Aras River Riparian Corridor: Ecological Characterization and Potential Threats Associated with Hydrological Impediments in Turkey

A report to

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Executive Summary

The Lower Aras River Corridor (40.117°N, 43.615°W) in the extreme southeastern corridor of Turkey is an area of rare, remnant high biodiversity that in turn provides essential ecosystem services to this region of Turkey. These services will likely be severely reduced or completely eliminated should the proposed Tuzluca Dam be erected immediately westward of the Aras-Kars River confluence (i.*e.* ~0.5 km westward of the Armenian Boarder).

All riparian plants and animals currently residing in this comparatively robust riparian region will be eliminated by inundation from at least tens of meters (and possibly hundreds of meters in some locales) of impounded water behind this government-proposed, financed, and constructed dam. At least three villages and their associated agricultural landscapes will also be eliminated under the waters of the proposed reservoir stretching many kilometers westward of the proposed dam. A minimum of 6,500 fruit (apricot, apple, *etc.*) and 18,000 other (elm, aspen, *etc.*) mature trees (>10 years old and/or >9 m tall) would be drowned in the immediate vicinity of the exiting riverbed. Perhaps three times that many will be killed ultimately, depending upon ensuing water levels. Younger trees/woody shrubs lost would easily exceed >60,000 individuals.

Initial surveys of the soil/landscape of the particular upland areas which would become the defacto start of the new riparian/lacustrine zone under the elevated waterline leave little hope that anything like the existing vegetation could ever exist there in the foreseeable future (*e.g.* within the next 75 years). These currently devegetated hillside regions above the existing vegetated riparian regions harbor soil with a mean sediment particle size much larger (*i.e.* sandier) and saltier than existing riparian soils and so offers little hope of retaining nutrients and organic matter necessary for the growth of healthy riparian vegetation.

As the exiting vegetation disappears, so will the associated vertebrate and invertebrate fauna. We should expect to see a vastly reduced diversity and abundance of animals of all stripes. While the absolute number of mobile terrestrial organisms is harder to quantify than sessile woody vegetation, we can easily expect a 75% reduction, and likely >90% reduction in most terrestrial vertebrates (save European jackals, *Canis aureus moreoticus*) outside of actively managed domestic species. Invertebrates appear to be even more tightly associated with riparian vegetation and are likely to be reduced by >90% (both individuals and biomass), with several riparian-associated groups (*e.g.* odonates, lepidoptera) effectively driven locally ecologically extinct and often undesirable species increasing (*e.g.* Culicids) becoming more dominant.

Lastly, we can expect severe disruptions to the human community along this stretch of river with at least three villages disappearing. Extensive interviews in villages upstream that have been affected by similar impoundments show that villagers who choose to leave and take a ministry proffered buyout view the loss of their homesteads as a net loss and >3 years post displacement view their circumstances as worse off. Proffered government-built housing differs in quality and quantity from traditional village life, often without adequate space for livestock and other essential aspects of traditional Turkish rural life. Villagers who remained post dam construction report significant social disruption including spikes in domestic violence, inter- and intra-household conflicts, vastly reduced income potential, increased despondency over long-term fiscal prospects, greater likelihood of personal bankruptcy, increased likelihood for younger members to move away/to regional urban centers, and heightened levels of overall dissatisfaction/depression with life in general.

In summary, impacts of the proposed Lower Aras River Dam are likely to be universally negative in terms of ecosystem function, regional demography, and local village life. While there are potential benefits associated with the dam and impounded waters, it is unclear if the net profit will be positive. For those in the immediate wake of the dam and reservoir, all indications are that this construction and "development" project will actually prove a negative impact to the region and harm local economies. Given the stressors that already exist in the region, it is possible that this dam may well prove something of a death knell to various ecological and human communities currently residing in this oasis in eastern Turkey.

Project Scope & Terminology

This report concerns the Aras River in eastern Turkey. Please note that I will frequently refer to the "Lower" Aras River in this report. This description is Turkey-centric and should be interpreted as the lowest section of the river *within* the country of Turkey. The Lower Aras River should herein be taken to mean the region along the course of Aras River just before it enters Armenia/merges with the Arpaçay River. Please note that this region is roughly the halfway point of the river's geomorphological journey to the Caspian Sea and so not the "lower" river in the overall geographic sense.

Most of the riparian and upland data and observations collected and reported herein were made within 20 km of the confluence, although I did make qualitative assessments across the region as far as 60 river kilometers upriver from the confluence.

While I am affiliated with both Kuzey Doğa and California State University, the opinions expressed herein are my own and not necessarily those of my affiliated organizations nor colleagues. respectfully submitted as an expert in ecologist. They represent my professional interpretation of conditions on the ground.

Study Goals

This effort represents one subset of an ongoing, multi-year regional effort to characterize the conditions and trends of eastern Turkey. This particular report is a distillation of information and insights gleaned from numerous visits to the Lower Aras River area (proximate to the confluence with the Arpaçay River and the Turkish-Armenian border) between 2006 and 2013 and an intensive two week visit in late October 2013 which focused on exploring pre-dam conditions. In this brief summary, I attempt to:

1. Characterize the gross abiotic landscapes of the Lower Aras River.
2. Characterize the gross biotic community of the Lower Aras River riparian corridor.
3. Report on the impacts of other hydrological impediments upon nearby stretches of the Aras River.
4. Make initial predictions for what a dam and impounded reservoir would do to this section of the Lower Aras River.

Aras River Overview

The Aras River is a major river in the southern Caucasus Region of the Anatolian Plain. The headwaters proximate to the Turkish city of Erzurum are at an elevation of almost 2,000 m. From here, the river flows initially southward before turning eastward, ultimately flowing through three Turkish provinces (Erzurum, Ağrı, and Iğdır) and dropping nearly 1,000 m in elevation before merging with the Arpaçay River and entering Armenia (the Arpaçay delineates the Turkish-Armenian border) just west of the village of Aşağiçiyrikli (40.126°N, 43.650°W, elevation 950 m). Upon leaving Turkey, it flows through or alongside Armenia, Azerbaijan and Iran before merging with the Kura River and ultimately dumping into the Caspian Sea (39.229°N, 49.328°W, elevation -30 m) near Neftçala, Azerbaijan after a run of 1,072 km.

Lower Aras River Conditions

The Aras River flows through the narrow Aras Valley for almost 100 km before the confluence Arpaçay. Valley ridgelines are 500-1,000 m above the riverbed and help contain typical flows to a relatively restricted primary channel usually 75-150 m wide. True bankfull conditions are comparatively rare outside of spring flows (I have seen them only once). The riverbed itself is typically braided (owing to both the steepness of the river slope and high sediment loads) with a relatively high proportion of boulders (> 20 cm maximum diameter) and comparatively little cobble (> 0.5, < 20 cm) on the bed surface. Attempts to infer historic, undisturbed river flows are confounded not only by poor/non-existent data, but also by extensive historic and ongoing manipulations of the channel's geomorphology (many of which are intensifying). At least 75% of the river length within the valley is leveed or severely constricted by impoundments or diversions. A small subset of stretches such as the area in within a few kilometers of the confluence has an expansive primary channel (~ 800 m wide).

Strong variability in river flow is the norm in this arid region of the world and floods/droughts are a common experience of residents of this region. Generally, Aras River flow is driven by snow melt and intense precipitation events in the spring and early summer which drive heavy seasonal flows. That flow slackens by mid summer and moves the slowest in between October and December. The Aras River drops an average of nearly 2 m per km of river in its journey to the Caspian with the United Nations estimating the Aras discharges perhaps 2.5 billion m^3 into Armenia "annually" (UNDP/GEF 2006), although this estimate clearly varies greatly from hear to year. As with many aspects of the historic and extant hydrogeomorphic record, attempts to quantify environmental variation in this part of the world are quite problematic. Hard numbers are difficult to come by and the voracity of older data are unknown. Ever-increasing water demands for economic development-driven agricultural and herding sector expansion seems to have confounded at least some estimates of actual river flows, fostered greater water quality problems and helped to increase water insecurity.

Soils in the region are relatively friable, but the dearth of vegetation from overgrazing and poor soils management is clearly exacerbating erosion, although quantitative measures from this region are non-existent (but see my discussion of dam lifespan below). River flows are always high in total suspended solids, with the water typically appearing to be milk chocolate.

Partly in response to this variation in flow and the growing water demands/scarcity and water quality degradation across the region, Turkey has been actively building hydrological control structures for several decades, with an intensification of construction since the late 1990s (15 projects have been built or are proposed for the Aras and adjacent rivers; (Environment Ministry, *pers com*). This regional network of dams and diversions can purportedly now hold more than 5,100 million m^3 of surface waters (primarily for irrigation) and generate an unspecified amount of hydroelectricity (Environment Ministry, *pers com*). Again, no numbers are available, but it is highly likely large amounts of water lost to evaporation from reservoirs.

Generally, Aras River flow is characterized by an often intense snow melt-fueled fast spring flow that slackens by mid summer and moves the slowest in October/November. As with many aspects of the historic and extant hydrogeomorphic record/attempts to quantify environmental variation in this part of the world, hard numbers are difficult to come by. I have not been able to verify either realized reservoir capacity nor gross discharge rates, but these seem reasonable if one discounts reduction in holding capacity from sedimentation.

I have personally measured flow rates under heavy flow, springtime conditions only once (April of 2009; 3.5 kilometers per hour), but have frequently measured surface movement exceeding of 1.5 or 2 kilometers per hour during the lower (autumnal) flow period on several dates over various years.

Lower Aras Riparian Conditions

The entirety of the Aras River Valley has been settled and utilized by humans for millennia. Severe manipulation of the vegetative community began with various ancient empires and has included intensive grazing by domestic livestock, woody and herbaceous species clearing, and extensive, tilled row cropping. Some villages within the past few decades have begun active orchard development and/or silvaculture for economically important woody species. This has helped create limited pockets of elevated vegetative canopies proximate to the river channel.

The vegetation is dominated by often prostrate, low density desert species away from the riparian corridor/up the valley sides. This arid plant community lacks trees with the tallest woody species being shrubs <2 m tall.

Existing Ecological Communities: Invertebrates

I characterized insects with aerial arthropod ("sticky") traps in October of 2013 in Riparian Vegetation along the Aras River proximate to our Aras River Bird Banding Station. These aerial arthropod traps primarily sample flying insects.

The aerial arthropod traps were tanglefoot-covered yellow plastic sheets (Bioquip catalog #2873) placed on wire holders (Bioquip catalog #2874) and suspended over the vegetation or soil surface. Several years of extensive testing and experimentation have informed and refined our sampling protocols. These yellow plastic traps were supplied in 6" x 12" sheets which were cut in half to produce 6" x 6" sheets (or 14 cm x 15 cm) with an area of $0.021m^2$. The sticky-sheets were then placed such that the lower edge of the paper was approximately 5-10 cm above the soil surface (for dunes, salt pans, *etc.*) or uppermost edge of the vegetation canopy. In cases of short or sparse vegetation, the insect trap was set a minimum of 10cm above the ground to avoid potential inundation or entanglement with blowing plant stems (Anderson 2009). These traps were left out for 6 days, although deployments of 3 to 6 days produce statistically indistinguishable results when standardized for days of deployment (Anderson 2009). Upon collection, the traps were carefully wrapped with clear plastic wrap and returned to our field station for processing. This prevented additional items being stuck upon the trap surface, allowed traps to be stacked for storage without sticking to one another, and allowed the rapid inventorying of the trap via looking through the transparent plastic.

We successfully deployed a total of 11 traps which captured and enumerated 2,096 aerial invertebrates upon our suspended sticky traps. Each individual trap captured an average of 12.1 ± 3.0 species (mean ± 1 sd) and our riparian corridor had an insect productivity of 0.035 ± 0.016 g of (fresh weight) insects m^{-2} day^{-1}. These traps captured an a somewhat lower number of insects than a typical "healthy" wetland sites elsewhere in Turkey and the globe, but October is late in comparatively the season. In my interpretation, this abundance of insects in October suggests that this emergent riparian region is functioning quite well in terms of invertebrate support and that this riparian corridor is supporting these members of our riparian community and, in turn, a host of other animals (*i.e.* birds) which feed off these insects.

The most abundant group of insects we captured were flies. In descending abundance, mosquitos, honey bees, and grasshoppers rounded out the top four orders of insects. Perhaps most interestingly, I found very few spiders. On-going work elsewhere is showing that spiders are most abundant in disturbed areas and relatively rare in healthy, intact landscapes. As such, the low abundance of spiders suggests that our riparian corridor is health and stable.

Existing Ecological Communities: Vertebrates

The Lower Aras River corridor is home to a relatively wide array of vertebrates for this region of Turkey. I utilitzed infrared camera traps, deployed across our riparian area to document the species of non-birds occupying and actively using our riparian corridor. Data reported herein come from either ScoutGuard SG50 or any of a range of Reconyx Hyperfire cameras. In addition our bird banding station documented 59 species of birds in the Spring of 2013.

I have documented at least 26 mammal species at Aras spanning a large portion of the feeding guilds and body sizes across the region. In addition to the camera traps, I observed one snake and one wolf while driving around the region. Notable mammals included the European Marten, wild boar, At least eight

Existing Ecological Communities: Vegetation

For this study, I surveyed a series of 12 band transects haphazardly oriented in areas or more of less consistent vegetation. Most transects ran for 100m and delineated a swatch 2 m wide. All woody species were counted therein and their diameter at breast height and estimated height of the tree's apex was recorded. In addition, I harvested a subset of representative species, air dried them for >3 days at a temperatures of ~35° C, then weighed the with a spring scale to the nearest gram to determine "Dry weight." I then correlated this to the dimensions of the trees and was able to estimate the standing biomass of the trees in the Lower Aras Riparian Corridor.

A minimum of 6,500 fruit (apricot, apple, *etc.*) and 18,000 other (elm, aspen, *etc.*) mature trees (>10 years old and/or >9 m tall) exist in the region potentially inundated by the proposed Tuzluca Dam impoundment. Perhaps three times that many will be killed ultimately, depending upon ensuing water levels. Younger trees/woody shrubs lost would easily exceed >60,000 individuals.

Impacts from Dams: General Principals

Several trends have emerged for our detailed studied of larger dams on rivers over the past few years. These are almost universally negative for wildlife, cultural resources, and ecosystem services of the riparian corridor. Here I emphasize the most common ecological consequences. These may or may not occur in the wake of the proposed dam, but it is prudent to expect all of them.

1) As a result of sediment retention behind the dam, sediment nourishment to the channel or peripheral beaches effectively eliminated leading to aberrant channel morphology and stressing bank-side vegetation. Particularly relevant for our region is the concern that dams in regions with high erosion potential often

experience greatly reduced effective lifespan owing to the reservoir filling more quickly than predicted.

2) Archaeological sites are inundated/buried.

3) Fish movement/dispersal is restricted.

4) Greatly increased fish and invertebrate mortality. Some fish and invertebrates will be killed outright due to turbines and the associated structures. Changed hydrologic conditions will also tend to indirectly reduce recruitment rates via habitat degradation for eggs and/or larvae.

5) Water Quality parameters will change severely. Generally temperature will go up, oxygen will go down, redox will decline, surface water clarity will improve, and salinity will increase.

6) Movement/dispersal of terrestrial vertebrates is hampered or prevented.

7) Smaller terrestrial mammals and birds will tend to suffer increased rates of predation owing to dams fostering more disturbance-loving "weedy" plants and animals (*e.g*. corvids).

8) Algal blooms are more likely to expand and become a problem, especially monofilamentous chlorophyta. Often the largest visitor complaint at reservoirs with abundant algal growth in the summertime is that the reservoir is "too stinky," causing recreational use of the site decline.

9) Likely decrease in riparian mammals and birds who require healthy riparian or riverine areas for food or other provisioning. These changes can be subtle with the true impact not fully manifest for several years, but may also occur dramatically in the first year.

10) Non-native Aquatic Invasive Species are likely to spread and are more likely to establish stable (or growing) populations. Across the arid southwest, we tend to see the greatest number of non-native species behind dams or in the immediate downriver region in the dam shadow.

11) Evaporative losses with grow dramatically, with losses in some arid dam situations (*e.g*. the American Southwest) equal the volume used (year over year).

12) Water borne and mosquito-based diseases such as typhoid fever, malaria and cholera are much more likely to spread to adjacent to impounded water.

13) Microclimatic and potentially even some regional climatic changes may occur.

Perhaps the most important aspects of the general issues to be aware of are simply that 1) no modern water management agency is seriously considering large surface water storage projects in arid landscapes and that 2) the vast majority of dam-related engineering and planning work worldwide is now focused on dam *removal* not construction.

Impacts from Dams: Insights from Recent Adjacent Projects on the Aras River

In October of 2013, I had the opportunity to travel to several nearby dams and diversions above our primary focal area and speak with various villagers about the ecological and sociological benefits and costs these projects.

In general, very few people were happy with the dam projects. Those reporting they were satisfied and that they felt these projects brought a benefit to the community were uniformly security guards or were in some way being paid for the routine operations and maintenance of the structures. Most people related horror stories about the effect of dams on their homes and lives or were afraid to discuss these issues (apparently out of fear of retribution or a lack of decorum). The government essentially gives people residing in a dam building zone the option to either take a stipend (numbers varies, but it was as high as 3.5 times the median salary of the province; in which case most people then relocate to a large urban center) or to relocate a few tens of kilometers to standardized government-built housing (which is unsuitable for livestock or other agrarian pursuits).

All people with whom I spoke with reported seeing fewer of most species of animals post dam erection, the exception being corvids (crows) and jackals. Several also reported that reed beds grew differently post dam (although there were conflicting reports about how they differed, suggesting these reports are likely unreliable). Most reported increasing blooms of green algae in summer, especially after a string of many hot days and that when the winds blew consistently, the algae tended to build-up in one section of the reservoir and rot/stink. Finally several fruit sellers were quite vehement in saying their fruit trees (particularly a local variety of apples) produced substandard fruit post reservoir construction. I am uncertain of this effect or potential causal mechanism here as the farmers were not necessarily using irrigation water from these new reservoirs.

The story of one shop keeper best summarized the potential socioeconomic impacts of a dam completed approximately four years ago. This man had a apricot orchard and produced abundant apricots each year that was a major portion of his annual income. He reported that he easily made $5-6,000 USD per year, and some years much more than that from the sale of fruit from his several hundred mature trees. He claimed that his fruit was so desirous that he could sell a branch (for grafting to another tree) for as much as $500. With the construction of that dam and the associated impounded water, his entire orchard flooded and the trees were killed. The company which was building and operating the dam on a 49 year lease (note: this would differ from the proposed Tuzluca Dam which is a currently slated to be a government built and operated dam) compensated him to the tune of only a few thousand dollars. In other words his land was taken by eminent domain and he was neither compensated for the full current valuation of the land nor for his trees nor for his lost income from those trees over the lifespan of the dam operation.

Feeling wronged, this shop owner sought redress in the courts, but had a difficult road. By the time he eventually found a competent lawyer he had both lost his first claim and upon appeal, was told by the appellate judge that the dam company paid him too much money and ordered the shop owner to return a portion of the funds to the company, totally refuting the concept of lost income or just compensation for his loss of property and holdings. Upon looking into his savings (an account held jointly with his several brothers) he found the entirety of his payout gone. One of his brothers had absconded with the funds. Upon hearing this, his other brothers accused him of actually getting paid much more than he was asserting ("no one would have paid us so little for taking that much property" one retorted) and demanded their fair share. Exasperated, the family descended into divisiveness and infighting. Several members of the family were no longer on speaking terms while other members of the village had left the area to find better work and be away from their now blighted home. Reports of depression and other associated unfortunate, non-constructive behaviors also surfaced in the village. When I left the shop owner he was a mix of melancholy and stoicism; he had almost no money left to continue his legal appeal and felt the dam had taken away not only the plants that gave him position and income, but much of his family and village as well.

Lastly, I feel it is important to comment of the quality of the construction of the structures along the Aras River. I am no engineer, but have frequently work around water and associated in-water structures for more than 20 years. I have never seen the disturbing lack of quality control on some of these structures. Several diversion canals that had concrete poured less than six weeks before I arrived were either already cracking/fracturing (10-20 m long cracks) and being repaired in a shockingly piecemeal way or had (from what I could see) not been properly graded prior to construction, leading to the spillway canals filling in with large volumes of sediment eroding in from the adjacent hillsides. There were numerous other observations that raised serious questions as to the competency of the builders and the safety of these structures. While I am not competent to render an engineering opinion on these structures, my observations were deeply troubling and suggest that these structures may not be being built to the highest possible safety standards.

Potential Impacts from Tuzluca Dam on the Lower Aras River.

In general we are likely to see significant ecological displacements in the wake of the proposed Tuzluca Dam, if it is constructed. As the final design for the dam is still unsettled, I will restrict my observations to the area identified by Ministry personnel as certainly to be subtidal post-construction (~7km upstream from the confluence).

The proposed impounded dam water level will submerge essentially all of the existing croplands, orchards, homes, and vegetated riparian zone of the Lower

Aras River. A minimum of 6,500 fruit (apricot, apple, *etc*.) and 18,000 other (elm, aspen, *etc*.) mature trees (>10 years old and/or >9 m tall) would be drowned in the immediate vicinity of the exiting riverbed. Perhaps two to three times that many will be killed ultimately, depending upon ensuing water levels. Younger trees/woody shrubs lost would easily exceed >60,000 individuals. (Please note these numbers are conservative estimates and are limited by low resolution aerial imagery upon which my survey number were extrapolated; actual numbers could be much higher.)

There are no exact models to predict specific species shifts in abundance, *etc*. Nevertheless, it is obvious we will lose essentially all of the woody vegetation (natural and cultivated) and with that many of the terrestrial vertebrates (*e.g*. martens) are likely to disappear as overtime as they will no longer be able to rely on the vegetated buffer for forage or shelter from predators. With the loss of both the vertical relief of the woody canopy and the loss of the flowers/fruit we will see a marked reduction in a whole suite of insects ranging from bees to spiders. We are also likely to see a drop off in the residence time of avian migrants and fewer resident nesting pairs of birds for similar reasons. Migrating birds could show one of the quickest responses to the vegetation disturbance as these far-flying animals cue in on resting/foraging locales from the air. Once the vegetated buffer shrinks below a critical size (a number which, again, I am unable to predict at this point), individuals will simply continue to fly north or south in search of a more suitable habitat to alight upon. Ultimately the reduction/loss of these avian species may benefit certain larger insects (*e.g*. true flies, odonates) as these insects will have been released from avian predation pressure.

In similar situations in other arid locations, we see disturbance-loving, ruderal species doing well along the edges of newly formed disturbed patches (e.g. the lacustrine perimeter). Argentine ants, small canines, and avian scavengers/omnivores birds will likely either increase in number. If they do not increase in absolute number they will almost assuredly increase in relative abundance and come to dominate the new landscapes of the Lower Aras River.

Potential For Ecological Restoration to Offset Impacts from Tuzluca Dam

In general ecological restoration is a useful tool that can help mitigate losses of essential ecosystem services associated with activities such as this dam construction. In this case however, ecological restoration is unlikely to be of much help. This is primarily due to the fact the upland soils where the riparian vegetation could (in theory) be displaced to are extremely substandard. While it is in theory possible to amend the soils, water the saplings in, *etc*., this would require a massive capital outlay on the part of the Ministry and a serious long-term commitment I have not yet seen evidence of in Turkey. Essentially all the woody plant restoration efforts I have designed or helped facilitate over the past several years in eastern Turkey have failed due to a lack of commitment/support form the relevant ministry. Some of these were working well for a year or two, but all were eventually vandalized or subsequently defunded, leading to the loss of essentially all trees. The few examples of projects that have been able to reforest a plot of land have succeeded in creating mere monocultures of pines; not a diverse forest ecosystem capable to supporting diverse species assemblages and ecosystem services.

Were there to be serious interest in attempting to create a nascent riparian buffer, the plantings, soil amendments, watering infrastructure, *etc*. would need to be the very first step in any construction effort (*e.g*. beginning before ground was broken for the actual dam itself) so as to give the establishing vegetation several years of growth before the water line would be raised.

Of importance here is also the variable of climate change. Several of my research sites in arid California are experiencing the first two years of what seems likely to be a significant drought. This may very well become the new normal for much of our globe. One simple project vaguely similar to the Aras situation (planting only two species of trees with a "success criterion of 50% of the trees surviving by year three), but with much more appropriate soils, aspects, *etc*. has experienced near catastrophic failure. The project has now cost three times the original estimate and we are nowhere near an acceptable plant performance. I fear this could well be the fate of a woody vegetation project on the organic, sandy soils of the denuded Aras Valley hillsides.