2022 Cost-Share Proposal Form for NorthWestern Energy (NWE) Project 2188 TAC Funds

Project 2188 (Madison-Missouri River) License Protection, Mitigation and Enhancement (PM&E) projects are required to offset impacts to river resources from the continued operation of one or more of NWE's nine hydro developments (Hebgen, Madison, Hauser, Holter, Black Eagle, Rainbow, Cochrane, Ryan and Morony Dams). PM&E projects need to be prioritized toward in-river or on-the-ground measures that directly benefit fisheries and/or wildlife populations and their habitats:

Priority 1: 2188 License projects which meet License Article requirements and PM&E for fisheries or wildlife populations or their habitats within the main stem Madison River (Hebgen Reservoir to Three Forks) or Missouri River (Hauser Reservoir to Fort Peck Reservoir)

Priority 2: 2188 License projects which meet License Article requirements and PM&E for fisheries or wildlife populations or their habitats in primary tributaries or on adjacent lands and, in doing so, provide PM&E for Madison River (Hebgen Reservoir to Three Forks) or Missouri River (Hauser Reservoir to Fort Peck Reservoir) resources.

Priority 3: 2188 License PM&E projects which meet License Article requirements by providing scientific or other tangible PM&E benefits to Madison-Missouri River fisheries or wildlife populations or their habitats. These projects must be located in the greater Missouri River drainage upstream from Fort Peck Reservoir, but not necessarily located on the main stem Madison River or Missouri River or their adjacent lands or primary tributaries.

All TAC project proposals must include the following information:

Project Title: Age-structured stock assessment to forecast the effects of angling pressure on rainbow trout and brown trout in the Missouri River

Date: November 4, 2021

Explain how this Project addresses a specific Project 2188 License Article(s):
The proposed project addresses Article 416, specifically in the Missouri River downstream of Holter dam, task 3: "Propose additional measures to minimize fish loss and to mitigate for avoidable and unavoidable impacts, which are not limited to the additional mitigation measures listed" (Northwestern Energy 2018).

Provide justification for Priority 1, 2 or 3 (above) that you selected:
This is a priority 1 project as it provides PM&E benefit to the fishery by providing a better understanding of fish population monitoring data and potential loss due to angling on the Missouri River mainstem.

Project Sponsor (submitted by):

Hayley Glassic – MSU   Christopher Guy – USGS-MSU
Jason Mullen – MFWP   David Schmetterling - MFWP

Location of Proposed Project: Craig & Cascade sections of Missouri River

Geocode (in decimal degrees) 47.07674, -111.96117; 47.26975, -111.69624

Total Project Cost:
$268,817.59 (over 3 years)

TAC Funds (Cost-Share) Requested for Project:
$147,817.59 (over 3 years)

I. Introduction: brief statement of project to be completed with pertinent background information.

The economic influence of outdoor recreation in Montana is undeniable and 96% of Montanans believe it is important to the economic future of the state. Overall, outdoor recreation in Montana generates $7.1 billion in consumer spending, $286 million in local taxes, and 71,000 jobs as of 2019 (https://headwaterseconomics.org/economic-development/value-of-montanas-outdoors/). Visitation in Montana increased 40% over the last decade and anglers spent $919.3 million in 2017 and most of that is from Montana's coldwater trout fisheries (Cline et al. In review). Given the economic importance of Montana's fishery resources and the projected increase in use of those fisheries, it is imperative that natural resource agencies understand the influence of increased use on fish populations. Furthermore, the use of tailwater fisheries or those fisheries that are more "climate resilient" is expected in increase (Cline et al. in review). Many highly-valued fisheries throughout the world depend on population models to forecast the effects of fishing mortality (i.e., recreational, commercial, or both) on population abundance and resiliency to harvest. Montana's fisheries would benefit from a similar approach because they are also highly-valued. For example, the economic value of Montana's fisheries is higher than commercial landings for popular fish species in Alaska (Figure 1).

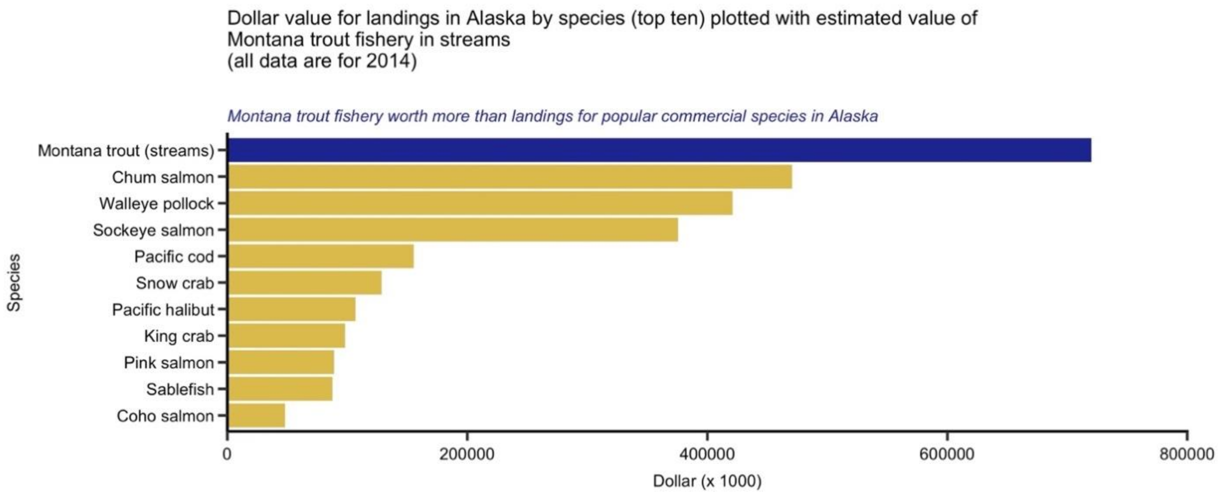


Figure 1. Economic value of Montana trout fishery compared to dollar value for landings of top ten species in Alaska.

Much of the contemporary data collected on Montana trout fisheries are used to estimate abundance, size structure, and body condition. These data are typically useful for characterizing the status of the fishery and historical time-series analyses. The major shortcoming of those data and analytical methods are that one cannot estimate rates of mortality (i.e., natural mortality and fishing mortality) because of missing detailed information on age structure. Mortality is a key metric in any stock assessment and is particularly important for forecasting the effects of increased fishing mortality on a population. For trout fisheries in Montana, much of the fishing mortality is probably in the form of delayed mortality from catch-and-release angling. The amount of delayed mortality from catch-and-release may not be trivial given the fishing pressure on some of Montana's most popular fisheries. Furthermore, it is estimated that the number of anglers will increase in Montana concurrent with warming water temperatures, which will likely exacerbate mortality associated with catch-and-release angling.

Another key metric for stock assessment and population modelling is a population abundance estimate. As stated above, abundance is estimated for most of the popular trout fisheries in Montana. Abundance estimates, vital rates, and age-structure data are the foundation for age-structured population models. Age-structured population models can be used to estimate current population abundance and forecast future scenarios related to changes in natural mortality, fishing mortality, and recruitment dynamics. We propose to develop a population model for the trout fishery in the Missouri River below Holter Dam.

The trout fishery in the Missouri River below Holter Dam is an excellent example of a Montana fishery with long-term abundance estimates, increases in catch-and-release angling pressure, and concern about the future sustainability of the fishery. Those data, coupled with detailed age-structure data (from otoliths), natural mortality estimates, and fishing mortality estimates, will be used to develop population-level effects of angling pressure on the trout population in the Missouri River. The models are useful because they allow natural resource agencies to be proactive rather than reactive to the effects of fishing mortality. The Missouri River brown trout and rainbow trout fishery is not currently managed by fishing mortality benchmarks because the effects of mortality from fishing have not been estimated on the population.

Management Implications

Knowing the amount of fishing mortality the populations can sustain will allow Montana Fish, Wildlife & Parks (MFWP) to quantify the number of angler hours that would not cause a decline in abundance and allow for a sustainable fishery. If a decline in trout abundance occurred below the estimated number of angler hours predicted to support a fishery then it would be plausible that changes in habitat availability or quality are responsible for the decline. The proposed project will allow for a better understanding of the mechanisms that influence the fishery and provide context for the monitoring data. In addition, the model will allow for the testing of hypotheses related to management actions (e.g., habitat improvements, angling regulations, or both), which is central to the adaptive management process. Furthermore, this research would identify whether angling pressure could explain changes in abundance from monitoring data. Currently, no empirical data exists to determine if angling or habitat can explain changes in trout abundance on the Missouri River. If angling was the reason for decline in fish abundance, this research would strengthen our understanding of the mechanisms causing fluctuations in fish abundance. Identifying the mechanisms affecting fish abundance would create a holistic adaptive management plan where habitat and angling pressure are both considered to sustainably manage this fishery. The population model will help ensure that trout fisheries continue to provide recreational and economic value to Montana.

II. Objectives; explicit statement(s) of what is intended to be accomplished.

To determine the effects of fishing mortality (delayed mortality from catch-and-release fishing) on the trout fishery in the Missouri River below Holter Dam, we have the following objectives:

a. Compile relevant data from MFWP for rainbow trout and brown trout populations.
b. Collect and age otoliths from rainbow trout and brown trout.
c. Compile data on fecundity, maturity, recruitment rate, and mortality rates (may involve a Delphi method for some metrics) by species.
d. Develop an age-structure population model for the rainbow trout and brown trout populations.
e. Run scenarios to determine the effects of fishing mortality on the rainbow trout and brown trout populations.
f. Establish critical thresholds (i.e., benchmarks) for acceptable fishing mortality rates.
g. Develop a R Shiny dashboard for agencies and stakeholders to run scenarios.

III. Methods; description of how Project objectives will be accomplished.

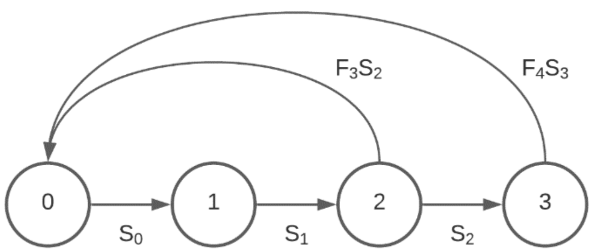
For data collection, we will communicate with MFWP to obtain data from biologists, use the Godzilla database, or both. We will join biologists from MFWP on bi-annual electrofishing surveys for rainbow trout and brown trout in the Missouri River below Holter Dam; one sampling session in the fall and another in the spring. We will collect 3-5 fish of each species per 1-inch length group. Sagittal otoliths will be collected from euthanized trout. Otoliths will be mounted in clear epoxy, and transversely sectioned about the nucleus using a low speed IsoMet saw (Quist et al. 2012). Cross sections (0.8–1.0 mm) will be affixed to microscope slides and polished using fine grit sandpaper until the otolith nucleus and annuli are clearly visible at 40× magnification. All euthanized trout will be necropsied to determine sex and maturity. Maturity will be assessed as a binary response variable of either mature or immature with mature trout identified by fully developed gonads and immature trout identified by underdeveloped gonads. Immature trout will be classified as unknown. Fecundity information will be derived from the literature (Grisak 2012). However, if fecundity data from 2012 no longer aligns with maturity data from 2021, then additional assessment of fecundity will be conducted. A length–frequency histogram will be constructed from the electrofishing samples to visualize population length structure. Somatic growth of rainbow trout and brown trout sampled will be described using the von Bertalanffy (VBF) growth model. Age-length keys will be used to assign ages to unaged fish. Age-length keys will be constructed using the FSA package in R (Ogle 2016; Ogle 2018; R Core Development Team 2021).

The age-structured population model will follow methods similar to Syslo et al. (2011), Ng et al. (2016), Fredenberg (2017), and Kaus (2019). Matrix models can be used for analyses in which age-specific vital rates (e.g., mortality, fecundity, maturity) need to be assessed to estimate future population growth rate (Morris and

Doak 2002). Vital Rate Sensitivity Analysis (VRSA) help rank the relative contributions of age-specific vital rates to future population growth and is a practical alternative to traditional sensitivity and elasticity analyses because it does not assume that the population has a stable age distribution (Fefferman and Reed 2006). Vital Rate Sensitivity Analysis quantifies the effects of variations in vital rates on population abundance projections over time, allowing for the assessment of management scenarios for changing population growth rate over varying time spans (Fefferman and Reed 2006). A benefit of VRSA is that it is a simulation approach, allowing the incorporation of uncertainty in vital rate values into management decisions.

Age-structured population models will be used to estimate the effects of varying fishing mortality rates on the rainbow trout and brown trout populations. Forward projections will determine the mortality rates that result in decreasing population growth (λ), and the age-classes have the largest effect on population growth given mortality, maturity, and fecundity. Some vital rates will be from the literature, such as survival from age 0 to age 1. In addition, values from the literature may be used to provide stochasticity in the vital rates. Levels of age-specific mortality required for a population decrease could be a threshold for management of the fishery.

Values of age-specific fecundity and survival, estimated from sampling, peer-reviewed literature, or both, will be inserted into a female-based age-structured Leslie matrix (Figure 1). Survival and fecundity values will be generated from distributions with specified means and variances. Age at maturity and proportion of mature fish spawning will be estimated from the Missouri River or from the literature. If data are from the Missouri River, then the proportion of fish in each age class that are mature will be calculated using logistic regression. As stated above, we may not have the ability to estimate pre-recruit survival from hatch to age 1 or age 2 for rainbow trout and brown trout because of a paucity of data for pre-recruit trout. Thus, the means, variances, and probability distributions for survival from hatch through recruitment will likely be determined from the literature.



$$\begin{pmatrix} 0 & 0 & F_3S_2 & F_4S_3 \\ S_0 & 0 & 0 & 0 \\ 0 & S_1 & 0 & 0 \\ 0 & 0 & S_2 & 0 \end{pmatrix}$$

Figure 2. Schematic of a population model and matrix, where F is the fertility element for age t (0-2), and S is the survival element of age t (0-2).

Differential mortality scenarios will be assessed within each matrix replicate. An abundance vector with a specified age distribution will be created based on data for the rainbow trout and brown trout from the Missouri River. The matrix replicate will be iterated with the abundance vector from empirical data, for the number of time steps specified by the management scenario (i.e., fishing mortality rate). The number of individuals in the abundance vector resulting from the unaltered matrix iteration will be recorded. The mortality vital rate will be altered creating a new matrix. Each new matrix will be iterated with the population abundance vector for the specified number of time steps. The resulting abundances will be recorded for each matrix. The abundances from the altered matrix iterations will be subtracted from abundances obtained in the unaltered matrix iteration, resulting in a ΔN value for each fishing mortality scenario. For example, if the population size obtained with the unaltered matrix is 50,000 and the population size obtained when changing instantaneous fishing mortality is 45,000, the ΔN for that scenario is 5,000. The model will be repeated for 1,000 simulations. The resulting distributions of ΔN values from each scenario will be compared and ranked (Fefferman and Reed 2006). In addition, population growth trajectories (λ) will be obtained for each scenario to estimate the effect of fishing mortality on λ.

Varying levels of fishing mortality will be simulated for age classes to determine the level of mortality required to cause a decline in the rainbow trout and brown trout populations. In addition, factors that influence natural mortality could be included in the model, such as the effects of warming water temperatures and decreased discharge on pre-recruit survival, adult survival, or both. However, this would require some understanding of the functional relationships of abiotic conditions on natural mortality.

Once the model has been developed and vetted, a R Shiny dashboard will be developed for natural resource agencies and stakeholders. The dashboard will allow for the manipulation of various vital rates and the subsequent population-level response to be observed in graphical form. The dashboard will be useful for stakeholders to better understand the mechanisms that influence rainbow trout and brown trout in the Missouri River.

IV. Schedule; when the Project work will begin and end.

August 2022 – December 2024

V. Personnel; who will do the work? Identify Project leader or principal investigator.

Principal investigators: Hayley Glassic (MSU), Christopher Guy (USGS-MSU)
Fieldwork: Jason Mullen (MFWP), Technicians (MFWP), Hayley Glassic (MSU)
Lab work: Hayley Glassic (MSU), TBD Technician (MSU)
Statistical analysis: Hayley Glassic (MSU), Christopher Guy (USGS-MSU), Jason Mullen (MFWP), David Schmetterling (MFWP)

VI. Project budget:

2022: After collecting trout samples during spring 2022, otolith processing will begin with help from a laboratory technician in August 2022 – December 2022. Complete potential fall sampling to collect any size classes that are deficient from 2021 sampling events.

- Postdoctoral research assistant will for 470 hours: 157.5 hours at $32 per hour requested from MoTAC, 312.5 hours at $32 per hour contributed by MFWP.
- Laboratory technician will work 700 hours at $15 per hour.
  - We anticipate collecting 120 fish from each species for a total of 240 fish, with each fish taking approximately 3 hours to fully process in the lab.
  - Laboratory processing will include: extraction of otoliths; sex and maturity identification; otolith molding, sectioning, and mounting; otolith aging including taking microscope photos for archive.

2023: Coordination meeting to discuss otolith processing and model development. Model development will continue through December 2023 with interim coordination meetings for continued updating and discussion with MFWP.

- Postdoctoral research assistant will work for 1650 hours: 1337.5 hours at $32 per hour requested from MoTAC, 312.5 hours at $32 per hour contributed by MFWP.
- Coordination meetings will occur in: February/March to discuss otolith processing and aging, and whether more samples need to be collected; June/July to discuss preliminary model development; September/October to discuss incorporation of fishing effort, environmental variables, or other variables of interest for simulations.

2024: Final model refinement, creation of R Shiny dashboard, preparation and completion of project report, preparation of manuscript for peer-review.

- Postdoctoral research assistant will work for 1040 hours: 727.5 hours at $32 per hour requested from MoTAC, 312.5 hours at $32 per hour contributed by MFWP.

Salaries and Wages - MSU	**2022**	**2023**	**2024**
Postdoctoral Research Assistant	5,040.00	42,800.00	23,280.00
Postdoctoral Research Assistant fringe (56%)	2,822.40	23,968.00	13,036.80
Laboratory Technician (700 hrs/yr @ $15/hr)	10,500.00	0.00	0.00
Laboratory Technician fringe (10%)	1,050.00	0.00	0.00
TOTAL	19,412.40	66,768.00	36,316.80
Travel - MSU			
Meeting Travel ($500/annual Montana AFS meeting)	0.00	500.00	500.00

Per diem for meeting travel ($30.50/day, 5 day meeting)	0.00	152.50	152.50
Lodging for meeting ($200/night, 5 nights)	0.00	1,000.00	1,000.00
TOTAL	0.00	1,652.50	1,652.50
MSU SUB TOTAL	19,412.40	68,420.50	37,969.30
MSU In-direct costs (17.5%)	3,397.17	11,973.59	6,644.63
MSU TOTAL	22,809.57	80,394.09	44,613.93
MFWP: Contribution, research travel, and contract with MSU*			
Staff time (time for data collection, data entry, data analysis) Meetings with Postdoctoral Research Assistant for consultation or feedback on model Development of Shiny App with additional feedback from FWP biologists and managers	22,000.00	22,000.00	35,000.00
MFWP contract with MSU for 312.5 hours per year at $32 per hour for Postdoctoral Research Assistant Salary	10,000.00	10,000.00	10,000.00
Research Travel	4,000.00	4,000.00	4,000.00
TOTAL contribution from MFWP	36,000.00	36,000.00	49,000.00

*does not include NWE funded technician or biologist FTE

VII. Deliverables; describe work product (reports, habitat restoration, etc.) which will result from this Project. How will "success" for this project be monitored or demonstrated?

The results from this study will provide fishing mortality benchmarks for the rainbow trout and brown trout fishery in the Missouri River. The model will provide a tool to assess the status of the current rainbow trout and brown trout population and forecast the effect of future fishing effort (i.e., mortality) on the fishery. Once the population model is developed, varying scenarios can be evaluated based on the needs of natural resource agencies and stakeholders. Furthermore, the model can be updated as new biological information becomes available. The model can also be used to better understand knowledge gaps in the rainbow trout and brown trout fishery (e.g., whether changes in abundance can be explained by fishing effort or could be better explained by habitat metrics). The user-interface R Shiny dashboard will allow for natural resource agencies and stakeholders to run simulations based on their needs. There will be a final report that details the data, population model, and assumptions. We also anticipate a peer-reviewed publication, scientific presentations, and lay-audience presentations.

VIII. Cultural Resources. Cultural Resource Management (CRM) requirements for any activity related to this Project must be completed and documented to NWE as a condition of any TAC grant. TAC funds may not be used for any land-disturbing activity, or the modification, renovation, or removal of any buildings or structures until the CRM consultation process has been completed. Agency applicants must submit a copy of the proposed project to a designated Cultural Resource Specialist for their agency. Private parties or non-governmental organizations are encouraged to submit a copy of their proposed project to a CRM consultant they may have employed. Private parties and non-governmental organizations may also contact the NWE representative for further information or assistance. Applications submitted without this section completed, will be held by the TAC, without any action, until the information has been submitted.

Summarize here how you will complete requirements for Cultural Resource Management: N/A

IX. Water Rights. For projects that involve development, restoration or enhancement of wetlands, please describe how the project will comply with the Montana DNRC's "Guidance for Landowners and Practitioners Engaged in Stream and Wetland Restoration Activities", issued by the Water Resources Division on 9March2016.
Summarize here how you will comply with Montana water rights laws, policies and guidelines: N/A

All TAC Project proposals should be 7 pages or less and emailed (as a WORD file) to each of:
- Andrew.Welch@Northwestern.com
- Jon.Hanson@Northwestern.com
- Grant.Grisak@Northwestern.com

References

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