential effects of a series of hydropower plants and turbines on downstream migration mortality and impacts on fish populations in the ecosystems as a whole.

23. DOWNSTREAM MIGRATION FACILITIES – TECHNICAL ASPECTS

105. Mr Gebler presented the technical aspects of downstream migration facilities. He informed the workshop about the aims of creating downstream migration facilities, which solve two problems. First, they prevent fish from entering the turbines and thus protect them from being injured. Second, they offer them a way to swim downstream bypassing the turbines. The underlying concept is to install barriers and bypasses. Options for downstream migration include: (i) bypasses; (ii) trap and transport; (iii) adaptation of turbine and weir management (e.g. to stop the turbines for a short time during intense migration periods to allow fish to swim downstream without being injured); and (iv) fish-friendly turbines (optimization of turbine discharge, blade angle, etc. to reduce fish mortality).

106. The common method that has been practised to physically prevent fish from entering the turbines is the use of bar screens. However, fish could still be trapped and injured at the screen owing to strong hydraulic power (water pressure). There are possibilities to reduce the likelihood of fish being trapped and/or injured at the screen, e.g. by reducing the bar interspaces and increasing the screen areas, thus reducing water velocity (and hence hydraulic pressure). However, the narrower bar spacing means higher maintenance needs. At smaller hydropower plants with moderate discharges, this can, to some extent, be avoided by using flat angles for the screens. Currently, some smaller hydropower plants use horizontal screens to reduce fish mortality by preventing fish from entering the turbines; however, problems with accumulated debris exist, requiring regular cleaning. It should be noted, however, that while a screen can prevent large fish from entering the turbine, small juveniles, larvae and fish eggs might still be injured by the turbine passage.

107. Mr Gebler presented information concerning examples of screens used in France. At Halsou on the Nive River, bar spacing of 5–6 cm, 3–4 cm and 2.5 cm showed, respectively, 10–20 percent, 60–70 percent and about 90 percent efficiency in preventing fish from entering the turbines. At St. Cricq on the Gave d’Ossau River, the total efficiency was 85 percent with a 2.5 cm bar spacing. Mr Gebler also reported on the Plauen hydropower plant on the Saale River in Germany, where a horizontal screen was successfully in use.

108. Other ways of trying to prevent fish from entering turbines include chain curtains, travelling screens and wedge-wire screens. In addition, there exist behavioural barriers that use visual, acoustic, electrical or hydrodynamic stimuli to scare away fish but they are of limited efficiency and were not recommended by the workshop resource persons.

109. To facilitate downstream migration, the provision of a bypass is common; however, this bypass needs an attraction flow to guide fish to the entrance of the bypass. A sufficient amount of water is needed to provide free passage for downstream migration during a certain period of time. As bypasses for downstream and upstream migration might be different channels, an extra amount of water is often required for downstream migration purposes.

110. Mr Gebler further elaborated on the use of other methods, i.e. (i) the temporary reduction of turbine discharge and opening of gates; (ii) the optimization of turbine blade angles; (iii) the temporary stop of several turbines; and (iv) the use of fish-friendly turbines, e.g. the hydrodynamic screw with a low rotational frequency and the water wheel. The hydrodynamic screw was mentioned as being appropriate for passing juveniles and larvae in downstream direction, but as being limited with regard to the height of weirs.

111. Furthermore, information was shared concerning a study undertaken in France where acoustic equipment was used to try to prevent fish from entering water intakes. It was pointed out that this study, however, showed that such equipment did not fulfil its purpose.

112. In summarizing, it was emphasized that a combination of several methods and strategies might be required in order to support downstream migration of different species and different developmental stages of fish.

113. At the end of the scheduled presentations, Mr Erdenebat acknowledged that there was a lot of experience available from foreign countries and thanked the presenters Mr Gebler and Mr Zitek for having shed light on so many interesting issues that were quite complex and sometimes even complicated. Mr Erdenebat also again thanked FAO for having provided funding and organizational support for the workshop.

24. DISCUSSION ON AND PRELIMINARY DEVELOPMENT OF THE POTENTIAL SOLUTION(S) FOR FISH PASSAGE AT THE PLANNED HYDROPOWER STATION ON THE EG RIVER

114. The workshop resource persons very much welcomed the proposal by the Taimen Conservation Fund (TCF) of Mongolia to give a presentation at the start of the fifth day of the workshop to describe in more detail the goals, structure, activities, achievements and future plans of TCF, and to recapitulate information concerning the taimen’s biology and population structure. At the same time, the resource persons requested that the Egiin Gol Hydro Power Plant Project Unit (EGHPPPU) presented more details on the planned Eg River hydropower project before the workshop would explore further the issue of the planned construction of this power plant and discussed potential solutions for fish passage should the planned hydropower station be built. The latter presentation was deemed absolutely crucial before any further discussion could take place.

115. Thus, at the start of the fifth day of the workshop, two presentations were made by the TCF and the EGHPPPU, respectively.

24.1. Presentation by the TCF

116. Mr Erdenebat, a member of the TCF of Mongolia, presented the relevant information concerning TCF and the taimen’s biology and population structure. He stressed that taimen were naturally rare, slow-growing and long-living and had a low reproduction rate, thus being highly vulnerable to overfishing (e.g. poaching) and environmental degradation. Spawning normally occurs between mid-May and end of June. A taimen size-distribution study based on 274 fish showed that the largest number of these fish was in the

range of 60–80 cm. The density was about 10–25 fish per kilometre of river. It was further clarified that the often-cited 92 km distance covered by a taimen was during downstream migration.

117. Poaching is still a severe problem, and the TCF has created a ranger system along the Eg and Uur Rivers, where 17 rangers, 4 volunteers and 3 guards try to keep poachers away, but sometimes with great difficulty. However, without this system, taimen would even be rarer. The TCF is also initiating studies, fighting for sustainable management of taimen and managing the catch-and-release recreational fishery in the Eg River.

24.2. Presentation by the EGHPPPU

118. Mr N. Nasanbayar, adviser to the EGHPPPU, gave the requested presentation on behalf of the EGHPPPU. He presented more detailed information about the intended construction of the Eg River hydropower plant and explained that – from a governmental point of view – there was a necessity to develop hydropower in Mongolia. In this connection, it was mentioned that an important aspect was that this hydropower plant was seen as becoming a reliable source of energy supply, thus being a priority project for implementation in the Government's policy. He also described the strategic importance of hydropower development for the independence of Mongolia from foreign energy supply and for the prosperity of the country. Mongolia is a country with a harsh and dry climate with greatly limited surface water resources, and it was believed that the construction of the Eg River hydropower plant dam would create an opportunity to increase the surface-water resources. Moreover, it is seen as contributing to the improvement of climate conditions. Most of Mongolia's energy production comes so far from coal-fired power plants, resulting in air pollution of the urban areas and, moreover, causing a heavy impact on the population's health. The development of the Egiin Gol power plant gives an opportunity to avoid burning about 400 000 tonnes of brown coal annually.

119. The technical details presented concerning the dam project included information and data on the height of the dam (95 m; crest elevation at 903 metres above sea level [m.a.s.l.]), the length of the crest (710 m), the dimensions and the volume of the reservoir (50–60 km long; 125 km^2; 4 billion m^3), the water level fluctuations in the reservoir and downstream of the dam (i.e. the different intended water levels [in m.a.s.l.] as a function of the different discharges and operational stages), the calculated sediment accumulation in the reservoir (25 million m^3), the turbine discharges, a review of the hydrology of the Eg and Selenge Rivers, the intended operational scheme (with hydropeaking during main operational hours, mainly in winter) as well as the planned all-time base flow (i.e. 40–50 m^3/s, which corresponds to 10 percent of the maximum turbine flow). It was also mentioned that the evacuation channel should be created by deepening the existing river channel.

120. The hydropower plant will be equipped with Francis turbines of 55 MW production capacity. The peak operating hours of the turbines seem to be planned for the late afternoon and evening (i.e. approximately between 17:00 and 23:00). The minimum filling height of the reservoir would be at 875.30 m.a.s.l.; the maximum filling height would be at 900.00 m.a.s.l. and the normal filling height would be at 892.40 m.a.s.l. The water level variations in the reservoir could thus exceed 24 m.

121. With an estimated sediment accumulation rate of about 250 000 m^3/year in the reservoir and an expected lifetime of the dam of 100 years, about 25 million m^3 sediment will accumulate in the reservoir. However, the aforementioned sediment accumulation rate is an estimate and no concrete data on sediment transport and erosion are available. The workshop resource persons strongly believe that this will cause an enormous sediment deficit in the Eg River downstream of the dam and in the Selenge River that cannot be ignored, either in terms of tonnage *per se*, or in terms of negative impact on the aquatic habitat and the living components.

24.3. Discussion on fish ecological and fish passage issues in the Eg River

122. The workshop participants exchanged views and discussed the direct and indirect impacts of the dam on fish and fish passage. With regard to fish passage, it was felt important to consider the physiological needs of fish and other aquatic animals, their spawning, nursing and feeding habits, their habitat preferences (summer/winter habitat), their need for shelter, and their recolonization strategies – all essential to the viability of populations of many riverine species and the maintenance of their genetic diversity. Participants discussed challenges in maintaining upstream and downstream migration of fish as well as the transformation of riverine habitats to stagnant water conditions, changes in physical and chemical conditions of the water and changes in species composition.

123. The workshop resource persons reiterated their view that based on their assessment during the field visit and the additional information and data provided earlier in the day – from a fish ecological, biodiversity and fisheries point of view – the dam must not be constructed at the planned location on the Eg River because it would inflict irreversible damage to the aquatic ecosystem. In fact, the excellent ecological status of the Eg River just upstream of the confluence with the Selenge River (and also further upstream in the watershed) calls for the preservation of the given morphological and hydrological characteristics. The expected impacts on the Eg River environment downstream of the dam and the Selenge River environment will be determined by:

- changes in the discharge regimes;
- changes in the erosion/sedimentation dynamics (and expected downstream erosion);
- hydropeaking (in particular in winter when ice covers the rivers);
- impacts on the aquatic environment upstream of the dam inflicted by the reservoir.

These factors are judged so important for the fish that a due account of these facts during a comprehensive and serious EIA study will necessarily lead to the result that this dam should not be constructed. While the construction of fish passage facilities could possibly partly mitigate for the lost upstream and downstream migration corridor, the lost ecological connectivity can under no circumstances be mitigated for by any fish pass.

124. After an ensuing discussion reviewing again all arguments in favour and against the construction of the Eg River dam, it was concluded that the workshop would not have a unanimous view on the need for, and on the usefulness and the environmental impacts of, the planned dam construction. However, all workshop participants unanimously agreed that, should the dam be constructed, there would be a need to create a fish passage system for mitigating the blocked upstream and downstream passage. This conclusion was seen as a success by most of the workshop participants as the inclusion of a fish passage facility was not originally foreseen in the construction design of the Egiin Gol hydropower plant.

125. With this issue clarified, the workshop proceeded to discuss the potential solutions to mitigate obstructed fish passage.

24.4. Discussion on the potential solutions for fish passage at the planned hydropower station on the Eg River and related issues

126. Based on the lessons learned from the presentations given by Mr Gebler and Mr Zitek, the workshop participants, under the guidance of the resource persons, discussed first the potential solutions for upstream and then the ones for downstream fish passage at the planned dam.

24.4.1. Upstream passage

127. To start with, unrealistic solutions such as a rock ramp, a fish ramp or a vertical slot pass were excluded by evaluating the pros and cons of these fish pass types under the given circumstances. The

construction of a fish sluice was also excluded. Remaining as potential solutions were the construction of a fish lift or the use of the trap-and-transport method.

128. After discussions of the challenges related in particular to the release of the fish into the reservoir with its fluctuating water level and the doubts expressed as to the capacity of taimen to swim through the approximately 60 km long reservoir to find their way upstream into the free-flowing Eg River, the idea of proposing a classic fish lift was abandoned. Instead, there was a suggestion to propose the construction of a crowding chamber similar to those used in France in connection with fish lifts (e.g. at Golfech on the Garonne River). From this crowding chamber at the foot of the dam, all or selected fish could either be transported upstream by truck (similar to what is done for example at the Carbonne trap-and-transport facility on the Garonne River) and released into the free-flowing Eg River (e.g. taimen) or released into the reservoir (e.g. species that are thought to be able to more easily cope with stagnant water conditions). The advantage of a crowding chamber with subsequent upstream transport by truck is that fish can be sorted for further handling, including also for scientific studies. The greatest advantage of the trap-and-transport method, however, was seen in the fact that taimen would not end up in the reservoir but could continue their upstream migration for spawning after upstream release.

129. It is necessary to place the entrance (or entrances) into the crowding chamber in such a way that fish will find it (or them) under the conditions of the hydropower station operations. Therefore, it is necessary to locate the entrance (or entrances) to the crowding chamber next to the turbine outlets. Mr Gebler presented a schematic proposal for such a potential layout during the workshop; it is here reproduced in Appendix 7. He strongly suggested that the crowding chamber be connected to the river bed by a submerged berm turning to a submerged bank. An example of such a berm is shown in Appendix 8. Because of the expected high flow velocities – especially under hydropeaking conditions – in the river stretch downstream of the dam, the river bank has to be specifically structured in the whole section from the turbine outlets to the confluence with the Selenge River (Appendix 9), i.e. it should include shallower parts and bays where the flow velocities are lower so as to enable migrating fish to reach the crowding chamber. As there is more space on the orographic left side of the Eg River for creating such a branched system of stream channels, the crowding chamber, and hence the turbine outlets, should be situated on the orographic left side of the dam. It is expected that using the left side would also make it easier for fish swimming up the Selenge River to detect the entrances of the channels leading to the crowding chamber.

130. It was furthermore strongly recommended that, in addition to the crowing chamber, structural provisions should be made in the dam design and construction that would allow to later add the structural parts to complement the crowding chamber with the lift structure, should it – after some years of testing – be felt necessary and appropriate.

131. While it is never guaranteed that 100 percent of the fish that swim upstream to a dam, and that would pass upstream if there were no dam, will manage to find the entrance to the fish pass – even if the entrance situation features the best possible conditions, and independent of the inner design of the fish pass provided – and while hence already there a certain human-induced genetic selection takes place, the risk of genetic selection is even higher when using the trap-and-transport method as a decision on which fish are allowed upstream is taken by the person or persons who handle the fish. This is a recognized disadvantage of the trap-and-transport method.

24.4.2. Downstream passage

132. As the water level fluctuations in the reservoir will be important (c.f. para 120) and it would therefore be extremely difficult, if not impossible, to capture downstream-migrating fish in the vicinity of the dam, it was suggested that a device or devices to deviate downstream-migrating fish (and in particular adult and juvenile taimen) should be installed in the Eg River upstream of the reservoir. Examples exist in France, Canada and Scotland (the United Kingdom of Great Britain and Northern Ireland), although for smaller rivers. In this way, taimen would not enter the reservoir, where they would probably be lost.

133. The deviated fish should be collected in an installation on the banks of the Eg River and transported downstream by truck to be released downstream of the dam. It is necessary to protect the deviating structure (or structures) against wood and debris floating downstream and it (or they) should be designed in such a way as to be movable or removable when discharge conditions (e.g. ice drift) require it. This methodology, of course, has a certain cost and is labour-intensive in terms of installing and removing the structure/structures, fish handling and cleaning of the screens, but it is the only logical and promising approach to maintaining the downwards genetic exchange between the Eg River fish population upstream of the reservoir and the one in the Eg River and the Selenge River downstream of the dam. In addition, it is proposed that grids – but no bypasses – should be installed in front of the turbine intakes to protect fish against entering the turbines. These grids have to have an appropriately narrow bar spacing so as to prevent all that fish from passing that must not be damaged by the turbine passage.

24.4.3. Eg River section downstream of the planned dam

134. The resource persons also again drew attention to the fact that the whole area in the stretch between the confluence of the Eg River with the Selenge River and the planned dam, which features extremely valuable habitat, would be heavily modified to a large extent, should the dam be built. In accordance with the opinion of one of the participants (c.f. para 78), they suggested that compensation measures, i.e. creating and maintaining artificial spawning habitat, should be implemented. However, it was stressed that such artificially created habitat could never fully replace the natural habitat, including spawning habitat, destroyed by the dam, the evacuation channel and the reservoir. Appendix 9 shows a schematic view of the proposed branched system of watercourses in the mouth area of the Eg River, which is highly suitable as spawning habitat.

24.4.4. Monitoring

135. The need for a comprehensive monitoring programme before, during and after dam construction was mentioned. In particular, it was strongly recommended that a comprehensive EIA, including all biotic and abiotic factors, but in particular fish, be carried out in the Eg and Selenge Rivers before the construction of the dam, and that biotic and abiotic data be linked when drawing conclusions. The workshop was informed by the TCF that a number of studies were under preparation that would provide further data.

24.5. Conclusions

136. The workshop, after evaluating the different types of upstream and downstream fish passage facilities that exist, agreed that, if the dam were to be built, the trap-and-transport method based on a crowding chamber, that could later maybe expanded into a classic fish lift, would be suitable for the Egiin Gol power plant. Moreover, the workshop participants approved the other aforementioned proposals for solutions and approaches. It was also agreed that, after the construction of the dam and the fish passage facilities, there would be a need to conduct a comprehensive monitoring programme for at least 1–2 years to check whether the passage facilities were functioning well and to make predictions about the development of the fish population upstream and, based on monitoring, prepare/improve the management plan of the upstream basin.

137. Approaching the end of the workshop, Mr Erdenebat acknowledged that a lot of interesting information had been presented during the five days of the workshop. The participants confirmed that they had learned a lot, and some of them even said that the workshop had been an eye-opening event with regard to behaviour of fish and fish pass design and construction. Mr Erdenebat again thanked FAO for having positively and in a very timely manner responded to the request to hold such a workshop in Mongolia. He thanked the resource persons for their very interesting presentations, explanations and discussions.

25. FEEDBACK ON THE USEFULNESS OF THE WORKSHOP BY THE PARTICIPANTS

138. The participants expressed their appreciation to the organizers for conducting the workshop, and to the resource persons for sharing their knowledge on fish passage facilities from the ecological and engineering perspectives, including *inter alia* the basic aspects of fish biology and behaviour relevant to migration, different types of fish passes that allow migration, ecological and hydraulic requirements for enhancing the effectiveness of fish passes, as well as the requirements for monitoring, evaluation and maintenance of fish passes. All participants were highly satisfied with the workshop content, the logistics and the documentation provided. All 21 participants rated the usefulness of the workshop as “very high”, the highest category possible on a scale of five possible ratings. Details of the workshop evaluation by the participants can be found in Appendix 10.

26. CLOSING OF THE WORKSHOP

139. Mr Erdenebat expressed his sincere appreciation to all participants for their contributions, active participation and great cooperation during the workshop. On behalf of the workshop participants he also thanked Mr Zitek, Mr Gebler and Mr Marmulla for their excellent contributions.

140. Mr G. Zolboo, Deputy Director, EGHPPPU, expressed on behalf of the whole EGHPPPU team his thanks to FAO for organizing such an important workshop. He stated that the information received was very useful and that it had been important for the whole EGHPPPU team to listen to new aspects concerning fish passage issues, especially now that the hydropower sector was growing in Mongolia. He emphasized that the EGHPPPU team was fully satisfied with the content of the workshop and the information shared. He further said that the EGHPPPU would do its best to minimize the damage that could occur during the construction of the dam.

141. In his closing remarks, Mr Purevdorj, Executive Director of the TCF, expressed his thanks to FAO for the great effort of organizing the workshop. He stated that the TCF was satisfied with the achievements of the workshop, and informed the workshop that the TCF would sign a contract with the EGHPPPU for a fish study in Eg River.

142. In their final statements, both Mr Zitek and Mr Gebler reiterated that it would be best not to construct the Eg River dam at the planned location for reasons discussed intensively during the workshop.

143. Mr Zitek remarked that in the latest EIA it was mentioned that a fish passage facility should be installed at the hydropower plant of the Eg River and that this was already progress compared with the first EIA that did not at all foresee the construction of a fish pass. He further stressed that the workshop had now considered and agreed that it was important for the fish populations that there should occur genetic exchange between the Selenge River and the Eg River. He recalled that the workshop had unanimously agreed that a fish passage system was needed and that trap-and-transport would probably be the most appropriate solution, fully supported by the workshop resource persons. He reiterated that it had also been considered that there was a need for mitigation measures downstream of the dam and that it was suggested that some spawning places be built downstream of the dam for the reproduction of the Selenge fish. In addition, it was also significant progress that the need for downstream passage was being considered. The downstream passage of the fish should be achieved with the help of a structure able to collect the fish from the river upstream of the reservoir. This fish would then be transported down to sites below the dam for release into the Eg River or the Selenge River.

144. Mr Zitek further stressed that adaptive management was needed as the envisaged fish passage solution for the Eg hydropower plant was primarily aiming at collecting and transporting fish. The envisaged design of the crowding chamber, however, needed to incorporate already the option of adding structures to make it part of a true fish lift, for the construction of which preadaptations should be incorporated into the dam structure from the beginning of its construction. Thus, everything would be set

for the case that sooner or later it is decided that a fish lift would be appropriate. The fish lifted up could then still be sorted, and selected fish also still be transported upstream by truck.

145. Mr Gebler stressed that experience showed that, at huge and high dams, in most cases several types of fishways, e.g. close-to-nature ones, cannot be taken into consideration for mitigation and that this was also the case for the planned hydropower project on the Eg River. This poses a problem because it limits very much the choice of devices that can be considered for mitigation at this site. Making reference to the final conclusion of the workshop, i.e. that a fish collection and transportation system was needed, which was agreed to by all workshop participants, he reiterated that successful examples existed in several countries and that a system to collect the fish in front of the dam, with subsequent upstream transport, seemed the only viable solution for the Eg River dam. He further mentioned that, if carefully planned, it would be technically possible to later add a lift structure once better information about the behaviour of the fish had become available and if it was then deemed appropriate to release some or all fish into the reservoir. He concluded by saying that using the trap-and-transport system would not limit further improvements in any way and that the experience gained would show how to advance in future.

146. Mr Marmulla also expressed his deep appreciation to all participants for their excellent contributions, their active and constructive participation as well as their openness and readiness for discussions during the entire workshop. He further thanked his colleagues, Mr Gebler and Mr Zitek for their excellent work and cooperation. He then expressed again his gratitude to the TCF for hosting the workshop and for the excellent arrangements made. Last, he expressed the hope that the workshop would contribute to the conservation of taimen and other fish in Mongolia's rivers.

147. Mr Erdenebat then declared the workshop closed on 11 April at 16:00.

Appendix 1

Agenda

Sunday 6 April 2014

Arrival of those participants in the Selenge Resort who take part in the field visit to the Eg River potential hydropower station site on Monday 7 April

Monday 7 April 2014

Scientific field excursion to the potential hydropower station site on the Eg River

Arrival of those participants in the Selenge Resort who do not take part in the field visit to Eg River

Tuesday 8 April 2014

Morning

Opening of the Workshop

- Taimen Conservation Fund
- FAO

Importance of fish passage (G. Marmulla)

Two presentations on fish passage issues in Mongolia (Designated Workshop participants)

(i) The status of fish passage development and construction in Mongolia (history; present status; future plans; existing fish passage facilities, the need for fish passage facilities; fish passage facilities planned and/or under construction) and fish pass research in different institutions in Mongolia, including legislation for fish pass construction (information from all relevant provinces and institutes compiled) and administrative aspects of fish pass planning and implementation on different relevant administrative levels, i.e. Ministry, Province government, watershed administration, etc.;
(ii) The biology and behaviour of the most important fish species to be considered in the planning of fish passage facilities in Mongolia, and in particular in Eg River;

General ecological considerations for building fish passes (A. Zitek)

Afternoon

Overview: Common types of fishways – examples of well-functioning fish passes (R.-J. Gebler)

- Overview of close-to-nature (rock ramp, fish ramp, fish pass, bypassing water course) and technical (vertical-slot pass, pool pass) fishways with examples. In addition fish lock, fish lift and “Trap and Transport”.

Swimming and orientation behaviour of fishes in upstream direction (A. Zitek)

Location of fish passage facilities and attraction flow (R.-J. Gebler)
- Optimal position of a fish pass (large-scale, weir, hydropower plant)
- Attraction flow at the outlet of a fish pass

Analysis of functionality of different types of fish passes – major reasons for dysfunction (A. Zitek)

Fish species and behaviour of different species in Mongolia (A. Zitek)

Wednesday 9 April 2014

Morning

Fishways at small weirs (R.-J. Gebler)
- e.g. rock ramp, fish ramp, bypassing water course

Common types of fishways at large hydropower plants (R.-J. Gebler)
- e.g. vertical-slot pass, bypassing water course

Ecological requirements for the construction of fish passes (A. Zitek)
- How to establish/select the main parameters important for passage (a basic requirement to define design criteria)

Fish lifts and fish sluices (R.-J. Gebler)
- General design, examples, experience

Afternoon

Fish pass design in relation to river types and relevant fish fauna (A. Zitek)

Design of vertical slot passes (R.-J. Gebler)
- pool dimension
- Length/width – ratio of a pool
- Discharge, flow pattern, velocities, power density

General hydraulic design (R.-J. Gebler)
- Elementary hydraulics
- Required amount of pools
- Required pool and opening/slot dimensions
- Flow velocity in an opening/slot
- Power density

Technical details (R.-J. Gebler)
- Design of the intake (headwater)
- Design of the outlet (tailwater)
- Lighting conditions

Thursday 10 April 2014

Morning

Case study: vertical slot pass at a hydro power station (R.-J. Gebler)

- Basic evaluation (relevant fish, hydrology, etc.)
- Selection of the optimal construction type and inner design
- Spatial arrangement
- Determination of the required amount of pools
- Pool and opening design

Monitoring (A. Zitek/R.-J. Gebler)

Maintenance of fishways (R.-J. Gebler)

Afternoon

Ecological requirements downstream migration (A. Zitek)

Downstream migration facilities – technical aspects (R.-J. Gebler)

Friday 11 April 2014

Whole day

Discussions on and preliminary development of the potential solution(s) for fish passage at the planned hydropower station on the Eg River

Late afternoon

Feedback on the usefulness of the Workshop by the participants (Sh. Purevdorj/G. Marmulla)

Closing of the Workshop (Sh. Purevdorj/E. Erdenebat)

Saturday 12 April 2014

Departure of the participants and resource persons from the Selenge Resort

Appendix 2

List of participants

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Appendix 3

Opening remarks

Opening remarks by Mr Shirendev Purevdorj
Executive Director, Taimen Conservation Fund (TCF)

Ladies and Gentlemen,

First of all, on behalf of the Taimen Conservation Fund, I would like to express thanks to FAO of the United Nations for providing funding for organizing this very important Workshop on “Fish passage design at cross-river obstacles – Experience from different countries, with potential relevance to Mongolia”.

I would like to express my special thanks to Mr Gerd Marmulla, Fishery Resources Officer, Marine and Inland Fisheries Branch, FAO, for his efforts in organizing this Workshop. Without his initiative and support we would not be able to organize this Workshop.

It is my great pleasure to inform you that in this Workshop are present invited representatives from the Ministry of Nature and Green Development, the Ministry of Energy and the Egiin Gol Hydro Power Plant Project Unit as well as fishery experts, hydropower plant experts, and other scientists, etc. In other words, here are represented policy and decision makers, Government and Non-Government organizations, scientists and international organizations.

On 16 November 2013, the Government of Mongolia decided to establish the Egiin Gol Hydro Power Plant Project Unit which is responsible for managing and building a new hydropower plant in Eg River.

Since 2003, TCF has been providing a full scale of fish studies in the Eg River involving a science team which consists of biologists, hydrologists and specialists from the Mongolian Geo-Ecology Institute, Institute of Biology, and American Universities namely, the University of Wisconsin, Madison, the University of Nevada, Reno, the University of California, Davis, the University of Rutgers, as well as other scientists from Russia, Canada, Mexico, etc.

The science team activities are focused on the basic ecology and life history of Taimen and other fishes that inhabit the study area. Activities included the collection of information on mean length and weight of Taimen, population size, seasonal movement patterns, critical habitat and community studies.

TCF, as a devoted non-governmental organization for protecting the fish in the northern part of Mongolia, is very concerned as regards the construction of the hydropower plant in the Eg River. Therefore, TCF has requested FAO to assist in organizing today’s workshop the main goal of which is to exchange information, knowledge, opinions and thoughts between all parties taking interest in the construction of the Egiin Gol Hydropower Plant.

I wish the workshop all the best.

Thank you very much for your kind attention.

Opening remarks by Mr Gerd Marmulla
Food and Agriculture Organization of the United Nations (FAO)

Distinguished Mr Tsogtsaikhan,
Distinguished Mr Purevdorj,
Honourable Workshop participants,
Dear colleagues and friends,
Ladies and Gentlemen,

It is my gratification and great honour to welcome you on behalf of FAO to the Opening Ceremony of this Workshop. Regretfully Mr Ahaduzzaman, Deputy FAO Representative in Mongolia and Head of the FAO Office in Ulaanbaatar, is unable to attend this Workshop due to other urgent commitments scheduled earlier. However, he conveys his greetings and best wishes to you for successful deliberations.

It is a great pleasure for me to be here in the Selenge Resort and I would like to express my deep appreciation to Mr Purevdorj of the Taimen Conservation Fund for welcoming us so warmly to Mongolia and to this Resort in particular. I like to thank the Taimen Conservation Fund for having so willingly engaged in the Agreement with FAO that covers this Workshop. We are really thankful that TCF offered to host this Workshop here in the Selenge Resort and that Mr Erdenebat took so well care of all the local arrangements. My thanks also go to my FAO colleagues in Ulaanbaatar who likewise provided valuable assistance to me while I was preparing this Workshop.

I take great pleasure in welcoming here participants from different institutions. From the list of participants I can see that they come from different Ministries, institutes, the hydropower sector, the private industry and the Taimen Conservation Fund. It is a great satisfaction for us to see present here so many representatives from the whole range of stakeholders, including administrators, biologists, engineers, and the collaboration of those is exactly what is needed to make protection, rehabilitation or restoration of fish passage successful.

Mongolia is not particularly rich in fish species compared to other regions in the world, such as the Mekong River basin, the Yangtze River or the Amazon basin where several hundreds or even well over 1000 species live, but there exist species here in Mongolia which are indigenous and therefore very precious. And one of this species is the Taimen which is a key species for biodiversity but is also important for the economy of Mongolia as a whole industry sector, namely the sport fishing, is based on this species which attracts many foreign visitors who bring foreign exchange to Mongolia.

However, Taimen is no longer as common as it was in the past! Stocks declined and a further decline cannot be accepted in order not to put at risk the survival of the species. In this context, care has to be taken that sufficient Taimen offsprings can be produced naturally and that all lifestages find the necessary habitats. As Taimen is a migratory species, free upstream passage is a must to allow the adult fish to reach their spawning grounds while free downstream passage is also needed for the dispersion of the juveniles so that Taimen can colonize appropriate areas.

Stocking is a common measure in the conservation of many species but is not always successful as shown by studies. Therefore, it needs a more sustainable general management approach to protect fish species.

Migrations, be they long-distance migrations or shorter movements, are a critical lifecycle feature of many fish. Longitudinal and lateral passage in the form of movements or migrations is very important for many fish species to successfully complete their lifecycles. Physiological requirements of fish need to be satisfied, e.g. through migrations to reach spawning and nursing grounds; through feeding migrations to ensure food availability for growth; through migrations to satisfy seasonal habitat preferences and/or the need for shelter and protection against environmental influences or predators; through migrations for the recolonization of river stretches after impacting events such as flooding or deterioration of water quality. All this is essential to the viability of populations of many riverine species.

Migrations and movements are also important to maintain genetic diversity and sometimes they even directly contribute to the influx and exchange of material such as nutrients as was shown by studies in North America. Hence, the diversity of communities of living aquatic organisms (including fish) is very important for the productivity, the stability in terms of resistance and resilience and the aesthetics of inland water ecosystems. And it is well recognized that biodiversity in fish communities is important for fisheries as only genetically diverse fish communities and populations can form the basis of a shriving and sustainable fishery.

The construction of cross-river obstacles, e.g. dams and weirs, for various purposes including hydropower production, continues in many countries of the world and many of these dams and weirs can have negative impacts on fish by hampering or blocking migrations. Dams and weirs – and not only those on big rivers – negatively impact fish migrations, and hence the biodiversity and the resilience of fish populations. This, in turn, has impacts on the fisheries but these impacts are not seldom underestimated or downplayed, especially by the dam promoters and hydropower lobbyists. Stocking alone is not a viable option. In fact, it is often seen that released fingerlings have little or no chance to survive or grow due to the release conditions and their behaviour which can be different from naturally grown-up fish. Therefore, it needs a more sustainable approach.

In general, it is now widely recognized that stocking can not successfully replace the natural reproduction in the long term and therefore natural reproduction has to be fostered. In recognition of the importance of biodiversity and the role that natural reproduction plays in this respect, the protection and conservation of, and the access to, the relevant natural aquatic environment is receiving increased attention and is explicitly addressed by several international instruments, e.g. the Convention on Biological Diversity (CBD), the Ramsar Convention, the FAO Code of Conduct for Responsible Fisheries and the related Technical Guidelines, as well as the EU Habitat and Water Framework Directives, to mention only a few.

This Workshop on "Fish passage design at cross-river obstacles – experiences from different countries, with potential relevance to Mongolia" aims at raising the general awareness of the usefulness, but also of the limitations, of fish passage facilities. The Workshop is meant to show which fish passage facilities have been developed on a global scale and what conclusions might be drawn from this knowledge for the development of fish passage facilities in Mongolia. However, under no circumstances, this Workshop must be seen as an encouragement to construct new dams because we learnt how to design and construct fish passage facilities!

With the help of the Workshop participants, the Workshop will also try to discuss and develop potential scenarios for a fish passage facility at the Eg River. But because of the importance of the Taimen, and its vulnerability, all efforts should be made to re-evaluate the need for and the overall usefulness of a hydropower station in the Eg River. No doubt, fish passage facilities can be constructed but we have to keep in mind that they can only mitigate the dam impacts to a certain extent, however basically never to 100 per cent. Fish passage facilities can keep up fish migration but cannot compensate for lost river connectivity. Alternatives for energy production might be found – alternatives for rich biodiversity can, however, not be found!

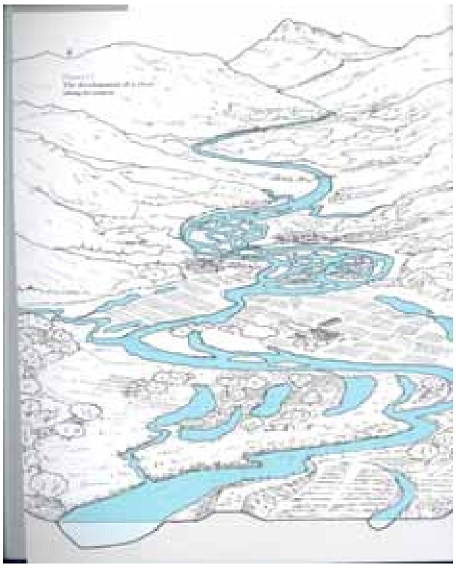
I do not want to go now into technical details anyway contained in the Workshop curriculum but I can promise you that my colleagues Dr Gebler and Dr Zitek, who are present here and who are leading experts in fish passage issues on a global scale in terms of ecology and engineering, with a very long experience, and myself have done our best to put together an interesting programme covering both theoretical and practical aspects. I would like to take this opportunity to herewith express my sincere gratitude to my colleagues Dr Gebler and Dr Zitek for having readily accepted to serve as resource persons for this Workshop.

With these remarks, and my renewed thanks to Mr Purevdorj and Mr Erdenebat, I wish this Workshop every success.

Thank you.

Appendix 4

Schematic view of the "ideal river" and, in comparison, a photograph of the Eg River, Mongolia



Eg River, Mongolia

On the left side is shown a schematic presentation of a river course featuring a very high variety of different habitats along its continuum (reproduced from the FAO/Fishing News Books publication "Rehabilitation of rivers for fish", FAO 1998). This river course could be seen as the "ideal river" in its most natural state as it occurred naturally before human interventions. On the right, in comparison, is shown a photo by Gerd Marmulla (FAO) of the Eg River section just upstream of the site of the planned Eg River hydropower plant in Mongolia. The river features here many habitat structures of the "ideal river" in the relevant section.

Appendix 5

The status of fish passage development, research and construction in Mongolia
by Mr T. Ganbold, General Manager for Site Infrastructure, MMC Hydropower engineer

1. General information

a. Climate

Mongolia is a land of extremes. Arctic-style winters are the norm and one can see snow in the Gobi desert as late as April. Here, summer temperatures hit 40°C, but winter temperatures can be minus 30°C or lower. Humidity is low and sunshine is intense, with over 260 sunny days a year. Winter can be very hard – minus 50°C is not unknown. There's a short rainy season from mid-July to September, but the showers tend to be brief. Mongolia is a windy place, especially in spring.

Aimag[1] (Province)	Annual Precipitation mm	Average January Temperature [°C]	Average July Temperature [°C]
Arkhangai	**350.5**	**-14.9**	**14.3**
Dornogovi	**116.7**	**-17.8**	**22.8**

b. Geography

Mongolia is covering an area of 1 564 100 square kilometers. Mongolia is a mountainous country with an average altitude of 1 580 meters above the sea level. The geography of the country is characterized by great diversity. From north to south it can be divided into four zones, i.e. mountain-forest steppe, mountain steppe, semi-desert and the desert. In the northwest, the mountain ranges and ridges are overgrown with wild forests and there exist big lakes and tempestuous rivers. The vast grasslands of the Asian steppe stretch across the eastern part of the country. The Gobi Desert lies in the south occupying somewhat less than one-third of the Gobi Region, the rest being semi-desert grassland. The typical landscape, a nature-lover's paradise, is an undulating steppe land providing fine pastures. The country is dotted with hundreds of lakes, the largest being Uvs-Nuur (covering an area of 3 350 square km) and Huvsgul-Nuur (2 760 square km).

c. Hydropower resources

The vast hydropower potential of Mongolia is regarded as one of the country's most valuable assets. The country's total hydropower potential has been estimated at more than 5000 MW, about 0,5 percent of which has so far been developed (see Table 1). That means that 99,5 percent is yet untapped. And hydropower development is now a major priority for the country, in particular in view of the shortage of electricity in remote areas due to the high cost of imported diesel fuel for the power generators under the control of the local district administrations ("Soum"[2]). Also, in the centre of Mongolia the energy production is ensured to 100 percent by coal-fired thermal powerplants causing heavy air pollution. At present, the country's total electricity production generated by seven coal-fired thermal powerplants is 3.0 billion kWh.

[1] "Aimag" is the Mongolian term for "Province"
[2] "Soum" is the Mongolian term for "District"

Table 1: Hydropower potential of the biggest river basins in Mongolia

Name of river	Gross theoretical hydropower potential [kWh/year]	Economically feasible hydropower potential [kWh/year]
r. Selenge	8650	3030
r. Kherlen	1647	160
r. Khovd	5887	2150
Others	34339	9950
Total	50513	15290

In Mongolia, hydropower production of up to 1 MW is classified as mini-hydropower, while production from 1 MW up to 15 MW is small-hydro. So far, a total of 13 mini and small hydropower plants were constructed in Mongolia. Two of them are small-hydropower plants (SHP) with a dam, designed to work all year round. Bogdiin HPP, with capacity 2 MW, is also classified as small hydropower plant but has no dam and can not work all year around. The other ten are equipped with mini turbines and operate also only during the summer (see Table 2).

Table 2: Existing hydropower plants

Name of hydropower plant	**Installed capacity [kW]**	**Year of commissioning**
Kharkhorin	528	1959
Chigjiin	200	1989
Bogdiin	2000	1997
Mankhan	150	1998
Guulin	480	1998
Munkhkhairkhan	150	2003
Taishir*	11000	2008
Dorgon*	12000	2008
Tosontsengel	380	2005
Erdenebulgan	200	2004
Uench	900	2005
Zavkhanmandal	110	2009
Tsetsen Uul	150	2009
** can operate all year round*	Total installed capacity: 28 248 kW	

At three of these hydropower plants fish passage facilities were constructed, i.e.:

- At Dorgon hydropower plant with a capacity 12 MW, constructed on the Chonokharaikh River in Khovd province.

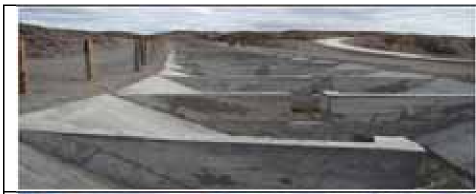
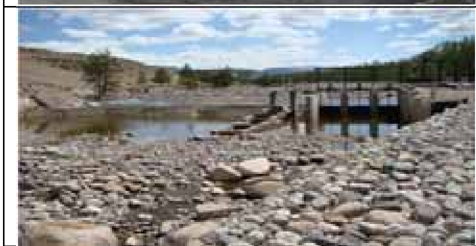
- At Bogdiin hydropower plant with a capacity 2 MW, constructed on the Bogdiin River in the Zavkhan province.

- At Tosontsengel hydropower plant with a capacity 0.38 MW, constructed on the Ider River in the Zavkhan province.

The Dorgon HPP can operate all year around, the Tosontsengel and Bogdiin HPPs are operating seasonally only in summer from 15th April until 15th October each year.

2. Existing fish passage facilities in Mongolia

As mentioned above, at present exist fish passage facilities at three hydropower plants in Mongolia (see pictures 1-3).

	**Picture 1**. Fish ladder constructed at the Dorgon HPP The Dorgon Hydropower Plant was constructed in the Khovd Province and started operation in 2008. Annual production in 2013 reached 40 million kWh. The length of the fish ladder is about 800 m.
	**Picture 2**. Fish ladder constructed at the Bogdiin HPP The Bogdiin Hydropower Plant in Zavkhan Province was constructed in 1997 and is operating seasonally in summer between April and mid of October in every year. The reservoir is created by a small concrete weir. The fish ladder is located next to the spillway on its right side.
	**Picture 3**. Fish passage facility at the Tosontsengel HPP The fish passage facility of the Tosontsengel Hydropower Plant is located between the powerhouse and the weir. It is a sort of fish sluice. The height of the concrete weir is about 2.5 m. The Tosontsengel Hydropower Plant is also operating seasonally during summer only. The capacity of the Tosontsengel is 0.3 kW.

3. The need for fish passage facilities

Environmental protection issues are being considered increasingly. In case of dam construction, fish passage facilities should now be built when needed to save the fish. Currently, the construction of fish passage facilities at the planned dam of the Egiin River hydropower plant has been considered and Mongolian scientists are working to find cost-effective and simple options.

At present, there are no fish passage facilities under construction in Mongolia.

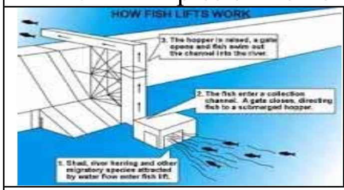
4. Fish passage facility research institutions in Mongolia

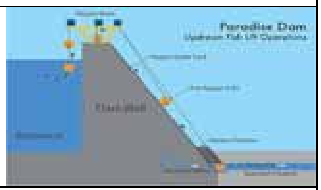
There are no specific research institutions for designing or studying fish passage facilities in Mongolia. However, Mongolian scientists are trying to familiarize with the issue of fish pass design and have compiled information on existing fish passage facilities from different countries.

Globally, mainly three types of the fish passage facilities exist:

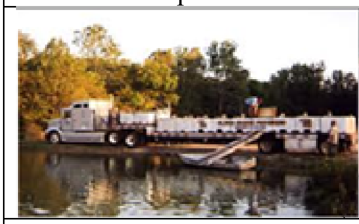
1. Fish lifts
2. Fish collecting facilities including fish transport by truck ("trap and transport"), and
3. Fish ladders.

1. Examples of the fish lift type facilities

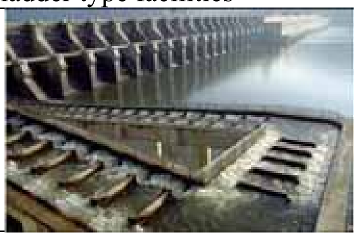


2. Examples of the fish transport by truck




3. Examples of the fish ladder type facilities


The Biological Institute of the Mongolian Academy of Sciences is currently carrying out fish studies and fish research work. Under the Biological Institute was established the "Fish growing research centre" which is headed by Dr. Dulmaa since 2 September 2009 and carries out research on the possibility of the fish growing. Also the Hydrobiology-fish Research Laboratory is making joint investigations for aquatic species and bio-productivity of the fish in collaboration with an international team from Germany, Russia, USA and Czech Republic.

5. Legislation concerning fish passage facilities in Mongolia

There is no specific law concerning fish pass construction in Mongolia.

Only in the clause 1.6 of the "Basic principles of designing works for hydraulic constructions" published in 2003 by the Ministry of Infrastructure is stipulated that during the designing phase fish protection measures should be planned.

6. Administrative Aspects

At present, at none of the different relevant administrative levels do exist administrative provisions for fish pass planning and implementation.

7. Proposal for fish passage facilities at Egiin Dam

The first design for the Egiin Gol dam prepared in 1992–1994 by Electrowatt (Switzerland) was without a fish passage facility. Today, Mongolian scientists consider two potential options for the Egiin Gol dam:

1. fish trapping and transporting by truck, or
2. constructing a fish lift at the dam.

As mentioned in the Feasibility Study prepared by the Electrowatt team, a fish lift requires a lot of construction work, is not easy to operate and is expensive. Therefore, Mongolian scientists suggest that the first option, i.e. fish trap and transport, is considered.

Appendix 6

The biology and behaviour of the most important fish species to be considered in the planning of fish passage facilities in Mongolia, and in particular in the Eg River

by P. Tsogtsaikhan[1] and B. Mendsaikhan[2]

The waters of Mongolia can be classified into three hydrogeographical regions according to their directions of drainage: Arctic Ocean Basin, Pacific Ocean Basin and Central Asian Closed Basin. The Mongolian Arctic Ocean basin is composed of the Selenge River, its tributaries, and the Shishkhid River which is not connected to the Selenge. It represents 20.6 percent of the territory of Mongolia. The area belongs to the continental climate zone which is characterized by wide variations of annual, monthly and diurnal temperatures, low range of air humidity, non-uniform distribution of precipitation within a year, and cold and long lasting winters and warm summers. Permafrost cover is significant and plays an important role in the water regulation. Annual precipitation in the upper river reaches of the basin is 350–400 mm, downstream annual precipitation is just 250–300 mm. Of the total annual precipitation, approximately 70 percent falls during the summer, typically during thunderstorms.

The Selenge River is a transboundary river in Northern Mongolia and Southern Siberia which is originating from the Mongolian mountains of Khangai and flowing down to Russia into Lake Baikal. The main tributary of the Selenge River is the Eg River. The Eg River originates from Hovsgol Lake which is the biggest freshwater lake in Mongolia. Its total length is 453 km, and its catchment area is 41 799 km^2. The flow of the Eg River is composed of 30 percent ground water, 17 percent snowmelt, and 53 percent rain water. Water discharge usually increases in May and decreases in June. In July and August, and occasionally in September, the river usually is in flood several times. The mean of annual discharge is 30.7 m^3/s. The maximum discharges of the Eg River occurred in 1994 with 190 m^3/s, and in 1995 with 118 m^3/s.

Discharge studies began in 1932 in the Selenge River. At present, seven monitoring stations, i.e. in the Ikh–Uul, Khutag, Khyalganat and Zuunburen districts[3], are working in the Selenge River basin.

According to the report of the Joint Soviet-Mongolian Biological Research Expedition of the USSR Academy of Sciences and the Mongolian Academy of Sciences (1983), a total of 20 species of freshwater fish belonging to eleven genera has been recorded in the Selenge River and 19 species of eleven families in the Eg River. Only one species, i.e. the Baikal omul (*Coregonus migratorius*), was not recorded in the Eg River. The fishes of the Selenge River are belonging to the Arctic Ocean drainage fauna.

As regards the fish composition of the Selenge River, 73.3 percent of the fish are native species, 20.1 percent are intentionally introduced, 3.3 percent are from unknown invasion and 3.3 percent are accidentally introduced species.

Since the 1930s, Asian common carp (*Cyprinus rubrofuscus*), East-Asian (Amur) catfish (*Silurus asotus*) and Prussian carp (*Carassius gibelio*) have been introduced in lakes and rivers of Baikal Lake drainage. During the year 1970, an alien species was recorded in Mongolian part of the Selenge River. In the last few years, distribution of the Baikal omul (*Coregonus migratorius*), bream (*Abramis bramaorientalis)* and Altai osman (*Oreoleuciscus sp.,*) was also recorded in tributaries of the Selenge River. Bream that was introduced in lakes and rivers in the Baikal Lake drainage in 1950 was recorded in tributaries of the

[1] Ministry of Environment and Green Development
[2] Institute of Geoecology, MAS
[3] in Mongolian: "soums"

Selenge, e.g. in the Orkhon River, in 2004. The Selenge River acts as an important pathway for the introduction of non-native fauna into Lake Baikal.

The Selenge River fish species are classified into conservation status categories according to the guidelines for the application of the "Red list categories and Criteria at a regional level". 5.2 percent are listed as Critically Endangered (CR), 15.7 percent as Endangered (EN), 5.2 percent as Vulnerable (VU), 5.2 percent as Near Threatened (NT), 21.1 percent as Data Deficient (DD) and 42.1 percent as Least Concern (LC).

The biggest fish of the Selenge River is the "river wolf" or "taimen" (*Hucho taimen*; Siberian taimen) which belongs to the family of the Salmonidae. The Siberian taimen, *Hucho taimen*, is the world's largest salmonid fish and a charismatic fish known within Mongolia and abroad. Typically, adult Taimen inhabit undisturbed habitat types, the character of the habitat depending on the size of the fish.

The genus *Hucho* includes five species. They are *Hucho hucho, Hucho taimen, Hucho ishikawai, Hucho bleekeri and Hucho perry.* Taimen is distributed from the Ob to the Lena River (Russia), the Okhotsk Sea Basin to the Amur River Basin (China, Russia, Mongolia), the western upper tributaries of Pechora River (Russia), Kama River (Russian and Kazakhstan). Presently, most taimen is distributed in Mongolian rivers and lakes. However, after the period of transition to market economy the taimen distribution has decreased by about 60 percent. The quality of the taimen habitat is declining due to mining, and the number of mature individuals decreases due to poaching.

Taimen is listed as "Rare/Near Threatened" under the Mongolian Law on Fauna, but it remains possible to obtain fishing licenses for this species. The Mongolian Law on Fauna prohibits catching of any fish between April 1st and June 15th, but there is difficulty in enforcing this ban. Mongolian anglers can catch a maximum of ten fish (except taimen) for domestic use with one license. Foreign anglers require a license for "catch-and- release" fishing (two taimen, ten other fish) from the Ministry of Environment and Green Development. Fishing camps and tour operators require concluding contracts with the local district administration, which first needs approval from the relevant provincial authority[4] before they can apply for the licenses. In the regional Red List, taimen is listed as Endangered (EN) (A2de and A3de and B2ab (iii,v)). In 2012, the Siberian taimen *(Hucho taimen)* was registered in to IUCN red list as a "vulnerable" species.

The taimen populations can either be strictly riverine, where fish live and feed all year round in the main rivers and tributaries, or anadromous, sometimes occurs in the lake near to river tributaries and then ascending the rivers in spring for spawning. A big freshwater species, taimen is attaining over 2 m in length and over 100 kg in body weight. In spring, taimen move to upstream parts of the rivers to reproduce and feed. The extent of movement varies among rivers, but some immature and resting fish (that have spawned in previous years but did not produce gametes) remain in downstream areas to feed.

In the Selenge River and its tributaries spawning migrations begin in early May and coincide with the ice-out. Immature taimen and resting mature fish leave the river first. The spawning areas are at sites of ground water upwelling at a water depth between 0.5–2.0 m. Males are the first to arrive in the spawning area, females are coming later. Both males and females together dig spawning redds of 1.0–1.5 m in diameter and 0.5 m deep. Eggs are deposited into gravel substrate 5 to 12 cm in diameter.

In general, Taimen reaches sexual maturity is at the age of 5–6 years. Taimen do not spawn each year. For spawning taimen migrates to the upper part of the river and during the fall migration again to the downstream part.

[4] in Mongolian: "aimag"

Sexually mature taimen begin to form groups of 2-3 individuals. Several days later, when the fish show increasing restlessness, a male and a female try to break out from each group, whereas the surplus males start fighting with another. The fights of the males are very intensive and last for several days, the rivals often inflicting serious injuries upon each other by biting. The victorious male then joins the female, which has been staying at some distance, and they migrate to the spawning site together. The pair stops in a selected site and prepares the spawning red. After several days of preparations, spawning proper takes place. The female arches her body over the redd, thrusting her abdomen downwards. She opens her mouth in a wide and convulsive gape and releases eggs, vibrating her caudal fin intermittently. At the same moment the male, pressing the rear part of his body to the female, releases the sperm. The phases of redd digging and tail beat frequency:

1. Nest initiation – high number of tail beats per digging episodes
2. Nest completion – low number of tail beats per digging episodes

Nest covering – intensity of tail beating is low.

Dr Manu Esteve, a biologist from the University of Toronto, joined the science team in Mongolia in April and May of 2006 for a study of taimen spawning behaviour and recorded taimen spawning using remote underwater video.

The taimen reaches sexual maturity at the age of 5–6 years and around 350–400 mm body length. In Mongolian rivers spawning takes place at water temperatures ranging from 8 to 12°C. The duration of the spawning time is different, depending primarily on the water temperature. The females produce from 5.500–30.000 eggs depending on their body weight. The diameter of the egg is 5.3–5.9 mm (on average 5.6 mm).

The incubation period depends on water temperature. The incubation period of the taimen eggs in the experiment carried out by Mongolian scientists lasted 33–45 days at temperatures 9.3–9.7°C. In the development of the taimen eleven embryonic and two larval steps can be distinguished. Two days after fertilization the blastula can be seen, and after five days the gastrula appears and when the water temperature was 9.4°C, after 11 days started pigmentation of the eye. At the age of 23 days the embryo reaches a total length of 8.0–10.0 mm; the embryo at the age of 33 days has a total length of 16.0–18.0 mm, while the alevin at the age of 45–48 days has a total length of 21.0–23.0 mm.

In the Russian literature the greatest age noted for taimen is 50 years. Mongolian scientists used otoliths for the age determination of the taimen. This study showed that taimen with a length of 120–140 cm was about 27–29 years old. This seems very close to what Russian scientists found.

A science team was set up in Mongolia and since 2004 more than twenty scientists from six countries have participated in the science team's research and the activities of the Taimen Conservation Fund. Field research funded by the World Bank was conducted in Eg-Uur watershed area in the north-western region of Mongolia.

The role of the science team is to provide the scientific basis for the management of a sustainable "catch-and-release" taimen fishery in the Eg-Uur river system. The research of the science team is divided into two broad categories, i.e. (1) the study of the basic taimen ecology and (2) fisheries modelling and management. The scientific team has been collecting basic information on the ecology and life history of the species specifically to a) estimate the population size of catchable taimen in the study area, b) quantify the seasonal movement patterns of taimen, c) identify the critical habitat of taimen and d) assess the role of taimen in the broader community assemblage.

For the study of taimen in the Eg-Uur system, the science team uses radio and acoustic telemetry systems. Radio-tagged fish were tracked. Most taimen collected by angling measured between 60–100 cm, and the largest was 161 cm in total length. In the Eg-Uur system, however, fish over 120 cm in length are relatively rare. The science team is conducting annual surveys to help identify critical spawning, rearing, and winter areas for taimen. These locations are termed "critical" because they are utilized by taimen during periods when their population is more susceptible to harm from "catch-and-kill"[5] fishing or environmental disturbance. The locations and characteristics of the critical taimen habitat were integrated into the management plan and associated fishing regulations for the Eg-Uur watershed.

The science team has tagged over 50 taimen with radio and acoustic transmitters and conducted 23 manual tracking surveys to determine the movement patterns and critical habitat of taimen. The results of the study indicate that while most taimen remain in a relatively small area throughout the year (mean annual range 16.8 kilometers), taimen are capable of making longer-scale migrations. The study has shown the following: the maximum annual range recorded was 90 km, the minimum annual range recorded 4 km and mean annual range approximately 15 km. Movement was greatest in May and June (spawning and post spawning period) with another peak period of movement in September and October (water temperature decreasing). This study documents movements of taimen within a pristine river system that will be important in the development of a population dynamics model, conservation programme, and in guiding management plans.

The mean air temperature in the region has risen by 1.8°C over the last 40 years which is three times faster than the change of the mean temperature globally. The Eg-Uur river system is relatively free of other anthropogenic changes such as dams and other habitat alteration, urban development, invasive species, and point-source pollution. This relative lack of confounding factors provides a unique opportunity to isolate the impact of climate change on aquatic ecosystems and to better understand the resilience of intact ecosystems.

Mongolian scientists are studying the respiration rate of salmonids. The optimal water temperature for taimen is 14–15°C. During the survey in July 2011, the water temperature of the Uur River increased to 24°C. It has been observed in other salmonids and represents an important adaptation in rivers where summer temperatures exceed the species' thermal tolerance. The study's observations of high taimen densities in deep pools during the summer provides circumstantial evidence that taimen may also use behavioural thermoregulation. The extent to which such pools provide a thermal refuge and the extent to which taimen use this refuge is currently unknown.

By linking air temperature and precipitation to water temperatures and stream flow, it is intended to improve the understanding of the physical changes likely to accompany climate change. By then linking these physical changes to fish distributions and behaviour, insight into the capacity for behavioural adaptations of Mongolian fishes to climate change will also be gained.

The research also includes studying the taimen diet and community food web structure using two approaches, i.e. gut content and stable isotope analysis. While the results of the study have yet to be finalized, preliminary results indicate that taimen feed at the top of the food chain, feeding predominantly on small fish, mammal, and birds. Taimen predominantly feeds on fish. According to the food web study, the taimen diet is dominated, in terms of frequency and weight, by the common minnow followed by the stone loach, the grayling, the small mammals and the birds. 61 percent of the diet consists of common minnow.

Globally, the Taimen is under threat from overfishing. Mongolian scientists are now determining whether the exiting recreational (catch-and-release) fishing is compatible with the conservation of taimen and are also evaluating the taimen movements with respect to the design of "concession areas".

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[5] as opposed to "catch-and-release" fishing

In recent years, there has been a rapid increase in catches and catch-and-release angling for taimen in Mongolia. In light of this, there is an urgent need for new management and regulatory structures that promote sustainable fisheries, which would include protecting taimen during critical periods such as spawning, while still allowing controlled levels of catch-and-release angling.

The second most important species is the Siberian sturgeon (*Acipenser baerii*), listed in CITES (Appendix II) and the Convention on Migratory Species (Appendix II). In the regional Red List, Siberian sturgeon is listed as Critically Endangered (CE) (B2ab(iii,v)). The Siberian sturgeon is also listed as Very Rare /Endangered/ under the Mongolian Law on Fauna. This is the only fish species under this status in Mongolia. It inhabits Baikal Lake and during the spawning time moves up to the upper Selenge and its tributaries. Male Siberian sturgeon reaches sexual maturity at the age of 20 years, with around 1.3 m length and 14 kg body weight. Females are mature at the age of 15 years, with around 1 m length and 7-8 kg body weight. Spawning starts mid of May to early June. The biology and behaviour of the Siberian sturgeon in Mongolian rivers is very little studied. According to the Red Book of fishes, the overall area of distribution is less than 10 km^2 with three spawning sites identified in the Selenge and Orkhon Rivers. Reconstruction of the population is very slow. There is a continuing decline in quality of habitat due to sedimentation and pollution from gold mining, and in the number of mature individuals due to poaching.

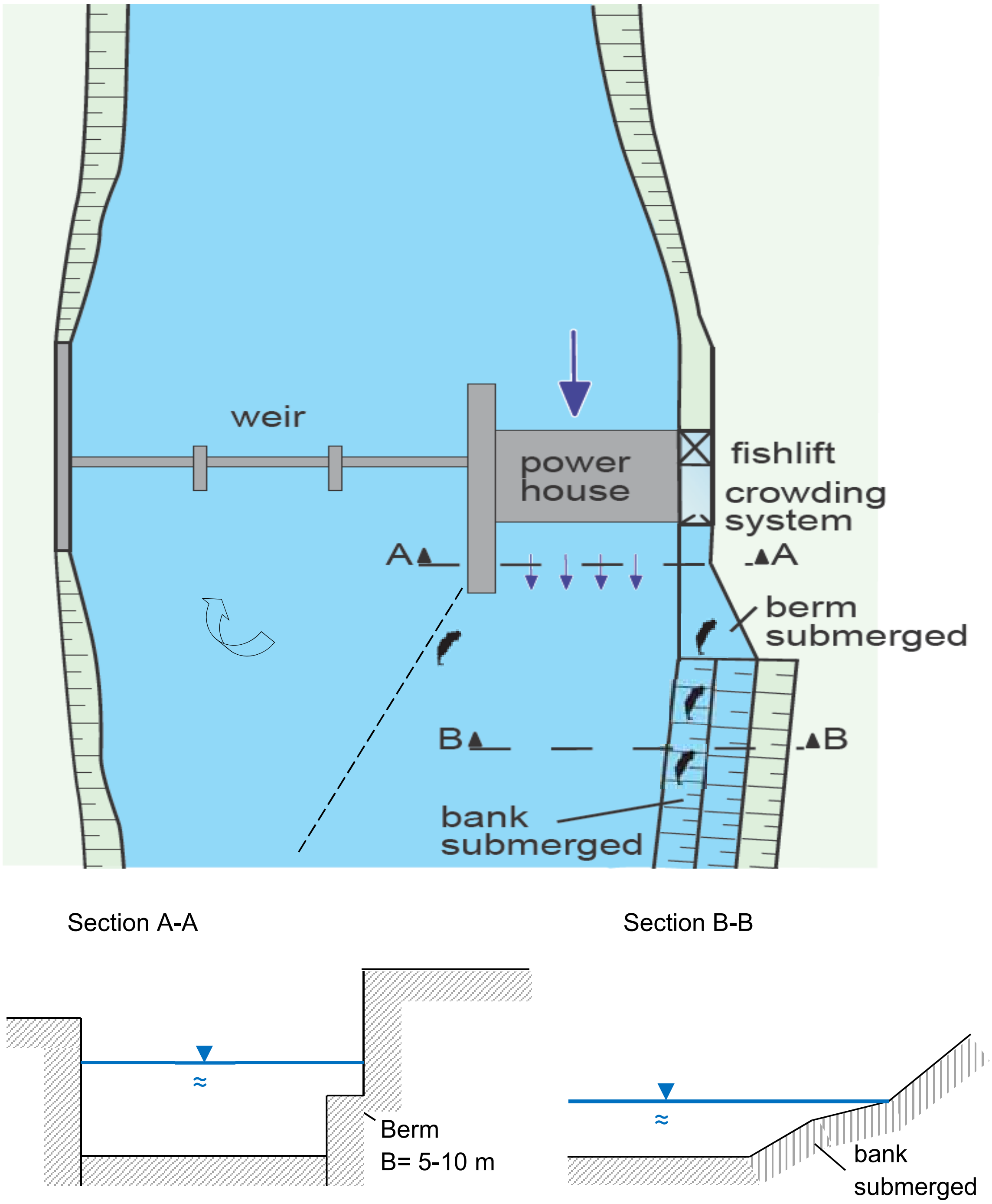
At present, three small hydropower plants are present in the Arctic Ocean basin. The energy production is limited, ranging from 200 kW for the Erdenebulgan soum power plant in the Eg River to 528 kW for the hydropower plant of Kharkhorin on the Orkhon River. Though hydropower is sometimes considered as eco-friendly as it does not directly produce green house gazes, hydropower plants have a wide range of adverse impacts on the aquatic systems. Ecological impacts and loss of ecological services should be carefully studied on a long-term basis, and studies should especially take into account the cumulated impacts of a succession of dams in the same river network.

In order to satisfy the increased energy demand, the construction of a dam is planned in the Eg River approximately 2.5 km upstream of the confluence of the Eg with the Selenge River The long-term benefits and impacts of a dam should be carefully studied and evaluated before its construction. Some impacts can be addressed in the design phase (e.g. by providing a fish way, flushing gate, etc.); other impacts can be mitigated by the management of the dam (discharge of water and sediments at critical times to reproduce the natural river runoff variability). While dams can provide valuable services to satisfy water or energy demand, they can have severe drawbacks regarding water quality and the floodplain functions along long stretches of rivers upstream and downstream of the dam. Modelling of the sediment accumulation in the reservoir and monitoring, as well as studying fish movements should be included in the feasibility study.

Appendix 7

Schematic view of a potential crowding system at the Eg River dam and its connection to the riverbed with a berm

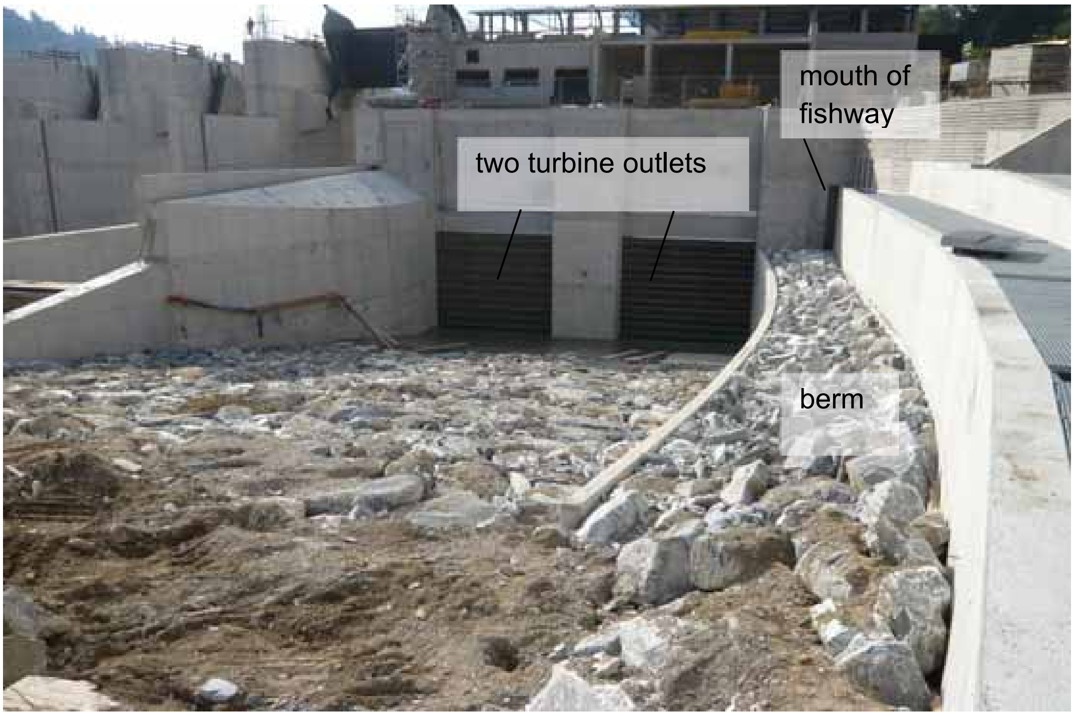
Dr.-Ing. R.-J. Gebler FAO/TCF Mongolia Workshop	**Layout of potential crowding system and connection to the riverbed with a berm**	



Appendix 8

Example of a berm and its connection to the riverbed

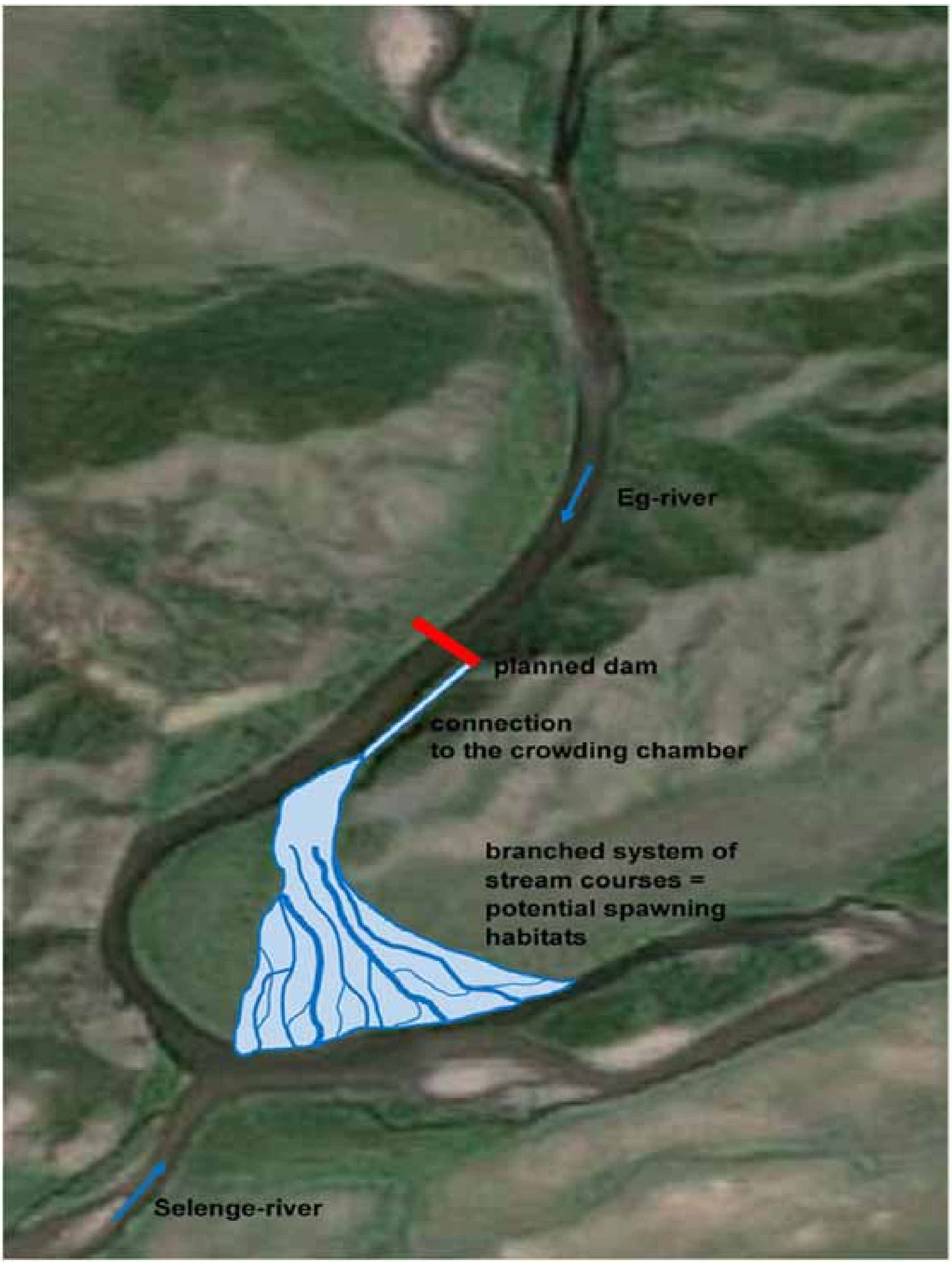
Dr.-Ing. R.-J. Gebler FAO/TCF Mongolia Workshop	Example of a berm and its connection to the riverbed	



Appendix 9

Schematic view of a proposed artificial system of branched stream courses for spawning downstream of the Eg River dam as mitigation measure for lost natural spawning habitat

Dr.-Ing. R.-J. Gebler FAO/TCF Mongolia Workshop	**Proposed mitigation measure at the mouth area of the Eg River**	



Source Map: Bilder © 2015 Landsat, Kartendaten © 2015 Google

Appendix 10

Workshop evaluation by the workshop participants

	Percentage of respondents [%]								
Criteria	very high (1)		high (2)		medium (3)	low (4)	very low (5)	Average score	number of participants answering
1. Usefulness of workshop	100		0		0	0	0	1.00	21
2. General course content	70		20		10	0	0	1.40	20
3. Course specifically on Eg river	70		15		10	5	0	1.50	20
4. Administration and logistic arrangements	76.2		23.8		0	0	0	1.24	21
5. Documentation and materials provided	76.2		9.5		9.5	4.8	0	1.43	21
6. Experienced expertise of resource person	76.2	4.8*	19		0	0	0	1.21	21
7. Capability to convey content	66.6		14.3	4.8*	9.5	4.8	0	1.55	21
	too short (1)		a bit too short (2)		optimum (3)	a bit to long (4)	too long (5)		
8. Course duration	0		5		70	20	0	3.25	20

* not ranked according to given categories but at intermediate value

The workshop "Fish passage design at cross-river obstacles – experiences from different countries, with potential relevance to Mongolia" was jointly organized by FAO and the Taimen Conservation Fund (TCF) of Mongolia and held in Mongolia in April 2014. Workshop participants included representatives from the Ministry of Nature and Green Development of Mongolia, the Egiin Gol Hydro Power Plant Project Unit (EGHPPPU), the Dorgon hydropower station, the Mongolian Mining Corporation, the National Water Association, civil society and the TCF. Workshop participants presented two country reports on the status of fish passage development, research and construction in Mongolia, and on the biology and behaviour of the most important fish species to be considered in planning fish passage facilities in Mongolia, and in particular in the Eg River. The resource persons presented knowledge on different fish passage issues from both the biological and the engineering perspectives. Although the known facts are mainly derived from studies in North America and Europe, the basic aspects can serve as "food for thought" also in other regions, including Mongolia. Information provided and designs presented should, however, under no circumstances just be copied but have to be adapted to local conditions (taking into due consideration the species present) while respecting the important basic design criteria which are valid for all passes of the same type at all locations, whether in Europe, North America or Asia. As regards the planned Eg River hydropower plant, the workshop did not have a unanimous view concerning the need for, and the usefulness and the environmental impacts of, the planned dam construction. However, all workshop participants unanimously agreed that, should the dam on the Eg River be constructed, a fish passage system would be needed to mitigate the blocked upstream and downstream passage for maintaining genetic exchange between fish in the Eg and Selenge Rivers. The workshop agreed that trap-and-transport for both upstream and downstream fish passage, with the option of later modifications, would be the only viable solution for this Eg River power plant. However, the resource persons clearly held that based on their assessment during the field visit and the additional information provided during the classroom sessions – from a fish ecological, biodiversity and fisheries point of view – the dam must not be constructed at the planned location because it would inflict irreversible damage to the aquatic ecosystem. In fact, the excellent ecological status of the Eg River just upstream of the confluence with the Selenge River (and also further upstream in the watershed) calls for the preservation of the given morphological and hydrological characteristics. Alternatives should be sought as regards either the location of the dam (i.e. consider to construct one dam or several smaller dams on one or several other rivers that are less important for taimen) or the type of energy produced (solar or wind). Furthermore, the resource persons held that, most importantly, the workshop must not be seen as encouragement to construct new dams solely because the principles of the design and construction of fish passage facilities are known.

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