Economic Analysis of the Critical Habitat Designation Process for Endangered and Threatened Species Under the Endangered Species Act of 1973

An Honors Paper for the Department of Economics

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Abstract

Habitat destruction is the leading cause of biodiversity loss in the US. Under the Endangered Species Act (ESA), habitat deemed essential to endangered and threatened species recovery is proposed as critical habitat (CH). CH areas are subject to regulations that could alter land development plans or increase costs. The potential economic opportunity cost created by CH regulations may lead to the exclusion of land proposed for CH designation, thereby reducing the conservation benefits of the CH rule. In this paper, I use a unique dataset collected from Federal Register (FR) documents to estimate the reduction in CH acreage from proposed to final ruling, both on the extensive and intensive margin. I find a negative relationship between the level of household income in an area proposed for CH and the probability that a CH gains acreage or maintains acreage during the establishment process. I also find some evidence that higher household income in a CH area is associated with a greater relative loss in acreage between proposal and finalization. I also find that private land proposed for CH designation is less likely to be in the final designation than federal land. Overall, my results suggest that economic considerations influence CH allocation decisions. Whether reducing the amount of private land subject to CH designations is socially efficient depends on the unknown economic benefit of private land exclusions versus the cost of biodiversity and ecosystem service loss that may result from not protecting all land deemed vital to species recovery.

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Introduction

Biodiversity Background

Although species decline and extinction is a naturally occurring process, anthropogenic causes have accelerated the rate of species extinction (*Why Save Endangered Species?,*n.d.). Loss of habitat for cropland and urbanization is the main cause of accelerated species endangerment and extinction across the world (*Why Save Endangered Species?*, n.d.). For example, about 60 percent of the US (excluding Alaska) has lost the majority of its natural vegetation for economic development reasons (*Precious Heritage*, n.d.). Estimates state that approximately one-third of remaining U.S. species are at risk and in need of conservation efforts (*Precious Heritage*, n.d.).

There are many arguments for arresting the decline in biodiversity. In "Preserving Biodiversity as a Resource," Robert Sedjo breaks these preservation arguments into the "spiritual" and the "pragmatic" (Sedjo, 2010). The spiritual argument revolves around the feeling that "the wholesale disturbances of natural systems are somehow unethical or immoral" (Sedjo, 2010, p. 1). Related to this idea is the aesthetic value of nature, which is the intrinsic value that species and ecosystems have outside of humans' valuation for them.

This pragmatic reasons for conserving biodiversity come in many forms. For example, the direct use of a species for its natural chemicals or compounds to be used in the production of useful products (Sedjo, 2010). In addition, studies on the genetic makeup of species can be applied to the synthesis of new products (Sedjo, 2010). Further, biodiversity provides the potential for species with desired genetic makeups, making it useful for breeding or development purposes (Sedjo, 2010).

Humans also derive benefit from living and recreating among biodiverse communities. For example, consider a lakefront property or a vacation home in the mountains that provides the opportunity to contemplate and walk, run, and row among diverse tree and plant species and wildlife activity. Biodiverse ecosystems make healthy and aesthetically valuable open spaces that people enjoy using for recreation. The price premium added to these properties reflect the additional value we ascribe to living among biodiverse communities (Bolitzer and Netusil, 2000).

Finally, biodiversity richness also provides indirect value to humans by supporting the productive capacity and stability of ecosystems (Ehrlich and Ehrlich, 1997). Directly consumed goods produced by ecosystems include seafood, timber, biomass fuels, natural fiber, pharmaceuticals, and many more (Daily, 2003). Productive and stable ecosystems also provide services, such as water purification, waste decomposition, soil renewal and generation, pollination, seed dispersal, and climate stabilization, that humans do not directly consume but that support the processes our economic systems rely upon (Daily, 2003). Studies show ecosystems with declining biodiversity generate less valuable service to humans (Cardinale et al., 2012).

Because biodiversity provides value to people in many different ways, there are efforts to conserve it by setting aside the habitat that it relies upon to persist. However, the conservation of habitat may create economic opportunity costs by impeding development and other economic activities incompatible with natural landscapes. Therefore, administrators of the conservation programs undertaking habitat protection must balance program goals against economic opportunity cost.

In this paper I analyze this conflict in one such conservation program, the critical habitat (CH) rule of the ESA. Under the ESA, habitat deemed by scientists to be critical to endangered and threatened species recovery is supposed to be designated as CH. CH areas are subject to regulations that could alter land development plans or make development more costly. The potential economic opportunity cost created by CH regulations may lead to the exclusion of land that is proposed for CH designation. To that end, I identify the regulatory and landscape conditions that are associated with the curtailment of CH area from proposal to final designation. I find that the economic value on the land proposed for conservation largely explain the degree to which conservation plans are mitigated. Specifically, higher income values in areas proposed for CH mean less conservation activity then initially proposed in these areas. I conclude the paper by discussing the ramifications of uneven application of recommended conservation action for US endangered species.

Background on the Conservation Program Studied in this Analysis: Endangered Species Act

The Endangered Species Act (ESA), enacted in 1973, is a cohesive species conservation legislation that aims to protect threatened and endangered species and their ecosystems through cooperation with federal and state agencies (*About Us,* n.d.). The ESA protects endangered species via a series of regulatory steps. First, the service determines whether a candidate species should be listed as endangered or threatened based on several factors, including "the present or threatened destruction, modification, or curtailment of its habitat or range" (*Endangered Species Act of 1973,* p. 4). The determinization of endangered or threatened status is made "solely on the basis of the best scientific and commercial data" and cannot consider economic factors (*Endangered Species Act of 1973*, p. 5).

At the same time as listing a species under the ESA, administrative agencies are supposed to designate any necessary CH for the species (*Endangered Species Act of 1973*). CH is defined as,

> (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
> (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential for the conservation of the species. (*Endangered Species Act of 1973*, p. 2).

Federal funding or required federal authorization of any activity in a CH area is not supposed to proceed unless it is deemed "consistent with conservation goals of the ESA" (USFWS, 2017). Land-based projects in CH areas that somehow rely on federal permits or monies *and* are initially found in noncompliance with ESA rules can 1) be modified in accordance with regulations or 2) canceled. Either outcome generates additional costs for the landowner. Even when projects in CH areas are found in compliance with ESA regulations from the beginning, the delays and extra time associated with the additional federal scrutiny mean higher costs for the project developer than a similar project in non-CH areas (Sunding et al., 2003).

An important distinction between the species listing process versus the designation of CH area is that economic considerations are germane in CH decision-making. CHs are determined "on the basis of the best scientific data available after taking into consideration the economic impact, the impact on national security, and any other relevant impact" (*Endangered Species Act of 1973*, p. 4). Further, "the secretary may exclude any area from CH if he determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the CH, unless he determines based on the best scientific and commercial data available, that the failure to designate such area as CH will result in the extinction of the species concerned" (*Endangered Species Act of 1973,* p. 5). In other words, the CH establishment process is supposed to be the only part of the ESA where the conservation-economic opportunity cost tradeoff can be considered.

The CH establishment process proceeds thusly. A CH proposal is drafted at the time or within a year of a species being listed as endangered or threatened (in reality, the proposal for CH may take place many years after species listing). The US Fish and Wildlife Service (USFWS) (or the National Marine Fisheries Service (NMFS) if the listed species is marine) publishes this proposal in the Federal Register (FR) and requests public comments as well as announces the dates and locations of local hearings. Once the allocated comment period has concluded, the service reviews and responds to the comments. Taking the comments into account, the service will then either publish the final CH unchanged, publish the final CH with edits, or publish a revised proposal which will go through the previously described process again. Any final CH is subject to change, through another round of revisions, with new information or changed circumstances. Due to regulatory delay and the limited budget of the USFWS and NMFS, only 891 of the currently listed 1,600 species have CH designations ("Recovery Plans Updated for 42 Species," 2019, *Critical Habitat Report*, n.d.). Ideally, CH area will be removed from the landscape once the species in question has recovered enough to be delisted. A total of 39 species have been delisted from the endangered and threatened species list (Greenwald et al., 2019).

CH Controversy: Economic Costs and Development Conflicts

CH designation can be a controversial topic because of the effects, whether they be real or perceived, on economic development and property value in and around included areas. Auffenhammer et al. (2020) quantifies the effect of CHs designated in California on land value using a sample of data on vacant land transactions between 1993 and 2008. This paper finds a statistically significant decrease in land value as a result of CH designations (Auffenhammer et al. 2020). Additionally, Zabel and Patterson analyze trends in housing permits in California for areas with proposed CH in comparison to areas without proposed CH (2006). They find that median-sized CHs result in a 23.5 percent decrease in the supply of housing permits in the short run and a 37.0 percent decrease in the long run (Zabel and Paterson, 2006). Another study conducted in four counties in Arizona and using housing prices from Zillow finds a decrease in property value with the designation of CH and a subsequent increase when the designation was removed (Klick and Ruhl, 2020).

Conversely, a study by Malcolm and Li (2015) analyzed data on consultations of federal agencies for project compliance with CH restrictions and found that no project was stopped or extensively modified after consultation within the 2008 to 2015 period analyzed. Papers such as these address myths about the harms caused by CH designations and raise questions about their effectiveness at species preservation. This debate over the effect that CH designations have on land value and private landowners is much of what makes the ESA controversial.

The economic cost of CH is not the only ambiguity surrounding the regulation. Plantinga et al. (2014) emphasizes the lack of clarity around the incremental benefits, costs, and effects of establishing CH above and beyond ESA listing itself. (Plantinga et al., 2014) There is also ambiguity over what is and is not allowed on private land within CH designations (Gidari,1994).

Other studies examine the effectiveness of CH through private landowner response. A paper by Lueck and Michael examines the behavior of landowners of forest land in North Carolina (2003). They find evidence of increased probability of preemptive harvesting as the distance from red-cockaded woodpecker habitat decreases (Lueck and Michael, 2003). This suggests that landowners may be intentionally destroying habitat suitable for the species to ensure a lack of regulation associated with CH designation. Similarly, a study conducted by List et al. (2006) finds evidence of accelerated development following events that increase fear among landowners of habitat land. Finally, a survey of private landowners within the Preble's meadow jumping mouse's CH asked about their efforts to conserve the species (2003). Of those who responded, 25 percent said they sought to help the species, and 26 percent sought to harm it (Brook and Zint, 2003).

Despite being able to use cost-benefit analysis in CH establishment, it is not apparent how the USFWS uses the tool. Kroeger and Casey (2006) criticize ESA agencies for not fully considering the economic benefit of species preservation associated with CH designation. They conclude that there are valuation methods to quantify these benefits and that in seven of the eight scenarios regarding CH exclusions for the Canadian Lynx that they forecast, expected benefits of designation exceed expected costs (Kroeger and Casey, 2006).

In the case of CH designations, the USFWS weighs the economic costs against the biological benefits of establishing CH in a specific area. Economic costs can be thought of as the cost in terms of loss of development, growth, or partnerships with affected agencies/businesses. The biological benefit can be thought of as the benefit to the species in terms of preservation. Kroeger and Casey (2006) suggest that this may not be a complex enough way to view the cost benefit analysis in this situation.

Other studies focus on how species characteristics and taxonomy impact the establishment of CH (Metrick and Weitzman, 1996, Dawson and Shogren 2001, Fosburgh 2021). Fosburgh (2021) finds that animal species are significantly more likely to have CH designated than plant species. Since my paper focuses on the scope of protection provided by CH designations rather than whether CH is designated, it may be that preference for charismatic species will not play the same role that it has been shown to in listing and CH establishment decisions (Metrick and Weitzman, 1996, Dawson and Shogren 2001, Fosburgh 2021). However, this literature suggests that it is appropriate to control for taxonomy in my analysis.

Finally, some researchers have looked at how litigation impacts CH designation processes. Environmental groups file litigation against the USFWS for not properly protecting species, with the goal of establishing or expanding CH. Industry groups file litigation with the goal of rescinding CH designation (Parenteau, 2005). Langpap (2022) investigates the role of environmental organization lawsuits on behalf of species on ESA implementation, including listing, CH designation, and recovery spending. They find that species with lawsuits by environmental organizations are more likely to be listing, have CH, and have more recover spending (Langpap, 2022). This suggests that the complexity and regulatory burden introduced by these lawsuits may be outweighed by benefits in species protection.

Parenteau (2005) provides an assessment of the impact of CH litigation from both environmental groups and industry groups on the implementation of the ESA. This study finds that, of the 54 active lawsuits against the USFWS in 2005, 80 percent were filed by industry groups looking to rescind CH (Parenteau, 2005). In contrast to the evidence provided by Langpap (2022), Parenteau (2005) suggests that lawsuits frequently work against the goal of species protection and may hinder the ability of the USFWS to implement the ESA and establish CH.

Motivation for Empirical Model

There is no existing statistical analysis of the CH establishment process. This paper aims to fill that gap. In this section I identify the variables that conservation science, economic theory, and past literature suggests as important to the CH designation process.

The overall research question that this paper will explore is: What are the factors that influence the CH designation process, and do they reflect the Endangered Species Act's goal of species preservation? More specifically, what determines how much of the proposed CH area is downsized or excluded before CH is finalized? To answer this question, I will focus on two significant factors: aspects of the land in an area proposed for CH and aspects of the legislative/regulatory process that the CH goes through. Aspects of the land in CH area that I will focus on include the average median household income, change in household median income, and rate of development of land. Aspects of the process that I will focus on include complexity of the establishment process (i.e., the time length of the process) and political party in office. I will also control for region, decade, and taxonomic group.

Answering these questions is important because CHs are intended as a tool to provide continued protection to endangered and threatened species. In theory, the land first proposed as CH by the USFWS is the land that is biologically important to the conservation of the species. This paper offers an analysis of what impacts whether the protected area remains intact, therefore including all land determined important to species survival, or is reduced throughout the designation process, presumably leading to less species protection.

Household income in CH areas

Despite the well-studied connection between land value and CH designation, a close look at the CH FR documents (and many more that were later excluded from analysis) shows that it is rare for the USFWS to "officially" exclude land for economic considerations under section 4(b)(2) of the act. Of the 31 mammals, reptiles, and birds in my study, only four documents ever noted that a portion of CH was excluded for economic considerations.[1] However, if I find that CHs that cover higher-income communities tended to have larger decreases in acreage between proposal and finalization then USFWS' claims of limited consideration of economic costs are suspicious.[2] (High income in an area signals high land values and lucrative development opportunities in the area (Huang et al., 2006)). If this pattern between income and CH reductions in an area hold then it also means CH designations will tend to be more expansive in lower-income communities. This means that, all else equal, species designated in low-income areas are likely to be better protected.

Alternatively, if average median income is found to have a positive effect on acreage designated for CH, that could mean many different things. First, maybe the service recognizes lower-income communities as more vulnerable to the economic effects of CH designation and avoids them more than wealthier areas. However, this would theoretically be captured in the "economic considerations" section, which is rarely utilized. Additionally, wealthier people may welcome the preservation of open space and its positive affect on home values more than lost economic development opportunities in the area.

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[1] Information on exclusions is listed in each species FR document. A list of referenced documents is included in the Appendix.

[2] Presumably developers in wealthier areas would lead the charge for private land exemptions.

Land Type in CH areas

Much of the previously mentioned literature focuses on the connection between CH and development. Therefore, the land composition of an area proposed for CH may affect the economic opportunity cost of CH establishment. In addition, land cover will also determine effectiveness of conservation in the area. For example, areas with a higher percentage of natural land may meet less opposition and experience less reduction in acreage because of less development pressure (development tends to occur next to already developed land) and less developable land scarcity. Alternatively, natural land may be seen as development opportunity, making the opportunity cost of establishing CH in the area high. This relationship may differ across land tenure, as private landowners are more likely to see open land as development opportunity, whereas federal land is more likely to be protected without opposition. Additionally, rates of development may influence opposition to CH; rapidly developing areas may fight harder for the exclusion of land, due to the foregone economic benefits of growth.

Complexity in the CH process

The CH designation process can be complex. I may find that complexity is associated with significant winnowing of CH area. Further, long establishment processes may give landowners time to destroy species habitat before final designation (Lueck & Michael, 2003, List et al., 2006). Alternatively, complexity may not lead to an undesirable outcome for CH (acreage reduction). It could be that long and complex CH designation processes receive more funding, more attention, increased engagement of scientific experts, and ultimately results in a landscape that better protects the species.

Data

Information on the CH designation process for each species is tracked in the FR. I collected all FR notices published in 1978 or later that involved the CH establishment process for land-dwelling mammals, birds, reptiles, insects, and flowering plants. This set of FR notices does not include CHs measured in coastline and or water acreage and located in Hawaii or Alaska. Further, the set of studied FR did not include those that described the CH establishment process for a group of species and separate information for each species in the group was not made available. Additionally, due to time constraints, I was only able to collect CH-related FR notices for flowering plants in US Fish and Wildlife region 8 (therefore, my dataset is missing CH establishment information for 67 listed flowering plants located in the contiguous US). In the end I have data on the CH establishment process for 91 listed species.[3]

Dependent Variables

Percentage change in CH area from original proposal to latest final rule is the dependent variable I use most often in my analysis. This measurement captures how much land was omitted over the course of each CH rule-making. In most cases, the original proposal contains all of the land that is biologically important to a species, and then some of that land is eventually excluded from the CH based on economic impacts, impacts to national security, or "other relevant impacts" (*Endangered Species Act of 1973*, p.5). When this dependent variable is regressed on independent variables, large and statistically significant negative coefficients indicate significant conflict between the process represented by the independent variable and the goal of land protection for species preservation.

A second dependent variable I use in my analysis is a binary indicator of whether the species lost CH acreage or did not lose CH acreage during rule-making. In rare cases, the percentage change in CH acreage from the proposal to final stage was zero (or even positive). A

[3] There are a total of 131 mammals, insects, birds, and reptiles that reside in the contiguous United States that did not meet the criteria explained of did not have complete information available. There are also a total of 20 mammals, insects, birds, or reptiles that are listed as endangered or threatened but reside in HI. There are also 336 flowering plants that reside in HI.

positive change can be caused by new information, input from biologists, or mapping or reporting errors in the original document. While the aforementioned percentage change in CH area allows me to study the change in CH area on the intensive margin, this latter binary indicator on the sign of CH area change allow me to analyze relative acreage change on the extensive margin.

I also include analyses that only considers relative change in private land CH acreage as well as analyses that only consider the change in federal land CH area. By differentiating acreage change by land tenure I can explore whether the factors associated with change in acreage differ across private and federal lands. I suspect that pressures to reduce CH area over private land are stronger due to the economics concerns of private landowners and developers, pressure groups not found on federal land.

Summary statistics on proposed CH area, final CH area, and percentage change in CH areas by land tenure over all CHs in my database of CHs are found in Figure 1.[4]

Variable	**Variable Description**	Mean	Std. dev.	Min	Max
Proposed Area					
totalprop	Total proposed area	556409.9	2324887	12.28	17,200,000.00
privateprop	Private proposed area	167044.6	938698.3	0	8,382,720.00
federalprop	Federal proposed area	261309.7	1111390	0	7,932,711.00
Final Area					
totalfinal	Total final area	603923.6	2920692	6	24,900,000.00
privatefinal	Private final area	101798.9	783855.6	0	7,413,760.00
federalfinal	Federal final area	437785.4	1976149	0	15,000,000.00
Relative Change in Area (%)					
relchange	Total relative change	-16.54826	40.76358	-100	115.39
privaterelchange	Private relative change	-13.49343	77.64583	-100	512.90
fedrelchange	Federal relative change	40.10363	534.1898	-100	5,066.00

Figure 1. Summary statistics for proposed acreage, final acreage, and relative change in acreage for total, private, and federal lands in CH's. All areas are measured in acres.

[4] See *Reference* section of Appendix for references to specific documents for each species.

Independent Variables

Income: The ideal primary independent variable for my analysis is the representative land price in the proposed CH area. Land price represents the economic potential of land in its best use and therefore is a gauge for the cost of establishing CH in that area. However, nation-wide maps of land prices over time are not available. Maps of household (HH) median income area over time are available and I use the area-weighted average of median HH income in a finalized CH area as a proxy for the representative land value in the proposed CH area. Land prices and income have been shown empirically to have a strong positive correlation (Huang et al., 2006), making average median income a strong proxy for average land value.

Median household income data at the census tract level comes from the US Census data, downloaded from NHGIS, from 1990, 2000, 2010, and 2016. I converted the tract level maps to grid cell maps where each cell was given the income of its source tract. The shapefiles for the final CH for each species are publicly available on the U.S. Fish and Wildlife Service's Environmental Conservation Online System (ECOS) website. Using ArcGIS10.8, I created a model that finds the area-weighted average of grid cell-level median income within each species' final CH shapefile.

$$incomek_i = \frac{1}{1000} \frac{\sum_{j=1}^{J_i} medHHinc_j \times Area_j}{\sum_{j=1}^{J_i} Area_j}$$

where J_i is the set of grid cells in final CH map *i*, $medHHinc_j$ is the median HH income in grid cell *j*, $Area_j$ is the area of grid cell *j*, and diving by 1000 means this income measure is given in $1,000 units. I repeated this process for each of the four years listed for every species. The income level variable uses the data from the year nearest to the finalization of CH for each species and is adjusted for inflation to the 2016 level. Figure 2 shows the shapefile for the final CH of the Mexican Spotted Owl overlaid on top of the median income map.

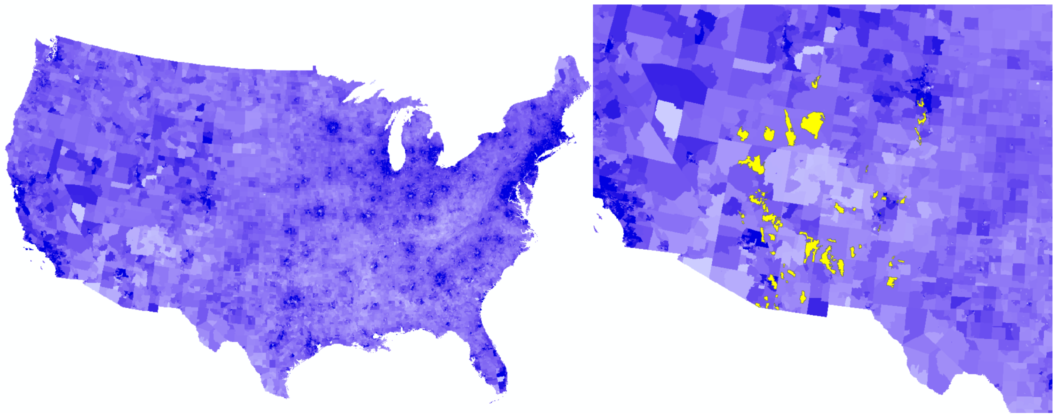

Figure 2. US Census Data 1990 income map downloaded from NHGIS (left) and the Mexican Spotted Owl final CH shapefile overload on top.

I also calculated the rate of change in income using the second nearest adjusted income level and the nearest adjusted income level for each species. For example, the final CH for the Canadian Lynx was established in 2014. Therefore, the static income level reported in the dataset is for 2016, which is $49,128.56. The second nearest income level calculated (going back in time only) is for 2010. The adjusted income for 2010 for the Canadian Lynx's final CH area is $51,592.65. Therefore, the percent change in income for the Canadian Lynx reported in my dataset is -4.78%. This value serves as a metric for the income trend of the area during the CH designation process.

One limitation of this data is that the calculation of average median income for each CH was generated using the final CH shapefile since the proposed CH shapefile was not available. This means that land proposed for CH but excluded in the final CH is not represented in this calculation of average median income. If higher-income areas lead to more exclusion of CH area acreage, then the average median income estimates may be lower than they would have been using the proposed CH shapefile. If anything, this means that my estimate of the effect of higher income on acreage reduction may be a conservative estimate.

Land Cover: I also use land cover data to analyze the impact of land cover mix on the CHs' designation process. Land cover data comes from the U.S. Geological Survey's National Land Cover Database (NLCD) for the continental U.S. for the years 1992, 2001, 2011, and 2016. This data was already in grid cell format. I used ArcGIS10.8 to calculate the mix of developed, cultivated, and "natural" land within each final CH. The land types that comprise developed, cultivated, and natural land are shown in Figure 3.

Land classifications were different in 1992 than in 2001, 2011, and 2016. The differences in classifications from 1992 to later years may result in some inconsistencies in the data. The groupings shown in Figure 3 attempt to remain consistent across classifications of land type over the four time periods. The largest difference between the two groups is that in 1992 there were much more detailed descriptions of cultivated lands. Therefore, I do not use "cultivated" as an independent variable in my analysis, but rather focus on developed and natural land. Classifications of natural and developed land remained mostly consistent across the years.

Land Classifications 1992		
Developed	**Cultivated**	**Natural**
low-intensity residential high-intensity residential commercial/industrial/transport	woody cultivated hay/pasture row crops small grains fallow/bare field urban/other grasses	deciduous forest evergreen forest mixed forest shrubland natural grassland/herbaceous woody wetland herbaceous wetland
Land Classifications 2001,2011,2016		
Developed	**Cultivated**	**Natural**
developed, open space developed, low intensity developed, medium intensity deveopled, high intensity	hay/pasture cultivated crops	decisuous forest evergreen forest mixed forest shrub/scrub herbaceous woody wetlands emergent herbaceous wetlands

Figure 3. NLCD classifications sorted by Developed, Cultivated, Natural for use in this paper.

Complexity: I have created two CH establishment complexity measures: 1) the difference in days from proposed to finalized CH and 2) an indicator variable that summarizes the rounds of edits the CH rule-making process went through. Figure 4 shows the difference in days from proposed to finalized CH rule plotted against the percentage change in acreage between proposed and final CH. This figure shows two major clusters of CH rule-making length: around 300 days and between 2000 and 3000 days, with some outliers above 4000 days.[5] These clusters provide motivation to use complexity bins rather than a continuous variable of days to measure the complexity of the CH process. A complexity of "1" indicates that there are only two CH documents for that species, meaning the CH went directly from proposed to finalized. A complexity of "2" suggests there are 3-4 CH documents for that species, meaning up to two

[5] Tables 5 and 6 show robustness checks that exclude these outliers.

rounds of edits were undergone. A complexity of "3" means the CH went through three or more rounds of edits, making it very complex.

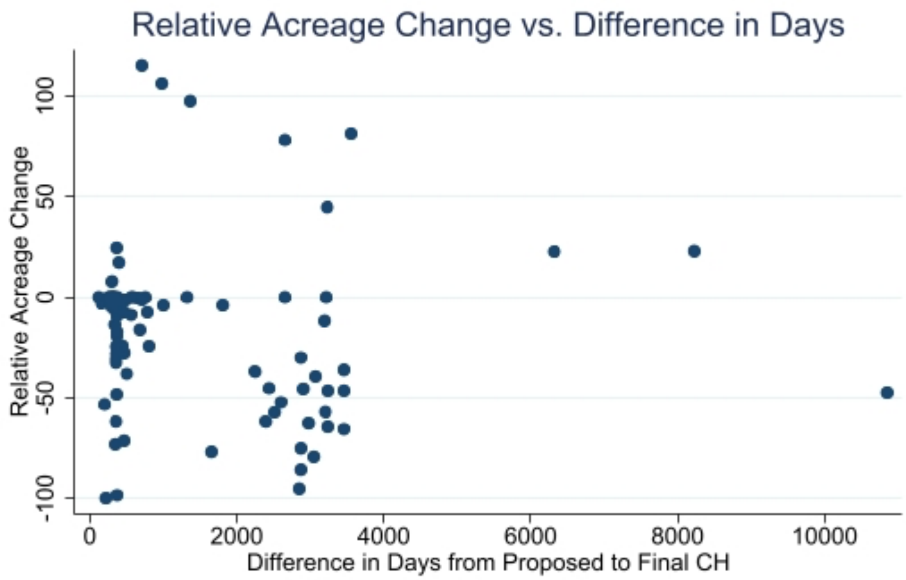

Figure 4. Scatter plot of relative acreage change vs. difference in days from proposed to final CH.

Another measure of potential CH rule-making complexity used in this study is the political administration in power throughout the time of each species CH designation process. For the "administration" variable, each observation is marked as "Dem," meaning the entirety of the CH process happened under a Democratic administration, "Rep." meaning the entirety of the CH process happened under a republican administration, or "Mix," meaning the CH process happened under a mixture of Democratic and Republican administrations. These variables allow me to analyze whether different political parties have a differing effect on the outcome of CHs. Additionally, CHs that were being established when the executive branch's political ideology changed could have been delayed further due to changes in USFWS's attitudes towards CH.

Other Variables: Other variables I have include in this study include indicator variables for taxonomy of each CH's target species (mammal, bird, reptile, insect, plant), indicator variables for region of the country the CH is located in (East, West, Central), and indicator variables for the time of CH establishment (pre-2000, 2000-2009, 2010-present). These variables serve primarily as controls but may provide interesting insights into the CH designation process.

Figure 5 shows summary statistics for continuous independent variables and Figure 6 shows summary statistics for dummy independent variables.

Continous Variable	Variable Description	Mean	Std. dev.	Min	Max
Income					
incomek	income (in thousands of $)	66.69396	24.45506	24.16421	136.27
changeincome	relativa change in income	-0.4148909	14.69269	-41.19057	44.99
Land Type					
dev	percent developed	7.696165	11.52424	0	61.87
nat	percent natural	78.9018	23.66635	0.097	100.00
changedev	relative change in develope	531.347	1948.769	-2.20E+14	11760

Figure 5. Summary statistics for continuous independent variables. Generated using Stata17.0.

Dummy Variables	Frequency	Percent
Taxonomy		
bird	10	10.99
insect	20	21.98
mammal	13	14.29
plant	40	43.96
reptile	8	8.79
Region		
Central	19	20.88
East	8	8.79
West	64	70.33
Complexity		
1	57	62.64
2	25	27.47
3	9	9.89
Administration		
Dem	18	19.78
Mix	30	32.97
Rep	43	47.25
Decade		
pre2000	10	10.99
from2000to2009	46	50.55
from2010topresent	35	38.46

Figure 6. Summary statistics for independent dummy variables. Generated using Stata17.0.

Methods and Estimation Strategies

First, I plot relative change in CH areas against 1) represented HH income in CH areas and against 2) percentage of natural land in CH areas to motivate the regression analysis structure. The first plot includes a smoothing spline that summarizes the plot's trend. I also create a table that describes acreage change for private versus federal land. The methods used for producing the smoothing splines for the relative change in acreage versus income can be found in Gareth et al., (2013).

The first multivariable analysis estimates the effect of income in a CH area, natural land in a CH area, the CH's complexity, and other controls on the likelihood that a CH gained or lost acreage throughout its designation process (extensive margin analysis). The exact linear probability is,

$$(1) \quad TotalGain_i = \beta_0 + \beta_1 Incomek_i + \beta_2 Nat_i + \boldsymbol{\gamma Complex}_i + \boldsymbol{\mu Pol}_i + \theta \boldsymbol{Tax}_i + \rho \boldsymbol{Reg}_i + \delta \boldsymbol{Decade}_i + \varepsilon_i$$

where *TotalGain* denotes a dummy variable equal to 1 if the CH gained acreage or maintained the same acreage throughout the designation process and equal to 0 if the CH lost acreage throughout the designation process. ***Complex*** is a set of dummy variables that indicate the complexity of the CH establishment process, ***Pol*** is a set of dummy variables that indicate the political party in charge of the executive branch during the CH establishment process, ***Tax*** is a series of dummies that indicate the taxonomic status of the CH's species, ***Reg*** refers to a set of dummy variables denoting the region of primary occupancy for each species, and ***Decade*** refers to set of dummy variables denoting the time frame for the designation process of each species.

The omitted groups are those with complexity equal to 1, mammals, Republican administration, and those established pre-2000.

A negative (positive) estimate of β_1 would suggest that CH areas with higher levels of HH income were more likely to have experienced a loss (a gian) in acreage than areas with lower HH incomes. A negative (positive) estimate of β_2 would suggest CH areas with more natural land were more likely to have experienced a loss (a gain) in acreage than areas with less natural land. Further, if longer designation processes were associated with a higher probability of acreage loss, we would expect the estimate of γ to be positive.

The second multivariate regression estimates the relationship between CH area income and other variables on the percentage change in CH area during the rule-making process. Rather than whether the CH lost or gained acreage throughout the CH process, the dependent variable in this model measures the relative change in acreage from proposed to finalized CH.

$$(2) \quad RelChange_i = \beta_0 + \beta_1 Incomek_i + \beta_2 Nat_i + \boldsymbol{\gamma Complex_i} + \boldsymbol{\mu Pol_i} + \theta \boldsymbol{Tax_i} + \rho \boldsymbol{Reg_i} + \delta \boldsymbol{Decade_i} + \varepsilon_i$$

Signs of explanatory variables have the same interpretations as in the previous model except that they measure the effect on relative change (intensive margin) rather than probability that CH was lost or gained during the CH rule-making process. In other words, a one unit change in an independent variable relates to a percentage decrease or increase in acreage between the proposed and final CH. The dependent variable in equation (1) denotes total relative change, meaning it includes all land ownership types. As an additional robustness check I repeat the analysis of equations (1) and (2) with the subset of the data including limited to FWS Region 8 (California and Nevada). Many of the observations are plants for which I only have data for

Region 8. Therefore, I limit the analysis to this section for all species and compare the overall results to the results of the section which contains the most observations.

Further, I re-estimate (2) using relative change in private land and then again with relative change in federal land (in the original estimate of (2) the dependent variable includes all land ownership types).

The coefficients of the explanatory variables have the same interpretations as with equation (2) aside from the dependent variable being specifically relative change of *private* land or relative change in *federal* land. Comparing the coefficients on change across the different categories of land tenure (all, private only, and federal only) will shed light on how factors such as income influence the treatment of private or federal land differently in the CH designation process. For example, if β_1 is negative and significant for the estimation with private acreage change as the dependent variable but not for the estimation with federal acreage change as the dependent variable that would suggest that income increases exclusion of private land in the CH designation process but not federal land.

Next, I incorporate the relative change in income and the relative change in developed land into both model (1) and (2). This will allow me to determine how changing rates of income, a proxy for changing rates of land value, as well as rate of development affect CH designations on both the extensive (1) and intensive (2) margins. If I find that the coefficient on the relative change in income variable is negative and statistically significant, that implies that an area with faster growing income levels is more likely to have a reduction in CH acreage when compared to areas with a slower or negative rate of income growth, all else equal. Similarly, if I find that the coefficient on the change in percent developed variable is negative and statistically significant, that implies that an area with faster changing development rates is more likely to have a reduction in CH acreage when compared to areas with a slower growth in development, all else equal

Then, I explore interaction effects between income and other independent variables including percent natural land and relative change in developed land. This analysis will allow me to examine whether there is a significant combined effect of income and land type or income and rate of development. I will incorporate these interactions into both models (1) and (2) to determine how they affect CH designations on the extensive (1) and intensive (2) margins. If I find the coefficient on the term which interacts income and percent of natural land to be significant, that implies that the extent to which income affects the amount of land designated as CH varies across different percentages of natural land.

Finally, I conduct robustness checks using various model specifications for both models (1) and (2). First, I limit the analysis to only those observations in Region 8, considering that is where the bulk of my data is collected from. Second, I limit the analysis to only those species which fall into complexity group 1. This is the group for which only one round of edits occurred. Due to the uncertainty surrounding the cause of complexity in the process, I limit the analysis to this subgroup as it may be a less noisy estimate. Lastly, I limit the analysis to CHs with process lengths of 4000 days or less to exclude outliers.

Results

Preliminary Analysis

Figure 7. Smoothing spline of relative change in the acreage of CH and average median income generated using R.

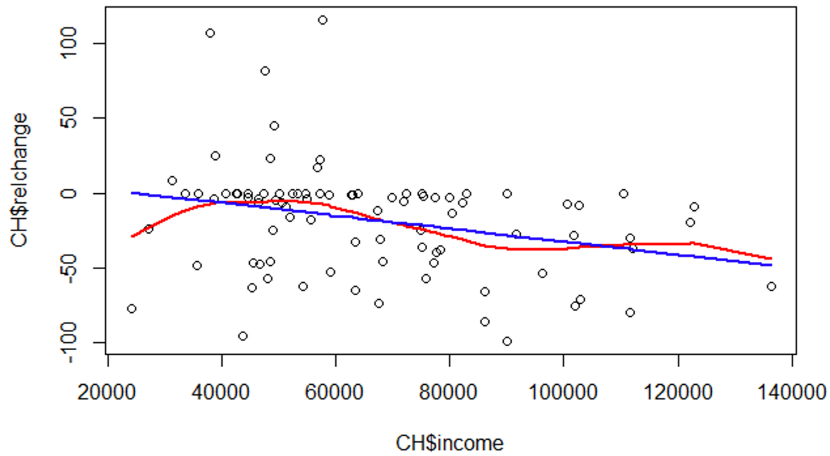

Figure 7 displays results from a smoothing spline of relative change in the acreage of CH and average median income and shows a negative relationship between the two variables. This preliminary analysis would suggest that an increase in income is correlated with a greater negative value for relative change of CH area. The trend line shows that at an average median income level of around $20,000, the relative change in acreage is approximately 0. However, at an average median income of approximately $120,000, relative change in acreage is approximately - 40%. This analysis suggests a relationship between income and relative change in acreage from proposed to final CH that I will explore more thoroughly through regression analysis.

Table 1. Private versus federal land on the extensive and intensive margins

Land Tenure:	Percent of CHs that lost acreage (extensive):	Average relative change of acreage (intensive):
Private	56.04%	-13.49
Federal	45.05%	40.10

Table 1 shows a breakdown of acreage change by land tenure on both the extensive and intensive margins. This table shows that private land was excluded from CHs more frequently than federal land. It also shows that private land, on average, experienced relative decreases in acreage, whereas federal land, on average, experienced relative increases in acreage. This preliminary analysis shows that land tenure could be very important in describing how CH is designated.

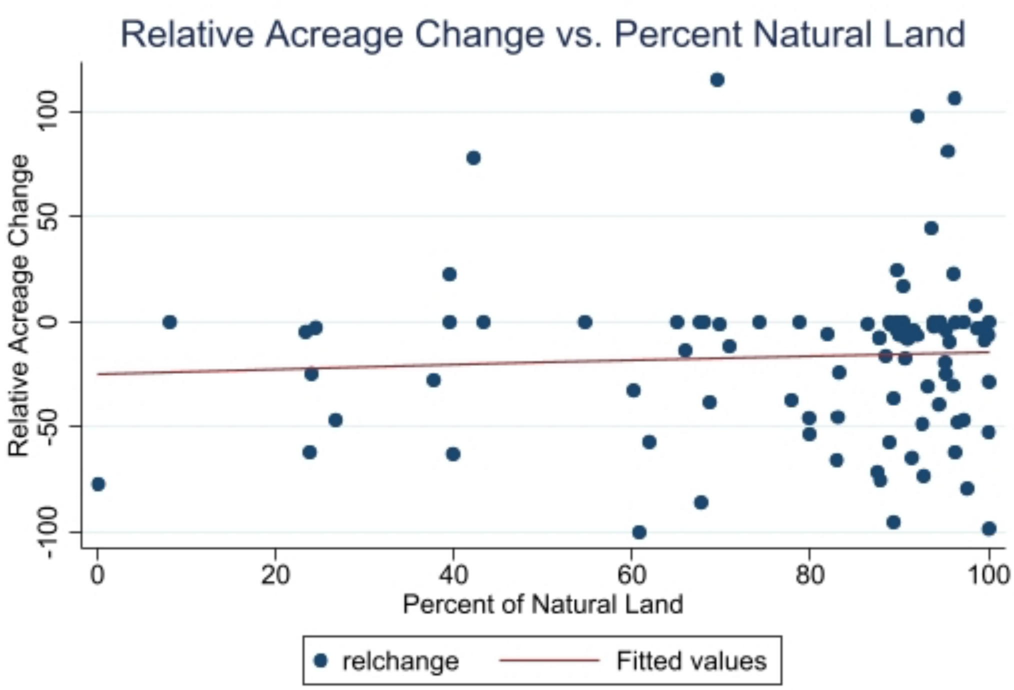

Figure 8. Scatter plot of relative change in acreage vs. percent natural land

Figure 8 shows a scatter plot with the best fit line of relative change in acreage vs. percent natural land. The markers and best fit line show a positive correlation between relative change in acreage and percent natural land in a CH. This trend is less obvious than that shown between relative change in acreage and income in Figure 7, but still warrants further investigation through statistical analysis.

Regression Analysis

The results of equation (1), presented below in Table 2, indicate the effect of the independent variables listed on whether a CH gains or loses land throughout the designation process. This analysis focuses on the effect of acreage gain or loss on the extensive margin. Coefficients and standard errors are displayed for each variable.

Table 2. Multiple linear regression model of equation (1) generated using Stata17.0. Dependent variable is a dummy variable denoting whether CH gained/remained the same or lost acreage.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	totalgain	totalgain	totalgain	totalgain	totalgain
Incomek	-0.00625***	-0.00626***	-0.00645***	-0.00560**	-0.00515**
	(0.00177)	(0.00180)	(0.00190)	(0.00218)	(0.00229)
Complex2	-0.268***	-0.196*	-0.139	-0.110	-0.109
	(0.0844)	(0.102)	(0.114)	(0.116)	(0.134)
Complex3	0.115	0.203	0.339*	0.422**	0.486**
	(0.180)	(0.200)	(0.202)	(0.207)	(0.210)
%Natural	0.000258	0.000345	0.000331	0.000255	-0.000831
	(0.00221)	(0.00224)	(0.00223)	(0.00214)	(0.00238)
Mixed Admin.		-0.120	-0.232*	-0.292*	-0.297*
		(0.110)	(0.139)	(0.155)	(0.168)
Dem. Admin.		-0.110	-0.201	-0.283	-0.247
		(0.126)	(0.149)	(0.177)	(0.185)
Insect			0.232	0.297*	0.331*
			(0.177)	(0.178)	(0.191)
Bird			0.178	0.188	0.241
			(0.175)	(0.171)	(0.182)
Plant			0.134	0.217	0.346
			(0.161)	(0.174)	(0.246)
Reptile			0.311	0.310	0.341*
			(0.197)	(0.198)	(0.204)
Decade Fixed Effects	No	No	No	Yes	Yes
Region Fixed Effects	No	No	No	No	Yes
Constant	0.759***	0.785***	0.667***	0.751***	0.807***
	(0.207)	(0.222)	(0.246)	(0.270)	(0.289)
Observations	90	90	90	90	90
Adjusted R-squared	0.173	0.163	0.149	0.142	0.144

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Variables included in column 1 are income in thousands (Incomek), complexity groups (Complex2, Complex3) with a complexity of 1 as the omitted variable, and percent natural land (%Natural). Since totalgain is a dummy variable equal to 1 if the CH gained acreage or remained the same, a positive coefficient denotes an increase predicted probability of gaining acreage or remaining the same (i.e. *not* losing acreage), whereas a negative coefficient denotes an increase in the predicted probability of losing acreage. Income is significant at the 1percent level with a coefficient of -0.00625. This suggests that, on average, a $1000 increase in income is associated with a 0.625 percentage point increase in the predicted probability of *not* losing CH. Complex2 is statistically significant at the 1 percent level with a coefficient of -0.268. This suggests that, on average, CHs with a moderately complex process (3-4 documents) are associated with a 26.8 percentage point increase in the predicted probability of losing CH compared to observations in complexity group 1. The coefficient on Complex3 is not statistically significant, suggesting that CHs in complexity group 3 do not significantly affect the probability of gaining CH acreage compared to being in complexity group 1. %Natural is not statistically significant and therefore has no observed effect on the probability of CH avoiding land reduction.

Column 2 includes the administration variables "Dem. Admin.," which is Democratic administration, and "Mixed Admin.," which is mixed administration. Neither of these variables have a statistically significant effect on the dependent variable. The coefficients for the income and natural land variables do not change in a meaningful way with the inclusion of the administration variables. However, the effect of Complex2 decreases in magnitude as well as significance, suggesting that the inclusion of administration controls may capture some of the effect of being in complexity group 2.

Column 3 includes dummy variables for each taxonomic group in addition to each of the previously discussed variables. None of the taxonomic group coefficients are statistically significant, suggesting that taxonomy does not have an observed effect on whether a species' CH gains land or remains the same versus loses land. However, Complex2 is no longer statistically significant in this estimate. Complex3 is statistically significant at the 10 percent level with a positive coefficient. Mixed. Admin. also has a negative effect, statistically significant at the 10 percent level.

Column 4 includes decade fixed effects, and column 5 includes both decade and region fixed effects. The coefficient on income changes to a significance level of 5 percent with the inclusion of time fixed effects and remains significant at the 5 percent level with the inclusion of region fixed effects. However, the magnitude of the income coefficient does not change meaningfully across estimations. Complex3 remains statistically significant and positive at the 5 percent level and Mixed Admin. remains statistically significant and negative at the 10 percent level. Columns 4 and 5 show that the taxonomic group "Insects" variable is statistically significant at the 10 percent level and positive, suggesting that insects are more likely to avoid CH acreage reduction when compared to mammals.

Table 3 estimates the effects of the same independent variables in Table 2 on the relative change in acreage rather than probability gained or lost. This analysis focuses on the effect on acreage gain or loss on the intensive margin (equation 2). Coefficients and standard errors are displayed for each variable.

Table 3. Multiple linear regression models of equation (2) generated using Stata17.0. The dependent variables are relative change in total acreage (columns 1 and 2), relative change in private acreage (columns 3 and 4), and relative change in federal acreage (columns 5 and 6) from proposed to final CH.

VARIABLES	(1) relchange	(2) relchange	(3) privaterelchange	(4) privaterelchange	(5) fedrelchange	(6) fedrelchange
Incomek	-0.483***	-0.192	-0.689*	-0.187	-1.084	0.549
	(0.149)	(0.157)	(0.363)	(0.206)	(0.937)	(1.059)
Complex2	-24.90***	4.032	-34.73**	-5.123	-7.638	-30.89
	(7.622)	(13.34)	(13.70)	(25.98)	(20.04)	(84.34)
Complex3	10.39	70.76***	-51.17**	-13.70	570.9	613.1
	(20.51)	(22.27)	(22.09)	(28.66)	(544.3)	(576.0)
%Natural	0.246	0.207	0.137	0.201	2.266	1.265
	(0.170)	(0.190)	(0.288)	(0.389)	(2.180)	(1.571)
Admin. Controls	No	Yes	No	Yes	No	Yes
Tax. Controls	No	Yes	No	Yes	No	Yes
Decade Fixed Effects	No	Yes	No	Yes	No	Yes
Region Fixed Effects	No	Yes	No	Yes	No	Yes
Constant	1.033	2.846	36.24	51.22	-121.8	37.37
	(15.77)	(19.53)	(28.59)	(41.16)	(129.1)	(152.9)
Observations	90	90	90	90	90	90
Adjusted R-squared	0.174	0.318	0.058	0.073	0.074	0.038

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3b. Multiple linear regression models of equation (2) generated using Stata17.0. The estimate in column 2 is limited to observations from the years 2000 through 2009.

VARIABLES	(1) relchange	(2) relchange (2000s only)
Incomek	-0.192	-0.300*
	(0.157)	(0.169)
%Natural	0.207	0.263
	(0.190)	(0.269)
Complex2	4.032	-28.45
	(13.34)	(22.04)
Complex3	70.76***	2.351
	(22.27)	(34.77)
Mixed Admin.	-57.37***	-37.20
	(15.90)	(29.93)
Dem Admin.	-17.74	
	(15.83)	
Tax. Controls	Yes	Yes
Region Fixed Effects	Yes	Yes
Decade Fixed Effects	Yes	No
Constant	-13.36	-22.33
	(19.63)	(30.26)
Observations	90	46
Adjusted R-squared	0.318	0.357

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The relative change variable ranges from -100 to 100 in value, meaning a positive coefficient denotes less acreage loss or more acreage gain, whereas a negative coefficient denotes more acreage loss or less acreage gain. In column 1, income is significant at the 1 percent level with a coefficient of -0.483; on average, a $1000 increase in income is associated with exclusion of 48.3 percentage points more of acreage from CH. Complex2 is statistically significant at the 1 percent level with a coefficient of -24.90. This suggests that, on average, CHs with a moderately complex process (3-4 documents) are associated with a 2490 percentage point decrease in relative change of CH acreage compared to observations in complexity group 1. The coefficient on Complex3 is not statistically significant, suggesting that CHs in complexity group 3 do not have a significantly different relative change in acreage than observations in complexity group 1. %Natural is not shown to have a statistically significant effect on CH acreage change.

Once controls for administration, taxonomy, time, and region are included in the model, income becomes no longer statistically significant (column 2). Interestingly, Complex3 becomes statistically significant at the 1 percent level once controls are included (column 2). It is possible that the decade and region fixed effects capture some of the effect of income. A correlation test between income and each decade variable shows that there is a high correlation between the variable *from2000to2009*, denoting the 2000s, and income. Column 1 of Table 3b repeats the estimation done in column 2 of Table 3. Column 2 of Table 3b limits the sample to only CHs established during the 2000s. Income is statistically significant at the 10 percent level with a magnitude of -0.300. This suggests that for every $1000 increase in income, there is an associated 30 percentage point decrease in relative change in acreage. This comparison shows that income negatively affected the scope of CH acreage protection more significantly during the 2000s than other time periods.[6]

Columns 3 and 4 of Table 3 show the estimate without and then with controls for the relative change in private land acreage. In column 3, the coefficient on income is statistically significant at the 10 percent level with a coefficient of -.689. This suggests that for every $1000 increase in average median income, there is a 68.9 percentage point decrease in the relative change of private land acreage. In other words, higher income is associated with more loss in private land. This is the expected sign given that private land owned by wealthy individuals likely has a higher land value and, therefore, a higher opportunity cost of designation. Both the coefficients on Complexity2 and Complexity3 are significant at the 5 percent level and are negative. This suggests that higher complexity (more rounds of edits) is associated with a larger amount of excluded private land in comparison to complexity group 1. None of the independent variables remain significant once controls are added. It may be that controls for region capture some of the effects of income and that controls for administration, specifically mixed, capture some of the effects of complexity.

Estimates displayed in column 5 show that none of the variables of interest had a statistically significant effect on the relative change of federal land. This is not surprising given that federal land does not face the same opposition as private land. Landowners, developers, and other private industries with a stake in land value do not have the same stake in or sway over what happens to federally protected land. Therefore, it makes sense that income level, percentage of natural land, and complexity would not significantly impact the amount of federal land

[6] "Dem. Admin." was omitted from estimates limited to the 2000s due to collinearity.

designated. Table 3 provides evidence for complexities being focused more on private than federal land.

I re-estimate equations (1) and (2) with variables denoting the percentage of developed land, the rate of change of income, and the change in percentage of developed land (see Table A1). Neither the percentage of developed land nor the change in percent developed land were statistically significant. This suggests that the amount of CH already developed as well as the rate of development of the area does not affect CH acreage reductions on the intensive or extensive margins. The rate of change of income was also statistically insignificant on both the intensive and extensive margins. This suggests that the static level of wealth is more influential in affecting the CH acreage designation process that the trend in wealth of the designated area.

I also re-estimate equations (1) and (2) including interaction terms between income and percent natural land as well as income and rate of development. The interaction between income and rate of development was not statistically significant, suggesting that the effect of income does not vary across places with different rates of development (see Table A2). Estimations of equations (1) and (2) including the interaction between income and percent of natural land are displayed below in Table 4.

Table 4. Multiple linear regression models of equations (1) and (2) generated using Stata17.0. This estimation includes an interaction term between income and percent natural land.

VARIABLES	(1) relchange	(2) relchange	(3) totalgain
Incomek	0.547	0.599	0.00740
	(0.528)	(0.581)	(0.00636)
%Natural	0.994**	0.744	0.00769*
	(0.390)	(0.469)	(0.00451)
Incomek*%Natural	-0.0109*	-0.00943	-0.000149**
	(0.00592)	(0.00680)	(7.34e-05)
Complex2	3.843	5.901	-0.0795
	(13.13)	(13.13)	(0.129)
Complex3	52.17**	71.46***	0.497**
	(25.81)	(22.50)	(0.205)
Admin. Controls	Yes	Yes	Yes
Tax. Controls	Yes	Yes	Yes
Decade Fixed Effects	No	Yes	Yes
Region Fixed Effects	No	Yes	Yes
Constant	-72.61**	-59.09	0.0116
	(32.97)	(39.40)	(0.418)
Observations	90	90	90
Adjusted R-squared	0.258	0.324	0.160

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Columns 1 and 2 estimate the effect of the model including an interaction term for income and percent of natural land on relative change in acreage (intensive margin). Column 1 includes controls for administration and taxonomy, but no decade or region fixed effects. The interaction term between Incomek and %Natural is statistically significant with a magnitude of -0.109 in column 1. This suggests that, prior to the inclusion of decade and region fixed effects, the interaction between income level and percent of natural land has a significant impact on the relative change in acreage. However, this effect becomes insignificant with the inclusion of decade and region fixed effects. Column 3 shows the impact of the included independent variables on the probability of a CH gaining land or remaining the same (extensive margin). The coefficient on %Natural is positive and statistically significant at the 10 percent level. The coefficient on the interaction between Incomek and %Natural is statistically significant at the 5 percent level with a magnitude of -0.000149 with the inclusion of all listed controls. This suggests that the positive relationship between percent natural land and probability of a CH maintaining or gaining acreage is mitigated as average median income of CH area increases.

Table 5 includes a series of robustness checks for the original equation (1). Column 1 limits the analysis to those species whose CHs went through only one round of edits (complexity group 1). I include this robustness check because of the uncertainly surrounding what makes a designation process complicated. Previous estimates suggest mixed results of being in complexity groups 2 or 3, relative to 1. Since more than half of the observations are in complexity group 1 and this is also the simplest designation process group, I repeat estimations with data limited to the complexity group 1 subset. In column 2, I limit the analysis to CHs located in Region 8. Since I was only able to collect data on plants for Region 8, this is the region with the most data. In column 3, I exclude observations whose CH designation lengths were outliers. I limit the estimation to observations with "daysdiff" or difference in days from proposed to finalized CH, was less than or equal to 4000 days (see Figure 4 for visual of outliers). Every robustness check conducted for equation (1) shows the coefficient on income remaining statistically significant at the 5 percent level at similar in magnitude. This suggests that the effect of income on acreage change on the extensive margin is very robust to alternate model specifications.

Table 5. Multiple linear regression model for equation (1) with multiple model specifications produced using Stata17.0. Column 1 limits observations to those in Complex1, column 2 limits observations to those in Region 8, column 3 limits difference in days to less than or equal to 4000 days to exclude outliers.

VARIABLES	(1) totalgain (complex1 only)	(2) totalgain (region 8 only)	(3) totalgain (daysdiff <= 4000)
Incomek	-0.00881**	-0.00627**	-0.00538**
	(0.00330)	(0.00285)	(0.00231)
%Natural	-0.00527	0.000383	-0.000378
	(0.00381)	(0.00324)	(0.00245)
complex2		-0.249	-0.106
		(0.188)	(0.133)
complex3		-0.309	0.446**
		(0.461)	(0.218)
Tax. Control	Yes	Yes	Yes
Admin. Controls	Yes	Yes	Yes
Decade Fixed Effects	Yes	Yes	Yes
Region Fixed Effects	Yes	No	Yes
Constant	1.241***	0.307	0.720**
	(0.390)	(0.336)	(0.278)
Observations	56	58	87
Adjusted R-squared	0.092	0.095	0.133

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 estimates the same three robustness checks for equation (2). In columns 1-3 the dependent variable is relative change of total acreage and in columns 4-6 the dependent variable is relative change of private acreage. In column 1, the coefficient on Incomek becomes statistically significant at the 5 percent level and negative. Income was not significant for the estimate which included all the complexity groups, but Comlpex3 was. This suggests that higher income levels are associated with a more significant decrease in acreage with a less complex process. It could also indicate that the Complex3 variable was capturing some of the effect of income in the initial model. Column 2 shows that %Natural is significant at the 10 percent level with a magnitude of 0.310. This suggests that, among CHs located in Region 8, a 1 percentage point increase in natural land percentage is associated with a 31 percentage point increase in the relative acreage change. This means natural land is associated with either a larger gain or a smaller loss of acreage throughout the CH designation process. Columns 4 and 5 both show a statistically significant negative coefficient on Incomek (at the 10 and 5 percent levels respectively). This suggests that relative acreage change of private land is more affected by income level for observations that have less complex processes and that are in Region 8. Exclusion of outliers does not appear to significantly change estimates on the extensive or intensive margins.

Table 6. Multiple linear regression model for equation (2) with multiple model specifications produced using Stata17.0. Columns 1and 4 limit observations to those in Complex1, columns 2 and 5 limit observations to those in Region 8, columns 3 and 6 limit difference in days to less than or equal to 4000 days to exclude outliers. The dependent variable is relative change in total acreage in columns 1-3 and relative change in private acreage in columns 4-6.

VARIABLES	(1) relchange (complex 1 only)	(2) relchange (region 8 only)	(3) relchange (daysdif <= 4000)	(4) privaterelchange (complex1 only)	(5) privaterelchange (region 8 only)	(6) privaterelchange (daysdif <= 4000)
Incomek	-0.361**	-0.208	-0.207	-0.431*	-0.440**	-0.202
	(0.158)	(0.136)	(0.154)	(0.214)	(0.210)	(0.204)
%Natural	0.104	0.310*	0.286	-0.0243	0.470	0.321
	(0.233)	(0.176)	(0.198)	(0.745)	(0.347)	(0.456)
Complex2		-17.74	5.046		-52.30**	-3.444
		(17.23)	(13.36)		(24.56)	(27.19)
Complex3		15.90	79.73***		-5.590	4.417
		(36.14)	(23.13)		(65.99)	(41.24)
Tax. Controls	Yes	Yes	Yes	Yes	Yes	Yes
Admin. Controls	Yes	Yes	Yes	Yes	Yes	Yes
Decade Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	No	Yes	Yes	No	Yes
Constant	3.035	-14.43	-18.66	51.01	98.83	56.21
	(23.24)	(28.48)	(19.21)	(61.37)	(110.2)	(44.81)
Observations	56	58	87	56	58	87
Adjusted R-squared	0.286	0.432	0.339	0.207	0.403	0.081

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Conclusion

This paper conducts one of the first statistical analyses of the CH designation process. I use data from the FR documents of each species included in the dataset, including measures of complexity, land type, income levels, controls for taxonomy and administration, and decade and region fixed effects, to predict changes in acreage designated as CH. I conduct multiple linear regressions with dependent variables on the extensive margin, whether a species lost CH acreage or not, and on the intensive margin, the relative change in acreage from proposed to final CH. On the intensive margin, I compare private and federal acreage change as dependent variables. I test the effect of interactions, most notably between income and percent natural land. I also include many different robustness checks including limiting analysis to CHs established in the 2000s, limiting analysis to complexity group 1, limiting analysis to Region 8, and excluding CHs that are outliers in terms of CH designation process length. This paper represents the first attempt to explain how CH land and regulatory process characteristics influence the scope of CH designation.

Results provide strong empirical evidence that income has a negative effect on CH acreage change on the extensive margin. The coefficient on income is statistically significant and negative for every model specification with *totalgain* as the dependent variable, showing that this result is robust. This result implies that, on average, as the average median income of an area increases, the probability that CHs proposed in that area will maintain all proposed acreage or gain acreage throughout their designation process decreases. This result is consistent with the hypothesis that more land will be excluded in areas with higher average median income as the land value in those areas is likely also higher, making the opportunity cost of establishing CH there higher than in areas with lower land value.

There is weaker evidence that income causes CH acreage changes on the intensive margin. For models with relative change in acreage as the dependent variable, the coefficient on income is statistically significant and negative only before the inclusion of decade and region fixed effects. However, when the estimate is limited to CHs established in the 2000s, income becomes a statistically significant variable in explaining relative change in acreage even after the inclusion of decade and region fixed effects. This suggests that high correlation between the decade fixed effects and income could explain the lack of significance of the income variable in the previously described model.

Similarly, for the model with relative change in private acreage as the dependent variable, the coefficient on income is statistically significant and negative only before the inclusion of decade and region fixed effects. Again, this could be due to the decade fixed effects capturing some of the effect of income on relative change of private acreage. The model with relative change in federal acreage as the dependent variable does not have any statistically significant independent variables of interest even before including decade and region fixed effects. This is not surprising, as the level of opposition to CH designations on federal land would be expected to be lower than on private land.

Measures of complexity (*complex1, complex2, complex3)* have effects that vary in significance and magnitude across the different model specifications. These indicator variables may not be the most accurate way to represent the complexity of the designation process, and therefore are not significant in explaining acreage changes. Additionally, there may not be a consistent relationship between complexity and the scope of CH designation. The logic that complexity hinders the CH designation process, and that complexity aids the process by forcing more attention on a species, could be correct in different instances. The models used in this paper are not able to capture such variable effects.

The percent of natural land within a final CH designation is insignificant in explaining acreage change on both the extensive and intensive margin for almost all model specifications.

The lack of significance on this variable means that we cannot conclude whether the percent of natural land in a finalized CH has any effect on the change in acreage from proposed to final designation. One explanation for this is that the more controversial non-natural land may have already been excluded from the final CH shapefile, meaning that the calculation from this shapefile would not capture the effect of that excluded land type. Additionally, there could be error in the calculation of the percent of natural land. However, the interaction between income and percent natural land is statistically significant on the extensive margin and on the intensive margin before the inclusion of decade and region fixed effects. This result suggests that the positive relationship between percent natural land and relative change in acreage (on the extensive margin, and to a lesser extent, on the intensive margin) is mitigated by an increase in the average median income of area within a CH designation.

Neither the relative change of income over time nor the percentage point change of developed land over time were statistically significant in explaining CH acreage change on the extensive or intensive margin. This suggests that the way a landscape is changing in terms of land value and development are not as influential in determining CH acreage change as the static level of land value at the time of designation.

Overall, this paper provides evidence for a strong relationship between higher levels of income and a higher probability of CHs with land reduction between proposed and final designations. Weaker evidence suggests a relationship between higher levels of income and either a smaller relative increase in acreage or a larger relative decrease in acreage. On both the extensive and intensive margins, private acreage change is influenced by income, whereas federal acreage change is not.

These results imply that the USFWS may be prioritizing the interests of land developers and private property owners over species protection. This has implications for both the protection of species under the ESA and the impact of CHs on communities. If lower-income communities are less likely to have the size of CHs in their area reduced, these communities may be affected by designations more than affluent communities. If CHs impede development and reduce land value as previous literature suggests (Auffenhammer et al., 2020, Zabel and Patterson, 2006, Klick and Ruhl, 2020), this means that CHs could be disproportionately hindering the economic growth of lower-income areas. Additionally, species that happen to reside in areas with higher land value may not be as fully protected as other species. These potential impacts of the current CH designation process are important to address to carry out the ESA in a way that is both equitable to U.S. residents and in line with the ESA's goal of unbiased species protection.

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Appendix

Tables

Table A1. Multiple linear regression of equations (1) and (2) generated using Stata 17.0. This table includes the percent developed land, change in income, and change in percent developed land as additional independent variables.

VARIABLES	(1) relchange	(2) totalgain	(3) relchange	(4) relchange	(5) totalgain
Incomek	-0.103	-0.00497**	-0.206	-0.0990	-0.00406*
	(0.141)	(0.00214)	(0.163)	(0.143)	(0.00229)
%Natural	0.0993	-0.000812	0.240	0.130	-0.00133
	(0.176)	(0.00246)	(0.238)	(0.172)	(0.00248)
%Developed			0.130		
			(0.330)		
Complex2	-3.050	-0.127	4.506	-4.892	-0.0994
	(13.81)	(0.149)	(13.43)	(13.32)	(0.139)
Complex3	74.93***	0.467**	71.20***	74.15***	0.504**
	(21.28)	(0.223)	(22.51)	(21.28)	(0.215)
	(13.04)	(0.168)	(16.50)	(12.35)	(0.173)
Changeincome	-0.0973	0.000998			
	(0.298)	(0.00352)			
Changedev				-0.00134	1.24e-05
				(0.00227)	(3.03e-05)
Admin. Controls	Yes	Yes	Yes	Yes	Yes
Tax. Controls	Yes	Yes	Yes	Yes	Yes
Decade Fixed Effects	No	No	Yes	No	No
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes
Constant	-52.40**	0.445	-15.24	-53.44**	0.396
	(22.27)	(0.327)	(20.75)	(21.90)	(0.333)
Observations	80	80	90	77	77
Adjusted R-squared	0.335	0.105	0.310	0.372	0.099

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

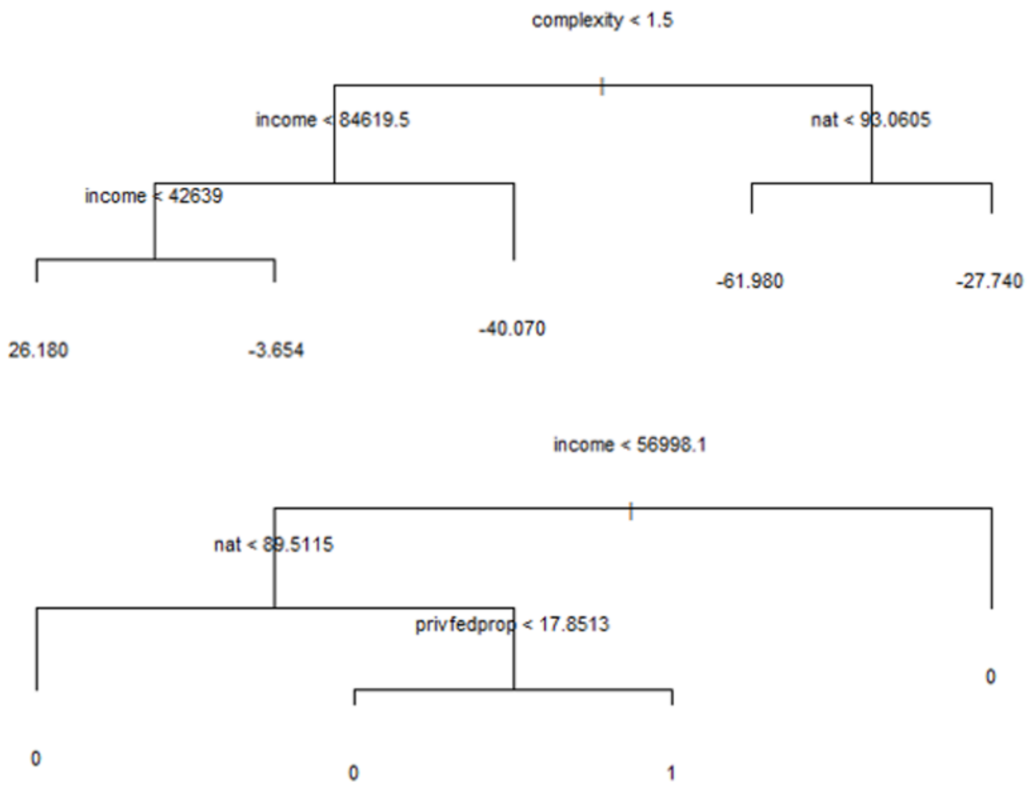
Table A2. Multiple linear regression of equations (1) and (2) generated using Stata 17.0. This table includes an interaction between income and change in percent of developed land.

VARIABLES	(1) relchange	(2) relchange	(3) totalgain
Incomek	-0.287**	-0.0965	-0.00417*
	(0.143)	(0.142)	(0.00230)
%Natural	0.356**	0.132	-0.00128
	(0.174)	(0.172)	(0.00249)
Incomek*changedev	-2.11e-05	-2.11e-05	5.25e-08
	(3.33e-05)	(3.32e-05)	(3.71e-07)
complex2	-1.689	-4.881	-0.105
	(14.13)	(13.32)	(0.140)
complex3	61.06**	74.17***	0.501**
	(25.50)	(21.27)	(0.215)
Admin. Controls	Yes	Yes	Yes
Tax. Controls	Yes	Yes	Yes
Region Fixed Effects	No	Yes	Yes
Constant	-31.89	-53.63**	0.404
	(20.45)	(21.81)	(0.333)
Observations	77	77	77
Adjusted R-squared	0.243	0.373	0.096

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figures

Figure A1. Decision trees of important variables for relative acreage change (top) and total gained vs lost (bottom).



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