energies

IMPACT FACTOR 3.252

CITESCORE 5.0

Review

Understanding the Environmental Study Life Cycle in the United States Hydropower Licensing and Federal Authorization Process

Matthew S. P. Aldrovandi, Esther S. Parish and Brenda M. Pracheil

MDPI

https://doi.org/10.3390/en14123435

energies

MDPI

Review

Understanding the Environmental Study Life Cycle in the United States Hydropower Licensing and Federal Authorization Process

Matthew S. P. Aldrovandi, Esther S. Parish and Brenda M. Pracheil *

Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA; maldrova@vols.utk.edu (M.S.P.A.); parishes@ornl.gov (E.S.P.)
* Correspondence: pracheilbm@ornl.gov

Abstract: We analyzed United States Federal Energy Regulatory Commission (FERC) documents prepared for 29 recently licensed hydropower projects and created two novel datasets to improve understanding of the environmental study life cycle, defined here as the process that begins with an environmental study being requested by a hydropower stakeholder or regulator, and ends with the study either being rejected or approved/conducted. Our two datasets consisted of summaries of information taken from (1), study determination letters prepared by FERC for 23 projects that were using the integrated licensing process, and (2), environmental study submittals and issuances tracked and attributed to seven projects using the FERC record. Our objective was to use the two resulting environmental life cycle datasets to understand which types of environmental studies are approved, rejected, and implemented during FERC licensing, and how consistently those types of studies are required across multiple hydropower projects. We matched the requested studies to a set of 61 river function indicators in eight categories and found that studies related to the category of biota and biodiversity were requested most often across all 29 projects. Within that category, studies related to river function indicators of presence, absence, detection of species and habitat/critical habitat were the most important to stakeholders, based on the relative number of studies requested. The study approval, rejection, and request rates were similar within each dataset, although the 23 projects with study determination letters had many rejected studies, whereas the dataset created from the seven projects had very few rejected studies.

Keywords: hydropower; hydropower regulation; environmental impact

Citation: Aldrovandi, M.S.P.; Parish, E.S.; Pracheil, B.M. Understanding the Environmental Study Life Cycle in the United States Hydropower Licensing and Federal Authorization Process. *Energies* **2021**, *14*, 3435. https://doi.org/10.3390/en14123435

Academic Editor: Helena M. Ramos

Received: 23 April 2021
Accepted: 5 June 2021
Published: 10 June 2021

1. Introduction

The Energy Information Agency projects that renewable hydropower will continue to provide a significant proportion (~18%) of electricity in the United States (US) through 2050 [1]. Many US hydropower projects are undergoing relicensing by the US Federal Energy Regulatory Commission (FERC), and a variety of new hydropower projects have been proposed to help generate electricity with fewer greenhouse gas emissions. The FERC is the agency responsible for licensing non-federal hydropower projects and oversees approximately 55% of all hydropower facilities in the US [2]. The Electric Consumers Protection Act of 1986 requires FERC to give equal consideration to the protection and enhancement of, and mitigation of damage to, wildlife, environmental quality, and recreational opportunity during the licensing process [3]. The FERC licensing process is stakeholder-driven and can be time-consuming, taking on average more than six years to complete [4]. A variety of factors are associated with the licensing timeline length, but in general, projects with increased environmental complexity—i.e., projects with significant environmental effects, including projects with multiple facilities or dams, endangered species, water quality issues, and/or projects that have not been relicensed since the passage of environmental

protection legislation such as the National Environmental Policy Act (NEPA)—tend to have longer licensing timelines [4].

The portion of the licensing process focused on environmental study negotiations is a critically important part of the hydropower licensing process for understanding and mitigating the potential effects of hydropower construction and operations on the riverine ecosystem. This part of the negotiation process can be especially contentious, since it involves stakeholders and the licensee working together to understand project impacts and the best approaches to acquire missing information about potential impacts. Existing datasets and information may be insufficient to address all stakeholder concerns. However, requesting additional environmental studies to inform mitigation requirements can incur extra expense for the license applicant and delay project implementation. Given these potential tradeoffs, a greater understanding of the environmental study life cycle—meaning the process that begins with an environmental study being requested by a hydropower stakeholder and ends with the study either being conducted/approved or rejected—could be useful information for hydropower stakeholders preparing for licensing negotiations and might help focus discussions and facilitate consensus about which studies are most necessary, relevant, and feasible.

To improve understanding of the environmental study life cycle, we mined data from FERC documents, for documenting what studies are proposed, rejected, or accepted/completed, and mapped those studies to a set of key river function indicators (RFIs) previously developed through an extensive literature analysis [5]. We then analyzed these data to answer two key questions:

1. Which types of environmental studies are approved, rejected, and implemented during FERC licensing?
2. How consistent are those types of studies across multiple hydropower projects?

We share key insights learned during this analysis and make recommendations for future study.

2. Materials and Methods

We created two datasets to gain a more mechanistic understanding of which environmental studies are proposed and disputed during FERC hydropower licensing negotiations. This two-pronged approach involved: (1), mining information from study determination letters issued by FERC from projects using the integrated licensing process (ILP); and (2), tracking issuances and submittals in the FERC e-Library (available online: https://elibrary.ferc.gov, last accessed 7 June 2021) on a particular licensing that pertained to environmental studies for the seven case study projects addressed by [5]. One of the seven case study projects used the ILP and had a study determination letter, so it was analyzed using both methods, for a total of 29 US hydropower projects included in our study (Figure 1). Both datasets created as part of this study are available online: www.hydrosource.ornl.gov, last accessed 7 June 2021.

Figure 1. Map of all 29 project locations. Blue dots indicate the 23 projects assessed for Dataset 1 using study determination letters. Red dots indicate the seven projects studied in detail for Dataset 2. Note that Jackson has a red dot with a blue outline because it is included in both datasets.

2.1. Dataset 1 Based on Study Determination Letters

Our first dataset contained summaries of information contained in study determination letters. While each of the three FERC hydropower licensing process types—traditional licensing process, alternative licensing process, and ILP—have some general steps in common, each process provides different considerations and caveats to licensees and stakeholders (Figure 2). Specifically, during the licensing process, stakeholders and applicants must collaborate to determine which environmental impact studies to conduct. These studies are then written into the final license application that is filed with FERC by the license applicant; the applicant is then bound to conduct these studies. If stakeholders believe that important studies are missing, they can file a study dispute with FERC. In the ILP, FERC will then make an official determination on all disputed studies via a study determination letter (sometimes referred to as a study plan determination or study determination) that summarizes which disputed studies must be conducted (hereafter, approved studies), and which ones do not (hereafter, rejected studies).

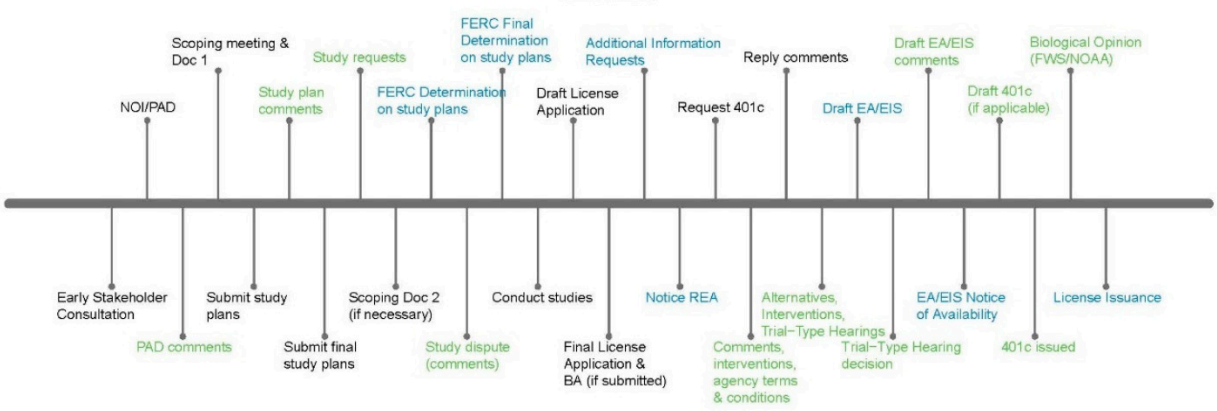

Figure 2. Example timeline showing the relative order of FERC hydropower licensing milestones for the ILP, with milestones completed by the license applicant (black), stakeholders/regulators (green), and FERC (blue). The total number of years, and years taken between each step, vary by project.

The 23 projects included in the study determination letter dataset included all projects using the ILP that were included in a dataset of 107 randomly selected projects [4]. For each approved, rejected, or modified study listed in the study determination letters, we assigned an environmental category as defined by [6] (i.e., biota and biodiversity (BB), connectivity and fragmentation (CF), geomorphology (GM), landscape and land cover (LC), water quality (WQUAL), and water quantity (WQUAN)), in addition to the two new categories of cultural resources (CR) or recreation (RC) (Table 1), an RFI as defined by [5], and a study type (e.g., fish passage, species presence, turbidity). Additional RFIs were created for this analysis for the CR and RC categories.

Table 1. Categories [7] and RFIs [5] assigned to studies documented in the two novel environmental life cycle datasets. Note that recreational and cultural RFIs were only recorded for the 23 projects documented through analysis of FERC study plan determination letters.

Category	RFI ID	RFI Name	RFI Definition
BB	1	Abundance, Density	Count/other measures of organisms/area
BB	2	Life History Traits	Spawning duration, reproduction, fecundity
BB	3	Presence, Absence, Detection	Occupancy, detection probability
BB	4	Diversity	Species diversity, richness, indices-of-biotic-integrity
BB	5	Behavior, Movement, Colonization, Extinction	Movement, colonization, behavior
BB	6	Demographics, Age, Sex, Size	Population characteristics
BB	7	Survival, Reproduction, Growth	Fitness, condition, mortality, etc.
BB	8	Functional Group, Species, Trait Composition	Guilds, functional/traits, age composition (%)
BB	9	Genetics, Mixing, Metapopulation	Population dynamics
BB	10	Habitat/Critical Habitat	Indices of habitat; area, suitability, etc.
BB	11	Internal Composition, Nutrient Abnormalities	Organismal nutritient composition; includes stoichiometry, physiologic homeostasis, anatomical or physiologic abnormalities caused by contaminants
BB	51	Algae/Primary Productivity	Measures for algal populations/communities
CF	12	Basin Area	Area of river basin
CF	13	Dendritic Network and Riverscape	Length of river fragments, connectivity indices
CF	14	Fish Passage	Presence of up/downstream passage, length of the bypass
GM	15	Catchment and Basin Attributes	Soil characteristics, landscape erodibility, and topography in uplands
GM	16	Channel	Channel properties including channelization, bankfull width, channel slope, braided channel,
GM	17	Floodplain Valley	Channel migration, entrenchment, confinement
GM	18	Sediment and Substrate	Particle size, bedrock composition
LC	19	Area Impacted, Project Area	Areas impacted by the project, unrelated to land cover changes or reservoir inundation
LC	20	Floodplain/Riparian Vegetation	Channel vegetative encroachment, floodplain area
LC	21	Land Cover Class	Land cover type and land cover changes
LC	22	Protected Land	Spatial statistics of protected lands
LC	23	Reservoir Inundation	Spatial statistics of the reservoir, upland/floodplain inundation, biomass inundated/lost
WQUAN	24	Basin Attributes	Attributes related to factors influencing hydrology including climate, catchment size, soils, geology
WQUAN	25	Diversion	Quantitative diversion statistics including diversion discharge, consumptive use, and other water uses
WQUAN	26	Downstream Discharge Duration	Period associated w/specific flow condition
WQUAN	27	Downstream Discharge Frequency	How often flow greater than a discharge threshold occurs over a particular time period
WQUAN	28	Downstream Discharge Magnitude	Water volume moving past a fixed point per unit time
WQUAN	29	Downstream Discharge Periodicity	Order of occurrence of events of a certain magnitude
WQUAN	30	Downstream Discharge Rate of Change	Flashiness; how quickly flow changes

Table 1. *Cont.*

Category	RFI ID	RFI Name	RFI Definition
WQUAN	31	Downstream Discharge Timing	Regularity with which flow of a defined magnitude occurs
WQUAN	32	Groundwater	Groundwater characteristics
WQUAN	33	Reservoir Hydrology	Residence time, fluctuation, surface area, degree of regulation, etc.
WQUAN	34	Upstream Inflow Duration	Period associated with specific flow condition
WQUAN	35	Upstream Inflow Frequency	How often flow above a given magnitude recurs over a particular time interval
WQUAN	36	Upstream Inflow Magnitude	Amount of water moving past a fixed location per unit time
WQUAN	37	Upstream Inflow Periodicity	Magnitude of flow over a specified time period such as 7-day, 30-day minimum/maximum flow
WQUAN	38	Upstream Inflow Rate of Change	Flashiness; how quickly flow changes
WQUAN	39	Upstream Inflow Timing	Time of day/month/year flow of defined magnitude occurs
WQUAL	40	Algae/Primary Productivity	Algal concentration; measures of chlorophyll A, cyanotoxin, etc.
WQUAL	41	Buffering Capacity	pH, alkalinity
WQUAL	42	Dissolved Gasses	Water non-greenhouse gas concentration
WQUAL	43	Dissolved Oxygen	Water dissolved oxygen concentration
WQUAL	44	Ecosystem Function	Vital ecosystem rates or processes; biochemical oxygen demand, primary production
WQUAL	45	Gas Emissions	Water concentration/ebullition of greenhouse gasses
WQUAL	46	Key Elements	Elements and compounds not listed on US Environmental Protection Agency toxic and priority pollutants list
WQUAL	47	Macromolecular Pollutants	Compounds listed on US Environmental Protection Agency toxic and priority pollutants list that are not included in other categories
WQUAL	48	Nutrients, Organic Material	Dissolved oxygen concentration, other organic non-pollutants; nitrogen, phosphorus, carbon
WQUAL	49	Solid Transport, Turbidity, Conductivity	Turbidity, total dissolved solids, total suspended solids, conductance
WQUAL	50	Water Temperature	Temperature measurements
RC	52	Aesthetics	Visual resources related to project flows, operation, etc.
RC	53	Visitor Surveys	Surveys of visitor experiences, wants, needs, etc.
RC	54	Recreation Use	Studies related to recreational use in the project area
RC	55	Land Use	Studies related to specific uses of land including permanent/seasonal recreation
RC	56	Boating	All issues related to boating; whitewater, wake, etc.
RC	57	Fishing	All fishing related rec activities including creel/angler usage surveys
RC	58	Noise	Studies relating to noise from boats, PWCs, groups of people, etc.
CR	59	Presence of Cultural Resources	Desktop analysis and fieldwork related to locating cultural resources
CR	60	Archaeology	Any archaeological activities
CR	61	Historic Property	Desktop analysis and fieldwork related to locating, identifying, and/or preserving historic properties

2.2. Dataset 2 Based on Environmental Study Submittals and Issuances

Our second environmental life cycle dataset documented the back-and-forth of study submittals and issuances for seven licensed hydropower projects, leveraging information previously documented for six of the projects in Pracheil et al. (2019) [5]. To create this new dataset, we first documented project characteristics, natural resource issues, and the types of environmental studies that were conducted. Because the Holtwood project captured

in [5] described a license amendment, we replaced this project with the Wallenpaupack project for this analysis.

To analyze the seven previously licensed hydropower projects, we examined a total of 1066 FERC documents obtained from the FERC e-Library including: scoping documents; national Environmental Policy Act (NEPA) documentation; biological opinions; biological assessments; additional information requests; notices of intent and/or preliminary application documents; draft and final license applications; license orders; license terminations; license transfers; license amendments; comments; contentions; surveys; requests and orders; health advisories; responses to orders, issuances, and comments; agency recommendations; agency prescriptions; programmatic agreements; settlement agreements; study plans; operation and monitoring reports; compliance filings; inspection reports; recreation reports; environmental reports; motions; interventions; Form 80 s; time extensions; and miscellaneous filings. We recorded and attributed the qualitative information contained in issuances and submittals from regulators/agencies, other stakeholders, stakeholders, license applicants and FERC regarding environmental studies, as well as the timing of common events, information on approval rates, study types, study and RFI category, dates of entries, and requesting entity in a spreadsheet. This process led to the creation of 2052 records in a new format over a period of two years of dedicated time.

Descriptions of case study hydropower projects are given in [1] except for the Wallenpaupack project that is described below. These seven projects were chosen to provide insight into projects of a range of sizes across the diverse regions of the US. Note that the Jackson project was also addressed through the study plan determination letter dataset.

2.3. Description of Wallenpaupack Project (FERC Docket P-487)

The Wallenpaupack project is located within the Delaware River Basin in Pike and Wayne Counties, Pennsylvania, and is a 44 MW facility operated in peaking mode at the Wilsonville Dam on Wallenpaupack Creek in Pennsylvania. This project is located in the Eastern Temperate Forests Ecoregion, and is currently owned by BIF III Holtwood, LLC. There are 56 fish species in the project watershed. Threatened and endangered species, and species of special concern located within the project boundary, include: bald eagle, osprey (*Pandion haliaetus*), roseroot stonecrop (*Sedum rosea*), slender panic-grass (*Panicum xanthophysum*), Canadian white-face skimmer (*Leucorrhinia prozima*), and dwarf wedgemussel (*Alasmidonta heterodon*). Lake Wallenpaupack supports fisheries for brown trout (*Salmo trutta*), walleye (*Sander vitreus*), channel catfish *(Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieu*), and panfish species such as yellow perch (*Perca flavescens*), black crappie (*Pomoxis nigromaculatus*), and brown bullhead (*Ameiurus nebulosus*) [7]. This project noted several chronic water quality issues during relicensing including hydrogen sulfide gas emissions, dissolved oxygen, pH, and nutrients.

3. Results

3.1. Study Determination Letter Dataset

We found that a total of 520 studies were requested across the 23 ILP projects. Of these, 389 (74%) studies were approved. Studies classified in the BB category were the most frequently disputed, followed by studies classified in the RC category (Figure 3). However, the approval rate of disputed BB studies was not as high as the approval rate for disputed studies in other categories. Disputed studies in the CF category were the most frequently rejected, with 50 out of 199 (40%) of CF studies disputed being rejected. Disputed studies in the WQUAN category were the second most frequently rejected, at 26 out of 74 (35%), and the GM category was the third most frequently rejected, at 17 out of 50 (34%). The CR category was the most common category of disputed studies, with 33 out of 34 (97%) of disputed CR studies being required, followed by the RC category, with 50 out of 61 (84%) disputed studies approved. Although BB had the most studies requested at 199, the approval rating was the third-highest rating among all categories, with 149 of 199 (75%) disputed studies approved.

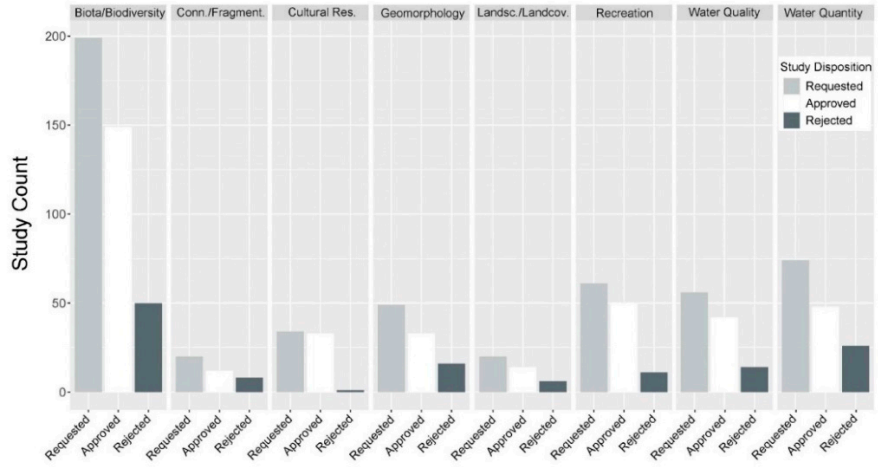

Figure 3. Total number of studies that were approved, rejected, or requested in each category for the 23 projects in dataset 1, analyzed using study determination letters.

The Loup Canal Project had the highest proportion of approved studies; the Mason Project had the next highest proportion, at a little more than half of the Loup Canal's total number of approved/disputed studies (Figure 4). Across all RFIs irrespective of category, RFI 3 (BB: presence, absence, detection) was the most studied, followed by RFI 10 (BB: genetics, mixing, metapopulation). Roughly two-thirds of the RFIs were assessed across the 23 projects (Figure 5).

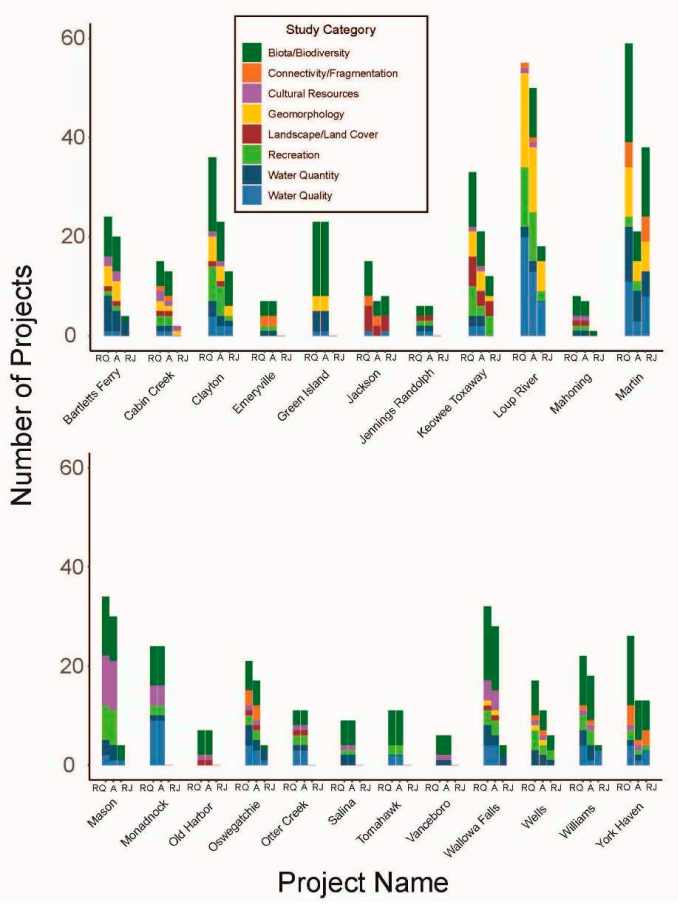

Figure 4. The number of requested, approved, or rejected studies by study category for the 23 projects in dataset 1, analyzed with study determination letters.

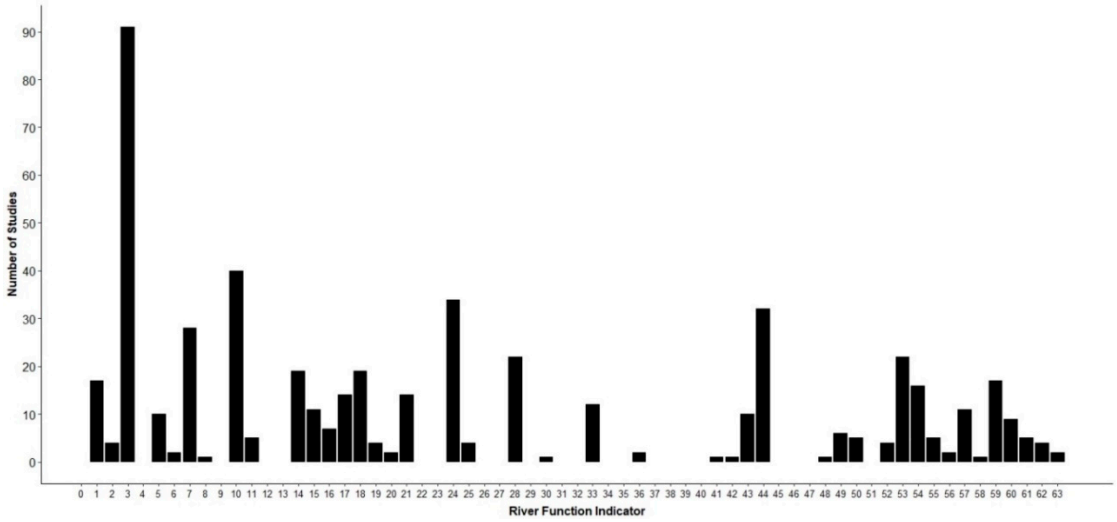

Figure 5. Number of studies requested by RFI for the 23 projects in dataset 1, analyzed with study determination letters.

3.2. Environmental Study Submittals and Issuances Dataset

Of the six categories used in the analyses of multiple FERC document types, the data for the seven case studies show BB to be the most studied out of the six categories represented in dataset 2 (Figure 6). The rate of requested studies vs. completed studies was high across several categories. The BB category had 14 more studies completed than requested, the GM category had one more study completed than those requested, and in the WQUAL category, all studies that were requested were completed. The rest of the categories came close, with only four studies not completed that were requested.

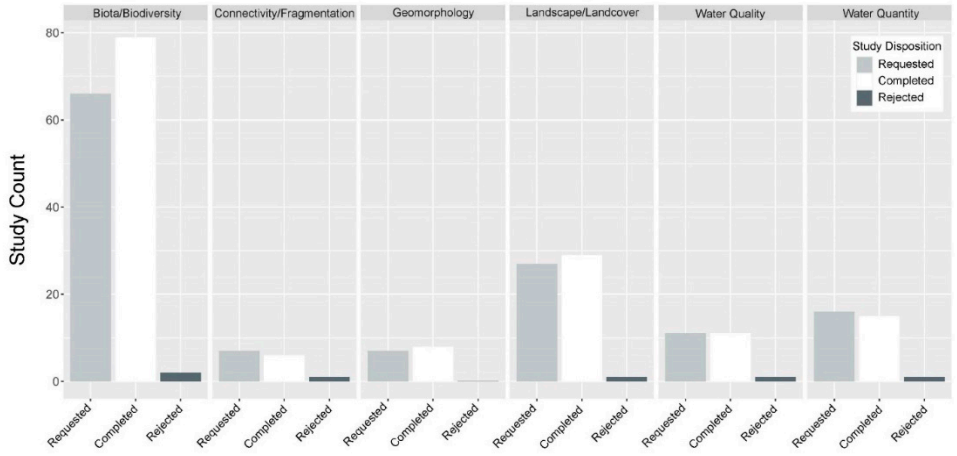

Figure 6. Number of studies that were completed, rejected, or requested, by study category, for the seven case study projects in dataset 2.

Most projects had around the same number of studies, except Bowersock, which had fewer (Figure 7). All projects except Bowersock had BB as the most studied category, which had WQUAL as the most studied category. The seven case studies had a high study completion rate, with half of the categories having a 100% or more completion rate. Again, since data compiled for case studies included the numbers of studies requested, rejected, and completed, there were many times more completed studies than requested, due to inconsistencies in the FERC record. For example, Dorena had a benthic macroinvertebrate study that was recorded as completed in the license, but had no official record of being requested anywhere in the FERC e-library or related documentation. When examining

approval vs. rejection rates, the data show that all categories have fewer rejected studies than completed.

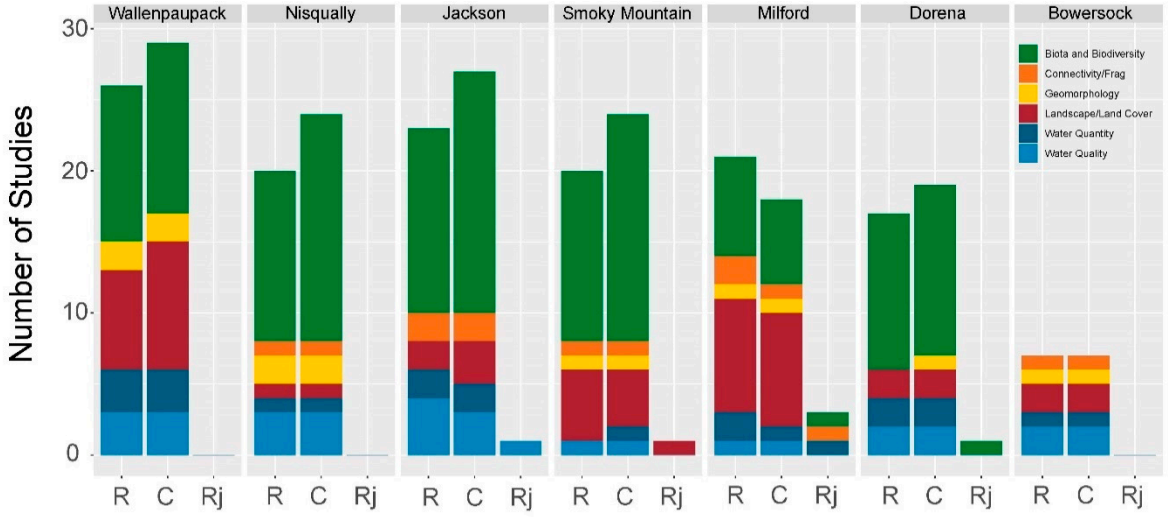

Figure 7. The number of studies by category that were requested (R), completed (C), or rejected (Rj) for each of the seven case study projects in dataset 2.

3.2.1. Nisqually

A total of 22 environmental studies were recorded for the Nisqually Project. The studies represented five of the six categories: 15 in the BB category (68%), one in the WQUAL category (5%), two in the GM category (9%), two in the CF category (9%), and two in the WQUAN category (9%). No studies were conducted in the LC category. No requested studies were rejected at the Nisqually project (Figure 7). A total of 22 environmental studies were completed and 18 were requested, which meant that there were four more completed than originally requested.

Studies conducted at the Nisqually project were mainly focused on the BB category, with an emphasis on the anadromous salmon and the presence of rare, threatened, and endangered (RTE) species that inhabit the river downstream of LaGrande Dam. LaGrande reservoir creates a natural barrier to anadromous salmonids, which likely explains why there were only two studies in the CF category. There is fish passage in the LaGrande Bypass Reach; it was monitored annually as a requirement under the 1997 FERC License Article 416 for potential barriers and obstacles, as well as for fish absence/presence. Fish were found to be able to pass through this area, though spawning areas were absent. Additionally, no abnormal injuries or migration delays were found. The duck survey was part of an annual wildlife management report ordered in the license, the fish risk severity assessment was part of a license requirement, and the snag survey was also conducted as part of the annual wildlife report. Several required studies had no formal evidence of a request in the record including annual duck and snag surveys that were part of an annual wildlife management report and a fish risk severity assessment.

The single study in the WQUAL category conducted at Nisqually was conducted as part of a larger study and report detailing reservoir stratification, water temperature, and dissolved oxygen levels. No data collected in this study suggested the turbines affected dissolved oxygen levels, so there was no need for further water quality investigation or mitigation measures as part of the license.

The two WQUAN studies conducted at the Nisqually project pertained to flood handling capabilities (probable maximum flood and critical flow studies). A critical flow study was conducted, to determine fish stranding sites, and was estimated to be 350 cfs. A probable maximum flood study used hydrological and meteorological measurements to determine how much precipitation would need to occur in order to overtop the dams.

The results were considered normal and recorded in the FERC record, and were typical of safety-related studies ordered by FERC at other projects.

The GM studies examined the erosion of reservoir banks and gravel for spawning in the bypassed reach, the latter of which was remediated through a relatively successful gravel augmentation in the early 2000s. The erosion study pertained to any land clearing or disturbance and was also included as part of the gravel study and sediment budget.

There were no LC studies completed or requested at the Nisqually project, which shares borders with not only state parks, but a national forest as well.

3.2.2. Jackson

A total of 25 environmental studies were recorded for the Henry M. Jackson hydroelectric project. The completed studies represented five of the six categories: 15 in the BB category (60%), two in the WQUAL category (8%), five in the CF category (20%), three in the WQUAN category (12%), and one in the LC category (4%). No GM studies were conducted at the Jackson project. Percentages do not add up to 100% as an artifact of rounding. A total of 25 environmental studies were completed and 22 were requested, which meant that there were three more completed than requested. All other categories had as many studies completed as rejected, except the BB category, which had four more studies completed than requested. These studies included a steelhead/chinook escapement survey; gill net survey; special-status plant surveys; and a plankton/neuston survey. While they were not requested, these studies were ordered to be completed by FERC. Only one study was rejected at the Jackson project—a study in the WQUAN that was considered to be duplicative of existing flood control efforts at the project (Figure 7). No GM studies were conducted at the project.

The Jackson project had far more studies conducted in the BB category than any other as well, with 15 studies conducted. These studies were focused on biota in Puget Sound (due to the relative proximity of the Sound to the project), the salmonid population in the Sultan River, and the species of special concern in the area, and included studies on aquatic habitat, juvenile salmonid outmigration studies, project impacts to killer whales (*Orcinus orca*) and considered tribal fisheries issues.

The two WQUAL studies were conducted at the Jackson project and included a 13-year monitoring project to measure project operational improvements, and a study determining the effects of side-channel enhancements for a potential protection, mitigation, and enhancement measure. The five CF studies conducted focused on tailwater dewatering, and fish passage both for the diversion dam and the March Creek slide, the latter of which blocked or reduced the upstream passage of adult anadromous salmonids. Only one LC study was conducted, a study that assessed the condition of riverine, riparian, and wetland habitat.

3.2.3. Smoky Mountain

A total of 21 environmental studies were recorded for the Smoky Mountain project. The studies represented all six categories: 15 from the BB category (71%), one from the WQUAL category (5%), one from the GM category (5%), two from the CF category (10%), one from the WQUAN category (5%), and two from the LC category (10%). Percentages do not add to 100% as an artifact of rounding. Only one study (in the LC category) was rejected at the Smoky Mountain project (Figure 7). A total of 21 environmental studies were completed and 17 were requested, which meant that there were four more completed than requested.

The BB and WQUAL categories had more studies completed than requested; all other categories, with the exception of the LC category (which had one rejected study), had all studies completed that were requested. The required BB studies pertained to species of special concern, such as the bald eagle and osprey, including studies on their habitats and population and presence studies. All other categories, with the exception of the LC category (which had one rejected study), had all studies completed that were requested.

One study in the WQUAL category was conducted at the Smoky Mountain project to check for seepage in the north embankment of the Chilhowee Development and was not related to the Section 401(a)(1) certifications issued by the states of North Carolina and Tennessee. Similarly, one study was conducted in the GM category and included measures to augment gravel in the bypassed reach, followed by annual evaluations on aquatic resources with respect to the augmentation.

Two studies conducted in the CF category pertained to fish passage, species translocation, and entrainment. One study was conducted in the WQUAN category, to inform instream flow requirements consistent with a biologically diverse cool-warm water fishery specified in both the settlement agreement (SA) and the license order.

The Smoky Mountain project had four studies conducted in the LC category pertaining to terrestrial resources, and had only one rejected study in the LC category. A shoreline management study was denied, but a Shoreline Management Plan was later required in the license order and was specified to be developed in collaboration with a group of 21 members of natural resource agencies, NGOs, Native American tribes, private citizen groups, and representatives from towns and counties.

3.2.4. Milford

A total of 14 environmental studies were recorded for the Milford project. The studies represented all six of the categories: seven from the BB category (50%), two WQUAL (14%), one GM (7%), two CF (14%), one WQUAN (7%), and four LC (29%). Percentages do not add to 100% as an artifact of rounding. One requested study each in the BB, CF, and WQUAL categories were rejected at the Milford project (Figure 7). A total of 14 environmental studies were completed and 17 were requested, which meant that there were three more completed than requested. No study category at the Milford project had more studies completed than requested; however, the GM, LC, and WQUAN categories had all studies completed that were requested.

The Milford Project had six studies recorded for the BB category: three focused on the migration of salmonids and alosines; one assessed fisheries resources, and two assessed biodiversity and species of special concern. Additionally, the comprehensive settlement agreement also worked to resolve anadromous fish issues among agencies. The rejected BB study was a wildlife study initiated to examine the project's effects on bald eagles.

The only study in the WQUAL category conducted for the Milford project examined the conditions by which the project would meet Section 401(a)(1) certification criteria, and included soil erosion, groundwater impacts, construction impacts, dissolved oxygen, water temperature, and dioxins. This study was included in the final NEPA document for the Milford project and assessed the conditions the project would have to meet in order to maintain federal and state water quality standards. FERC found in their NEPA document that the licensee either had already or would in the future provide protection, mitigation, and enhancement measures for all WQUAL concerns. The rejected WQUAL study was a contaminant study that requested licensee assistance with a Penobscot Indian Nation contaminant screening study of aquatic resources/habitats, with a focus on chlorinated benzene derivatives and heavy metals. The study was proposed by the US Department of the Interior, and included the monitoring of sediments, fish tissue, and other aquatic organisms in an inundated area that was later determined to be part of Penobscot Indian Nation lands. Because these lands were not determined to be part of Federal lands, the Department of the Interior did not have mandatory conditioning authority for requiring this study.

One study each was conducted in the GM, CF, and WQUAN categories. The GM study examined the effects of erosion and the subsequent sedimentation caused by construction. The one study in the CF category required the license applicant to monitor the effectiveness of fish passage facilities and flows for alosine species, and qualitative and quantitative monitoring of American eels. The rejected CF study was a study of adult blueback herring (*Alosa aestivalis*) and sea-run alewife (*A. pseudoharengus*) up-/downstream

passage effectiveness study that was melded with the fish passage effectiveness study. In the WQUAN category, the one study was focused on whether the operations qualified as run-of-river and whether this flow would significantly affect other resources.

The LC category had four studies conducted at the Milford project, including air quality, navigation, and wetland and terrestrial resources. Specifically, these studies required the licensee to ensure safe navigational use by filing a monitoring and removal plan for semi-buoyant logs in the Milford impoundment. Air quality was studied as part of the final NEPA document for the project; this study mainly concerned air pollution during construction from various sources and was determined not to be an issue. Wetland resources were also studied before and during the NEPA process, mostly due to the proposed construction of the Basin Mills Development and the decommissioning of the Orono Development. It was determined that the continued operation and addition of a fifth turbine at Milford would have no effect on adjacent wetlands. This was also the case with the study of terrestrial resources at the project.

3.2.5. Bowersock

The Bowersock project had no rejected studies in any category. The project operated in a run-of-river mode both before and after licensing, and the additional environmental impact created by the expanded generation capacity was decided to be marginal according to the EA, which included a finding of no significant impact issuance. A total of five environmental studies were recorded for the Bowersock project and represented four out of six categories: one WQUAL (20%), one CF (20%), two WQUAN (40%), and one LC (20%); no BB or GM studies were conducted. No requested studies were rejected at the Bowersock Project.

This FERC license was unique among the case studies in that while this facility generated power for the grid prior to the licensing proceeding, it qualified for a license exemption. The expansion of generating capacity led to the requirement of a license. This project also had two categories, BB and GM, that had no studies conducted. In this case, the project operated in a run-of-river mode both before and after the license, and the additional environmental impact created by the expanded generation capacity was decided to be marginal. Construction activities required for project expansion only raised the head of the reservoir a few feet, which was also determined to have a marginal environmental impact, and no federally endangered species were determined to be impacted by the project expansion construction or operation. It was also determined that construction at the project would only cause short-term impacts, and measures proposed by the license applicant were considered sufficient.

A single CF study was conducted at the Bowersock project, concerning fish passage. This was later incorporated into the EA for resident and RTE fish. To protect fish from impingement or entrainment, Bowersock proposed limiting the dimensions of the intake structure, so that water velocities at maximum hydraulic capacity did not exceed 1 foot per second (fps). There were no species documented in the impoundment that needed passage around the dam to complete their life history requirements, and Bowersock Dam was determined to provide a barrier to the spread of Asian carp species that can be dangerous to boaters and impact native fish. In addition, a single study in the WQUAN category was conducted at the Bowersock project—a velocity test conducted at various points downstream of the turbines. It was determined that further velocity testing would be conducted only if natural resource agencies determined it to be necessary.

There was one study conducted in the LC category at Bowersock. This was a floodplain study conducted in 2010 because Bowersock had proposed raising the existing flashboards by 1.5 feet, which in turn would increase the water surface elevation upstream by the same amount and increase the surface area of the Bowersock millpond by 94 acres, which was determined to have a minimum effect on the ecosystem.

3.2.6. Dorena

The Dorena project was the only license that was issued to add power to a non-powered dam. As a result, many of the environmental impacts of this hydropower facility were decided to be marginal in comparison to those created by the already existing dam. A total of 17 environmental studies were recorded for the Dorena Project and included five out of six categories: 12 BB (67%), two WQUAL (11%), one GM (6%), one CF (6%), and two WQUAN (11%). No LC studies were conducted at the Dorena Project. Percentages do not add up to 100% as an artifact of rounding. Only one study (in the CF category) was rejected at the Dorena Project (Figure 7). There were two more studies completed than requested. No LC studies were conducted, since the project was adding power to a non-powered dam, and there were no land-disturbing activities associated with construction and no operational changes being made to water releases.

There were 12 studies in the BB category, mostly consisting of long-term biota studies, intended to survey the area, that were later incorporated into the license. Two studies in the WQUAL category were conducted at the Dorena project: an overall water quality study and a mercury study due to existing high levels of mercury in fish from non-point sources, and one examining seasonal mercury bioaccumulation in fishes. Only one GM study was conducted to examine sediment interstitial void measurement. This study was conducted in conjunction with a rainbow trout (*Oncorhynchus mykiss*) spawning study to document relationships between sediment characteristics and fish survival. Because rainbow trout early life-history stages are so closely tied to sediment characteristics, this study helped to add an additional layer of insight into fish population impacts. In addition, the BB category had two studies completed that were not requested, and the GM category had one. The benthic macroinvertebrate and rainbow trout spawning studies (BB) were coupled with the interstitial void measurements (GM). Although these studies were incorporated into the final license application, there was no official record of their request in the FERC e-library.

Fish passage was considered during the FERC licensing of the Dorena Dam, but was not included in the final license order. The Row River historically did not support an independent population of Chinook salmon, protected by the ESA, which may explain why no CF studies were required. The two WQUANT category studies examined ramping conditions and hydrology/project operations. In the license order, findings of these studies led to conditions within the scope of Section 10 (j) as recommended by the NOAA National Marine Fisheries Service (NMFS) and the Oregon Department of Fish and Wildlife.

3.2.7. Wallenpaupack

A total of 23 environmental studies were completed, of the 22 studies requested across the 6 categories: 11 BB (48%), three WQUAL (13%), two GM (9%), one CF (4%), three WQUAN (13%), and three LC (13%). No requested studies were rejected at the Wallenpaupack project (Figure 7). A total of 23 environmental studies were completed and 22 were requested, which meant that there was one more completed than requested and no requested studies were rejected.

There were 11 studies conducted in the BB category, mostly consisting of biota surveys intended to characterize habitat and populations for both RTE and non-threatened species. The BB category had one study completed that was not requested, which determined the response of algae in lake water to allochthonous inputs.

Three studies in the WQUAL category were conducted at the Wallenpaupack project. These studies pertained to general water quality, groundwater, and emissions of hydrogen sulfide (H_2S) from the project tailrace. Two GM studies were conducted at the Wallenpaupack project: both erosion studies and the EA recommended that erosion control measures be included in a shoreline management plan for Lake Wallenpaupack. An entrainment study was the only study in the CF category, conducted based on a large, previous fish kill that prompted the study of entrainment mortality. Ultimately, that fish kill was attributed to water temperature.

Three studies in the WQUAN category were conducted at the Wallenpaupack project: an instream flow incremental methodology study, a supplemental creek flow release study, and a drought operations study. There were three studies in the LC category that were conducted: a wetlands inventory, a noise survey due to noise from recreational boating, and a terrestrial resources study, and were included as part of the first scoping document.

4. Discussion

Understanding the types of environmental studies that are approved or rejected during the hydropower licensing process can help stakeholders involved in licensing to gain a greater understanding of which proposed studies are most likely to be required by FERC, which may, in turn, assist them in prioritizing which studies to propose or dispute. For example, across all 29 projects analyzed, the BB category appeared to have the greatest importance in environmental studies, suggesting both its relative importance to hydropower stakeholders and the influence of legislation on the studies being ordered. In particular, the frequency of studies under RFI 3 (BB: presence, absence, detection) and RFI 10 (BB: habitat/critical habitat) are important in assessing linkages between hydropower, endangered species, and migratory species. Studies in other categories, such as WQUAL and WQUAN, may also be directly related to the BB category. For instance, if an environmental study for lake sturgeon spawning is requested, the study falls into the BB category, but water quality testing of lake sturgeon habitat would be categorized as WQUAL, which also clarifies the reason for the high number of BB studies.

The analysis for the seven case studies in the submittals and issuances portion of this study differed from the analysis of the 23 projects with study determination letters. Without a study determination letter, it was difficult to ascertain from the FERC record whether a study was approved, rejected, or completed. We did our best to compile these numbers accurately, but sometimes we could not tell when modifications to original study requests had been made, because documentation found on the FERC e-library was incomplete. For example, keywords for finding information were misspelled or omitted, and parts of the record are frequently miscategorized, missing, or only captured by document formats that require visual inspection (e.g., .jpeg and .gif file formats). Another important difference was that we did not capture RC or CR categories of studies for the Environmental Study Life Cycle analysis (although many of the BB RFIs did relate to commercial fishing). Thus, we urge caution in comparing results from analyses of these two datasets.

Endangered species, such as several salmonid fishes and northwestern pond turtles, were frequently the subject of studies that were completed, requested, and/or approved. This may explain why RFI 3 and RFI 10 were more regularly recorded in our data, as not only do these RFIs fall within the BB category, but they also pertain to habitat quantification, including that of species of special concern. In dataset 2, the only rejected study in the BB category was a wildlife study that was never conducted at Milford, despite being part of the NEPA document. Projects with study determination letters also frequently had salmonids and ESA-listed species as the subject of studies that were completed, requested, and/or approved. These often extended to studies of forage or riverine conditions suitable for these species, such as macroinvertebrate sampling and other aquatic resource assessment. Commonly rejected studies mostly included requests for modifications to original studies and involved the geographic expansion of the study area or the expansion of the study scope to include more specific material. Management of federally endangered species falls under the jurisdiction of the US Fish and Wildlife Service and NOAA NMFS, both of which often require additional studies or information to be able to make determinations on project impacts on endangered species. Our study suggests that proposed studies seeking information about endangered species are frequently approved by FERC.

There were several types of CR studies frequently required across projects, including generalized cultural resource surveys that were mostly conducted in the office and by site visits. Only one study was not approved, which was a study into extending an Area of Potential Effect to include more potential cultural sites. Since the advent of the National

Historic Preservation Act in 1966, every state and US territory has had a State Historic Preservation Office protecting the interests of the general public regarding historically and culturally valuable areas and resources. One of the main duties of this office is the careful consideration of the impact of large renewable energy projects on historic landscapes or archaeological sites [8]. During the FERC hydropower licensing process, the State Historic Preservation Office will conduct comprehensive surveys of historic properties that have been inventoried previously; provide consultation to stakeholders and the public; coordinate with Native American tribes on historic preservation matters; enforce historic preservation easements [8]; and survey for additional archaeological and cultural sites missed in previous inventories. Prior to the passage of the National Historic Preservation Act, development was permitted with limited consideration of historic and archaeological resources. Rules enacted after the passage of the National Historic Preservation Act require a balance between hydropower development and cultural resources, where cultural resource managers must balance the protection of cultural heritage, including currently or potentially submerged archaeological resources, such as prehistoric sites that have been, or may be, impacted by hydropower development, without denying or unfairly restricting economic development [9]. There can be a wide variety of sites included in studies in this category, including archaeological sites, tribal lands, existing historical structures, submerged archaeological sites, and entire Areas of Potential Effect. Methods largely included resident surveys, but physical surveys of cultural resources were also used.

Many hydropower projects provide a source of recreation, and dam operators may work with local communities and recreational stakeholder groups to allow for recreational access (NHA 2020b). This may lead to requests for, and approvals of, RC studies. Reservoirs provide swimming, boating, and fishing; scheduled releases provide whitewater rafting and boating; and lands around projects provide hiking and camping. Recreation is a common category of protection, mitigation, and enhancement measures, and environmental studies frequently target gaining an understanding of the ecosystem for informing protection, mitigation, and enhancement measures [3]. Recreation is always considered during hydropower licensing; until 2018, FERC required a report on the use and development of recreation facilities at hydropower projects licensed by FERC under the Federal Power Act, known as FERC Form No. 80 [10]. Although this reporting requirement has since been eliminated, Section 10(a)(1) of this act requires FERC to ensure that any licensed waterway is for a variety of beneficial public uses, including recreational use.

A common finding from dataset 2 was that there were as many or more studies completed than were requested. For example, half of the six categories for the environmental study life cycle analysis had more or as many completed studies as requested; the rest had few that were requested and not completed. As mentioned earlier, it was often difficult to tell when a study request was truly new or simply a modification of an earlier request. However, there were also many "completed" studies that were not "requested" because they were considered protection, mitigation, and enhancement measures, even though they were not explicitly categorized as such in the official record. Because stakeholders, regulators, licensees, and FERC are each responsible for uploading their submittals and issuances into the FERC e-Library, it is difficult to speculate whether our tallies over- or under-count approvals, rejections, etc. in the FERC record or even whether potential over- or under-counting may be consistent across projects.

5. Conclusions

In the US, deciding which environmental impact studies to conduct as part of the hydropower regulatory process can be highly contentious. FERC's process of determining which environmental studies to conduct brings parties with diverse priorities such as developers, regulators, NGOs, indigenous people, and concerned citizens to the table to weigh in on the potential impacts of hydropower development and operation. Although there are codified steps towards determining these impacts, our analysis of 29 formerly licensed hydropower projects shows that the actual process is complex, not well-synthesized, and

heavily influenced by stakeholder priorities. Our approach to analyzing the FERC e-Library record provides insights into the actual regulatory process surrounding environmental impact assessment, illuminating which types of studies are most often requested and which studies are ultimately approved or rejected by FERC. Adding environmental life-cycle information about additional licensed hydropower projects to the two novel databases created through this project has the potential to help hydropower stakeholders preparing for licensing negotiations by giving them tools to focus discussions and facilitate consensus about which studies are most necessary, relevant, and feasible. Swifter consensus will ultimately save time and money for the wide variety of stakeholders involved in US hydropower development.

The FERC eLibrary online repository contains a wealth of information about species, environmental impacts and mitigations, and ecosystem and infrastructure characteristics, that be used to create a greater understanding of the regulatory process, environmental science, and the intersection of the two. Greater cataloging and synthesis of information in the FERC eLibrary may provide insights that can lead to more efficient ecosystem management and mitigations that can be leveraged by policymakers and stakeholders involved in the licensing process. Future research should focus on creating datasets and analyses that leverage the extensive information in this online repository.

Author Contributions: Conceptualization, methodology, formal analysis, investigation, data curation, visualization, and writing—original draft preparation, M.S.P.A.; writing—review and editing, project administration, funding acquisition, E.S.P.; conceptualization, methodology, data curation, visualization, writing—review and editing, project administration, supervision, funding acquisition, B.M.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the U.S. Department of Energy Water Power Technologies Office.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Study data available online: hydrosource.ornl.gov (last accessed 7 June 2021).

Acknowledgments: This research was supported by the US Department of Energy (DOE) under the Water Power Technologies Office. We would like to thank Aaron Levine and Taylor Curtis of the National Renewable Energy Laboratory for their review.

Conflicts of Interest: The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. United States Energy Information Administration (EIA). Annual Energy Outlook 2019 with Projections to 2050. 2019. Available online: https://www.eia.gov/outlooks/archive/aeo19/ (accessed on 7 June 2021).
2. Uria-Martinez, R.; Johnson, M.; Shan, R. Challenges in the post-licensing stage of U.S. hydropower development: Current status and some potential solutions. *Electr. J.* **2020**, *33*, 106729. [CrossRef]
3. Schramm, M.; Bevelhimer, M.; DeRolph, C. A synthesis of environmental and recreational mitigation requirements at hydropower projects in the United States. *Environ. Sci. Policy* **2016**, *61*, 87–96. [CrossRef]
4. Levine, A.; Pracheil, B. *An Examination of the Hydropower Licensing and Authorization Process*; Department of Energy Report, National Renewable Energy Laboratory: Golden, CO, USA, 2021.
5. Pracheil, B.; McManamay, R.; Parish, E.; Curd, S.; Smith, B.; DeRolph, C.; Witt, A.; Ames, S.; Day, M.; Graf, W.; et al. A Checklist of River Function Indicators for hydropower ecological assessment. *Sci. Total. Environ.* **2019**, *687*, 1245–1260. [CrossRef] [PubMed]

6. Parish, E.; Pracheil, B.; McManamay, R.; Curd, S.; DeRolph, C.; Smith, B. Review of environmental metrics used across multiple sectors and geographies to evaluate the effects of hydropower development. *Appl. Energy* **2019**, *238*, 101–118. [CrossRef]
7. *PPL Wallenpaupack Project No. 487: Offer of Settlement*; PPL Corporation: Allentown, PA, USA, 2004.
8. National Conference of State Historic Preservation Officers (NCSHPO). What is a State Historic Preservation Officer (SHPO)? Available online: https://ncshpo.org/about-us/what-is-shpo/ (accessed on 7 June 2021).
9. Evans, A.; Firth, A.; Staniforth, M. Old and new threats to submerged cultural landscapes: fishing, farming and energy development. *Conserv. Manag. Archaeol. Siteures* **2009**, *11*, 43–53. [CrossRef]
10. Elimination of Form 80 and Revision of Regulations on Recreational Opportunities and Development at Licensed Hydropower Projects. A Rule by the Federal Energy Regulatory Commission on 12/28/2018. US Federal Register, 83 FR 67060: 67060-67069. Available online: https://www.federalregister.gov/documents/2018/12/28/2018-28250/elimination-of-form-80-and-revision-of-regulations-on-recreational-opportunities-and-development-at (accessed on 7 June 2021).