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Influence of project characteristics, regulatory pathways, and environmental complexity on hydropower licensing timelines in the US

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A B S T R A C T

In the U.S., hydropower is expected to play an important role in supporting a zero-carbon energy transition so it's becoming increasingly important the hydropower regulatory process provides robust environmental and other protections while maintaining regulatory efficiency. In this study, we created a dataset of project and license characteristics and milestones using hydropower licensing documents from 107 randomly selected projects to 1) quantify the length of steps in the licensing timeline and 2) quantitatively identify factors associated with licensing timeline length and sources of uncertainty. We found original licenses had shorter average timelines than relicenses and project capacity was only related to timeline length when license type (i.e., original, relicense) was included in analyses. Both licensing timeline length and variability were impacted by the licensing process (Alternative, Integrated, Traditional) used. Projects with greater environmental complexity (e.g., endangered species) had significantly longer timelines than projects that were less environmentally complex. We attributed shorter timelines for original licenses to lower environmental complexity (e.g., no endangered species) because most original licenses involved development of already impacted sites. Projects with greater environmental complexity significantly impact resources that may require greater stakeholder involvement and increased study that can lead to longer licensing timelines.

1. Introduction

Fossil fuel generation sources account for 60% of total electricity generation in the United States (EIA, 2021). Most plans to reduce carbon emissions from energy generation rely heavily on shifting base load generation to zero-carbon renewable generation sources like solar and wind; however, because these sources only generate when the sun is shining or the wind is blowing, flexible generation sources are more important than ever for reliability of the electric grid. Currently, generation flexibility in the United States is provided by natural gas, but many zero-carbon plans rely on hydropower for helping to provide that flexibility (IEA, 2019). The hydropower regulatory process can be very contentious owing in part to involvement of a diverse group of stakeholders with equally diverse priorities ranging from environmental protection to increased energy generation revenue leading to disagreements that can cause delays in the regulatory process (Pracheil et al., 2021). Given the important role hydropower is expected to play in supporting the zero-carbon energy transition, understanding the points in the regulatory process where disagreements and delays are occurring is of urgent concern (Uncommon Dialogue, 2020).

In this United States, many non-federal energy projects are regulated by the Federal Energy Regulatory Commission (FERC) and each form of energy infrastructure goes through a unique regulatory process. Most hydropower projects are required to obtain federal authorization in the form of a license from the or an exemption from needing a license (due to small size or construction in a conduit) from the FERC, or a Lease of Power Privilege from the Bureau of Reclamation. Hydropower licenses from the FERC are required for approximately 55% of non-federal hydropower projects. These licenses have a 30- to 50-year term which allows for project construction and/or operation (16 U.S.C. §§ 791a-823g). Embedded within this process are several statutory and regulatory requirements under the Federal Power Act that must be completed before license issuance to ensure project compliance with a variety of energy, economic, societal, and environmental considerations (16 U.S.C. § 803 (a)(1); 16 U.S.C. § 797(e)). A diverse group of hydropower stakeholders is involved in many steps in the licensing process, particularly those steps that determine what the project impacts are and how to mitigate them. In this way, the hydropower licensing process offers an opportunity for a diverse suite of stakeholders such as development interests (e.g., project developers, utilities), non-governmental organizations, and

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representatives from federal, state, and tribal regulatory authorities and governments to work together to satisfy a mutually beneficial set of power and non-power objectives.

The need for stakeholder inputs in this process is codified in the Electric Consumers Protection Act of 1986 and is used to balance energy and non-energy related values in licenses by giving "equal consideration to the purposes of energy conservation, the protection, mitigation of damages to, and enhancement of, fish and wildlife (including related spawning grounds and habitat), the protection of recreational opportunities, and the preservation of other aspects of environmental quality" (16 U.S.C. § 797(e) as amended). In addition, this amendment required consultation between the licensee, the FERC, and affected federal and state resources agencies and Indian tribes. Specifically, the amended section provided an opportunity for resource agencies and affected Indian tribes to provide recommendations on how to make a hydropower project consistent with federal and state comprehensive plans for improving, developing, or conserving waterways affected by the project. This amendment also provided an opportunity for the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA), and state fish and wildlife agencies to provide recommendations under the Fish and Wildlife Coordination Act to protect, mitigate damages to, and enhance fish and wildlife affected by development and operation of the hydropower project (16. U.S.C. § 803(a) and (j)).

With so many steps, policies, and considerations in the hydropower licensing process, it can be difficult to see whether there are certain steps that contribute more to licensing timeline length and variability (can range from months to decades) and whether there are shared characteristics among projects with longer or shorter licensing timelines. This uncertainty in licensing timelines can have far-reaching and uncertain economic and time costs for all stakeholders involved. The large number of stakeholders that may be brought to the table during a licensing negotiation can have an economic impact on all stakeholders and taxpayer funded governmental agencies due to uncertain labor and legal costs linked to uncertain timelines. Regulatory timeline uncertainty can impact the length and cost of project development relevant to project financing and economic constraints (Uria-Martinez et al., 2018). For example, hydropower projects being relicensed see a strong, direct relationship between licensing timeline length and costs of relicensing (Levine et al., 2021). For projects seeking original licenses, longer timelines are not related to increased costs, but protracted licensing timelines may lead to license abandonment prior to license issuance as unlicensed projects are unable to generate revenue (Levine et al., 2021).

While there is some information available detailing the length of hydropower regulatory timelines in the United States, there is limited quantitative data on the factors that may be influencing the length of these timelines and where in the process challenges may occur. Previous studies have provided some insight into factors affecting hydropower regulatory timelines, but they either were published prior to the regulatory framework that currently exists (Kosnik, 2006) or focused on collaborative licensing processes (Ulibarri, 2018). In this study, we extracted quantitative data from hydropower licenses and sought to identify factors associated with timeline length, where in the regulatory process bottlenecks may occur, and the greatest sources of uncertainty in the hydropower licensing and federal authorization process using a quantitative, statistical analysis of timeline steps.

2. Methods

2.1. Overview of the hydropower licensing process

Hydropower licensing begins with the pre-filing stage prior to a license applicant filing a final license application (FERC, 2017). Although each of the three license processes—Alternative Licensing Process, Integrated Licensing Process, and Traditional Licensing Process— have pre-filing stages that vary, each generally requires some level of stakeholder engagement to identify natural resource and other issues and gather information. This information is then used for filing the final license application and conducting the environmental review (i.e., National Environmental Policy Act (NEPA)) process (FERC, 2017). The first formal filing required as part of the hydropower licensing process is a Notice of Intent that the license applicant intends to file a license application and a Pre-Application Document (hereafter, only Notice of Intent will be used). Projects being relicensed must file the Notice of Intent between 5 and 5.5-years of the expiration date of the current license (FERC, 2017). The ILP is the default process and projects wanting to use the Alternative or Traditional Licensing Processes must gain approval from FERC (18 C.F.R. §5.3(a)(2)).

Post-filing steps in the licensing process, that is, those steps that occur after the final license application has been filed, are more comparable among the three license processes. Once the final license application has been submitted by the license applicant, FERC will determine whether the application is Ready for Environmental Analysis. If yes, the FERC issues a public notice for formal agency and stakeholder comments and motions to intervene as part of the NEPA process. Comments submitted in this process can include recommendations, prescriptions, terms, or conditions, depending on the jurisdiction (FERC, 2017). The NEPA process is concluded with the publication of a final environmental review document, the Environmental Assessment (EA) or Environmental Impact Statement (EIS) that will address stakeholder comments (18 C.F.R Part 4; Levine and Flanagan, 2019).

During the post-filing stage, outside agencies also must provide inputs and/or certifications that are required prior to license issuance. These certifications include a water quality certification issued by applicable state or tribal water quality authority or the U.S. Environmental Protection Agency as part of the U.S. Clean Water Act (18 C.F.R. Parts 4 and 5) and determination of whether the hydropower project is likely to jeopardize existence of a federally threatened or endangered species as a part of the U.S. Endangered Species Act by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service (NMFS) (16 U.S.C. §§ 1531–1544). Conditions listed in the water quality certification become terms of the FERC license as do mandatory conditions from federal and state agencies with mandatory conditioning authority (e.g., state water quality authority, state/tribal/federal fish and wildlife agencies). Once these requirements are met, the FERC can issue the final license order which will also include mandatory terms and conditions the project must comply with (FERC, 2017).

2.2. Stakeholder Working Group

We convened a Stakeholder Working Group to help identify timeline points, variables and other relevant insights into the hydropower licensing and federal authorization process (Fig. 1). This group was comprised of a diverse group of 31 hydropower stakeholders that included members from federal and state regulatory and resource agencies, Indian tribes, non-governmental organizations, consultants, developers, utilities, and other hydropower industry representatives with direct hydropower licensing experience. The Stakeholder Working Group met approximately four times per year including in-person and virtual meetings from 2018 to 2021 and advised on policy- and science-relevant analyses as well as interpretations of these analyses so we could gain a better understanding of factors influencing timelines in the hydropower licensing and federal authorization process. With respect to this study, the Stakeholder Working Group played a key role in timeline analysis by providing expert opinion on which data points to collect from Federal Energy Regulatory Commission licenses and hypotheses to test using these data.

2.3. Data collection

We created a dataset of dates and characteristics of original and relicensed FERC hydropower projects by extracting information from

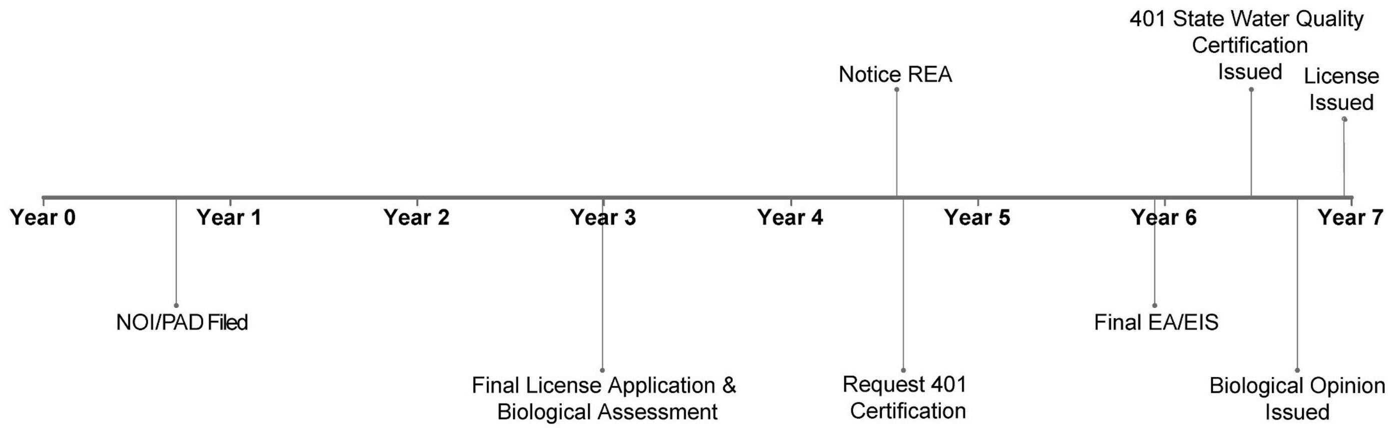

Fig. 1. Example timeline the showing order of steps and approximately average timelines for hydropower project licensing. Abbreviations are as follows: NOI/PAD = notice of intent/Preliminary Application Document, REA = Ready for Environmental Analysis. EA/EIS = Environmental Assessment/Environmental Impact Assessment. For more detail on the licensing process, please see Levine et al. (2021).

licensing documents such as license orders and NEPA documents found in the FERC e-Library. To determine which licenses to include in our dataset, we randomly selected 129 hydropower projects from a FERC-maintained list of 296 licensed projects that have received their license since October 1, 2005. We then used the Existing Hydropower Assets Database (Johnson et al., 2020) to ascribe project characteristics to each project and filtered out projects that did not fit our criteria for this study including marine hydrokinetic, transmission line, and pumped storage projects. We also filtered out one project that had its FERC license vacated by a U.S. District Court (i.e., Coosa River Project) for a

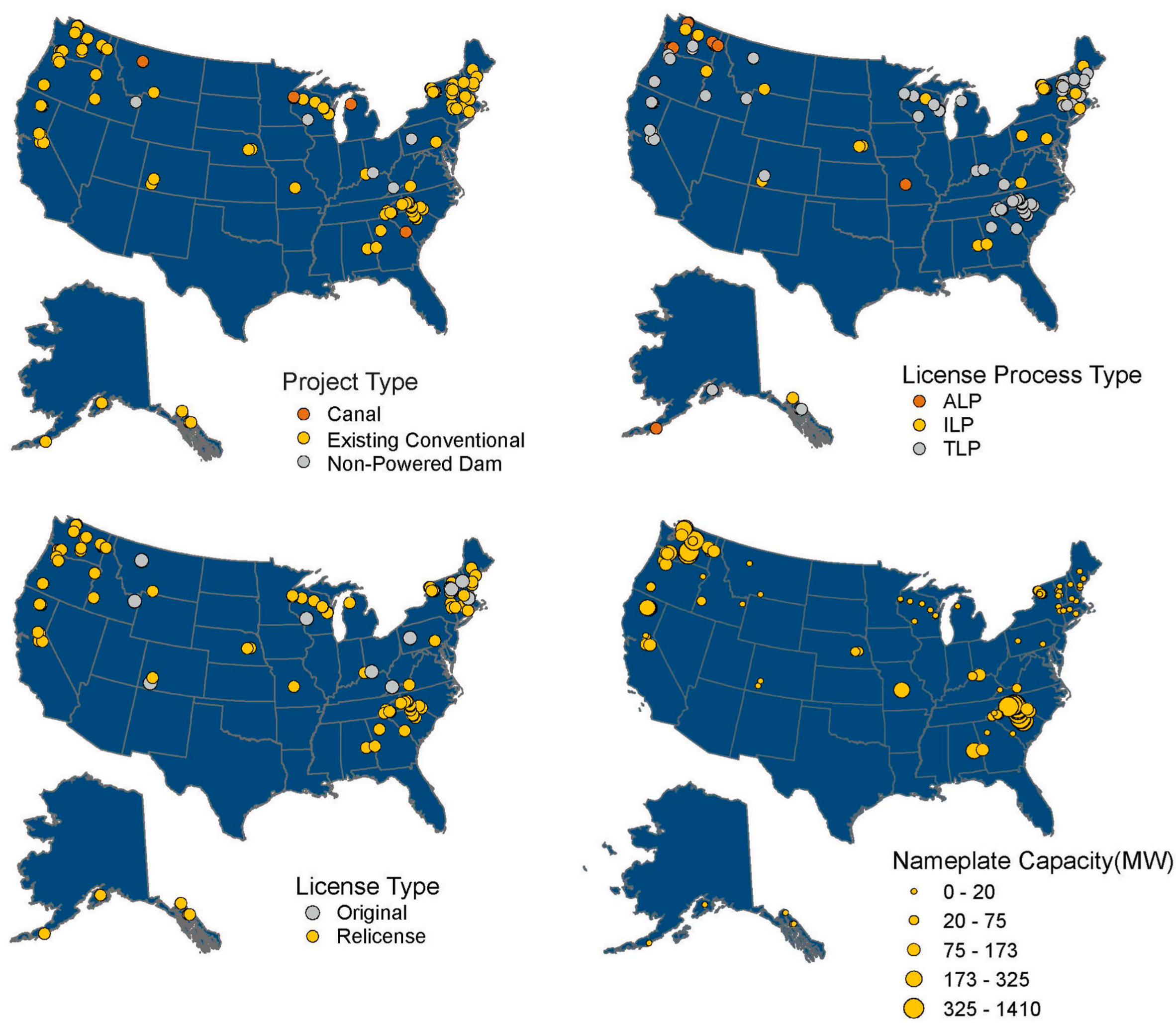

Fig. 2. Locations and (top left) type of hydropower facilities, (top right) license process, (lower left) license type, and (lower right) facility nameplate capacity (MW) where size of dots correspond to the capacity of the facility for the 107 projects included in timeline analysis.

final sample size of 107 licensed hydropower projects (Fig. 2). However, we did not filter out projects that were licensed but not constructed.

In coordination with the Stakeholder Working Group, we first generated a list of factors that could influence licensing timelines (Table 1), created hypotheses for these factors (Table 2), and then extracted information on these factors from the 107 licenses that could be used to test these hypotheses. We extracted information from licenses such as filing dates, type of license acquired (original or relicense), dates that license documents were filed, type of NEPA document (EA, EIS), license process used (Alternative, Integrated, Traditional), project nameplate capacity (recorded in MW), number of hydropower facilities in the project, FERC licensing region in which a project was located, whether or not a project had a Settlement Agreement (an agreement between the license applicant and stakeholders on terms and conditions to be included in the license or actions that the applicant will take towards environmental protection), or endangered species, and dates that state water quality certification requests under the Clean Water Act Section 401 (hereafter, state water quality certification), were filed and approved.

The FERC licensing documents examined for this study contained a variety of milestones pertaining to timeline information that was collected; thus, the following protocols were followed to make sure that the correct date for the milestone was recorded. To calculate the timeline for compliance with Section 7 of the Endangered Species Act (hereafter, endangered species consultation), we first reviewed FERC license orders to determine if endangered species consultation was required for the project. If formal consultation was required, we then recorded the date in which FERC staff requested formal consultation and the date US Fish and Wildlife Service (USFWS) and/or NOAAissued the Biological Opinion or Letter of Concurrence which serves as the endpoint in the endangered species consultation process. An example of text that signaled the beginning of the endangered species consultation process was, *"Staff requested consultation with the USFWS on September 30, 2005,"* whereas an example of text that signaled the end of this process was, *"USFWS issued a Biological Opinion on September 15, 2006."* However, because the date FERC requests endangered species consultation is not always the same date as when the USFWS and NOAA receive all the required information to begin the process, we also included the date in which each agency received complete information which were supplied by each agency.

To calculate the timeline for compliance with state water quality certification requirements, we reviewed hydropower licenses to determine the date of the first water quality certification request to the relevant state agency and the date the relevant state agency issued the final water quality certification or certification waiver. An example of text that signaled the beginning of the water quality certification application process was, *"On February 3, 2005 PacifiCorp applied to Washington Ecology for water quality certification,"* and an example of text that signaled issuance of the state water quality certification was, *"On October 26, 2006, Washington Ecology issued the certification."* Although water quality certifications were frequently withdrawn and resubmitted prior to certification, we only recorded the first request from the license applicant because subsequent requests were not always available in the FERC eLibrary.

To calculate the timeline for NEPA compliance, we reviewed FERC project dockets to determine the date on which the project was deemed Ready for Environmental Analysis and the date on which FERC issued the final NEPA document (i.e., EA or EIS).

To calculate the overall timeline for the hydropower licensing process, the project team reviewed project licensing dockets and recorded the following dates: date the license applicant filed the Notice of Intent,

Table 1
Variables extracted from licensing documents from 107 US Federal Energy Regulatory Commission (FERC) licensed projects used in analyses including the variable name and variable description. Italicized variables are response variables and **bolded variables** are were included as predictor variables in linear regression analyses.

Variable	Variable Description
Response variables	
Days NOI to License Application (LA)	Number of days from notice of intent to final license application filings
Days LA to LI	Number of days from final license application filing to license issuance
Days NOI to LI	Number of days from notice of intent filing to license issuance
Project characteristics	
Capacity	Project nameplate generation capacity in MW
Number of Facilities	Number of hydropower facilities included in project license; this does not include, for instance, dams that are used to produce head but do not directly generate power
Project Type	Type of project on license (four levels: existing conventional, new stream reach, in-canal conventional, retrofitting a non-powered dam)
FERC Region	Licensing region (six levels: Northwest, West, Midwest, Northeast, Mid-Atlantic, South)
Mode of Operation	Mode of operation used at project (two levels: storage/peaking, run-of-river)
License characteristics	
License Process	Type of license process used (three levels: Alternative, Integrated, Traditional)
License Type	Type of license issued (two levels: original, relicense)
Settlement Agreement Presence	Whether settlement agreement was negotiated by stakeholders (two levels: yes, no)
Environmental complexity indicators	
REA to EIS Timeline	Years from when project was Ready for Environmental Analysis to final National Environmental Policy Act (NEPA) document
Endangered Species Presence	Whether endangered species were present at project (two levels: yes, no)
Endangered Species Consultation Timeline	Years from endangered species consultation request to final biological opinion
EA or EIS	Type of NEPA document filed (two levels: Environmental Assessment (EA), Environmental Impact Statement (EIS))
Fishway Order Presence	Whether fishway construction was required (two levels: yes, no)

Table 2
A priori hypotheses and predicted direction of effect of variables on FERC licensing timelines. All hypotheses were generated by the project Stakeholder Working Group.

Variables	Hypothesized Effect on Overall License Timeline
Project Characteristics	
Project Size	Larger project size, Longer licensing timeline
FERC Region	Northwest and New England regions, Longer licensing timeline
Project Type	Adding power to non-powered dam, shorter timeline
License Characteristics	
License Type	Relicense = longer timeline; Original license = shorter licensing timeline
License Process	Alternative = longest timeline; Integrated = shortest licensing timeline
Environmental Characteristics	
Settlement Agreement	Presence of settlement agreement = longer license timeline
NEPA Document Type	EIS = longer license timeline, EA = shorter license timeline
Presence of Endangered Species	Endangered species present = longer license timeline
Fishway Requirement	Presence of fishway requirement = longer license timeline
Environmental Process Timelines	
State Clean Water Act 401 Certification	Longer CWA 401 timeline = longer license timeline
NEPA Process	Longer NEPA timeline = longer license timeline
Section 7 Consultation Timeline	Longer ESA Section 7 timeline = longer license timeline

date the license applicant filed the final license application, and date the FERC issued the hydropower license.

To determine whether a Section 18 Fishway Prescription (hereafter, fishway requirement) was issued by the USFWS or NOAA, we reviewed the FERC license orders and recorded a defined fishway requirement as a "yes." All other projects, including those where USFWS and/or NOAA reserved authority to provide fishway requirements at a later date were recorded as a "no." Reserved authority to add a fishway requirement to a project was recorded as a "no" because to date, reserved authority has not been exercised (Frankie Green, *Personal Comm.*).

To determine whether a Settlement Agreement was in place for a project, we searched hydropower licenses for the term "Settlement Agreement" and searched the entire FERC eLibrary docket of each project for the presence of a Settlement Agreement.

To gain insight on whether conflicts among stakeholders negotiating environmental impact studies led to longer timelines, we collected information on whether FERC required a study as proposed (hereafter, approved study), required a disputed study with modification, or did not require a study (hereafter, rejected study), from Study Determination Letters which provide a succinct summary of required studies from the 23 Integrated Licensing Process hydropower projects in our sample of 107 projects used for timeline analysis. Only Integrated Licensing Process projects were used for this analysis because the Alternative and Traditional Licensing Processes do not issue Study Determination Letters.

2.4. Data analysis

We used regression analyses (R, *lm* function) to look for associations between bolded variables in Table 1 and overall (Notice of Intent to license issue), pre-filing (Notice of Intent to Final License Application) and post-filing (License Application to license issue) timelines. Summary timeline values reported are mean ± standard deviation (range).

Prior to running regression models, assumptions of normality and homogeneity of variance were checked using comparison of mean and median for each treatment group, visual inspection of quantile-quantile plots (for normality assumptions), and Levene's test (for homogeneity of variance assumptions). We initially included license type and project size and their interactions in each model because these variables had a statistically significant association with overall timeline. If the effects of either license type, project size, or their interactions were not significant, they were removed from the model. We did not examine effects of license type on information collected from Study Determination Letters because of the small sample size of original licenses (N = 4) compared to relicenses (N = 16).

We controlled Type I error using the Benjamini-Hochberg procedure. This procedure controls for a low proportion of false null hypothesis rejections by adjusting the p-value of each individual test based on the number of comparisons, the ranking of the p-value for an individual test among other individual test p-values, and acceptable false-discovery rate of those tests. Statistical tests were considered significant at $\alpha = 0.05$ level (i.e., a false-discovery rate of 5%).

Timeline analyses can also be conceptualized as a time-to-event analysis where license issue serves as the "event." This analysis calculates the cumulative probability of a project being licensed in *n* years post-Notice of Intent filing. However, to minimize Type I error by using this type of analysis in addition to regression analysis, we only used time-to-event analysis to examine a limited number of hypotheses where additional analytical resolution was desired. For time-to-event analyses, we used a Cox regression model to estimate the probability of a project having an overall timeline while accounting for the covariate license type. Estimates from these models were then compared using 95% confidence intervals.

3. Results

Irrespective of other project, license, or environmental characteristics, overall FERC licensing timelines took 6.6 ± 3.4 (1.1–19.5) years (Table 3; Fig. 3). The prefiling period was shorter than the post-filing period at 2.7 ± 1.1 (0–7) years compared to 3.8 ± 3.0 (0.5–16.5) years although this was not statistically compared.

3.1. Project characteristics

There was no statistical difference in overall, pre-filing, or post-filing timelines for original or relicenses among existing conventional, in-canal conventional, adding power to non-powered dams, or new stream reach development (Tables 4 and 5). There was also no statistically significant effect of project mode-of-operation (i.e., run-of-river, peaking) on overall timelines.

While we found no statistically significant overall relationship between project capacity and licensing timelines, there was a significant, positive relationship between project capacity and licensing timelines for each license type (ANCOVA: $F_{2,\,99} = 7.915$, $p < 0.001$; Table 5; Fig. 3a).

Subdividing data by FERC licensing regions created regional sample sizes that were either too small to detect statistical differences, not representative of the hydropower fleet, or both, so we did not test the hypothesis about regional differences in timelines.

3.2. License characteristics

License type was a master variable whereby there were significant differences in regulatory timelines between original and relicensed projects in all models (Table 5Table 5; Table 6). Projects undergoing relicensing had significantly longer timelines than projects obtaining an original license ($F_{1,\,96} = 28.23$, $p < 0.001$; Table 3; Table 4). Projects seeking an original license or relicense had overall timeline of 5.0 ± 2.9 years and 7.6 ± 3.3 years, respectively. A graph of curves from time-to-event Cox Hazard analysis illustrates a significant difference between licensing timelines being shorter for original licenses because half of the original licenses were issued within 5 years of Notice of Intent filing ($p < 0.001$; Fig. 4). In fact, the 10 shortest overall timelines are all original licenses ranging in timeline length from 1.1 years to 3.4 years (original license: median = 4.7 years, n = 36). In contrast, the ten shortest relicensing timelines range from 3.5 years to 5.0 years (relicense: median = 6.5 years, n = 62). There was no significant difference among overall timelines of projects using the Alternative, Integrated, or Traditional Licensing Processes.

Table 3
Years ± SD (N) from beginning to end of step in licensing process.

Timeline of Licensing Process Steps	Original	Relicense	Total
Notice of Intent (NOI) to License Issuance	5.0 ± 2.9 (36)	7.6 ± 3.3 (62)	6.6 ± 3.4 (98)
NOI to Final License Application	1.9 ± 1.3 (36)	3.2 ± 0.3 (62)	2.7 ± 1.0 (98)
Final License Application to License Issuance	2.9 ± 2.3 (45)	4.4 ± 3.3 (62)	3.8 ± 3.0 (107)
Application to NEPA (Final License Application to REA)	1.1 ± 0.7 (45)	0.8 ± 0.5 (62)	0.9 ± 0.6 (107)
NEPA (REA to EA or EIS)	0.9 ± 0.5 (45)	1.3 ± 0.9 (62)	1.2 ± 0.8 (107)
State Water Quality Certification (First application to certificate issuance)	1.2 ± 2.4 (34)	2.8 ± 3.3 (51)	2.2 ± 3.1 (85)
Endangered species consultation (FERC Request to Biological Opinion (BO)/ Letter of Concurrence (LOC))	1.2 ± 2.0 (19)	1.2 ± 1.6 (38)	1.2 ± 1.7 (57)
USFWS Section 7 (Applicant Complete Info to BO/LOC)	0.5 ± 0.8 (13)	1.0 ± 1.7 (28)	0.8 ± 1.5 (41)
NOAA Section 7 Consultation (Applicant Complete Info to BO/LOC)	0.8 (1)	1.7 ± 1.4 (10)	1.5 ± 1.3 (11)

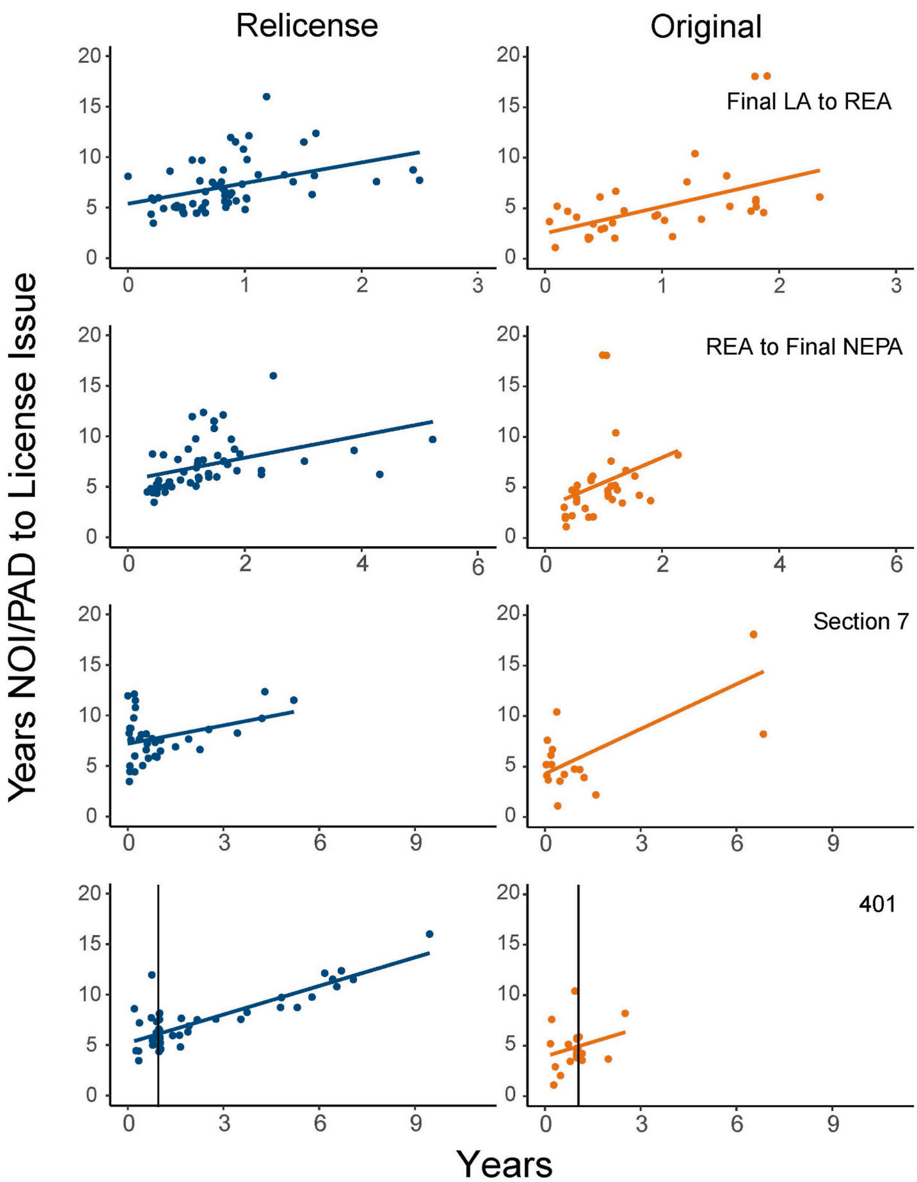

Fig. 3. Scatterplots showing the length of the hydropower licensing process in years from the notice of intent to license issue for timelines of (from top down): final License Application (LA) to Ready for Environmental Analysis (REA), REA to Final NEPA document, endangered species consultation (Section 7), and state water quality certification (401) for projects seeking an original (orange) or relicense (blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.3. Environmental characteristics and complexity

The state water quality certification timeline was significantly, positively associated with overall timelines and there was a significant difference between projects seeking original and relicenses (Table 4; Fig. 3b; $F_{2,74} = 107.5$, $p < 0.001$). Timelines for state water quality certifications were longer for projects being relicensed than for those applying for an original license. The mean ± SD state water quality certification timeline for projects seeking original licenses was 1.2 ± 2.0 years versus 2.8 ± 3.3 years for those seeking a relicense.

Project NEPA timeline had a significant, positive association with licensing timelines (Table 4; Fig. 3c; ANCOVA: $F_{2,\ 95} = 26.22$; $p < 0.001$). Timelines for the NEPA process were longer for projects being relicensed than for projects obtaining an original license. The length of the NEPA process was 0.9 ± 0.5 years for a project seeking an original license and 1.3 ± 0.9 years for a project being relicensed. Projects seeking original and relicenses with Environmental Assessment documents had significantly shorter timelines than those with Environmental Impact Statement documents and relicenses had significantly longer NEPA timelines than projects seeking original licenses both for projects with Environmental Assessments and Environmental Impact Statements (Table 3; ANOVA: $F_{2,\ 95} = 10.32$, $p < 0.001$).

Projects with Settlement Agreements had significantly longer timelines both for projects seeking original and relicenses (Table 3; ANOVA: $F_{2,\ 99} = 0.26$, $p < 0.001$). The number of disputed studies from the 23 Integrated Licensing Process projects included in our dataset was significantly, positively related to overall timelines (Fig. 3e; Pearson's correlation: $r^2 = 0.66$, $p = 0.003$, d.f. = 16) and the number of disputed studies approved was significantly, positively related to licensing timelines (Fig. 3f; Pearson's correlation: $r^2 = 0.64$, $p = 0.004$, d.f. = 16). There was no significant relationship between the number of rejected disputed studies and overall timelines. Project size was removed from the models because it was not significant.

3.4. Species protection

Endangered species consultation timelines had a significant, positive association with overall licensing timelines (ANCOVA: $F_{2,\ 99} = 17.56$, $p < 0.001$; Table 4; Fig. 3d). Projects with endangered species had significantly longer timelines than those without for both original and relicenses (ANOVA: $F_{2,\ 99} = 17.56$; $p < 0.001$; Table 4; Fig. 3d).

There were no significant differences in timelines for projects with or

Table 4
Mean years +SD (N) for variables used in regression models.

NOI/PAD to License Issuance Predictors	Original	Relicense	Overall
Project Type			
Existing Conventional	13.0 ± 8.8 (3)	7.4 ± 3.0 (59)	7.7 ± 3.6 (62)
In-Canal Conventional	3.4 ± 2.4 (3)	6.2 ± 1.9 (3)	4.9 ± 2.4 (9)
New Development	5.0 ± 2.5 (3)	(0)	5.0 ± 2.5 (3)
Non-Powered Dam Retrofit	4.7 ± 1.9 (27)	(0)	4.7 ± 1.9 (27)
Mode-of-Operation			
Run-of-River	5.0 ± 2.2 (30)	7.3 ± 3.2 (26)	6.0 ± 2.9 (56)
Peaking/Storage	7.1 ± 7.4 (3)	8.0 ± 3.2 (24)	7.8 ± 3.8 (27)
License Process			
Alternative	3.6 ± 2.5 (3)	7.8 ± 2.5 (8)	6.7 ± 3.2 (11)
Integrated	6.2 ± 2.7 (4)	5.9 ± 1.1 (22)	6.0 ± 1.5 (26)
Traditional	5.2 ± 3.1 (29)	8.5 ± 3.8 (32)	6.8 ± 3.8 (61)
Settlement Agreement			
Yes	6.2 ± 3.4 (4)	8.3 ± 2.8 (32)	8.4 ± 3.3 (36)
No	5.1 ± 3.0 (32)	6.4 ± 2.9 (30)	5.6 ± 3.0 (62)
NEPA Document			
Environmental Assessment	5.3 ± 3.7 (35)	6.8 ± 3.0 (46)	6.2 ± 3.4 (90)
Environmental Impact Statement	6.1 (1)	9.0 ± 2.2 (16)	8.8 ± 2.2 (17)
Endangered Species			
Yes	6.7 ± 4.9 (17)	7.8 ± 2.4 (38)	7.5 ± 3.3 (55)
No	4.2 ± 1.5 (19)	6.6 ± 3.7 (24)	5.6 ± 3.1 (43)
Fishway Prescription			
Yes	–	7.9 ± 2.4 (18)	7.9 ± 2.4 (18)
No	5.3 ± 3.7 (36)	7.1 ± 3.2 (44)	6.4 ± 3.5 (80)

without fishway prescriptions for projects seeking either original licenses or relicenses (Table 3; Table 4).

4. Discussion

Our analyses suggest that environmental complexity of hydropower projects is a key factor in timeline length and may also be driving the differences between shorter timeline original licenses and longer timeline relicenses. It is true that projects seeking relicensing are required to file their Notice of Intent documents 5–5.5 years prior to license expiration and their final license application no later than 2 years prior to license expiration while there is no time requirement for filing original license applications. However, since the average relicensing proceeding lasts in excess of 7 years, this study suggests that relicensing timelines longer than 5–5.5 years are due to factors other than application timing requirements. For example, projects seeking an original license had shorter state water quality certification timelines, lower probability of having endangered species and/or shorter than average endangered species consultation timelines, and shorter than average National Environmental Policy Act timelines. All original licenses included in our sample were for projects adding power to a previously non-powered existing dam or constructing a hydropower facility in a canal. In these cases, the alterations to the ecosystem that resulted from building the dam or the canal are not considered: only the environmental impacts caused by the new hydropower addition and operation are considered impacts that must be studied and mitigated. Adding hydropower to existing dams or canals also allows developers to select from sites with lower environmental complexity which is a luxury not afforded to

Table 5
Summary of results of regression analyses for factors hypothesized to be related to Notice of Intent to License Issuance timelines. All models also included a term for license type and initially included a term for project size (i.e., Project Capacity (MW)). Project size was only significant in the model including License Type. Model p-values shown have been adjusted for multiple comparisons using the Benjamini-Hochberg procedure. Acronyms are as defined in Tables 1 and 3.

Model Predictor Variable	$F_{num, denom}$	Adjusted R^2	Model P-value	Direction of Effect
Project Characteristics				
Project Capacity (MW)	$F_{2, 95}$ = 7.869	0.28	<0.001	Larger projects, longer timeline
Project Type	NS	NS	NS	NA
Mode of Operation	NS	NS	NS	NA
License Characteristics				
License Type	$F_{1, 96}$ = 28.23	0.22	<0.001	Relicense, longer timeline
License Process	NS	NS	NS	NA
Environmental Characteristics				
NEPA Document Type	$F_{2,95}$ = 10.32	0.16	<0.001	EIS, longer timeline
Endangered (ESA) Species (Y/N)	$F_{2,51}$ = 13.08	0.31	<0.001	ESA species present, longer timeline
Settlement Agreement (Y/N)	$F_{2,99}$ = 0.26	0.27	<0.001	Settlement agreement present, longer timeline
Fishway Prescription (Y/N)	NS	NS	NS	NA
Required Authorizations and Procedural Steps				
NOI/PAD to Final License Application (FLA)	$F_{1, 96}$ = 29.07	0.22	<0.001	Longer prefile period, longer timeline
FLA to Notice REA	$F_{1,94}$ = 15.79	0.13	<0.001	Longer FLA to REA, longer timeline
Notice REA to Final EA or EIS	$F_{2, 95}$ = 26.22	0.34	<0.001	Longer NEPA timeline, longer timeline
FLA to License Issuance (LI)	$F_{1, 96}$ = 927.6	0.91	<0.001	Longer NOI/PAD to FLA, longer timeline
Section 7 Consultation	$F_{2, 51}$ = 13.08	0.31	<0.001	Longer consultation timeline, longer timeline
Section 7 Consultation Complete USFWS Package	NS	NS	NS	NA
Section 7 Consultation Complete NOAA Package	NS	NS	NS	NA
401 Certification	$F_{2, 74}$ = 107.50	0.74	<0.001	Longer 401 certification timeline, longer timeline
Number Disputed Studies	$F_{2, 17}$ = 8.82	0.45	0.002	More disputed studies, longer timeline

projects going through relicensing. Moreover, increased environmental complexity can lead to a need for more environmental studies which, in turn, can increase licensing timelines (Aldrovandi et al., 2021).

Presence of a settlement agreement may be associated with a longer timeline, but the environmental and other benefits that create positive outcomes for all parties entering into the agreement. Terms of settlement agreements, particularly large-scale settlement agreements like those created in the Klamath River, Catawba-Wateree Project, or the Penobscot River frequently provide greater benefits to the environment and the parties entering into the agreement than would have been ascertained without the agreement. Some of these benefits can include basin-wide fish passage, mitigation and enhancement funds, preservation of historic properties, recreational enhancements in exchange for expansion of generation at certain locations, and cost sharing among parties in the settlement agreement for operation and maintenance of recreational facilities (Levine et al., 2018).

Table 6
Summary of regression models testing the effect of variables on overall license timelines (Notice of Intent/Preliminary Application Document to license issue) where + means timeline was relatively longer, - means timeline was relatively shorter, ↑ means longer timeline (i.e., ↑401, ↑ license means longer 401 timelines is associated with longer overall licensing timelines), NS means not significant, and NA means no statistical test was conducted.

Variables	Statistical Effect on Overall License Timeline	
Project Characteristics	Original	Relicense
Project Size	+	–
FERC Region	NA	NA
Project Type	NS	NS
Mode-of-operation	NS	NS
License Characteristics		
License Type	–	+
License Process	NS	NS
Environmental Characteristics		
Settlement Agreement	+	+
NEPA Document Type	EIS: +, EA -	EIS: +, EA: -
Presence of Endangered Species	Yes: +, No: -	Yes: +, No: -
Fishway Requirement	NS	NS
Environmental Process Timelines		
State Clean Water Act 401 Certification	↑ 401, ↑ license	↑ 401, ↑ license
NEPA Process	↑ NEPA, ↑ license	↑ NEPA, ↑ license
Section 7 Consultation Timeline	↑ Section 7, ↑ license	↑ Section 7, ↑ license

New legislation, specifically the Electric Consumers Protection Act, and the impact of court decisions and newly listed protected species since the time of last licensing in some cases may have led to relatively longer timelines for projects being relicensed versus those that are obtaining an original license. All of the relicensed projects in our sample had their previous license issued since passage of major environmental legislation, such as the Endangered Species Act, Clean Water Act, and National Environmental Policy Act, but prior to the passage of the Electric Consumers Protection Act that requires consideration of non-power values. In addition, new regulations related to these acts and a general trend toward more comprehensive analysis to protect federal agencies against litigation may have led to changes in how agencies reviewed these relicensed projects. However, in a study of hydropower relicensings (but not original licenses) occurring between 1982 and 1998, hazard ratios reported by Kosnik (2006) suggested that Electric Consumers Protection Act served to reduce Final License Application to license issue timelines. Although the impact of Electric Consumers Protection Act on relicensing timelines was not explicitly examined in our study, both our study and the Kosnik (2006) study report similar mean Final License Application to license issue timelines (Kosnik (2006): 4.0 ± 3.3 years; N = 222 licenses; This study:4.4 ± 3.3 years; N = 62 licenses).

Direct relationships between project size and timeline length are practically a maxim of hydropower regulation, so it was quite surprising there was only a direct relationship between project size and timeline length when license type was incorporated. This was a particularly interesting finding because our hypothesis was informed by extensive discussions with our Stakeholder Working Group who all have extensive and direct hydropower licensing experience. Like our overall finding of environmental complexity driving licensing timelines, the relationship between project size and timeline length depending on incorporating license type also looks to be due to differences in projects seeking original licenses versus those being relicensed. Projects seeking original licenses appear to be much smaller (mean ± SD (median): 10.5 ± 17.6 (4.9) MW) than projects going through relicensing that are much larger (mean ± SD (median): 95.8 ± 231.0 (16.8) MW). From an environmental perspective, project impacts do not necessarily scale with project size. Other factors such as ecosystem type, type and numbers of species present, and where the project is positioned in the watershed are highly influential in what resources are impacted by a project (Ziv et al., 2012; Jager et al., 2015). As well, differing stakeholder perspectives and priorities may mean that an impact or prescription of protection, mitigation, and enhancement measures for that impact may not be studied or mitigated equally across geographies (DeRolph et al., 2016; Parish et al., 2019; Oladosu et al., 2021; Aldrovandi et al., 2021). Moreover, our finding that project size is related to overall timeline length is supported by previous studies. Ulibarri (2018) and Kosnik (2006) both found that for relicenses, which were the focus of those studies, larger projects have longer licensing timelines.

It was also surprising that our hypothesis on license process timeline length was not supported by our analyses although we did find the

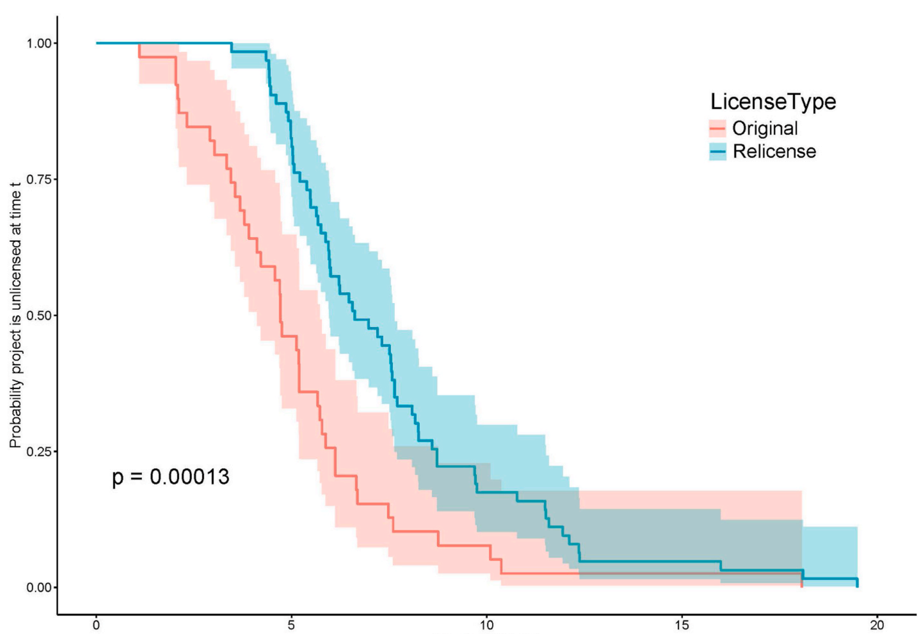

Fig. 4. Probability a project is unlicensed at time (t; Years NOI to LI). Time *t* is Years from filing of notice of intent to license issue for original (pink) and relicensed (blue) projects. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Integrated Licensing Process to have significantly shorter final license application to license issue timelines than the Traditional Licensing Process. In an analysis of projects using the Integrated Licensing Process and Alternative Licensing Process, Ulibarri (2018) found that projects using the Integrated Licensing Process for relicensing have shorter overall relicensing timelines than projects using the Alternative Licensing Process likely owing to structured deadlines in the prefiling period. One key difference between our study and the Ulibarri (2018) study was that our dataset of 107 projects included Traditional Licensing Process projects (hypothesized to have longer timelines than Integrated Licensing Process and shorter timelines than Alternative Licensing Process) which dominated our dataset (N = 77). Projects using the Traditional Licensing Process had a longer mean overall timeline, but because it also had higher statistical variance compared to projects using the Alternative Licensing Process (N = 11) or Integrated Licensing Process (N = 20), differences in timelines were statistically indistinguishable. While our statistical analyses do not show differences in overall timelines among license processes, we recommend considering this finding as a potential artifact of the makeup of our dataset (i.e., much larger number of Traditional Licensing Process projects that had higher variability than other license processes) rather than a counterpoint to the findings of Ulibarri (2018). As noted in the methods section, the Alternative Licensing Process – Integrated Licensing Process – Traditional Licensing Process composition of our dataset reflects that of licensed projects: most projects licensed since October 1, 2005 have used the Traditional Licensing Process for their licenses.

All steps in the hydropower licensing process (e.g., state water quality certification, endangered species consultation, National Environmental Policy Act) are significantly and positively associated with licensing timeline length. Increased length in any of the steps in the licensing process with the exception of the timeline from when either the USFWS or NOAA receives the required information for the endangered species consultation process occurring after filing the final License Application lengthen the post-filing timeline because some parts of the licensing process can be held up unless these steps are completed thus leading to longer overall timelines. Some steps in the process can occur concurrently such as the endangered species consultation and National Environmental Policy Act processes. However, endangered species consultation is not generally completed by issuing the Biological Opinion and Incidental Take Statement until the NEPA process has been completed to ensure they have considered all relevant environmental information.

Although the steps in the licensing process have different responsible agencies or organizations, there can be factors that are not documented in the licensing record that can lead to longer or shorter timelines. Information from our project Stakeholder Working Group has suggested that incomplete submission of application materials is a major source of longer timelines. For instance, in the endangered species consultation process, consulting agencies then have a 135-day window, with the possibility of a 60-day extension (or more with applicant consent) to complete endangered species consultation requirements once all information has been received. Our analysis showed that receipt of incomplete information causes average delays of several months to a year for both agencies and these timelines which were not significantly related to either endangered species consultation or overall timelines.

Similarly, anecdotal information from members of the project Stakeholder Working Group also suggested that timelines in the state water quality certification process are also lengthened by license applicants submitting incomplete application materials. There are federal requirements that the state water quality certification process must be completed within a one-year time frame. Our analysis showed that states generally meet this requirement, and most state water quality certifications are issued within or around the one-year mandated timeframe. The timeline from the date the first time the state water quality certification was requested to the date of certification shows that 73% (78 of 107) were waived (22 of 78) or completed (56 of 78) within or around the 1-year required time frame (<400 days) and 84% (90 of 107) had certificates waived or issues within or around 2 years (<800 days) from the time of first application. State water quality authorities cite incomplete state water quality certification applications as being one of the primary reasons that certifications are held-up. Unfortunately, our data mining process was unable to take this into account because the licensing record inconsistently contains records of incomplete submission of state water quality certification applications. Gaining a full understanding of how the state water quality certification process influences licensing timelines requires more information on submission of incomplete applications.

Our study showed that projects with Settlement Agreements have statistically longer overall timelines than those without. Projects with Settlement Agreements often have unique resource protection issues that have terms that must be carefully negotiated among project stakeholders. These agreements can be beneficial to all parties entering into the agreement as it may lead to greater environmental or other benefits than would have been otherwise possible. Some examples of these win-wins resulting from Settlement Agreements can include increased generation capacity at some dams in exchange for added recreational amenities, dam removal somewhere else in the watershed, or improved fish passage in addition to building positive stakeholder relationships. Given the potential complexity of issues for a project where a Settlement Agreement has been negotiated, it is possible that the Settlement Agreement prevented an even lengthier process that may be influenced by the number of controversial issues that were dealt with inside versus outside of the Settlement Agreement process.

5. Conclusion and policy implications

Our research suggests that environmental complexity is an important factor in licensing timelines although not in the same manner for original versus relicense proceedings. For projects seeking original licenses, projects with less environmental complexity generally led to shorter timelines, although environmental complexity appears to drive site selection. When developers have a choice of sites, as they do when obtaining an original license, sites with less environmental complexity and less environmental impacts are often chosen. For example, most of the original licenses in our sample are have limited construction impacts because the license called for adding power to existing non-powered dams or were constructed in previously developed man-made canals. The sites selected for original licenses have notably fewer endangered species issues and are unlikely to require expensive studies and mitigation measures such as fish passage. Projects being relicensed, on the other hand, may have pre-existing, complex environmental issues, potentially involving multiple jurisdictions or significant or rare cultural, recreational, biological, or ecological resources that require increased time and attention during licensing. Additionally, recent innovations to the licensing process have focused on procedural changes to projects applying for original licenses at projects with lower environmental complexity. For instance, the American Water Infrastructure Act of 2018 directed the FERC to introduce an expedited licensing process for qualifying non-powered dams and closed-loop pumped hydropower storage projects. For developers of qualifying projects who request using the expedited process, the final license decision must be issued no later than two years from final license application submission.

Environmentally complex projects will require, at a minimum, extensive and meaningful collaboration among stakeholders, applicants, and regulators in order to achieve shorter licensing timelines. The large number of projects with complex environmental issues expected to be relicensed in the coming decade demands new and unique regulatory approaches, products, best practices, and tools to navigate the regulatory process, while still protecting ecosystem services and function. While extending or expediting license expiration dates to coordinate relicensing multiple facilities within a basin has begun to be viewed as a viable way to ease relicensing regulatory burdens (Curtis and Buchanan, 2019), there is some evidence from our report and others that the license process selected may help reduce timelines. Ulibarri (2018) noted the Integrated Licensing Process yielded time savings over the Alternative Licensing Process. While our study did not have the statistical power to detect differences in overall timelines among license processes (although we did find the Integrated Licensing Process had a significantly shorter post-file timeline than the Traditional Licensing Process), we did observe that projects seeking relicenses using the Integrated Licensing Process had mean relicense timelines over two years shorter than project relicenses using either the Alternative or Traditional Licensing Processes in addition to lower variability about overall licensing timelines. The Ulibarri (2018) study also reported that collaborative engagement among stakeholders, as required by the Integrated Licensing Process, during the licensing process was not linked to longer timelines which may also point to using the Integrated Licensing Process to help reduce licensing timelines without reducing environmental rigor. Early stakeholder engagement in the Integrated Licensing Process may help to reduce timeline length, especially for environmentally complex projects, resulting from greater levels of stakeholder cooperation and fewer study disputes. On the other hand, license applicants generally like the flexibility of the Traditional Licensing Process compared with the Integrated Licensing Process since the Integrated Licensing Process has regimented timelines that can be difficult for all licensing participants to meet (Pracheil et al., 2021).

CRediT authorship contribution statement

Brenda M. Pracheil: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft. **Aaron L. Levine:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Writing – review & editing. **Taylor L. Curtis:** Data curation, Investigation, Writing – review & editing. **Matthew S.P. Aldrovandi:** Data curation, Investigation, Writing – review & editing. **Rocío Uría-Martínez:** Resources, Writing – review & editing. **Megan M. Johnson:** Resources, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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