# IRES: People, power, and rivers: social-ecological dynamics of hydroelectric development in northern Mongolia

## 1. Background

### 1.1 Global Hydroelectric Development and its Impacts within the Selenge River Watershed

The search for low carbon, low cost, energy production has driven a global dam-building boom with over 3,700 large (> 1 MW) hydroelectric projects under construction or planned as of 2015 (Fig. 1., Zarfl et al. 2015). Despite increases in wind and solar energy production, hydroelectric accounts for more than 75% of global renewable energy production (World Bank 2014a, b).

Much of the planned hydroelectric development over the next two decades is in Asia, and while attention has focused largely on mega-dams in the Mekong basin (Winemiller et al. 2016), Central Asia is already experiencing conflict over transboundary impacts of smaller hydroelectric development. For example, the proposed Rogun Dam on a tributary of the Amu Darya in Tajikistan has pitted that country against downstream Uzbekistan (Jalilov et al. 2016). Russia has alternately supported and opposed the Rogun Dam and others in the region (Hashimova 2014), while at the same time pursuing hydropower development in its own territory, particularly in the Amur basin of Siberia (Zarfl et al. 2015).

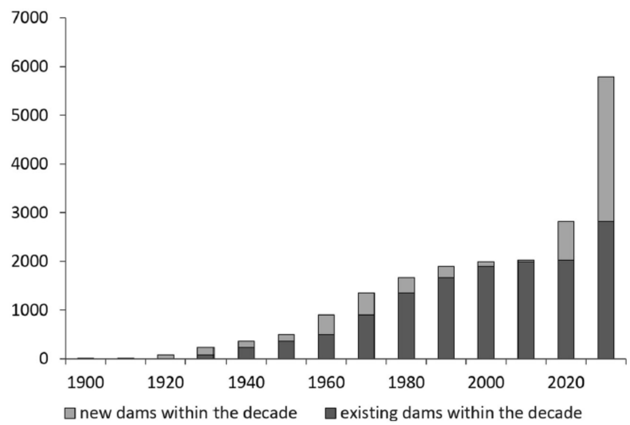


Figure 1. The number of existing and planned hydropower dams in the world. From Zarfl et al. 2015

In Mongolia, an era of hydropower development is just beginning. A handful of small (< 10 MW) hydroelectric projects were built during the Soviet period (pre-1991), all but two of which are run-of-river projects with a diversion, but no dam. Two larger hydropower projects have been built since Mongolia's democratic transition in 1991: the Taishir dam (11 MW) on the Zarkhan River and the Dorgon dam (12 MW) on the Chono Kharaih River, both completed in 2008 in western Mongolia. One large hydropower project, the Shuren project (300 MW) proposed for the lower Selenge near the Russian border (Fig. 2), is undergoing advanced stage feasibility studies funded by the World Bank.

A second large hydropower project is in the early stages of construction on the Eg River, a large tributary of the Selenge River (Fig. 2). This Egiin Gol Hydropower Project (EGHPP) includes an 82 m high dam, a 75km long reservoir and 315 MW of power generation, far greater than the total existing hydropower capacity in Mongolia to date. The EGHPP would produce enough power to offset the electricity that Mongolia currently imports from Russia, making Mongolia's electric grids nearly self-sufficient. Construction of access roads and a bridge for the EGHPP began in late 2015 when the first installment of a loan from the Chinese Export-Import Bank was released. Pressure by Russia, nominally driven by concerns over water and sediment supply to Lake Baikal, was sufficient to cause China to temporarily withhold further loan installments. This pause in construction provides an opportunity during this three-year IRES project to study pre-dam social-ecological conditions and, potentially, social and ecological changes during the construction phase.

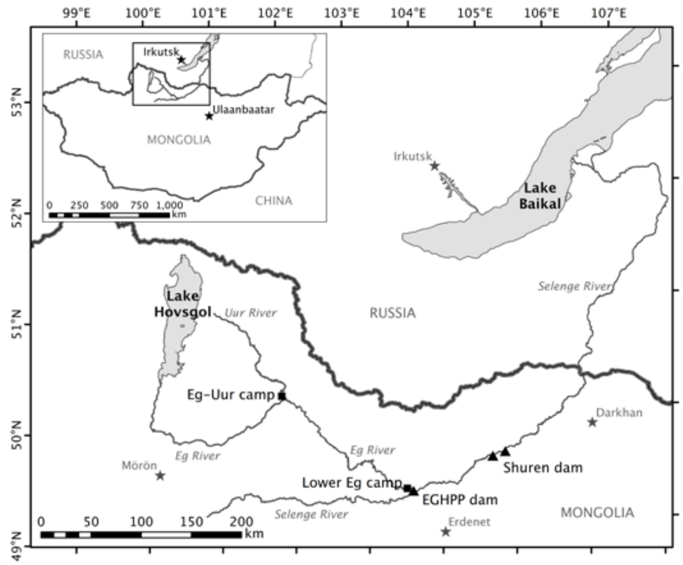

Figure 2. The study site in northern Mongolia including the two field camps and proposed dams.

The rivers of northern Mongolia represent an ideal laboratory for examining the impacts of hydropower development as they start from a nearly pristine baseline. Land use in the northern Mongolian portion of the SRW has changed relatively little in the past two centuries, with most land still forested or pasture. Localized impacts of mines (Stubblefield et al. 2005) and agricultural fields on water quality do occur, but their impact is minimal in our core study area on the Eg and Uur Rivers (Fig. 2). Untreated surface waters remain the dominant water source for people and livestock in the region. Although fishing is important here, the low population density keeps total fishing pressure low compared to most other large rivers of the world with an average of 4-6 Mongolian anglers per day per 100 km of river during the summer (Jensen unpublished data) and foreign anglers restricted to tightly regulated catch-release fisheries with little impact on the target species (Jensen et al. 2009).

Our ecological focus for this project is fish, as they are one of taxonomic groups most likely to be severely impacted by hydropower development. They also represent an important link to human communities through fishing and are often among the species of greatest concern when evaluating dam impacts. As top predators in the system, they also serve as a focal point for changes in habitat and the abundance of lower trophic level species on which they rely. Four fish species are of particular interest: taimen (*Hucho taimen*, the largest salmonid in the world and a primary target of foreign and urban Mongolian anglers), lenok (*Brachymystax lenok*, another large salmonid that is frequently targeted by local fishermen), Baikal grayling (*Thymallus arcticus baicalensis*, the most abundant salmonid and a frequent bycatch species), and Siberian sturgeon (*Acipenser baerii*, an extremely rare fish sometimes harvested illegally for its valuable caviar). All of these species except Baikal grayling are categorized as regionally threatened (vulnerable, endangered, or critically endangered) in Mongolia (Ocock et al. 2006), with climate change an important threat for some of them (Hartman & Jensen *In Press*).

Direct impacts of dams on fish include loss of habitat and population connectivity, changes in temperature both above and below the dam, alteration of the hydrologic regime, and increased methyl mercury body burdens (Kelly et al. 1997, Agostinho et al. 2008, Ziv et al. 2012). Additional impacts arise from a complex interplay of human and natural processes. For example, reservoirs are an important locus of aquatic invasive species introductions. Whether this is predominately a result of ecological processes, such as the increased invisibility of degraded ecosystems, or human-mediated processes, such as increased transport of invasive species through boats or bait buckets, remains largely unknown. While the basic ecology of direct dam impacts has long been understood (Baxter 1977), understanding human-mediated impacts is an important research frontier that has long been ignored (e.g., the comprehensive World Commission on Dams report (2000) makes no mention of such impacts).

Impacts of hydropower on human communities in the SRW are set against a backdrop of longer-term adaptations to climate change. Northern Mongolia has experienced an air temperature increase of more than 2 °C since the 1940s (Dagvadorj et al. 2009, Nandintsetseg et al. 2006). This rate of warming is more than three times faster than the global average, which makes northern Mongolia a key location to study climate change impacts that have not yet occurred elsewhere. Warming has been accompanied by dramatic alterations in precipitation patterns (Goulden et al. 2016), a more salient change (Marin 2010) for residents of the region who are primarily semi-nomadic pastoralists (i.e., herders). Elsewhere in Mongolia, changes to precipitation patterns have been linked to more frequent winter livestock mortality events or *dzuds* (Fernández-Giménez et al. 2012). *Dzuds* occur in winter, but are influenced by processes that impact livestock condition throughout the year. Climate changes experienced by herders are set within the economic shifts of the post-Soviet free and global market for livestock products like cashmere (Marin 2008).

Given the complexity of human and environmental responses to climate change and dams and the short time frame of most impact assessments, *a key challenge in the current era of global dam-building will be to develop innovative and rapid approaches to understanding the social-ecological dynamics within affected watersheds.*

## 2 Example Projects

During the course of the spring Distributed Seminar, student participants will design two-person (one grad student and one undergrad) research projects within an apprenticeship model that allows them to learn field-based research techniques within a discipline (e.g., ecology or anthropology). Students will also design and participate in one interdisciplinary whole-group project each year. Each of these projects will stand alone, but will also contribute toward the broader goal of understanding social-ecological dynamics of hydropower development. Because of the inherent uncertainty in dam construction timelines, students will focus on projects that do not require post-dam comparison data to be interesting and publishable, although many projects will set the stage for such comparison in the future. The following are a few examples of student projects, along with names of potential advisors in parentheses. The PI (Jensen) and Mongolian collaborators (Mendsaikhan and Tumurbaatar) are not mentioned as they will be involved in the development and mentorship of all projects.

### 2.1 Ecological Impacts of Hydropower and Associated Development

Despite many improvements over the years, standard environmental impact assessments (EIAs) remain an inadequate tool to predict the diversity of interacting changes brought about by hydropower projects and associated infrastructure developments (Morrison-Saunders & Retief 2012). Many EIAs for hydropower projects in developing countries consist of little more than literature reviews, sometimes coupled with brief field surveys and basic mapping of the most visible natural features, and they are frequently conducted after all relevant design and engineering plans have been made, thus providing no opportunity for the EIA to influence decision-making or inform public debate (Fearnside 2001). Given the explosive growth in hydropower projects worldwide (Zarfl et al. 2015), there is a pressing need for the development of more thorough and thoughtful methods of understanding and predicting impacts that can nevertheless be completed rapidly enough to have an impact on decision-making. Student projects will address this need through the use of emerging technologies including unmanned aerial vehicles (UAVs) and analysis of environmental DNA (eDNA) as well as the coupling of fish physiological studies to questions of hydropower impacts and mitigation.

Project 1: Evaluating the presence of endangered fish species using environmental DNA (Young, Isaak)

*Background*: Environmental impact assessments face a significant challenge determining impacts on extremely rare endangered species. On the one hand, these are exactly the species of greatest relevance as even small changes in their survival may be enough to extirpate them. On the other hand, assessing their presence or absence with certainty may require greater sampling effort than is feasible for most EIAs (Dextrase et al. 2014). This is exactly the challenge that Mongolian collaborator Mendsaikhan has faced in trying to determine whether the critically endangered Siberian sturgeon is present in the lower Eg river near the proposed dam site.

Analysis of aquatic environmental DNA, i.e., DNA shed by organisms in the water, has only recently been developed as a tool for surveying rare fish species (Ficetola et al. 2008, Jerde et al. 2011), but is already being deployed in a variety of invasive species monitoring programs, e.g., detection of lamprey (Gingera et al. 2016) and Asian carp (Lodge et al. 2012) in the Laurentian Great Lakes basin. The technique can also be used to understand the presence/absence of endangered species and their habitat use. For example, project collaborators Young and Isaak are using eDNA to monitor endangered bull trout in Western US rivers.

*H1*: Siberian sturgeon are present in the lower Eg and Selenge Rivers near the proposed dam site.

*Methods*: Sample collection protocols will follow methods developed by project collaborator Young and colleagues at the US Forest Service's Rocky Mountain Research Station (Carim et al. 2015), which involve pumping a given volume of water through glass fiber filters using a portable battery powered peristaltic pump. Laboratory analysis will employ the DNA extraction procedure described by Ficetola et al. (2008) using the same Siberian sturgeon primers used by Dejean et al. (2011).

*Leveraging Resources*: Rutgers University owns a peristaltic pump and filters. Analysis costs are low enough (< $65 per sample) that a sufficient number of samples (~50) can be analyzed within the budget of typical graduate student research awards available at many of the collaborating institutions.

Project 2: An unmanned aerial vehicle (UAV) based visual survey of taimen (Hrabik, Dickson)

*Background*: Taimen are the most economically important of the fish species that live in the SRW in Mongolia, supporting valuable sport fisheries that employ guides, cooks, and drivers. Estimating their abundance in the vicinity of proposed dams is made more difficult by their relative rarity and the fact that the methods used to capture and release them safely (primarily angling) are inefficient. On the upper Eg and Uur Rivers, it took four years and 612 tagged taimen to achieve a sufficient number of recaptures for a mark-recapture population estimate (Jensen et al. 2009). Boat-based or snorkeling visual surveys have been unsuccessful because taimen frequently move downstream to avoid the surveyors which leads to possible double counting.

Their low cost and ease of use make UAVs a promising emerging technology for a variety of ecological field applications. However, the slow development of a legal framework for research use of UAVs in the US has limited their application here. A June 2016 decision by the Federal Aviation Administration to allow "commercial" (including research) operation of UAVs without a pilot's license will soon open the door to greater use of this technology in the US. In Mongolia, UAVs may be operated without a permit. PI Jensen has tested the use of small quadcopter UAVs (DJI Phantom and 3DR Solo) equipped with cameras with polarized lenses for visual surveys of taimen in Mongolia and found that they can reliably detect taimen under a specific set of conditions (height, water clarity, wind speed, and sun angle).

*H1*: Taimen abundance within the 75km long section of the Eg River which will become a reservoir following construction of the dam is equal to abundance of this species in other high quality habitats.

*Methods*: UAV flights will be conducted over the river on clear days between 10am and 2pm to maintain optimum sun angle. Locations will be selected randomly within the study area. Overlapping transects will be flown perpendicular to the direction of river flow at a height of 50 feet above the water surface, until the UAV battery reaches 20%. During the flight, video will be recorded continuously from the UAVs camera and later downloaded to a portable hard drive. To estimate the detection probability, i.e., the probability that a taimen is seen given that it is within the UAV survey area, a radio telemetry survey will be conducted in the same location following the UAV flight. Jensen and Mendsaikhan have radio tagged 37 taimen within the study area. Relocations of these tagged fish will provide known presence of taimen for estimating the detection probability. Recorded video will be visually analyzed to count the number of taimen present.

*Leveraging Resources*: Rutgers University owns a radio receiver and two UAVs suitable for this project.

<u>Project 3: Swimming performance of Selenge River Watershed fishes (Hartman, Horodysky)</u>

*Background*: Fish passage devices are commonly used to reduce the impacts of dams on migratory fish species, however, they frequently still represent a formidable barrier to migration. For example, the passage rate of American shad (*Alosa sapidissima*) at fish ladders on four large U.S. East Coast rivers ranges between 4 – 32% (Brown et al. 2013). This is partly the result of the relatively poor swimming performance of this anadromous species, which typically spawns in low velocity, low gradient coastal plain rivers (Bilkovic et al. 2002).

A fish passage device has been proposed by the EGHPP following recommendations from an international working group (FAO 2015). The recommended passage device is a fish elevator, which transports a volume of water vertically from the river below the dam up to the level of the reservoir where it is released. While fish elevators do not require the same upstream swimming ability as the more well-known fish ladders, they do typically incorporate water currents to help guide migrating fish that orient into a current (rheotaxis). The appropriate current speed depends on the swimming performance of the target species, yet little is known about the swimming performance of the threatened and endangered fishes of the SRW.

*H1*: Taimen, a piscivore that inhabits fast flowing water, have higher critical swimming velocity ($U_{crit}$) than lenok, which feed primarily on benthos in pools and runs.

*Methods*: Protocols will follow recommendations given by Tierney (2011) for experimental assessment of critical swimming speeds. Taimen and lenok will be collected from wild populations in the Eg River and held in a large pool containing river water under ambient temperatures and acclimated for a minimum of 24 h. Fish will be introduced to a swim tunnel respirometer and acclimated for 1.5 hours at a low (non-swimming) velocity. Thereafter the fish will be forced to swim at increasing steps of velocity of approximately 0.10 $m \cdot sec^{-1}$ for 20 min increments until the fish reaches exhaustion. $U_{crit}$ is then calculated by:

$$U_{crit} = V_p + (t_f / t_i) V_i$$

Where $V_i$ is the velocity step (m/s), $V_p$ is the maximum velocity reached, $t_f$ is the time (s) elapsed from velocity increase until fatigue, and $t_i$ is the time (sec) between velocity increments. We will target a minimum of 10 individuals of each species and develop mean critical swimming speeds for each species.

*Leveraging Resources*: Rutgers University owns a 30-liter Loligo Systems swim tunnel respirometer, housed at the Taimen Conservation Fund's lower Eg field station in Mongolia, capable of maintaining precise water velocities in the experimental chamber.

**2.2 Social Dimensions of Hydropower Development**

The 75 km reservoir created by the EGHPP dam will displace an estimated 700 people from the village of Hantay and perhaps half that many people from among the nomadic herders currently living within the reservoir's footprint. While the number of displaced people does not compare to the massive impacts from dams in high population density countries such as China, the lower numbers provide a more manageable study population for 6 week student projects. Forced migrants displaced permanently by development projects are rarely able to regain their livelihoods, risking impoverishment as a result of landlessness, joblessness, food insecurity, and the loss of social networks (Cernea 2003, Scudder 2005). Understanding the decision-making process among those forced to migrate as well as the factors associated with post-migration livelihood outcomes will enable policymakers to better mitigate the impacts of forced migration related to hydropower development.

<u>Project 4: Shifting baselines: how elders have experienced environmental change (Crate)</u>

*Background*: The input of elders, or those inhabitants born in the early years of the twentieth century, is important to understand their memories of past change and human response, their perceptions of contemporary change in the context of rural existence, and their views concerning the future as change becomes more pronounced. This documentation is important not only to corroborate with other data sources of change but also as a critical local resource for the communities themselves as they grapple with change (Crate 2006).

*H1*: Elder members of herding families have experienced a more rapid pace of environmental change in northern Mongolia, with both the 1991 transition to a free market economy and the increasing effects of climate change.

*Methods*: Students will document oral histories of elder herders of the watershed using semi-structured interviews, a guided set of questions to maximize reliable comparative qualitative data (Bernard 2000). The oral history team will conduct up to 12 interviews with elders (aged 55+) of herding families. The objective is to understand the change they have seen in their lives and also to gauge how they perceive changes in the last 10 years. Students will transcribe and code oral histories to discern common themes.

<u>Project 5: Outmigration from rural areas: a baseline for comparison to dam-driven migration (Crate)</u>

*Background*: Analyses of the social impacts of hydropower development have quite rightly focused on the 40 – 80 million people worldwide who are estimated to have been displaced by dam building (World Commission on Dams 2000). However, such displacement occurs against a background of outmigration from rural areas for many other reasons. Youth outmigration and their overall alienation from rural life are common trends in the twenty-first century. Youth are increasingly alienated from rural life, largely due to the effects of increased exposure to western consumer culture and the disparity between elder and youth work ethics (Ericksen 2014). Similar youth alienation is and has been a common trend in many rural contexts, often for decades, "young people (are) not only in transition between childhood and adulthood but also in transition between two distinct ways of life" (Condon 1987, p. 188). Preliminary research in Mongolia suggests that the alienation of youth from rural life shares a similar trend to that of the Viliui Sakha people in Siberia (Crate 2014).

*H1*: Few young people living in herding families express a desire to continue living in their communities once they are old enough to be independent; most reference economic opportunity as the primary reason they wish to leave.

*Methods*: Students will facilitate focus groups (group interviews) with 3-5 young people in our field camp and nearby village centers. Focus groups are directed interviews that, in extended discussion, allow participants, in this case youth, to share their beliefs (Bernard 2000). The research team will facilitate up to four focus groups with the option of inviting select individuals for follow-up interviews.

Project 6: Social capital, dam building, and displacement (Randell, Klein)

*Background*: Social capital – the resources and support contained within social relationships – can play a key role in the ability for households and communities to cope with a shock such as displacement. Prior research has found that social capital enables communities to better recover from adverse events including natural disasters and economic shocks (Aldrich & Meyer 2014, Carter & Maluccio 2003, Marín et al. 2015). Studying social capital and networks before and after displacement is an effective way to understand: (1) the social structure of the community at baseline; (2) how displacement impacts social capital among community members; and (3) the role of social capital in enabling households to recover from displacement. This project examines baseline social capital and networks among households likely to be displaced by the EGHPP, including those in the village of Hantay and nomadic households.

*H1:* Households living in Hantay will have higher levels of social capital than will nomadic households.

*H2:* Among nomadic households, social capital will be positively correlated with levels of livelihood diversification (which will in turn be correlated with resilience to the negative impacts of displacement).

*Methods:* Students will collect social capital and network data from all households facing displacement through household surveys. These data provide baseline information on network structure and levels of social capital in order to understand which members of the community have stronger and weaker social ties before displacement. In addition, students will collect data on extra-local social networks and on membership in local organizations (e.g., religious groups, clubs, unions).

*Leveraging Resources*: Few resources would be required for the social science projects other than the use of one of the rented vehicles (boat or van) for transportation and the assistance of a translator. The Mongolian project collaborators are both fluent in English and will assist with translation.

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