
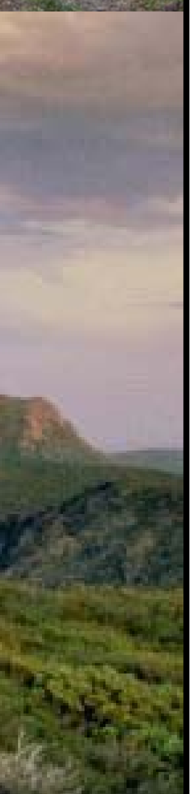
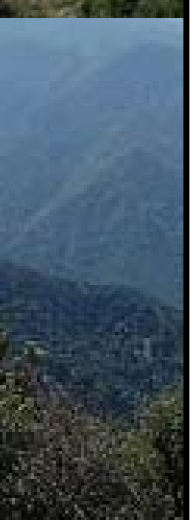

Assessing the Impact of Ecological and Administrative Considerations on Forest and Shrubland Biomass Projections for California

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Table of Contents

Table of Contents i
List of Figures i
List of Tables iv
Executive Summary v
Introduction 1
Purpose 3
Methods 3
Mapping Woody Biomass Potential in California 3
Datasets Used in the Assessment 8
Ecological Constraints 11
Other Considerations 12
Data Processing 13
Results 13
Old-growth Forests 13
California Focal Species 19
Designated Critical Habitat 19
Combined Ecological Constraints 31
Bureau of Land Management Lands 36
USDA Forest Service Lands 36
Combined Ecological and Administrative Constraints 46
Other Considerations 53
Discussion and Conclusions 62
Acknowledgments 64
Literature Cited 64
Appendix A. Reference map of California counties 65

List of Figures

Figure 1. Conceptual diagram of the different types of biomass. Adapted from CEC 2005. 4
Figure 2. Map of total gross non-merchantable tree biomass expressed as pounds/acre from the biomass dataset created by CEC (2005). 5
Figure 3. Map of total technical non-merchantable tree biomass expressed as pounds/acre from the biomass dataset created by CEC (2005). 6
Figure 4. Map of total FTTA non-merchantable tree biomass expressed as pounds/acre from the biomass dataset created by CEC (2005). 7
Figure 5. Map of total gross (A) and technical (B) shrubland biomass expressed as bone dry tons/acre from the biomass dataset created by CEC (2005). 9
Figure 6. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with mapped old-growth forests. 14

Figure 7. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped old-growth forest areas (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. 15
Figure 8. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped old-growth forest areas (A) and percent of total technical non-merchantable forest biomass (B) by county. 16
Figure 9. Technical shrubland biomass (bone dry tons) within mapped old-growth forest areas (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. 17
Figure 10. Technical shrubland biomass (bone dry tons) within mapped old-growth forest areas (A) and percent of total technical shrubland biomass (B) by county. 18
Figure 11. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with focal species important habitat as mapped by CA Natural Heritage Program. 20
Figure 12. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped focal species habitat (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. 21
Figure 13. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped focal species habitat (A) and percent of total technical non-merchantable forest biomass (B) by county. 22
Figure 14. Technical shrubland biomass (bone dry tons) within mapped focal species habitat (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. 23
Figure 15. Technical shrubland biomass (bone dry tons) within mapped focal species habitat (A) and percent of total technical shrubland biomass (B) by county. 24
Figure 16. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with designated critical habitat for northern spotted owl and marbled murrelet by the USF&WS. 25
Figure 17. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with designated critical habitat for Peninsular bighorn sheep and desert tortoise by the USF&WS. 26
Figure 18. Technical non-merchantable forest biomass bone dry weight (pounds) within designated critical habitat (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. 27
Figure 19. Technical non-merchantable forest biomass bone dry weight (pounds) within designated critical habitat (A) and percent of total technical non-merchantable forest biomass (B) by county. 28
Figure 20. Technical shrubland biomass (bone dry tons) within mapped designated critical habitat (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. 29
Figure 21. Technical shrubland biomass (bone dry tons) within mapped designated critical habitat (A) and percent of total technical shrubland biomass (B) by county. 30
Figure 22. Technical non-merchantable forest biomass bone dry weight (pounds) within the combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. 32

Figure 23. Technical non-merchantable forest biomass bone dry weight (pounds) within the combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by county. ... 33
Figure 24. Technical shrubland biomass (bone dry tons) within combined ecological values (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. ... 34
Figure 25. Technical shrubland biomass (bone dry tons) within combined ecological values (A) and percent of total technical shrubland biomass (B) by county. ... 35
Figure 26. Technical non-merchantable and FTTA forest and shrubland biomass in California with USDA Forest Service and Bureau of Land Management lands. ... 37
Figure 27. Technical non-merchantable forest biomass bone dry weight (pounds) within Bureau of Land Management lands (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. ... 38
Figure 28. Technical non-merchantable forest biomass bone dry weight (pounds) within Bureau of Land Management lands (A) and percent of total technical non-merchantable forest biomass (B) by county. ... 39
Figure 29. Technical shrubland biomass (bone dry tons) within Bureau of Land Management lands (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. ... 40
Figure 30. Technical shrubland biomass (bone dry tons) within Bureau of Land Management lands (A) and percent of total technical shrubland biomass (B) by county. ... 41
Figure 31. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service lands (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. ... 42
Figure 32. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service lands (A) and percent of total technical non-merchantable forest biomass (B) by county. ... 43
Figure 33. Technical shrubland biomass (bone dry tons) within USDA Forest Service lands (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. ... 44
Figure 34. Technical shrubland biomass (bone dry tons) within USDA Forest Service lands (A) and percent of total technical shrubland biomass (B) by county. ... 45
Figure 35. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion. ... 49
Figure 36. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by county. ... 50
Figure 37. Technical shrubland biomass (bone dry tons) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion. ... 51

Figure 38. Technical shrubland biomass (bone dry tons) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical shrubland biomass (B) by county. 52
Figure 39. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with recorded occurrences of northern and California spotted owls. 54
Figure 40. Count of recorded northern and California spotted owl occurrences by Jepson ecoregion (A) and by county (B). 55
Figure 41. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with recorded occurrences of G1/G2 and S1/S2 species. 56
Figure 42. Count of recorded G1/G2 and S1/S2 occurrences by Jepson ecoregion (A) and by county (B). 57
Figure 43. Locations of fine scale (1:24,000) hydrologic datasets used in the riparian area scale comparison. 59
Figure 44. Close-up examples of three comparisons between 1:100,000 (light blue) and 1:24,000 (dark blue) scale hydrologic datasets for each of the three national forests within three different Jepson ecoregions. 60
Figure 45. Histogram comparing riparian area using a 100m x 100m resolution derived from 1:100,000 and 1:24,000 scale hydrologic datasets for each of the three national forests within three different Jepson ecoregions. 61

List of Tables

Table 1. List of datasets used in the analysis. 10
Table 2. Attributes selected to identify potential old-growth forest. 11
Table 3. Summary table of statewide changes in available forest biomass totals (bone dry tons) as estimated by the California Energy Commission (CEC) after considering additional ecological constraints. 47
Table 4. Summary table of statewide changes in available shrubland biomass totals (bone dry tons) as estimated by the California Energy Commission (CEC) after considering additional ecological constraints. 48

Executive Summary

According to the California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (CDF FRAP 2005) there are over 340 million bone dry tons (BDT) of non-merchantable, technical (potentially available) forest biomass, and slightly over 62 million BDT of shrubland biomass, that could be used for energy production in California. However, these CDF estimates did not account for a variety of administrative and ecological constraints that may limit where or how much biomass can actually be removed, due for example to concerns about impacts to ecologically sensitive lands or areas of high conservation value. We therefore evaluated to what degree additional ecological and administrative constraints might reduce the CDF estimates of technical forest and shrubland biomass for energy production. This coarse evaluation is meant more to illustrate the nature and extent of the constraints these issues may present to biomass use, rather than provide a comprehensive and precise quantification of the issues.

Using available spatial datasets, we used GIS to quantify and map changes to the CDF biomass estimates by applying additional ecological and administrative constraints. We assumed all areas within these additional constraints would be completely removed from the potential biomass estimates. Values were examined individually and collectively and summarized at state, ecoregion, and county levels. Forest and shrubland biomass were examined and tracked separately. After the reductions were evaluated and mapped, biomass within wildland-urban interface (WUI) areas as defined by the SILVIS Lab at the University of Wisconsin-Madison was returned to the potentially developable biomass pool as a final adjustment at the state scale.

USDA Forest Service lands represent the largest category of land we removed from the estimates. They were removed due to questions about whether biofuel uses on Forest Service lands would be sustainable, and to reflect that they are excluded under the Renewable Fuel Standard in the 2007 Energy Independence and Security Act. We also examined the potential impact of removing Bureau of Land Management (BLM) lands as biofuel development sources.

Other mapable ecological constraints we evaluated included old-growth forests and mapped habitat or designated critical habitat for certain threatened and endangered species, including San Joaquin kit fox (*Vulpes macrotis mutica*), desert tortoise (*Gopherus agassizii*), Peninsular bighorn sheep (*Ovis canadensis cremnobates*), marbeled murrelet (*Brachyramphus marmoratus*), northern spotted owl (*Strix occidentalis caurina*), and California spotted owl (*Strix occidentalis occidentali*). Natural heritage element occurrence data were also examined for northern spotted owl and California spotted owl, as well as collectively for all other plant and animal species ranked as G1/G2 or S1/S2 by the California Natural Heritage Program. Finally, we evaluated the potential impact of hydrologic scale on defining riparian reserves and biomass availability by comparing biomass removals in three geographic sample areas using hydrologic datasets at two different scales (1:24,000 and 1:100,000).

Major results for the technical forest biomass included the following:

- Excluding all ecological value areas, USDA Forest Service lands, and BLM lands reduced the estimate of technical non-merchantable forest biomass by 183 million BDT (~54% of the original statewide CDF estimate).
- Of all the individual constraints we examined, exclusion of Forest Service lands resulted in the greatest overall reduction in technical non-merchantable forest biomass (153 million BDT or 45%).
- Excluding BLM lands reduced available technical non-merchantable forest biomass by only 2.6% (~9 million BDT).
- All ecological constraints combined reduced the technical non-merchantable forest biomass by over 70 million BDT (20.7%).
- Each individual ecological constraint we examined reduced technical non-merchantable forest biomass by 0.4 to 15.6%, with removal of old-growth forests producing the greatest effect (53 million BDT or 15.6%).
- WUI lands that overlap all ecological and administrative values contained 1.62% of the original technical non-merchantable forest biomass estimate (5.5 million BDT), which was returned to the availability pool.
- Under all restrictions (but returning WUI biomass to the availability pool), 47.8% of the original state estimate (163 million BDT) would be available for potential forest biomass development.

Major results for the technical shrubland biomass include the following:

- Combining all constraints -- ecological values, USDA Forest Service land, and BLM land – reduced technical shrubland biomass by 35 million BDT (~57%).
- Excluding BLM lands had the greatest effect on the statewide technical shrubland biomass estimate, reducing it by 16.5 million BDT (26.6%).
- Excluding USDA Forest Service lands reduces the technical shrubland biomass estimate by 14.8 million BDT (23.8%).
- The combination of all ecological values reduced the technical shrubland biomass estimate by 8.6 million BDT (13.8%).
- Of the ecological constraints considered, excluding focal species habitat caused the greatest reduction in technical shrubland biomass (6.2 million BDT or 10%).
- WUI lands contained 0.9% of the original shrubland biomass estimate (579 thousand BDT), which was returned to the availability pool.
- Under all restrictions (but adding WUI biomass back into the estimate), 43.9% of the original state estimate (27 million BDT) would be available for potential shrubland biomass development.

Additional findings:

- Over 39,000 individual natural heritage records (G1/G2 or S1/S2) occurred throughout California. The ecoregions with the most records were the Great Central Valley (n=8,715) followed closely by the South Coast (n=8,201). Protecting the habitat at these locations for rare species wherever they occur should be strongly considered during implementation of any biomass development plan. Doing so would impact the biomass supply minimally.

- The hydrologic scale comparison showed the 1:24,000 implementation scale captured up to 3.6 times as much riparian area as the 1:100,000 estimation scale. Results differed depending on the ecoregion due to geologic and terrain variability. Although impossible to quantify without a complete dataset, the impact this could have on defining riparian reserves off-limits to biomass development could be as high as an additional 5-7%.

Maps for each value and for all combined values show that ecoregions and counties are differentially affected by the constraints: some show little or no reduction in technical forest or shrubland biomass and others show very large reductions. These maps and accompanying statistics enrich the statewide findings by providing greater spatial detail for planning purposes. These results are relatively coarse and preliminary, but the methods could be repeated and refined to develop more complete estimates and recommendations to guide planning at multiple scales.

Introduction

With the growing concern over the environmental consequences of burning fossil fuels (especially climate change) and rising energy prices, alternative energy sources are being actively sought throughout the world. Particularly attractive are renewable energy sources that can help fill the growing energy demand while reducing environmental costs. One alternative renewable energy source being widely promoted is biomass derived from agricultural waste, forestry, municipal waste, and dedicated biomass crops. While only one percent of the world's energy consumption is derived from biomass today, it is estimated that as much as 15% can be achieved by 2020 (Bauen et al. 2003).

The consumption of biomass for energy production is sometimes referred to as a CO_2-neutral power alternative – meaning it does not increase atmospheric carbon dioxide, the major contributor to global climate change. Although biomass contributes significantly less to atmospheric carbon dioxide and other atmospheric pollution than fossil fuels, it is not precisely a net zero emission process. There are CO_2 emissions associated with biomass harvesting, transportation, and feed preparation operations, primarily through the consumption of traditional fossil fuels, as well as some air pollution associated with burning the biomass fuels.

The U.S. economy uses biomass-based materials as a source of energy in several ways. Waste from agriculture and forestry is burned for heating and electricity generation; biomass is converted to liquid form for use as a transportation fuel; and biomass materials are used in the manufacture of various products (Haq 2002).

The U.S. bioelectricity industry is located primarily in the eastern states and the Pacific coast, representing a $15 billion investment and 66,000 jobs (Bauen et al. 2003). Biomass has played a small role in terms of the overall U.S. electrical energy production, supplying 3.2 quadrillion BTUs of energy out of a total 98.5 quadrillion BTUs of energy in 2000 (EIA 2001), and increases are expected to be minor by 2020 under a business-as-usual scenario. However, if policy and incentives continue to promote biomass as a fuel alternative, the contribution to the U.S. electrical energy by 2020 could be significant (Haq 2002).

California has been a leader in developing biomass as a potential source of energy. The most recent forecast for statewide electricity consumption predicts an annual increase of 1.3% over the next ten years (CEC 2006). The current contribution from biomass to supply electrical power to California is very small, but it is believed that current and future supplies of biomass could be effectively developed to contribute as much as 15% of electrical energy demands by 2020, with the largest contributions coming from municipal solid waste, in-forest biomass, animal manures, landfill gas, orchard and vineyard residues, and field crop residues (CEC 2006).

Currently, biomass totals in California amount to approximately 83 million gross bone dry tons per year (BDT/y). By 2020, biomass is expected to increase to 99 million BDT/y (CEC 2006). A subset of the current gross amount is identified as "technically available and sustainable" (32 million BDT/y) growing to 40 million BDT/y by 2020. Of this estimated technical biomass, 8 million BDT/y are from agriculture, 14 million BDT/y from forestry, and 9 million BDT/y from municipal wastes. Dedicated crops are being grown mostly on an experimental basis at this time (CEC 2006).

A major challenge in forecasting biomass energy growth is estimating resource potential (Turhollow and Cohn 1994). This is particularly challenging for forests and shrublands. Springsteen (2000) estimated gross biomass from forest residues in California to be 13.8 million BDT/yr, with 5.5 million BDT/y from mill waste and 8.3 million BDT/y from slash and thinning. Based on recent harvest activity, the estimated portion available was 3.9 million BDT/y. The estimate from shrublands (or chaparral) was 7.7 million BDT/y gross potential, with only 0.8 million BDT/y available. Total gross biomass available from forests and shrublands was estimated to be 21.5 million BDT/y of which 4.7 million BDT/y would be available for energy production (Springsteen 2000).

The California Energy Commission (CEC 2004) reported a slightly higher gross forest biomass estimate of 15 million BDT/y, of which 7 million BDT/y were identified as technically available. Using the latest forest inventory data and vegetation maps, the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Prevention (CDF) conducted another assessment of forest and shrubland biomass resources in the state. They estimated gross biomass from forestry (mill waste and thinnings) to be 22 million BDT/y, with another 5 million BDT/y from shrublands (CEC 2005). Technical biomass was estimated to be nearly 12 million BDT/y from forestry and almost 3 million BDT/y from shrublands. Combined with a statewide fire fuels treatment strategy, the combined annual biomass opportunity for energy production is estimated to be approximately 4.3 million BDT/y: 2.4 million from fire treatment slash and thinnings, 1.5 million in slash and thinnings associated with timber harvest, and 459,000 from shrublands. Gross standing biomass volume for forest and shrublands for California was estimated to be 1.3 billion BDT. Non-merchantable, technically available biomass totals was estimated to be 698 million BDT (CEC 2005).

Although biomass offers an attractive alternative to fossil fuels on both economic, and in some cases environmental grounds, it should not be viewed as environmentally benign. If not carefully planned and implemented, biomass energy production could have many serious ecological consequences and create more greenhouse gas emissions than even fossil fuels. In a recent article in Science, Scharlemann and Laurance (2008) highlight a new study by Zah et al. (2007) that evaluated the relative merits of different types of biofuels. They found that not all biomass sources are equally beneficial to the environment. In fact, some are as damaging as the fossil fuels they are intended to offset.

Likewise, inadequately regulated biomass development could have significant negative ecological consequences across large areas of forests and shrublands. The consequences therefore should be carefully investigated before large-scale economic investments are made and market inertia takes hold. Rapid development of biomass as an energy alternative in California and elsewhere without careful consideration of the overall environmental impacts could help achieve climate change abatement goals on the one hand but devastate important biological and ecological values on the other.

Purpose

The purpose of this report was to build on the most recent forest and shrubland assessment by the California Department of Forestry and Fire Prevention (CEC 2005) by evaluating to what degree additional ecological constraints might reduce the amount of woody biomass available for energy production in California. The goal was to generate forest and shrubland biomass estimates, assessed and mapped at the state, ecoregion, and county levels that could be developed as an alternative energy source without damaging other important ecological values. Generating findings at these three levels was intended to provide information useful for overarching policy decisions as well as regional and local level planning.

Methods

Mapping Woody Biomass Potential in California

Mapping potential biomass over large geographic extents such as the State of California is a complicated and difficult task. Data are often incomplete or incompatible, tradeoffs must be made between scale and accuracy, with numerous assumptions made at various steps along the way. Rather than attempting to generate our own biomass estimates from the available raw data, we based our analysis on the results produced by the California Department of Forestry and Fire Protection for the California Energy Commission (CDF FRAP 2005, CEC 2005). Since our assessment relies heavily on these results, it is important to highlight the general procedure and findings of this report and dataset in order to provide the proper context.

Stand-level monitoring data from the Forest Inventory and Analysis (FIA) program was combined with the most recent land cover data, derived primarily from remote sensing, to create a wall-to-wall map of California that estimates biomass at a spatial resolution of 100 m x 100 m (or one hectare). Forest (or tree) biomass and shrubland (or chaparral) biomass were handled separately, and are individually tracked in this assessment.

Biomass values were organized in a conceptual framework that is important to review (Figure 1, CEC 2005). First, forest biomass was divided into two categories – merchantable and non-merchantable. Non-merchantable forest fiber (mill waste, slash, and small diameter thinning) is unsuitable for producing wood products and therefore presumably available for energy production. Gross non-merchantable biomass represents the total non-merchantable biomass in California (Figure 2). Technical non-merchantable biomass is that portion of the gross non-merchantable biomass that is potentially available for removal after administrative and operational restrictions are considered (Figure 3). Administratively, all “reserves” were removed from further consideration. These included: wild and scenic rivers, wilderness areas, USFS special interest areas and research natural areas, private reserves, state parks, BLM reserves, national parks, and wildlife reserves managed by the US Fish and Wildlife Service and the California Department of Fish and Game. Also, all coastal management zones and coastal sage scrub habitats were removed. Operationally, stream management zones (200 ft on either side of streams) and steep slopes (USFS lands slopes >35% and private and other public lands slopes >30%) were removed. Finally, Fire Threat Treatment Area (FTTA) potential was mapped for the state based on expected fire behavior and expected fire frequency to generate a fire threat surface (Figure 4). Areas identified as having High, Very High, or Extreme Fire Threat inside and outside the Wildland-Urban Interface (or WUI) were mapped as part of the FTTA.

For the forest biomass component of our assessment, we evaluated the potential impact of additional ecological constraints and new administrative constraints (US Forest Service and BLM lands removed) on technical non-merchantable biomass (measured as bone dry weight in pounds and summarized in tons) at the state-wide, ecoregion, and county levels. At the state level only, we also tracked the impact these restrictions would have on estimated available Fire Threat Treatment Area (FTTA) biomass as well as for a modified version of the FTTA biomass that reflects more-detailed prescription harvests assigned by state wildfire experts (denoted as Rx throughout this report). Ecoregion and county level maps were generated for each constraint independently and collectively (since multiple values could reside at the same location) regardless of whether the affected cells were inside or outside the WUI (as depicted by the SILVIS Lab at the University of Wisconsin-Madison). For the state-level summaries, we reinserted WUI totals, because these areas would be permitted to be managed for fuels to reduce wildfire risks to human communities, at least to some degree, regardless of the added values.

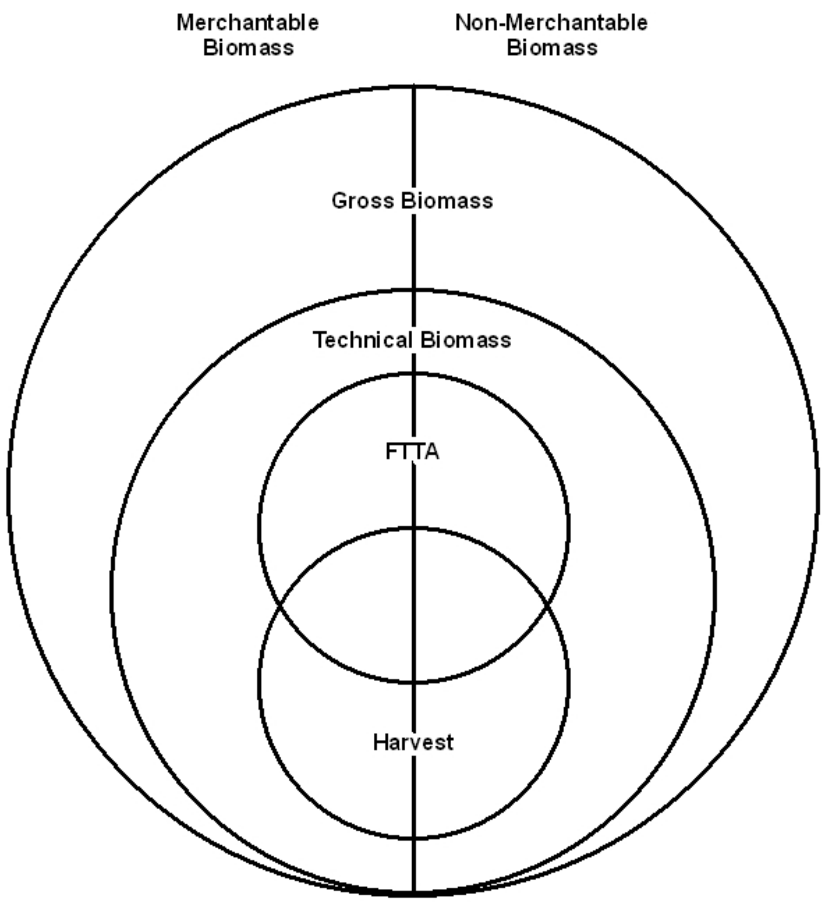


Figure 1. Conceptual diagram of the different types of biomass. Adapted from CEC 2005.

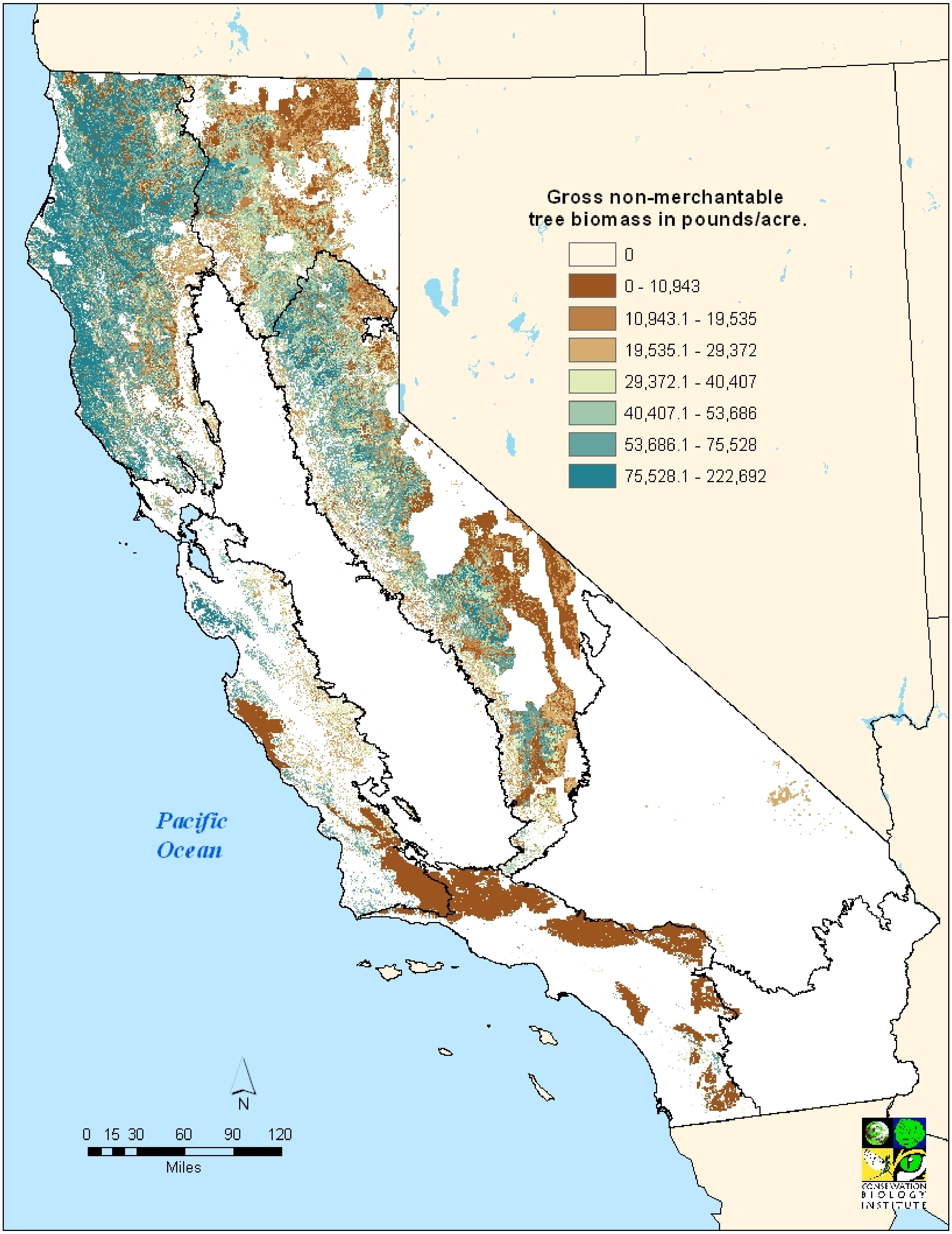


Figure 2. Map of total gross non-merchantable tree biomass expressed as pounds/acre from the biomass dataset created by CEC (2005).

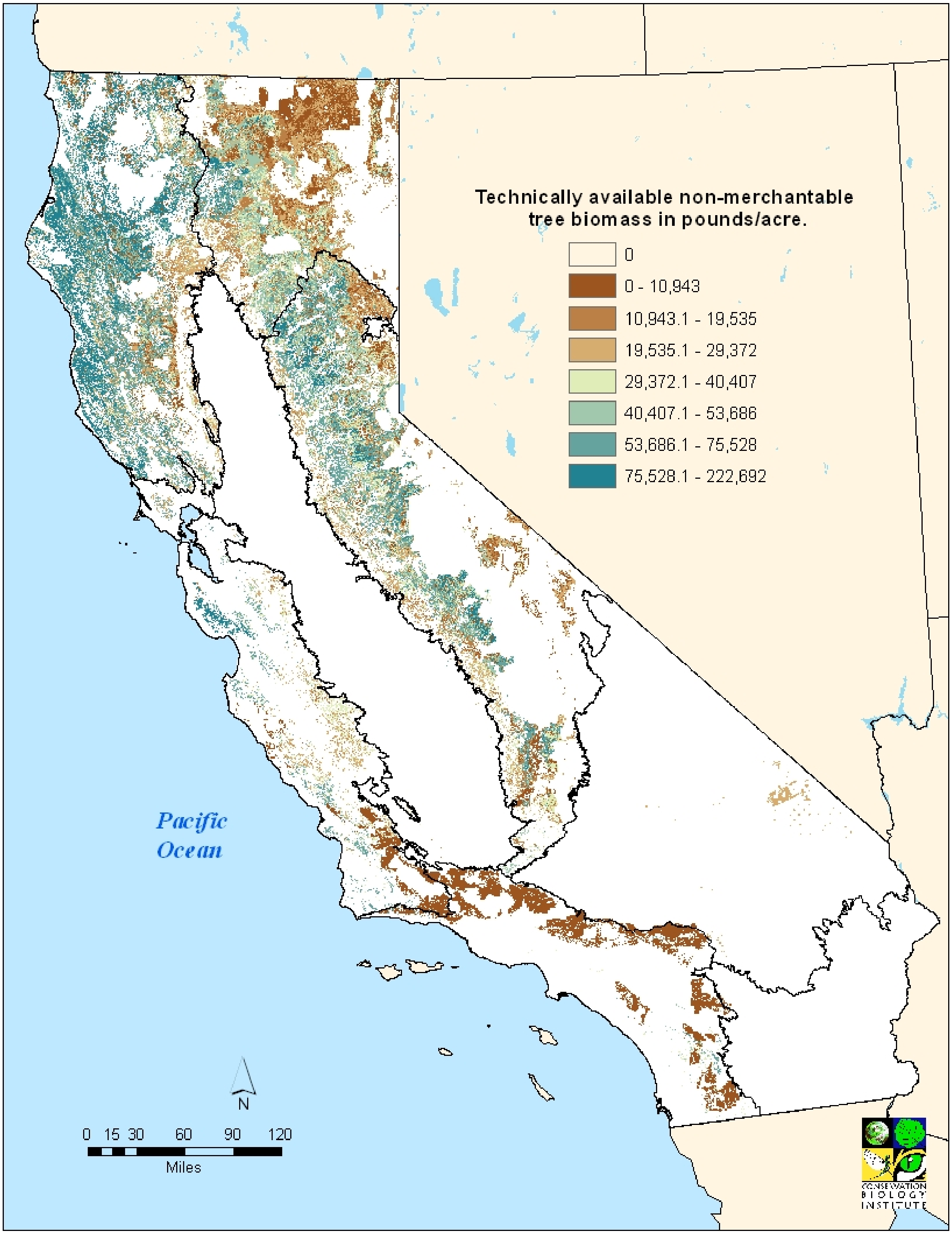


Figure 3. Map of total technical non-merchantable tree biomass expressed as pounds/acre from the biomass dataset created by CEC (2005).

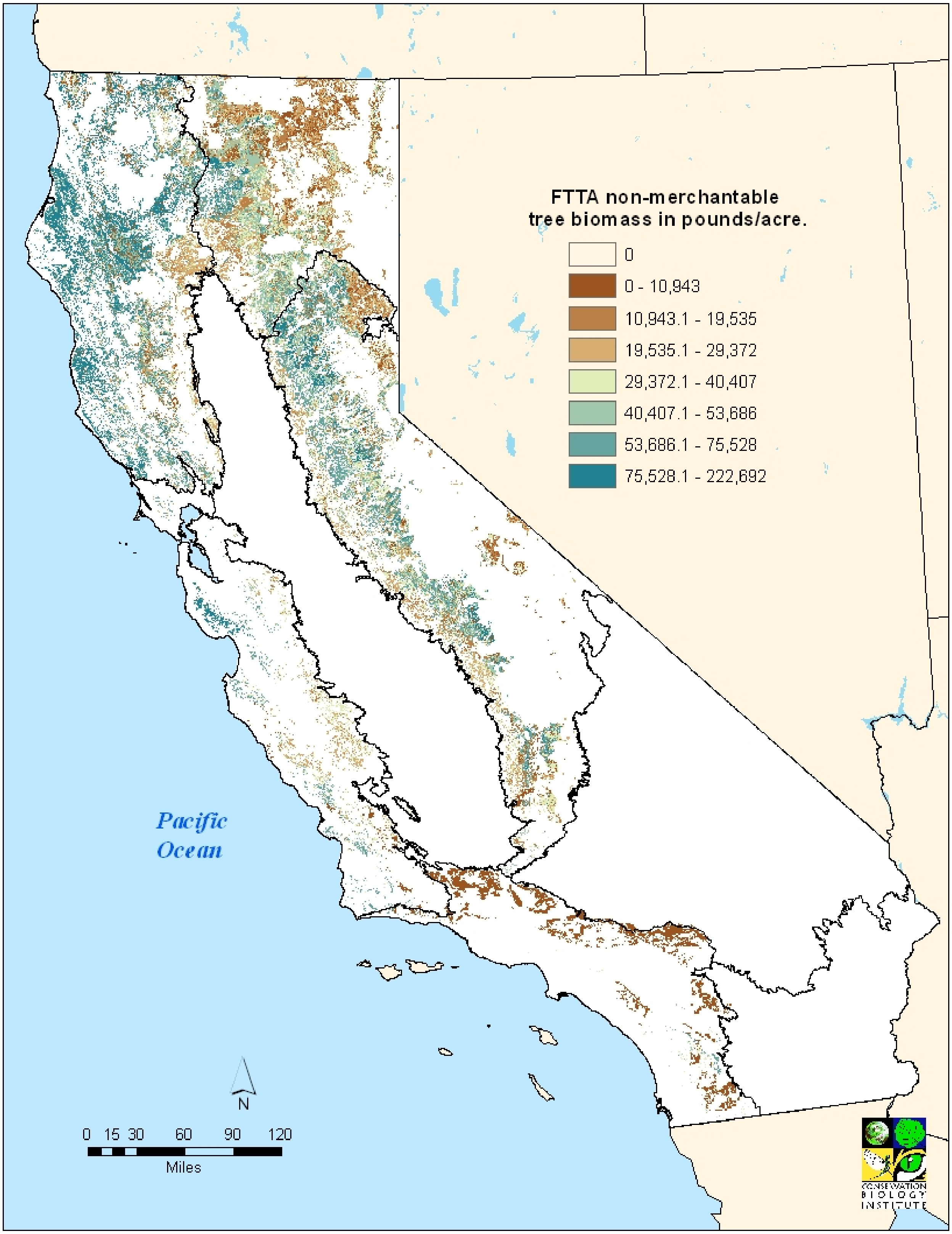


Figure 4. Map of total FTTA non-merchantable tree biomass expressed as pounds/acre from the biomass dataset created by CEC (2005).

We elected to keep the WUI and non-WUI components separate in our analysis since the impact of WUI areas depends entirely upon the WUI map used. For the CEC (2005) report, the WUI map was created by the Department of Forestry and Fire Protection. However, other versions of WUI exist, including the version developed and housed at the SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin-Madison. Because the SILVIS Lab model is widely recognized as the national standard, we used it in our analysis. A total of 7.2 million acres of WUI were mapped in California under the SILVIS Lab model.

The California Department of Forestry and Fire Protection mapped gross and technical shrubland biomass separately from the forest component in bone dry tons (BDT; Figure 5); our assessment, which was based on the same biomass dataset, did the same. For the shrubland biomass component, we evaluated the potential impact of additional ecological constraints and new administrative constraints (US Forest Service and BLM lands removed) on technical biomass (in BDT) at the state-wide, ecoregion, and county levels. Ecoregion and county level maps were generated for each constraint independently and collectively regardless of whether the affected cells were inside or outside the national standard WUI areas. As we did for the forest component, we reinserted WUI totals for the state-level summaries, as these areas would be permitted to be managed for fuels, at least to some degree, regardless of the values contained.

Summary statistics were calculated and maps generated for each criterion alone as well as for combinations of constraints.

Datasets Used in the Assessment

A variety of datasets were used in this assessment in conjunction with the main CDF FRAP (2005) biomass dataset provided to us courtesy of the California Department of Forestry and Fire Protection. Datasets for the various ecological and administrative screens we examined are listed in Table 1. These datasets came from a variety of sources, were in different formats, and created at different spatial scales. All datasets were related back to the operational resolution of the California biomass file, which was 100 meters x 100 meters.

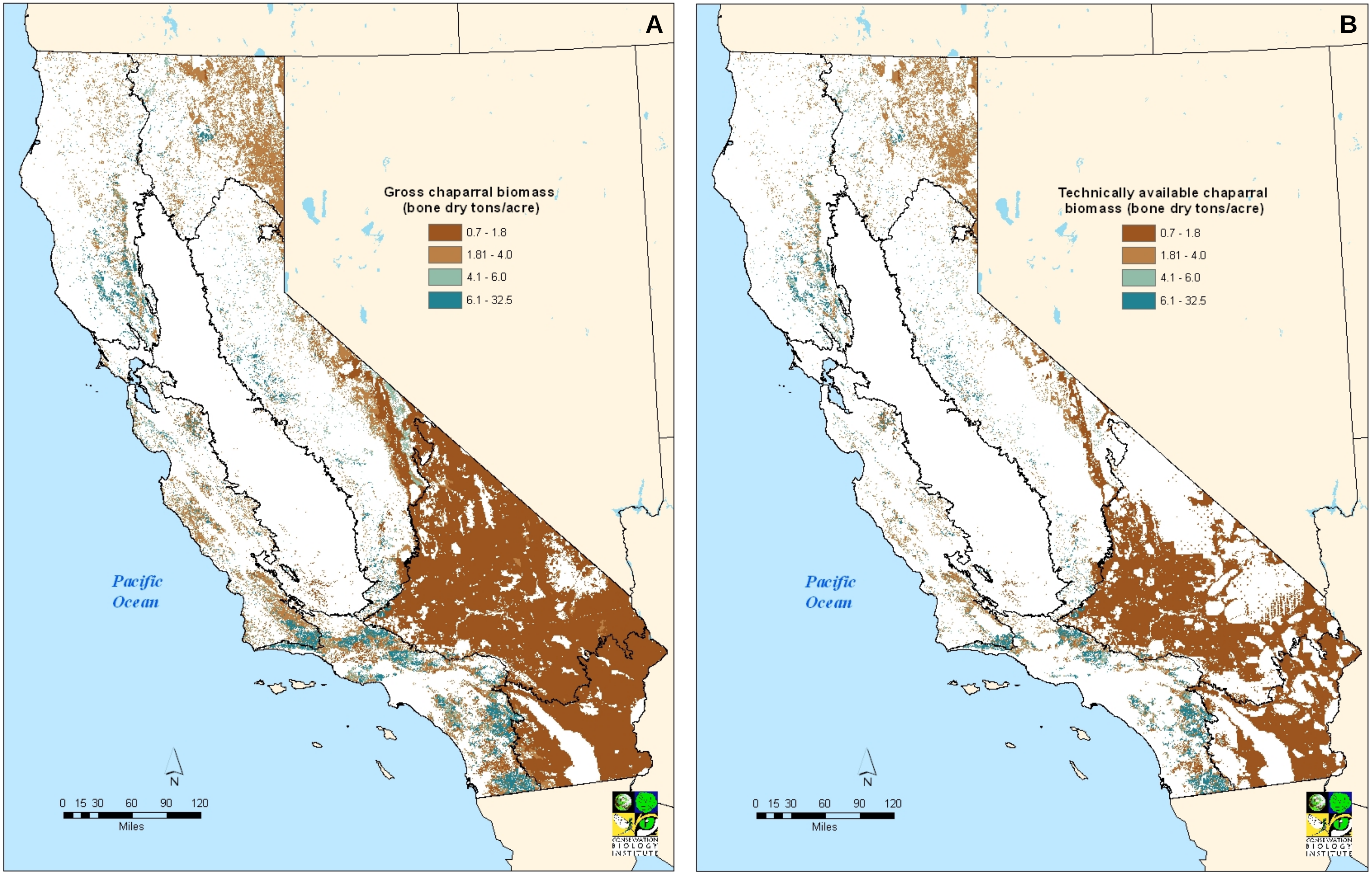


Figure 5. Map of total gross (A) and technical (B) shrubland biomass expressed as bone dry tons/acre from the biomass dataset created by CEC (2005).

Table 1. List of datasets used in the analysis.

Name	Type	Scale/ Resolution	Source
California Biomass	raster	100m	California Department of Forestry and Fire Protection
California WUI	raster	100m	California Department of Forestry and Fire Protection
Inventoried Roadless Areas	polygon	1:100,000	USDA Forest Service Geospatial Service and Technology Center. Retrieved from www.roadless.fs.fed.us
SBI old growth	polygon	based on 30m imagery	Sierra Biodiversity Institute
EVeg	polygon	1:100,000	USDA Forest Service Pacific Southwest Region Remote Sensing Lab. Retrieved from the USDA Region 5 GIS Clearinghouse: http://www.fs.fed.us/r5/rsl/clearinghouse/gettiles.shtml
Protected Areas Database (CBI-PAD)	polygon	1:24,000 – 1:100,000	Conservation Biology Institute
NHDPlus Region 18 flowline	polygon	1:100,000	US EPA and USGS. Retrieved from: NHDPlus; Horizon Systems Corporation: http://www.horizon-systems.com/nhdplus/data.php
NHD High Resolution data, Burney Quad	line	1:24,000	USGS, US EPA, USDA Forest Service. Retrieved from USGS NHD Geodatabase: http://nhdgeo.usgs.gov/viewer.htm
Eldorado National Forest hydrography	line	1:24,000	USDA Forest Service Region 5 Remote Sensing Lab
Mendocino National Forest Hydrography	line	1:24,000	USDA Forest Service Region 5 Remote Sensing Lab
Focal Species	polygon	varies	California Department of Fish and Game's Biogeographic Data Branch. Retrieved from RareFind3, CDFG CD Publication
Spotted Owl points	polygon	varies	California Department of Fish and Game's Biogeographic Data Branch. Retrieved from RareFind3, CDFG CD Publication
Biological Heritage Points	polygon	varies	California Department of Fish and Game's Biogeographic Data Branch. Retrieved from RareFind3, CDFG CD Publication
Critical Habitat	polygon	varies	U.S. Fish and Wildlife Service
National WUI	polygon	100,000	SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin-Madison. Retrieved from http://silvis.forest.wisc.edu/Library/WUILibrary.asp

Ecological Constraints

We evaluated the impact additional ecological constraints would have on forest and shrubland biomass estimates for California. We calculated the amount of technical non-merchantable forest biomass and technical shrubland biomass contained within each ecological value described below on a pixel-by-pixel basis and summarized the findings for the entire State of California, for each of the eight individual ecoregions (according to Jepson), and for each of the 58 counties in the state.

Old-Growth Forests

Statewide maps of old-growth forests are not very accurate or up-to-date. For this assessment, we estimated old-growth forest cover based largely on USDA Forest Service data. For the Sierra Nevada, we also included additional data from the Sierra Biodiversity Institute. Invariably, there will be the argument about what is "old growth" for any exclusion policy that is put forward. One approach is to try to define the term on ecological grounds. Another way is to be more general – delineate late successional management zones (forest stands that are largely old but may contain some young patches) rather than try to map finely mapped old growth stands. There are complications and challenges with either approach.

Old growth was identified from available USDA Forest Service Existing Vegetation Data (EVeg) for forested portions of California. Several attributes within the EVeg data were chosen to identify old-growth. Old-growth traits were classified as uneven-aged stands dominated by large trees in a multi-layered, mixed-density canopy. First, forested areas were identified by selecting "tree dominated order" category of physiognomic order attribute. A multi-layered canopy structure was included by selecting multi-storied canopy from northwest structure. To identify large trees, WHR size class 5 (>24" DBH) and 6 (multi-layered tree) were chosen and then areas mapped as planted from 1850 to the present were removed (Table 2).

The 81 available EVeg tiles were run through a spatial model based on the criteria highlighted above, and the outputs were merged into one polygon data layer. Additional existing old-growth polygon data created in 1994 by the Sierra Biodiversity Institute were joined to the merged EVeg data file to fill in the Sierra Nevada.

Table 2. Attributes selected to identify potential old-growth forest.

Physiognomic Order	Tree dominated
Northwest Structure	Multi-storied canopy
WHR Standards for Tree Size	DBH >24.0", Multi-layered tree
Year Planted	< 1850
Reforestation Status	not Planted Shelterwood Cut - Overwood Present Non-Stocked Timberland Overstory Removal - Overwood Not Present

Focal Species

The California Department of Forestry and Fire Protection (CEC 2005) had removed all coastal management zones and coastal sage scrub habitats from technical biomass because of their ecological sensitivity and support of numerous rare, threatened and endangered species. We further removed areas important to supporting a variety of threatened and endangered species, including modeled habitat areas for three species -- Peninsular bighorn sheep (*Ovis canadensis cremnobates*), desert tortoise (*Gopherus agassizii*), and San Joaquin kit fox (*Vulpes macroitis mutica*) -- and designated critical habitat for four species -- northern spotted owl (*Strix occidentals caurina*), marbled murrelet (*Brachyramphus marmoratus*), desert tortoise, and Peninsular Bighorn Sheep. Designated critical habitat includes areas considered essential to the continued survival and recovery of certain threatened and endangered species.

USDA Forest Service and Bureau of Land Management

To evaluate the impact of removing all Forest Service and Bureau of Land Management land from biomass development, we used the ownership attribute from the most recent CBI-PAD layer to select out these Federal lands.

Other Considerations

Natural Heritage

We also examined point locations for northern spotted owls (*Strix occidentalis caurina*) and California spotted owls (*Strix occidentalis occidentalis*) as well as for all species records for species that have been listed as G1/G2 or S1/S2 (high global or state endangerment) by the California Natural Heritage Program. For these cases, we counted the number of occurrences in each ecoregion and county in order to gain some insight as to the likely site-level restrictions required by existing law, but we had no analytical way to subtract quantitatively from the biomass estimates in a scientifically defensible way.

Riparian Reserves

The CEC (2005) report removes stream management zones (200 ft on either side of streams) from biomass estimates using 1:100,000-scale hydrology data. With a spatial resolution of 100 m, all buffered 1:100,000 streams were mapped as 100-m cells.

Map scale can have a large impact on resource estimates. For example, the Northwest Forest Plan mapped riparian reserves using medium scale data, but when the policy was implemented, agency staff found a much larger impact than was originally estimated, because implementation used a finer scale. A similar situation is likely to occur with the biomass estimates for California.

We therefore tested the potential impact of scale of riparian areas on technical biomass calculations by comparing hydrology data obtained at two scales – 1:100,000 and 1:24,000. Unfortunately, the finer scale data are not readily available for the entire state. We therefore sampled each of the major forested ecoregions using data available from the US Forest Service. We selected equal areas within one national forest from each of three ecoregions (North Coast, Modoc Plateau, and Sierra Nevada) and compared results at the two scales.

Data Processing

All ecological restrictions were analyzed using ArcGIS version 9.2 employing Model Builder programming. All datasets were projected into Albers Equal Area projection, North American Datum (NAD) 1983. Due to the size of the CEC biomass raster dataset, technically available and fire threat treatment areas (FTTA) were extracted from the original dataset. These were converted to vector data, each retaining their original unique identifying values. Using these two datasets, the technically available and FTTA portions of each ecological and administrative constraint were tracked. Our assessment calculated and summarized results by state, ecoregion, and county.

Results

Old-growth Forests

There were approximately 4.5 million acres of old-growth forest as defined in this analysis in California distributed mainly in three ecoregions – North Coast, Modoc Plateau, and Sierra Nevada (Figure 6). Old-growth forest data were limited or not available for the Central Coast and South Coast ecoregions, although some old-growth forests exist there. Over 53 million BDT of technical non-merchantable forest biomass was within old-growth forests in the state (15.6% of the statewide technical non-merchantable biomass mapped by the CEC (2005)). The redwood forest region (North Coast) contained the largest amounts, followed by the Sierra Nevada and the Modoc Plateau (Figure 7A). In ecoregions with complete data, old-growth forests represented 11-22% of the existing technical forest biomass estimated to be present in each ecoregion (Figure 7B). County profiles for this ecological value were concentrated in the northwest portion of the state, including Humboldt, Trinity, Mendocino, Siskiyou, Shasta, and Plumas (Figure 8A); however, the higher proportion of technical forest biomass at the county level was in Humboldt, Trinity, Glenn and one Sierra Nevada county – Alpine (Figure 8B). Very little shrubland technical biomass was contained inside old-growth forest areas (<0.5% of the state total) at the ecoregion or county level (Figures 9 and 10).

Figure 6. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with mapped old-growth forests.

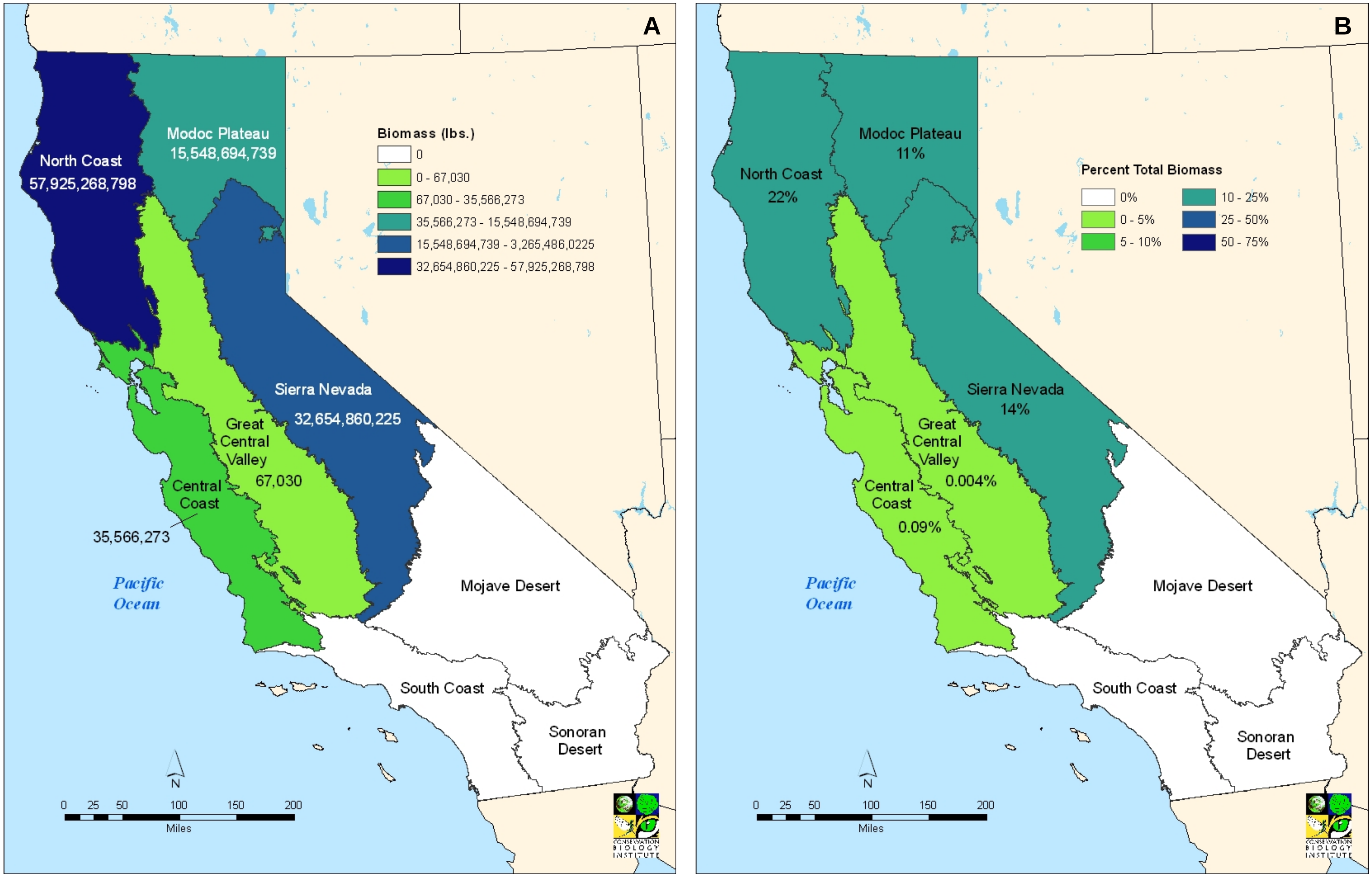


Figure 7. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped old-growth forest areas (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.

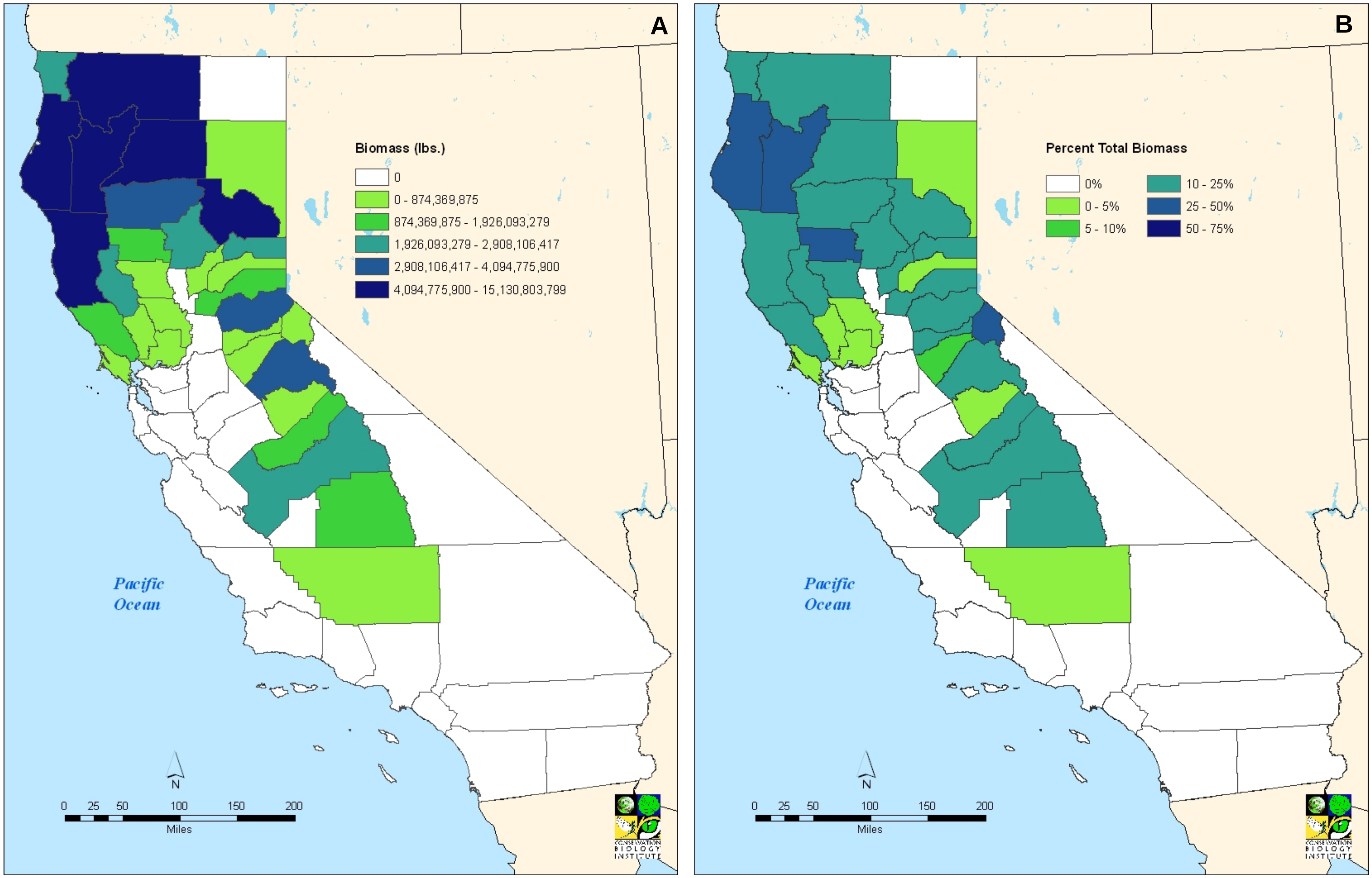


Figure 8. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped old-growth forest areas (A) and percent of total technical non-merchantable forest biomass (B) by county.

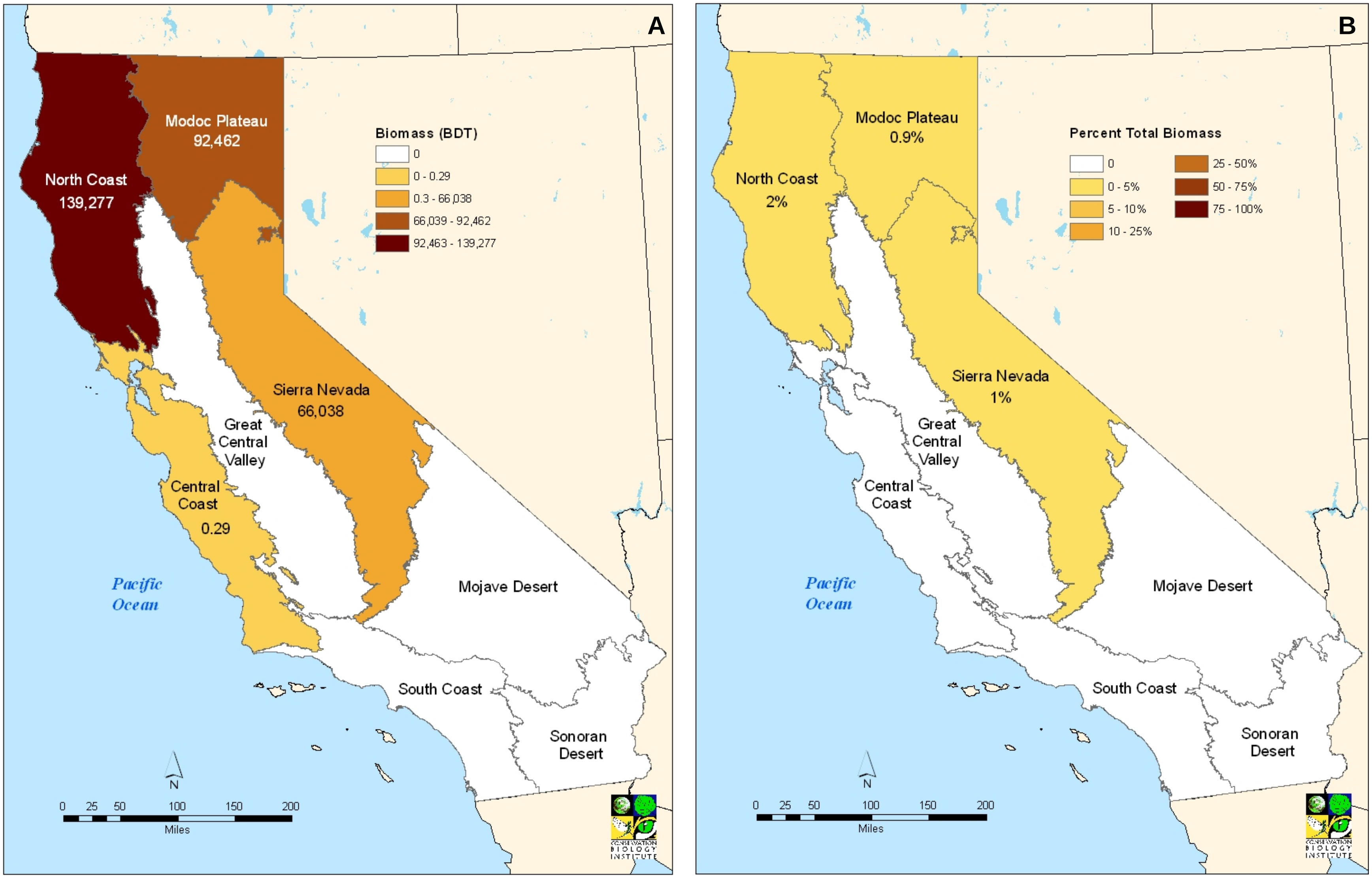


Figure 9. Technical shrubland biomass (bone dry tons) within mapped old-growth forest areas (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.

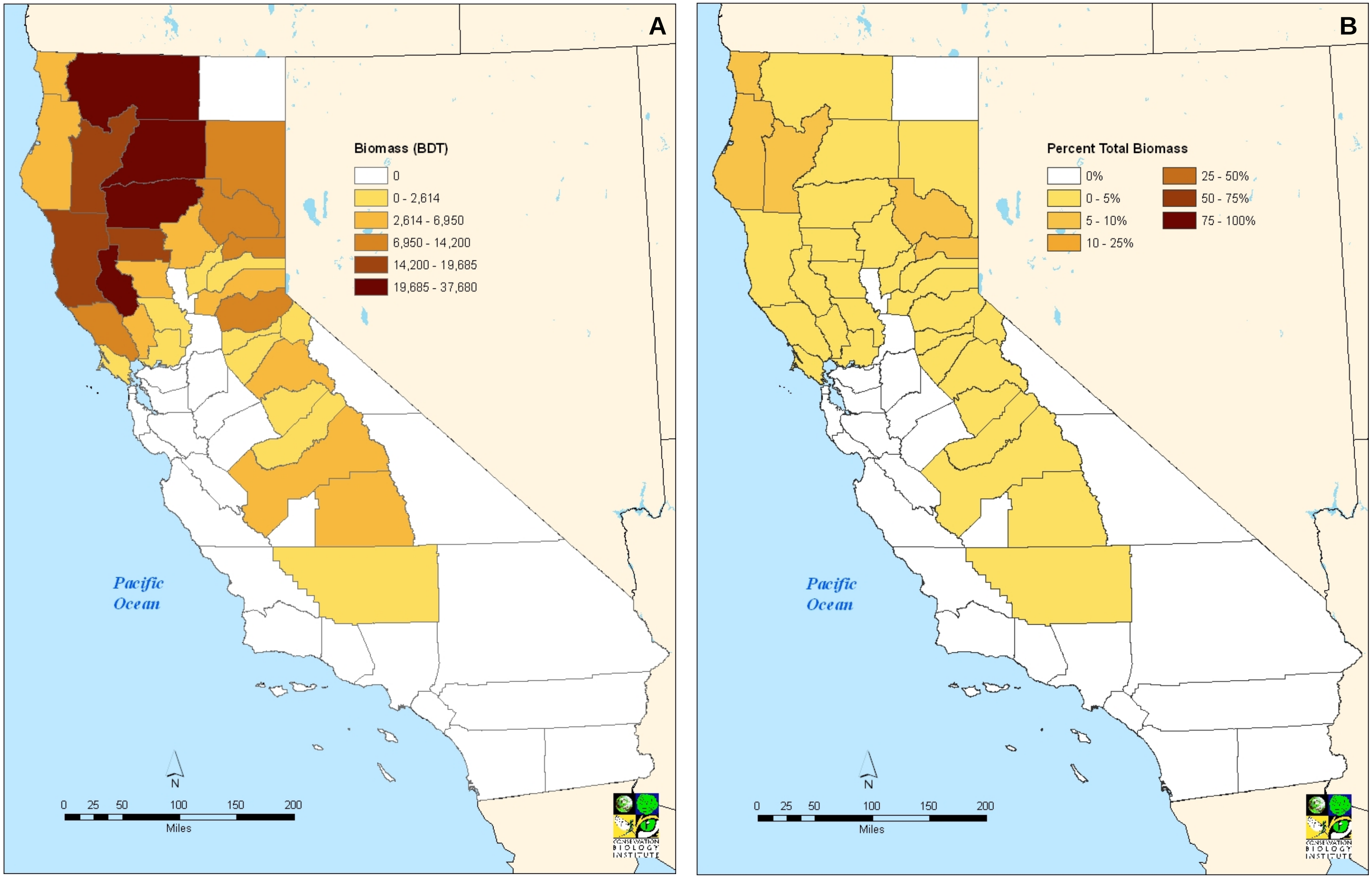


Figure 10. Technical shrubland biomass (bone dry tons) within mapped old-growth forest areas (A) and percent of total technical shrubland biomass (B) by county.

California Focal Species

Approximately 9.8 million acres of habitat has been mapped for the three focal species we evaluated (San Joaquin kit fox, Peninsular bighorn sheep, and desert tortoise). San Joaquin kit fox habitat covers approximately 5 million acres; the desert tortoise 4.8 million acres; and the Peninsular bighorn sheep 211,000 acres (Figure 11). The amount of technical forest biomass within these habitat areas is very low (1.4 million BDT or 0.41% of the statewide total). This is not surprising as these three species require non-forest habitats. For the ecoregions, the Mojave Desert jumps out with 46% of its technical forest biomass inside primarily desert tortoise habitat. This is a large percentage but accounts for relatively small amounts of forest biomass (Figure 12). The leading counties include San Bernardino in the Mojave Desert region and three counties in the South Coast ecoregion – San Luis Obispo, Monterey, and San Benito (Figure 13).

The technical shrubland biomass affected by habitat for these three species was much greater with nearly 10% of the state total (6.2 million BDT) inside these habitat areas. The Mojave Desert, Sonoran Desert, and Great Central Valley ecoregions contained the largest amounts (Figure 14A) with 66% of the technical shrubland biomass included in the Great Central Valley, 31% in the Mojave Desert, and 24% in the Sonoran Desert (Figure 14B). High levels of technical shrubland biomass within these habitats were found in San Bernardino, Kern, Riverside, and Imperial counties (Figure 15A) with San Bernardino and Kern counties showing the greatest proportion in the state (Figure 15B).

Designated Critical Habitat

There are 7.6 million acres of designated critical habitat in California for the four species we evaluated – northern spotted owls (1.5 million acres) and marbled murrelets (748,000 acres) in the north (Figure 16), and desert tortoise (4.7 million acres) and Peninsular bighorn sheep (861,000 acres) in the south (Figure 17). The amount of technical forest biomass within these areas totaled 26.5 million BDT (7.8%) statewide. The largest total reductions occurred in the North Coast and Modoc Plateau (Figure 18A). Proportionally, these reductions amounted to 56% of technical forest biomass in the Mojave Desert, 17% in the North Coast, and 5% in the Modoc Plateau (Figure 18B). The proportion value for the Mojave Desert was extremely high, although the amount of forest in this ecoregion is minute; the North Coast and Modoc Plateau values are much more significant. At the county level, all of the North Coast counties contained large technical forest biomass numbers within designated critical habitat, especially Humboldt, Trinity, and Siskiyou (Figure 19A). Besides San Bernardino County showing high proportion of technical forest biomass within critical habitat for the reasons described above, Del Norte and Trinity showed the more substantial reductions (Figure 19B).

The Mojave and Sonoran Deserts contained the largest amounts, in total and by proportion, of technical shrubland biomass within designated critical habitat areas (Figure 20A and B), with 28% of the Sonoran Desert and 25% of the Mojave (Figure 20B). San Bernardino, Riverside, and Imperial counties showed the largest amounts of technical shrubland biomass within critical habitat (Figure 21A) and San Bernardino, Del Norte, and Humboldt counties contained the greatest proportion (Figure 21B).

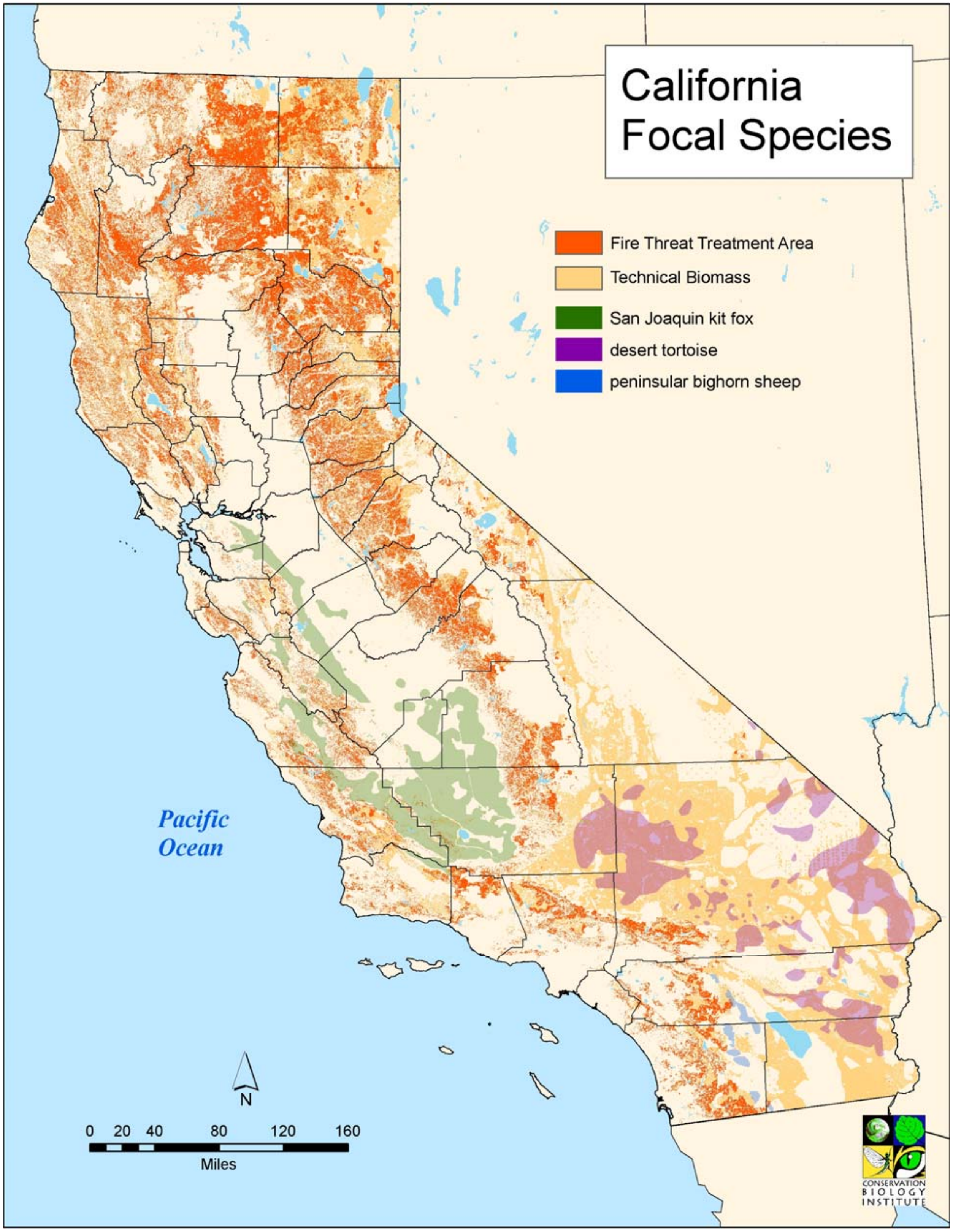


Figure 11. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with focal species important habitat as mapped by CA Natural Heritage Program.

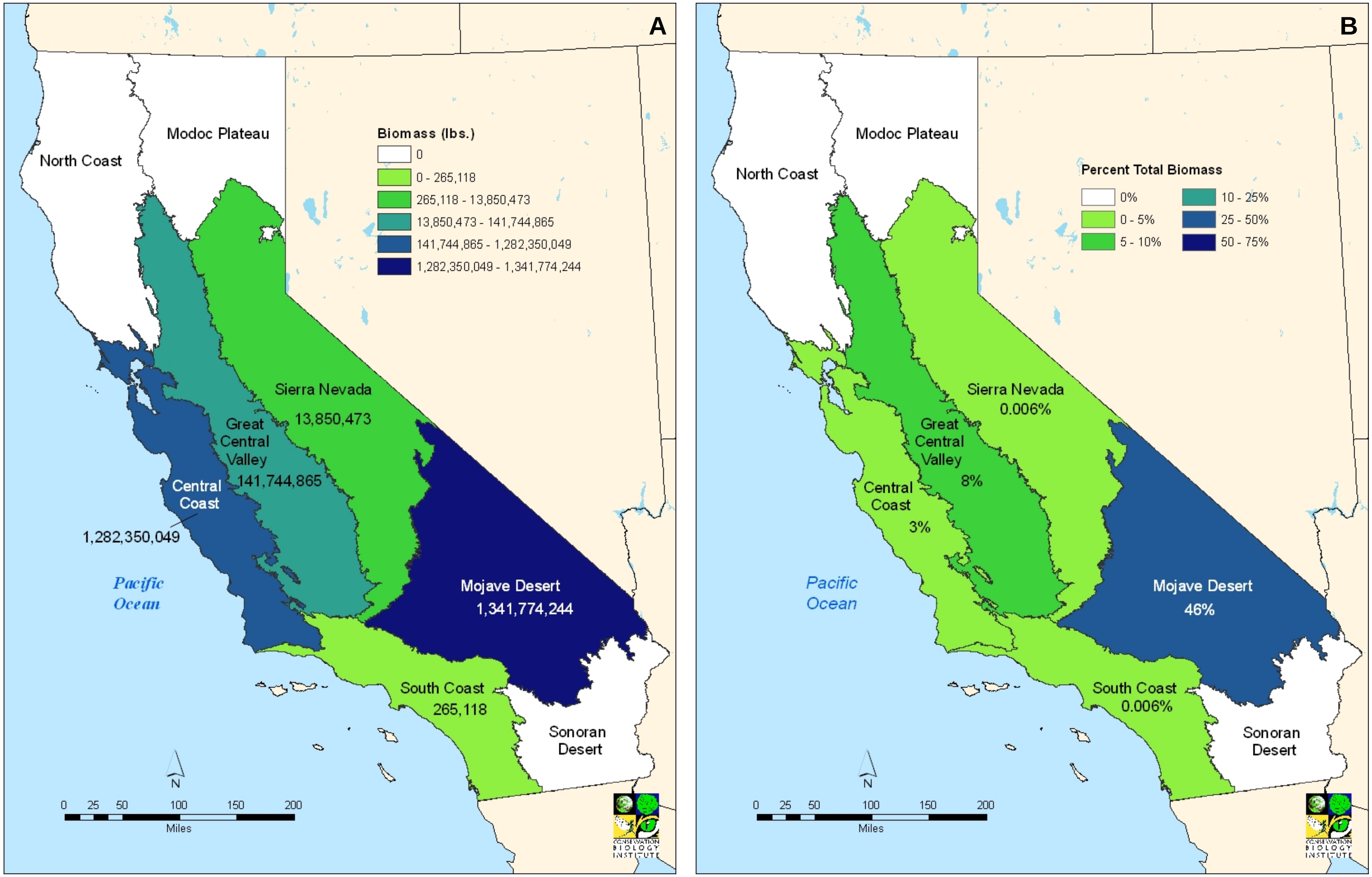
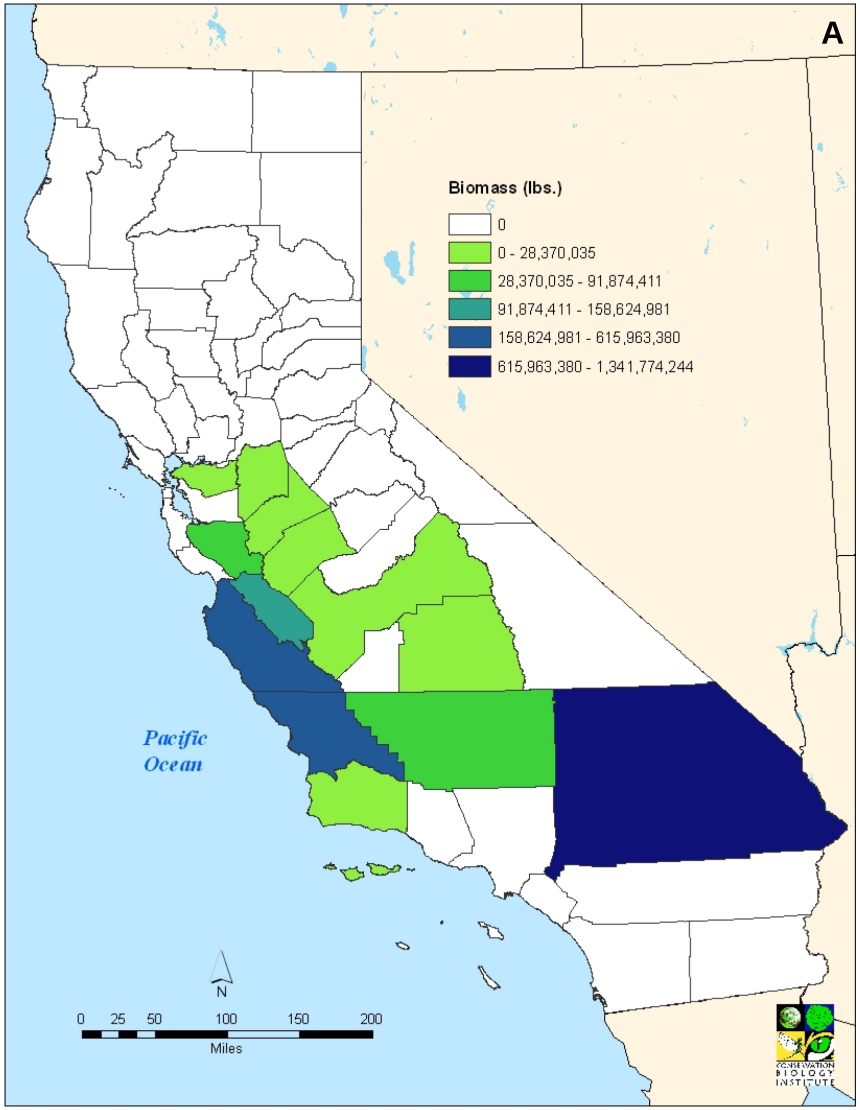


Figure 12. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped focal species habitat (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.



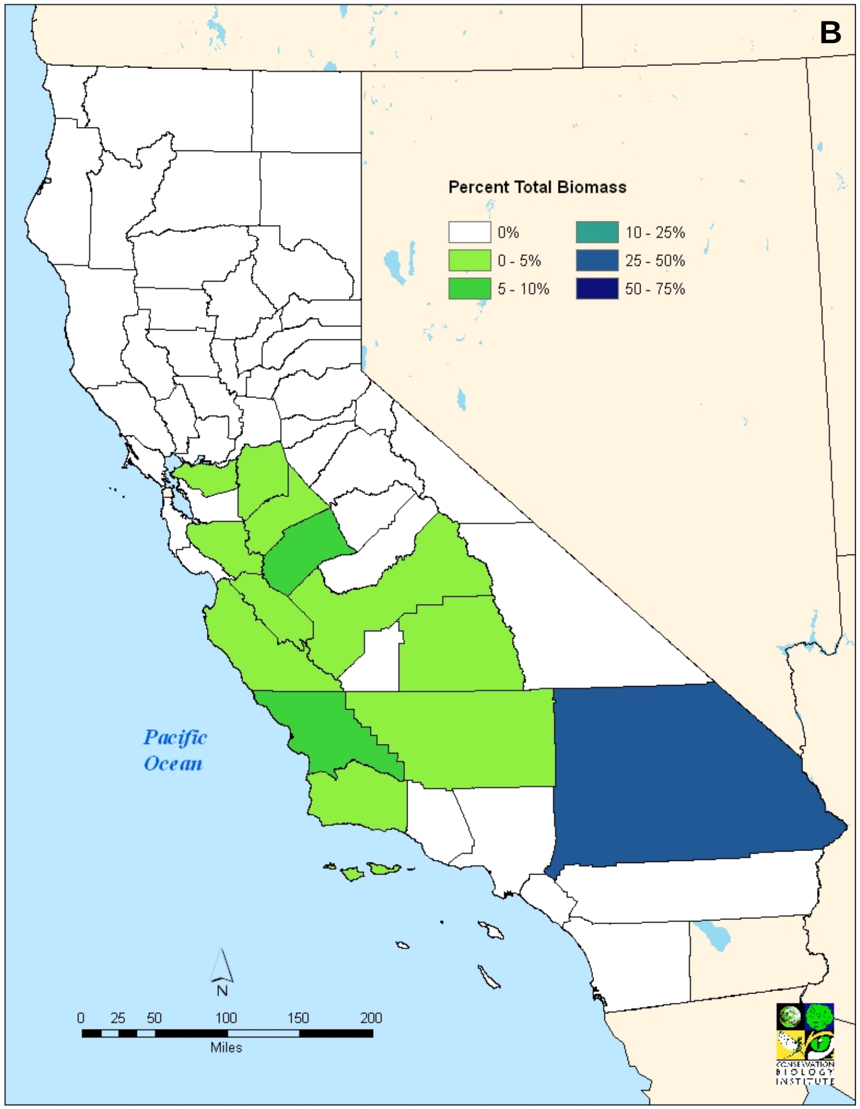


Figure 13. Technical non-merchantable forest biomass bone dry weight (pounds) within mapped focal species habitat (A) and percent of total technical non-merchantable forest biomass (B) by county.

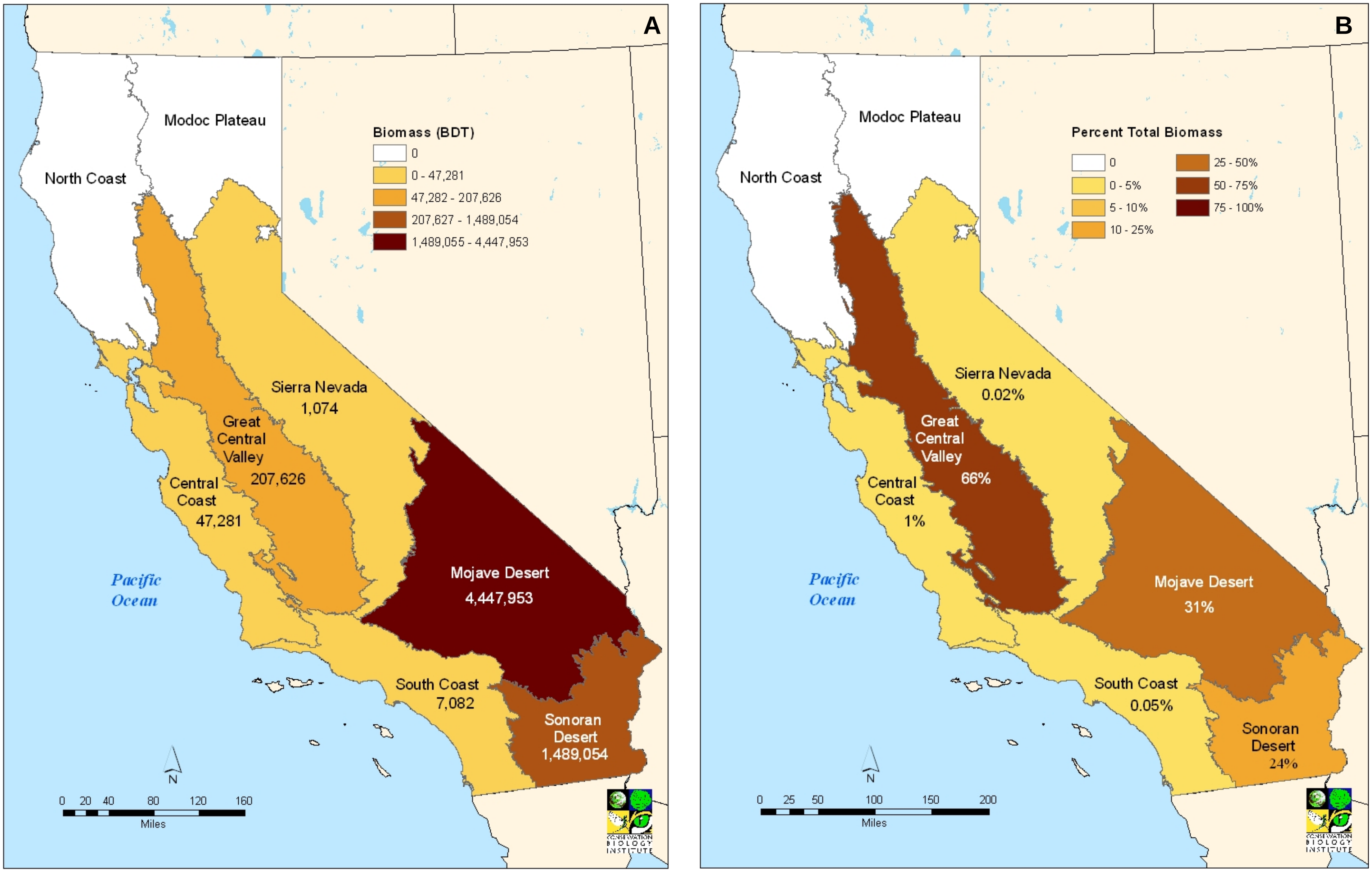


Figure 14. Technical shrubland biomass (bone dry tons) within mapped focal species habitat (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.

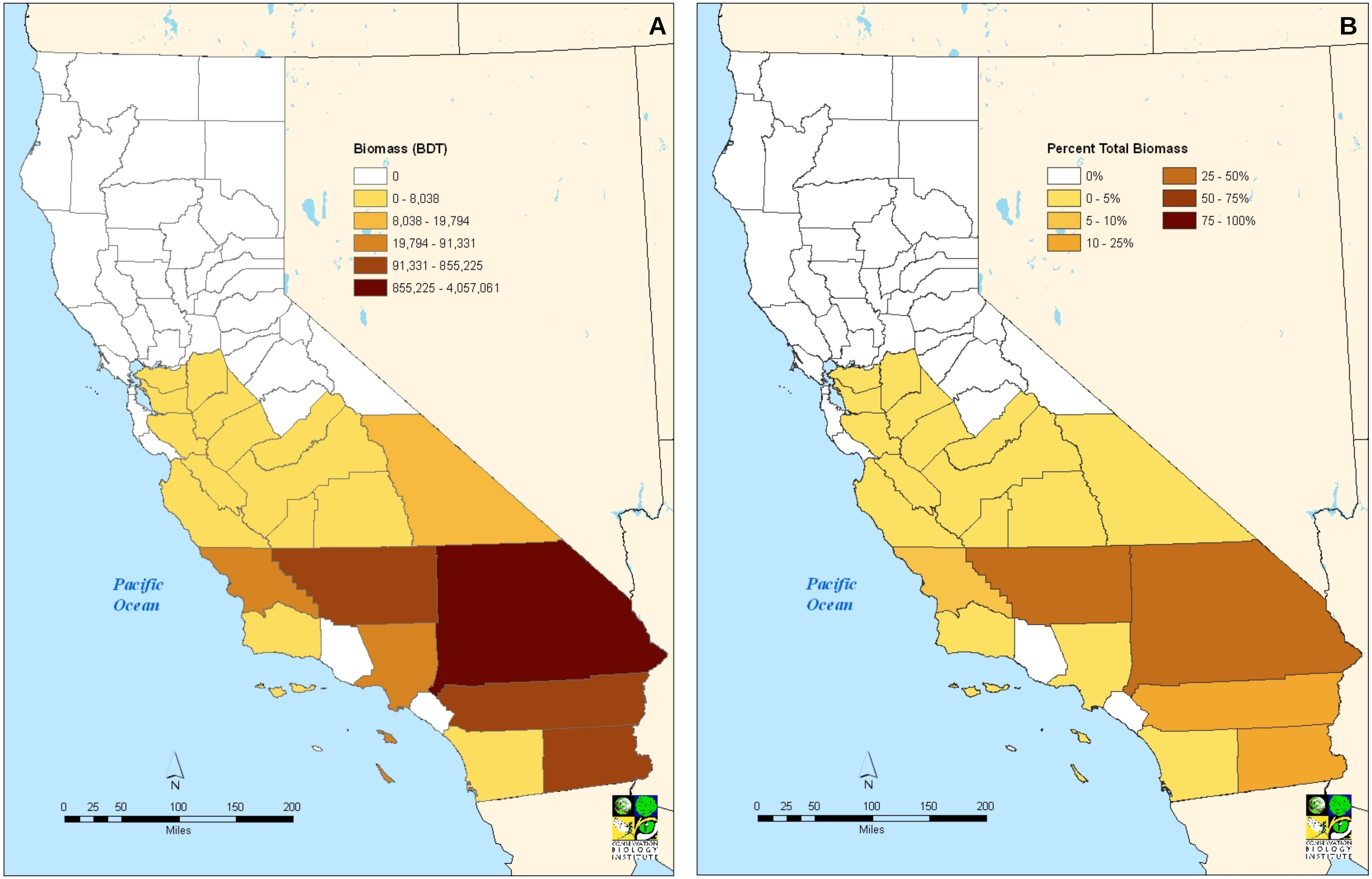


Figure 15. Technical shrubland biomass (bone dry tons) within mapped focal species habitat (A) and percent of total technical shrubland biomass (B) by county.

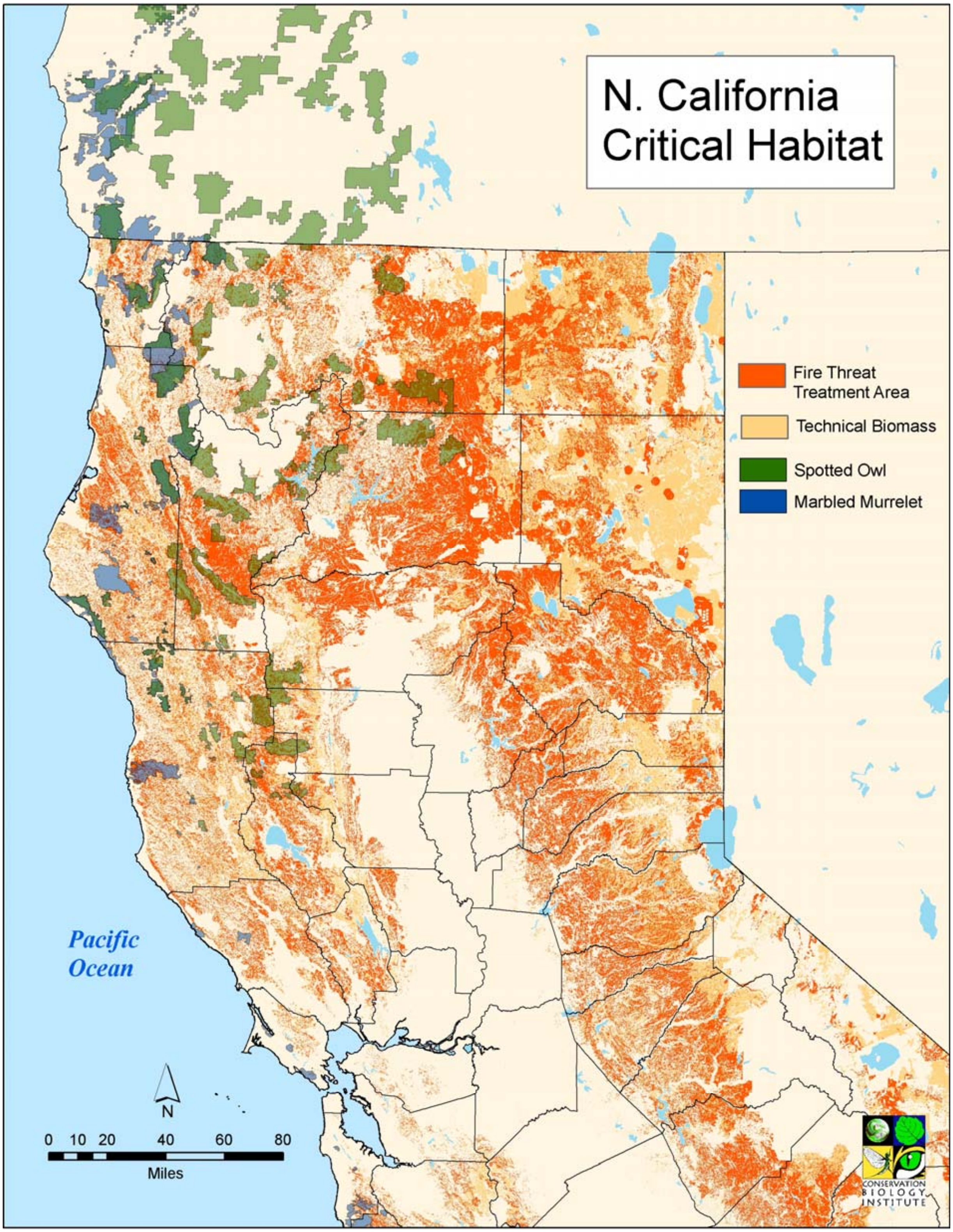


Figure 16. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with designated critical habitat for northern spotted owl and marbled murrelet by the USF&WS.

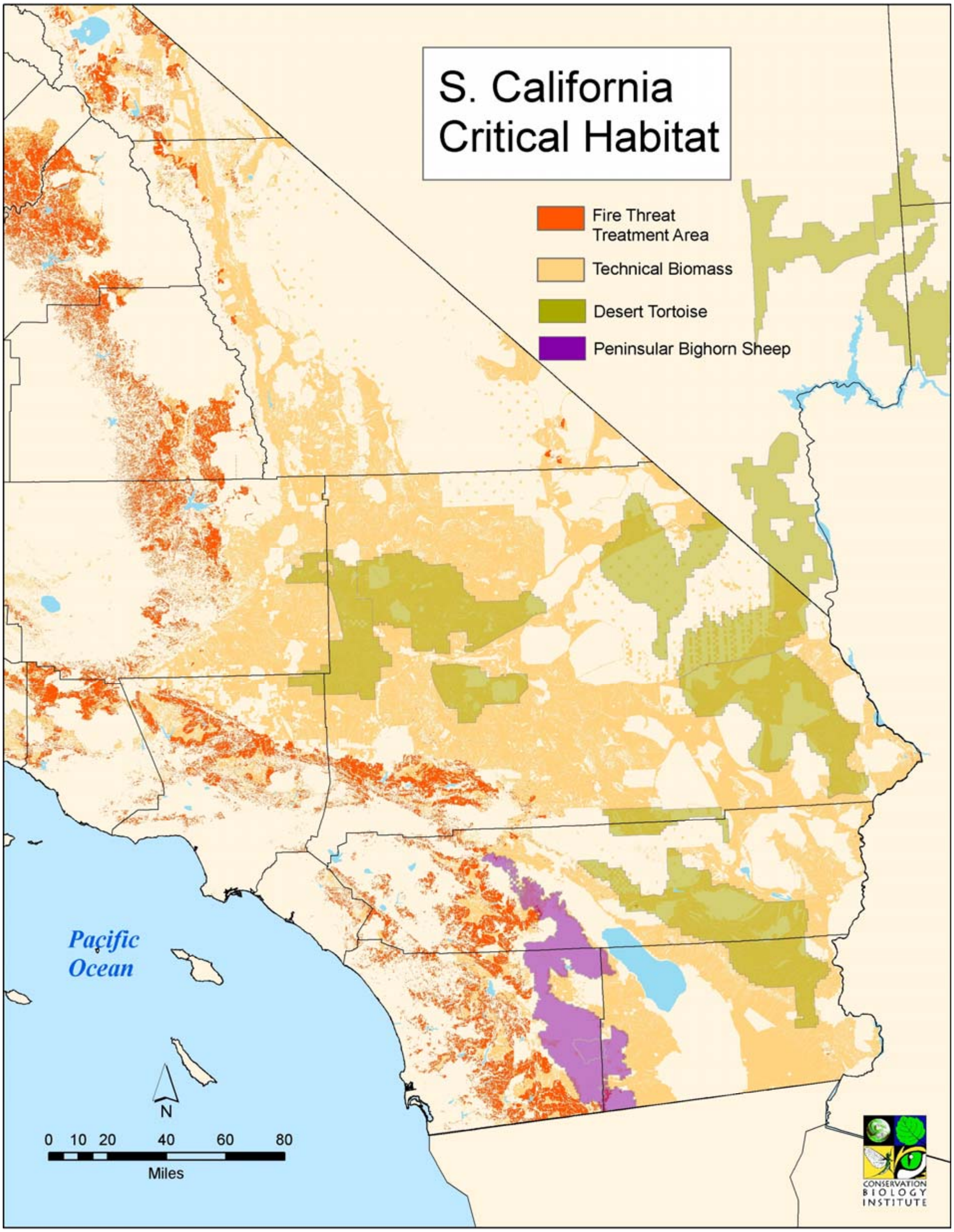


Figure 17. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with designated critical habitat for Peninsular bighorn sheep and desert tortoise by the USF&WS.

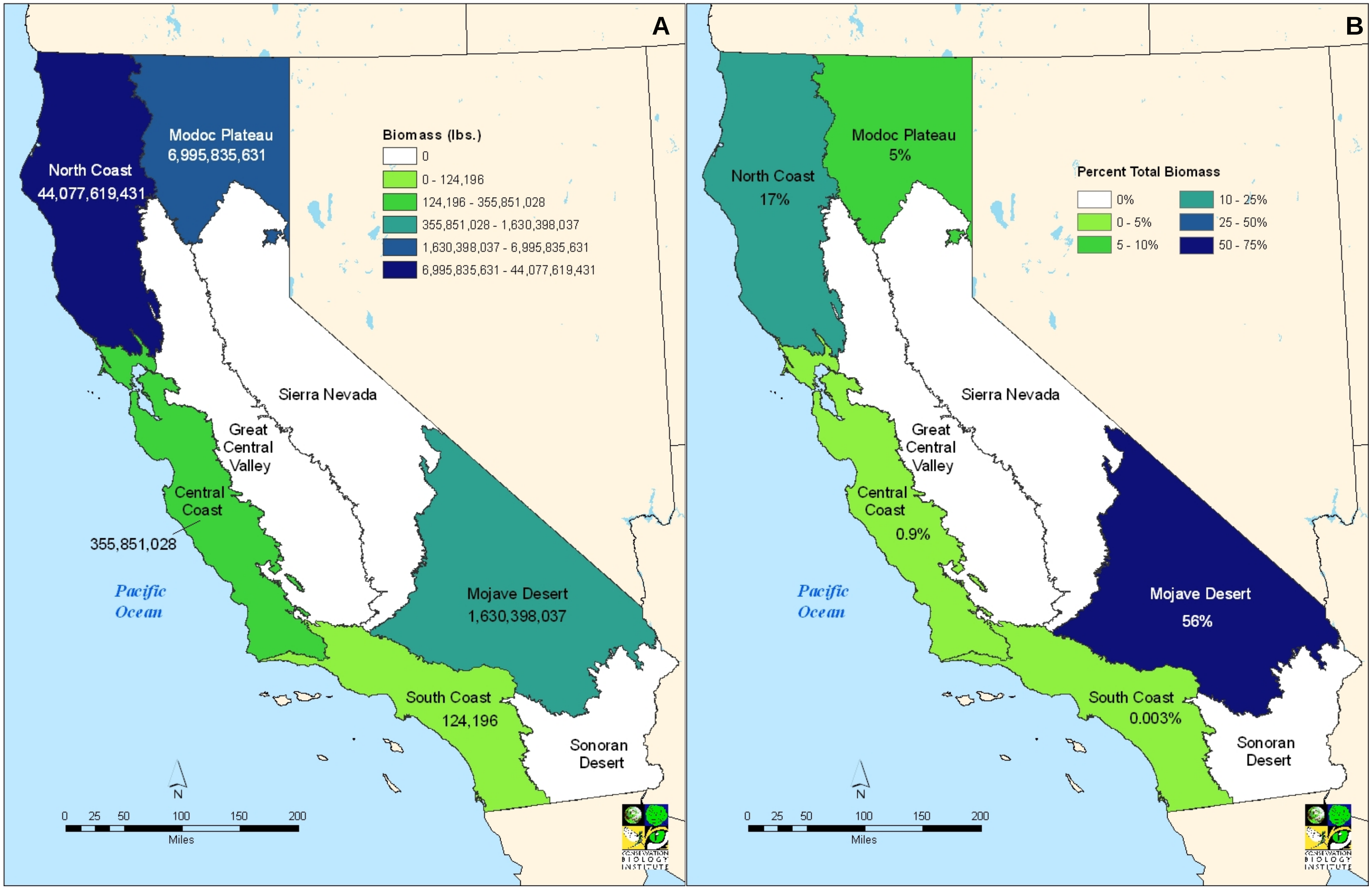


Figure 18. Technical non-merchantable forest biomass bone dry weight (pounds) within designated critical habitat (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.

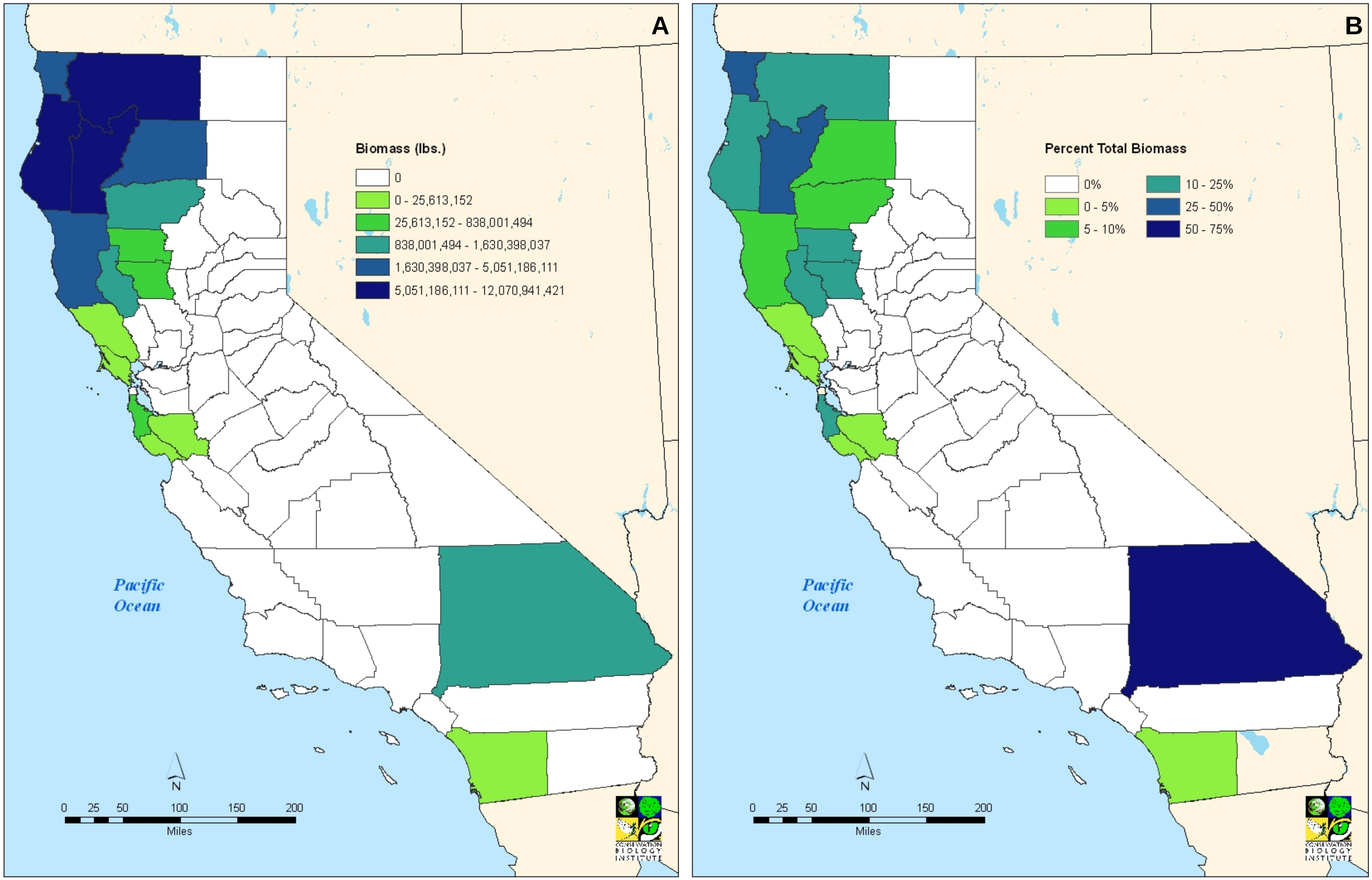


Figure 19. Technical non-merchantable forest biomass bone dry weight (pounds) within designated critical habitat (A) and percent of total technical non-merchantable forest biomass (B) by county.

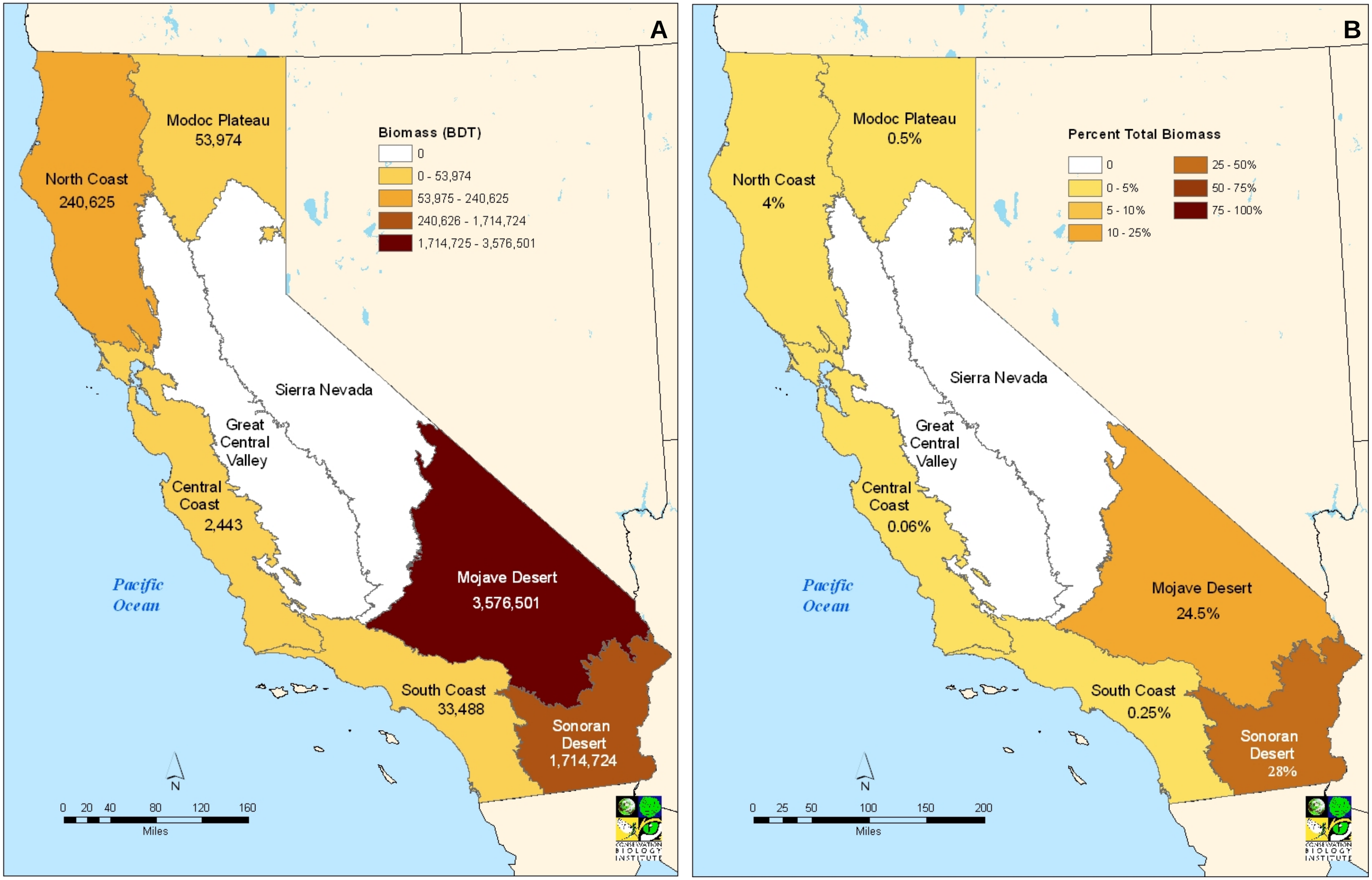


Figure 20. Technical shrubland biomass (bone dry tons) within mapped designated critical habitat (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.

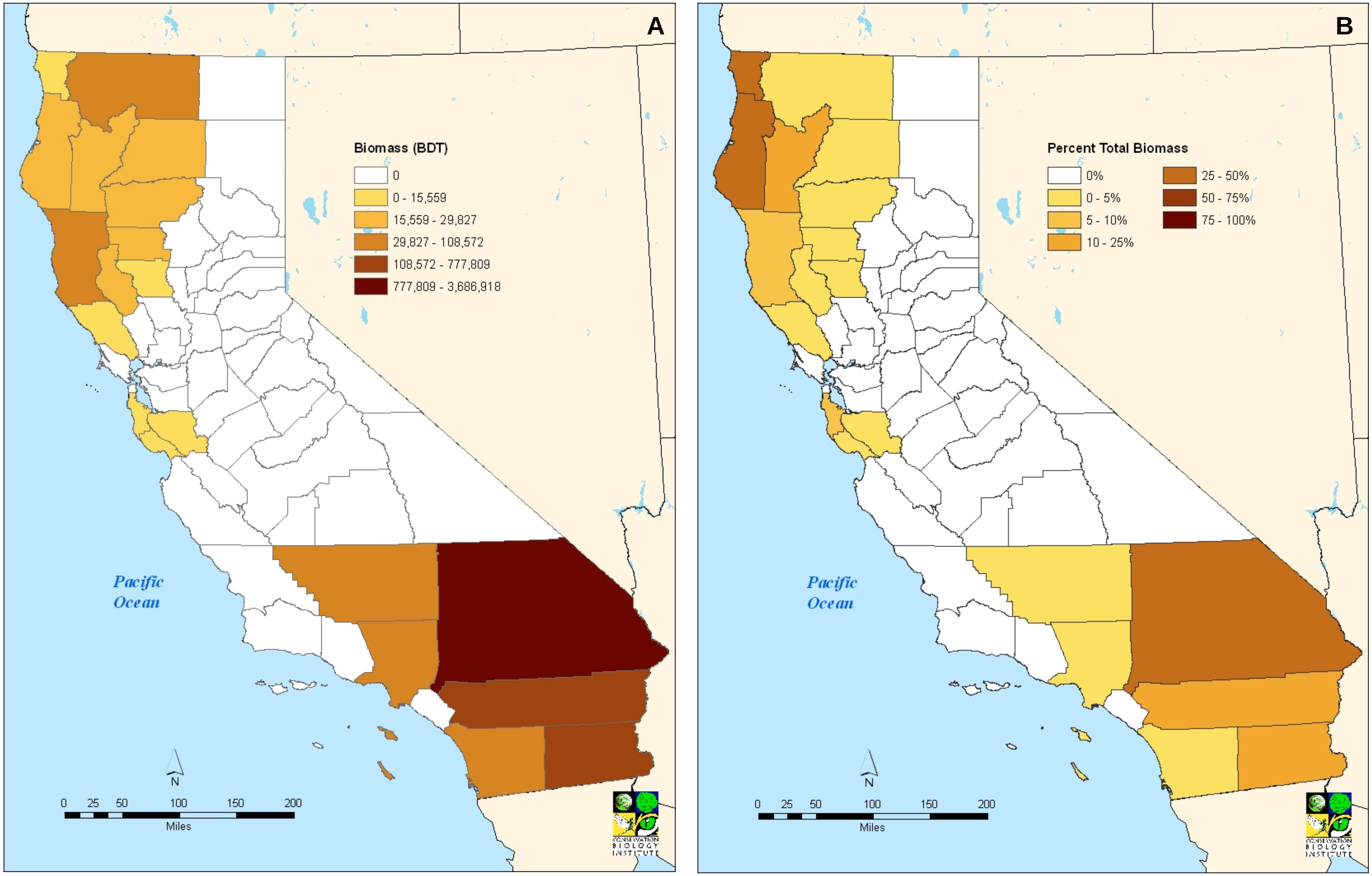
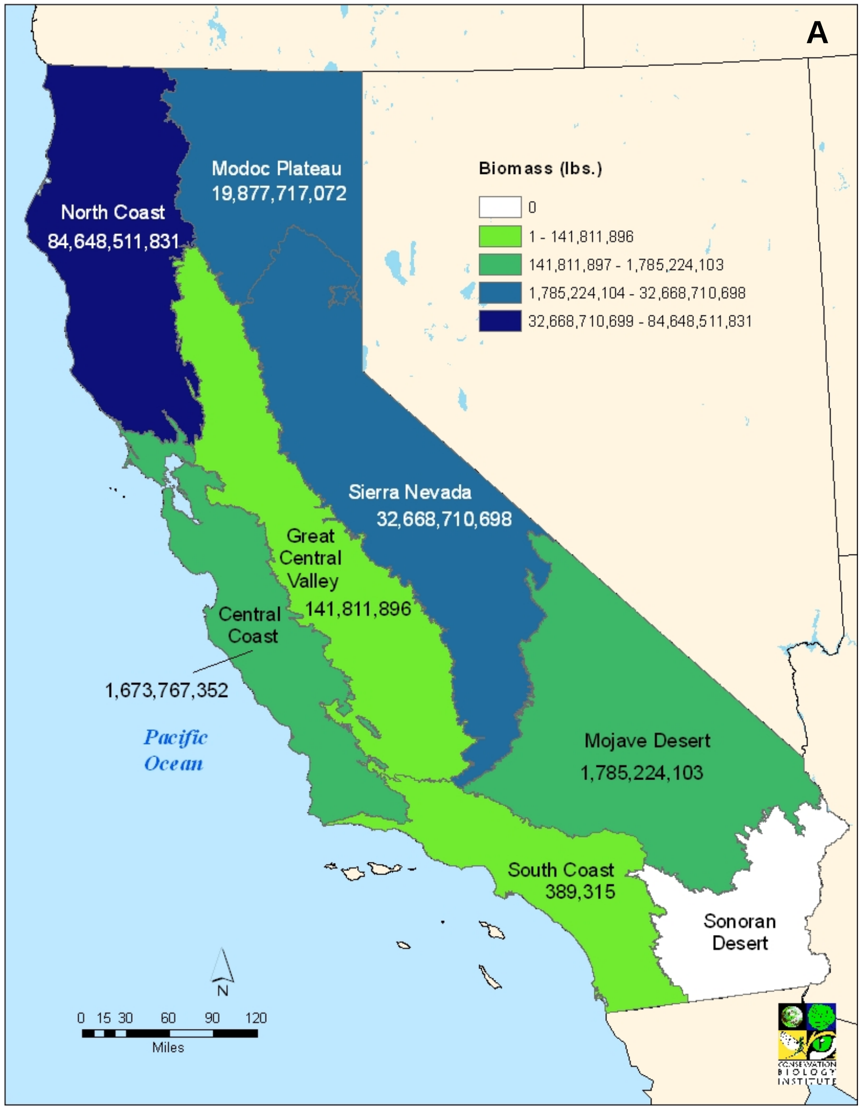


Figure 21. Technical shrubland biomass (bone dry tons) within mapped designated critical habitat (A) and percent of total technical shrubland biomass (B) by county.

Combined Ecological Constraints

Combining the previous values into a single composite screen resulted in the removal of 70.4 million BDT from the technical non-merchantable forest biomass estimates for California, which is nearly 21% of the state total estimate. At the ecoregion level, the largest amounts of forest biomass removed on these ecological grounds occurred in the North Coast, followed by the Sierra Nevada and Modoc Plateau (Figure 22A). Proportionally, the greatest impact occurred in the Mojave Desert (62%; Figure 22B), which can be somewhat misleading as the amount of forest biomass mapped in this ecoregion was extremely small compared to its size, and a large portion of that area overlapped with one or more of the ecological values examined. The more substantial reductions occurred in the North Coast, where there was a reduction in technical non-merchantable forest biomass of 32%, and the Sierra Nevada and the Modoc Plateau, both with 14% reductions. At the county level, the greatest reductions in available technical forest biomass was, not surprisingly, concentrated in the northwest region of the state (Figure 23A) with high proportional reductions located in this same region and along the Sierra Nevada (Figure 23B).

The technical shrubland biomass reduction as a result of combining all ecological values for the entire state was approximately 8.5 million BDT out of 62 million (or 14%) originally estimated for the state. At the ecoregion level, the Mojave and Sonoran Desert had the largest reductions in technical shrubland biomass amounts (Figure 24A). The Great Central Valley showed the largest percent reduction (66%), followed by the Mojave and Sonoran Deserts -- 39% and 34% respectively (Figure 24B). At the county level, the southern one-third of California showed the highest reductions, with San Bernardino leading all other counties. Counties in the northwest of the state also showed a concentration of reduced biomass availability (Figure 25A). A similar pattern was true for the percent reduction.



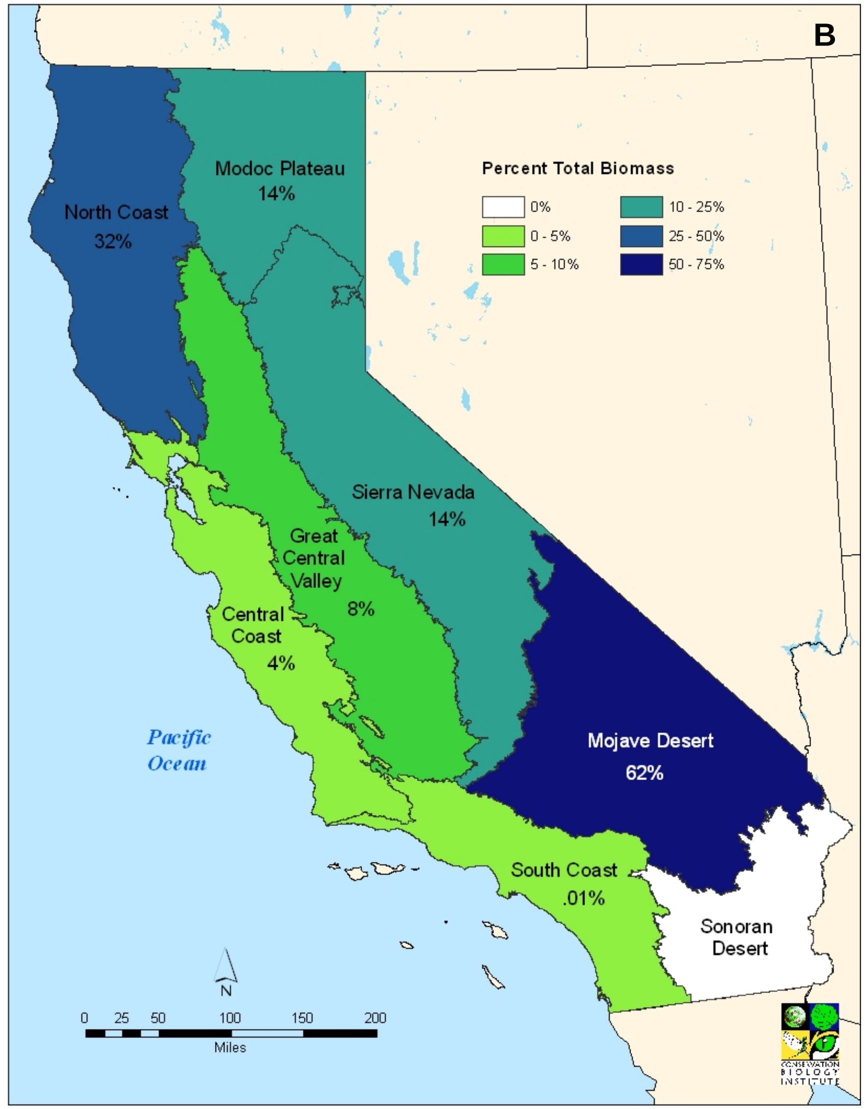


Figure 22. Technical non-merchantable forest biomass bone dry weight (pounds) within the combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.

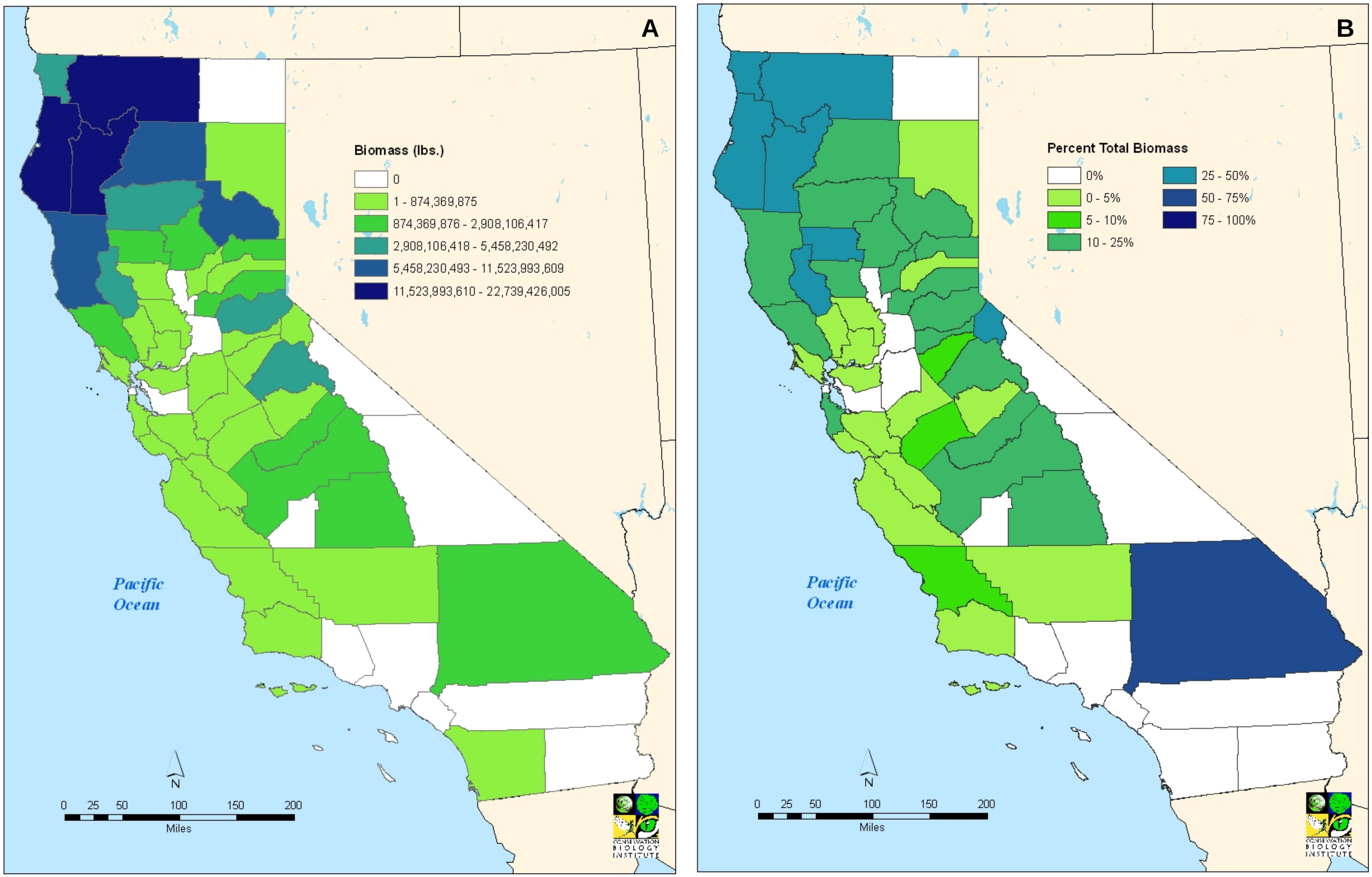


Figure 23. Technical non-merchantable forest biomass bone dry weight (pounds) within the combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by county.

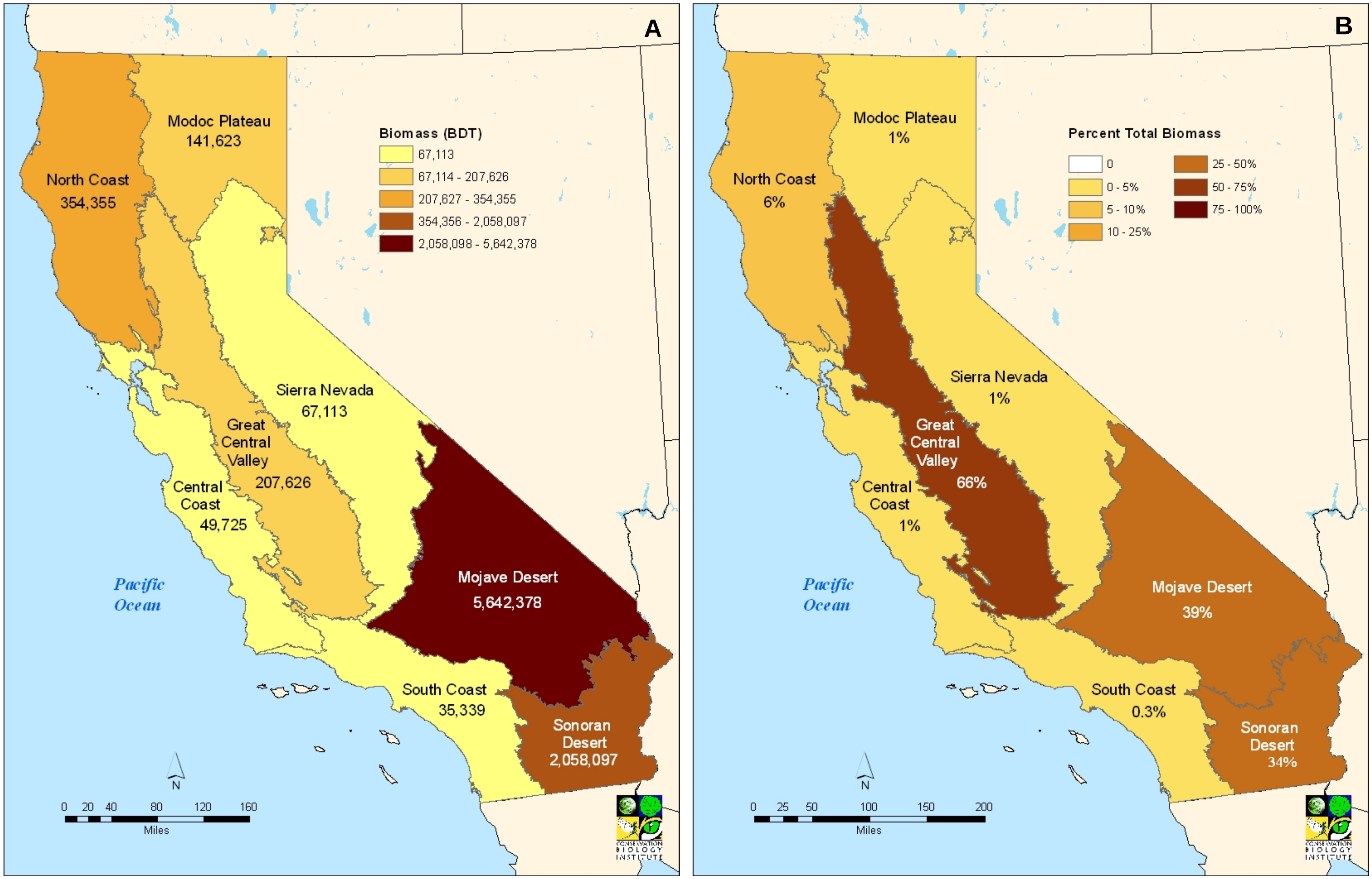


Figure 24. Technical shrubland biomass (bone dry tons) within combined ecological values (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.

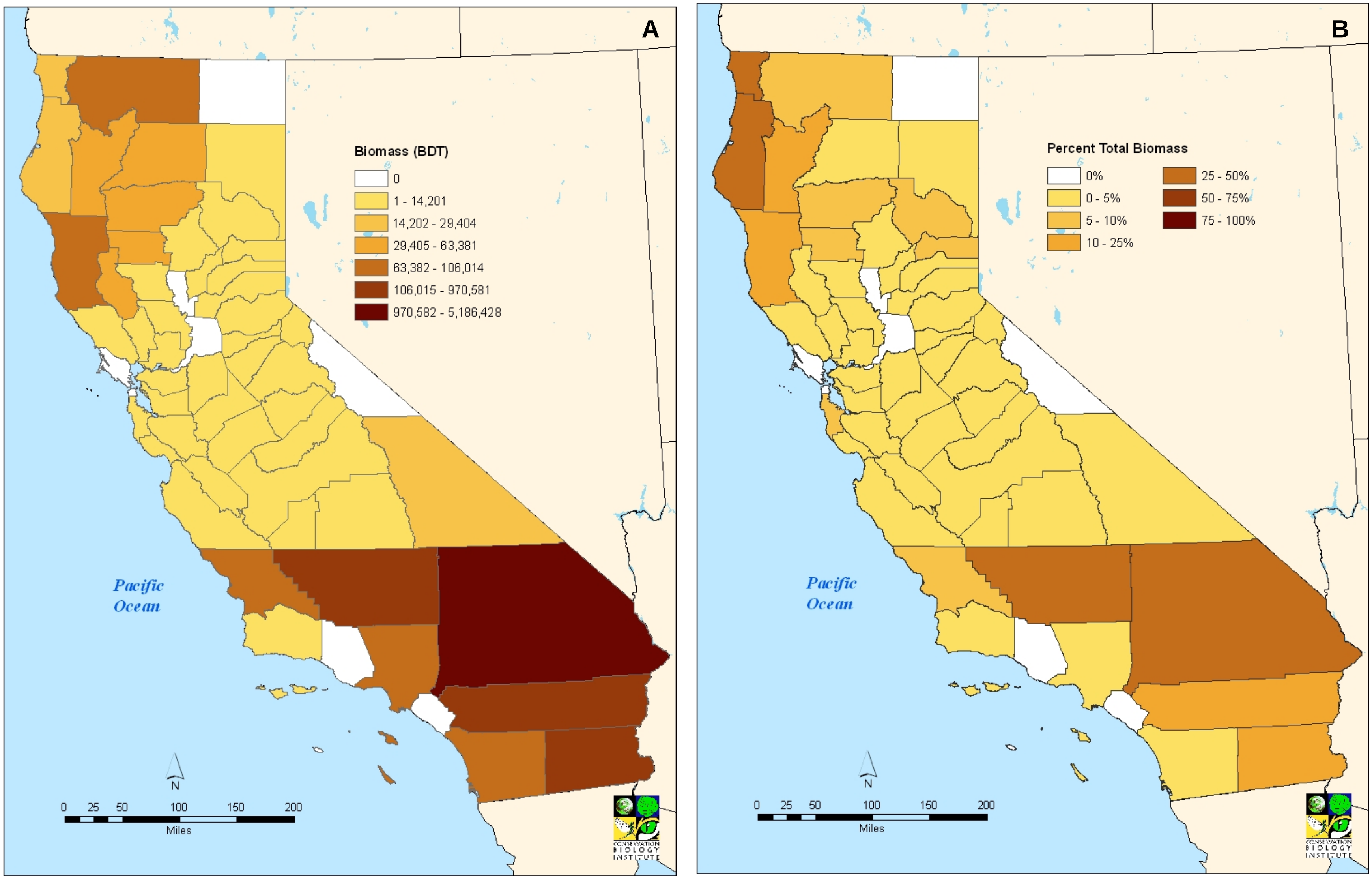


Figure 25. Technical shrubland biomass (bone dry tons) within combined ecological values (A) and percent of total technical shrubland biomass (B) by county.

Bureau of Land Management Lands

BLM lands cover approximately 15.2 million acres in California, mostly in the southeastern portion of the state and largely covered by non-forest vegetation (Figure 26). Technical non-merchantable forest biomass contained within BLM lands is nearly 9 million tons, or only 2.6% of statewide forest biomass. At the ecoregion level, the Sierra Nevada was affected the most, followed by the North Coast and the Modoc Plateau (Figure 27A). Proportionally however, this accounted for only 2-3% of the technical biomass in those ecoregions. The Mojave Desert (which supports little forestland) had the highest reduction proportionally, with a 73% of available forest biomass on BLM lands (Figure 27B). By county, Lassen, El Dorado, and San Bernardino showed the greatest reduction (Figure 28A) followed by several counties in the northern portion of the state. Proportionally, San Bernardino is the lone standout (Figure 28B).

The reduction in technical shrubland biomass, at 16.5 million tons, was nearly twice as great as the forest biomass reduction, and accounted for nearly 27% of statewide shrubland biomass totals. The Mojave Desert ecoregion showed the largest amounts of restricted shrubland biomass, at nearly 6 million tons, followed by the Sonoran Desert and the Modoc Plateau, which had 3.7 million and 3 million tons, respectively (Figure 29A). Proportionally, the Sonoran Desert had the greatest reduction, at 61%; the Mojave Desert had a 40% reduction, and the Modoc Plateau 28% (Figure 29B). At the county level, total biomass reductions were concentrated in the east and southeast portion of the state, particularly Lassen, Inyo, San Bernardino, Riverside and Imperial Counties (Figure 30A). Mono, Inyo, and Imperial Counties were affected the most proportionally with 50-75% reductions in each (Figure 30B).

USDA Forest Service Lands

Forest Service lands cover approximately 20 million acres in California (Figure 26). Removing all of these lands reduced the amount of available technical non-merchantable forest biomass by 153 million BDT (approximately 45% of the total statewide estimate).

At the ecoregion level, the Sierra Nevada had the greatest impact, followed by the North Coast and Modoc Plateau (Figure 31A). Percentage wise, removing Forest Service lands from the estimated technical non-merchantable forest biomass was greatest for the Sierra Nevada (61%) followed by the Modoc Plateau (49%) and North Coast (37%; Figure 31B). County results showed high overall technical non-merchantable forest biomass (Figure 32A) and high percent technical forest biomass (Figure 32B) reductions to be concentrated in the northern third of the state and along the eastern boundary.

Technical shrubland biomass reductions amounted to nearly 15 million BDT (24%). Reductions were highest in the South Coast and Modoc Plateau (Figure 33A) with the highest percent reductions observed in the South Coast ecoregion by nearly 50%, with other highly affected regions ranging from 25-35% (Figure 33B). Counties showing the greatest overall reductions were San Bernardino and Riverside Counties (Figure 34A) with the greatest percent reductions observed in Santa Barbara, Ventura, Tulare, and Del Norte counties (Figure 34B).

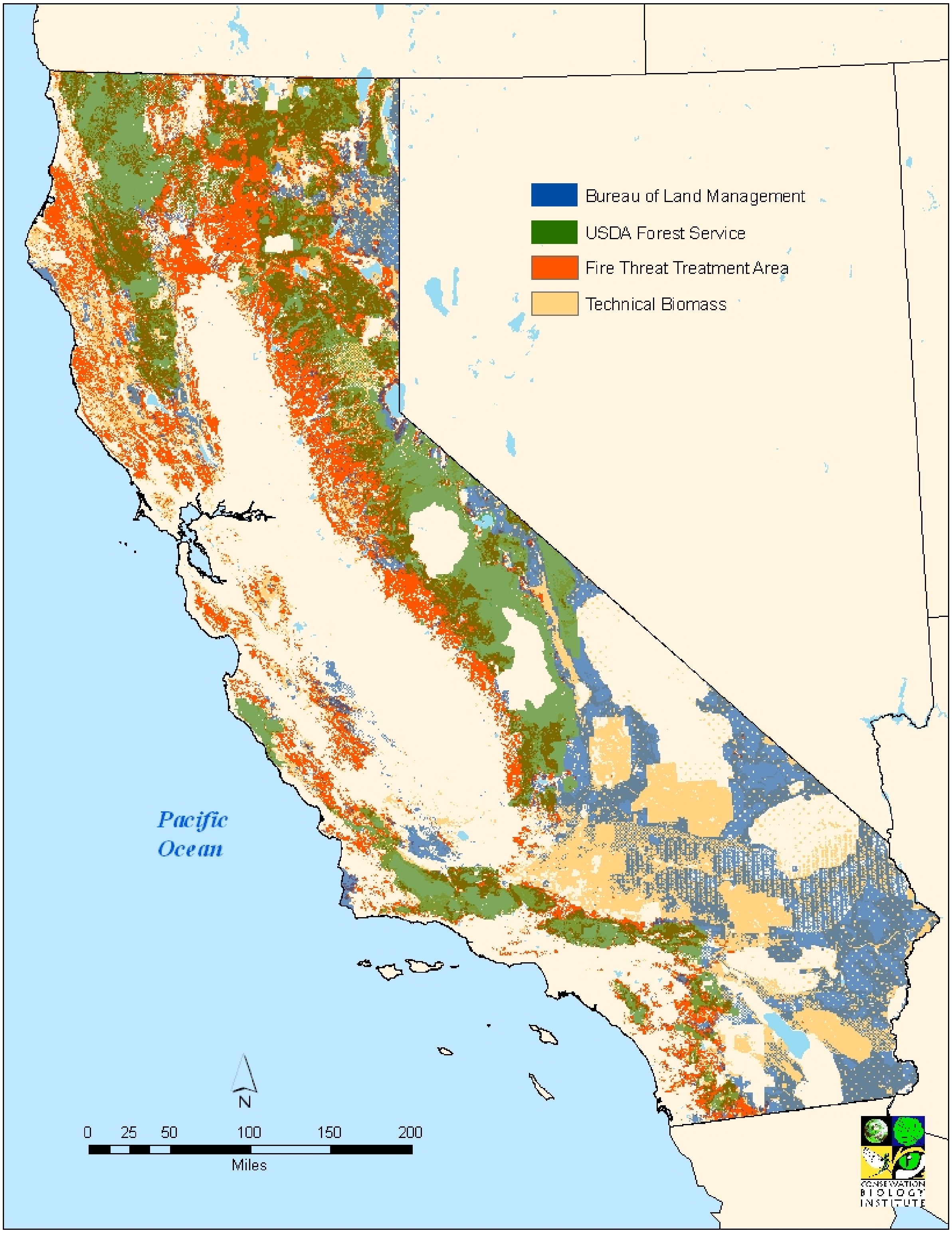


Figure 26. Technical non-merchantable and FTTA forest and shrubland biomass in California with USDA Forest Service and Bureau of Land Management lands.

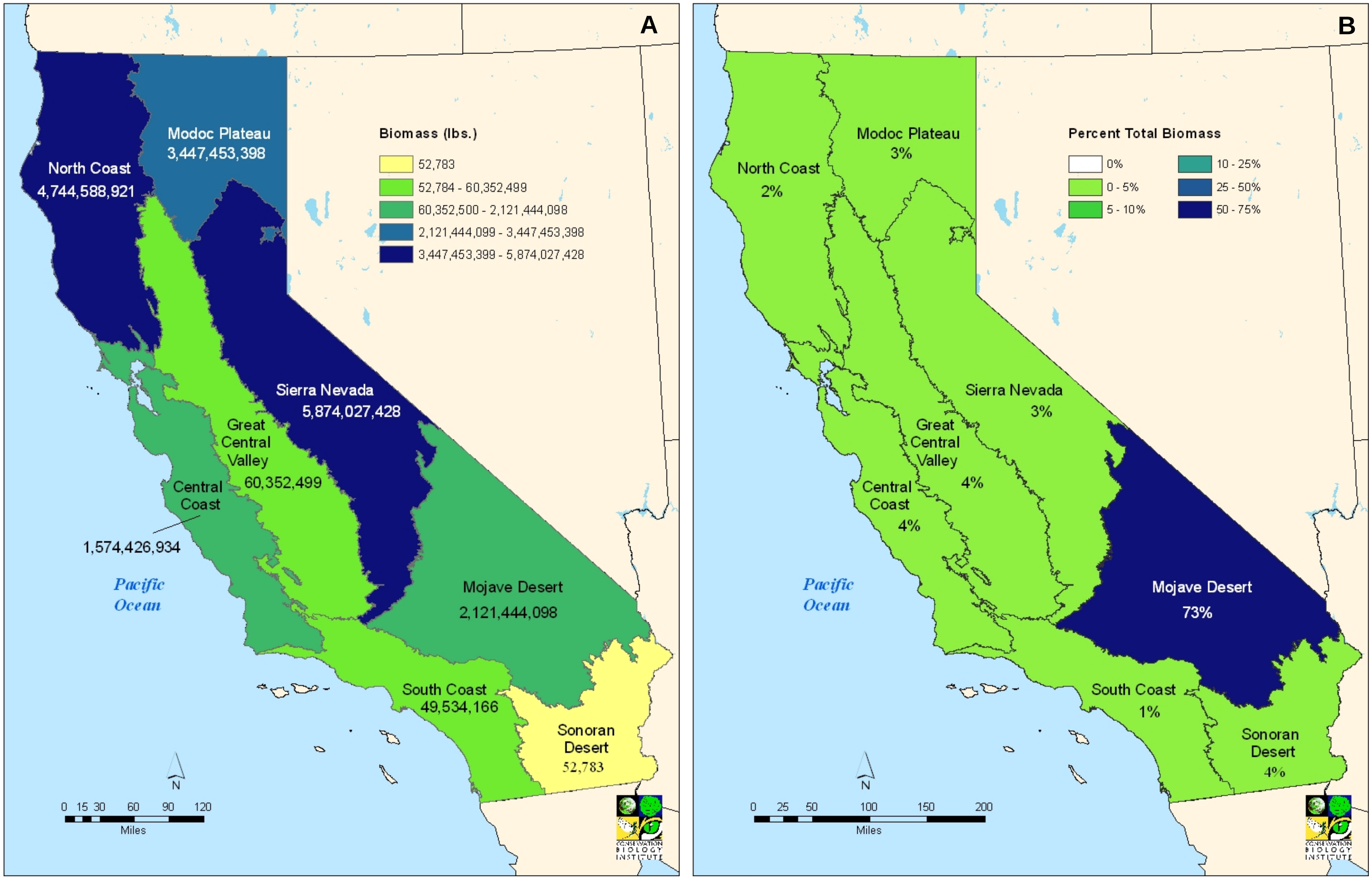


Figure 27. Technical non-merchantable forest biomass bone dry weight (pounds) within Bureau of Land Management lands (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.

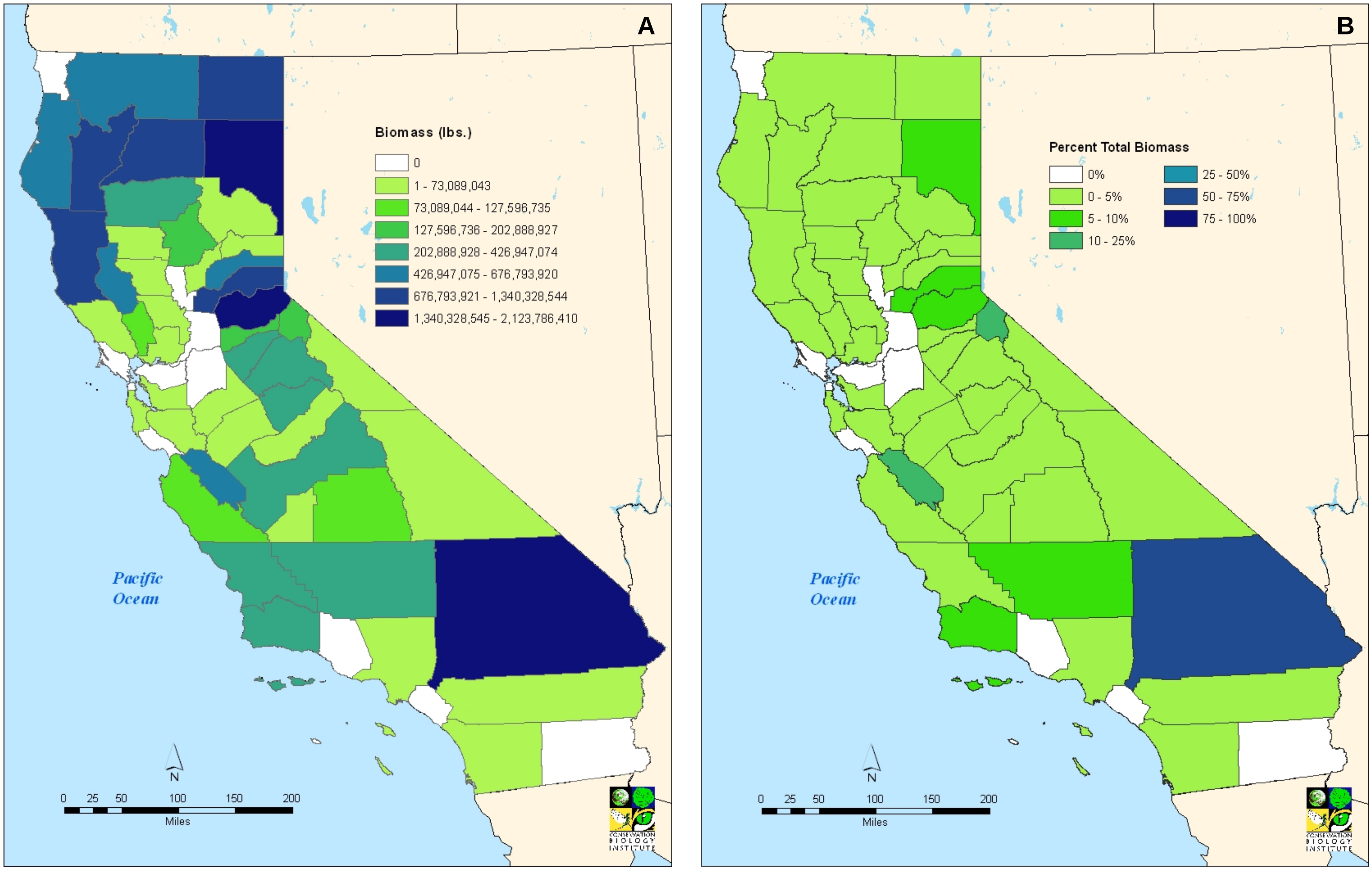


Figure 28. Technical non-merchantable forest biomass bone dry weight (pounds) within Bureau of Land Management lands (A) and percent of total technical non-merchantable forest biomass (B) by county.

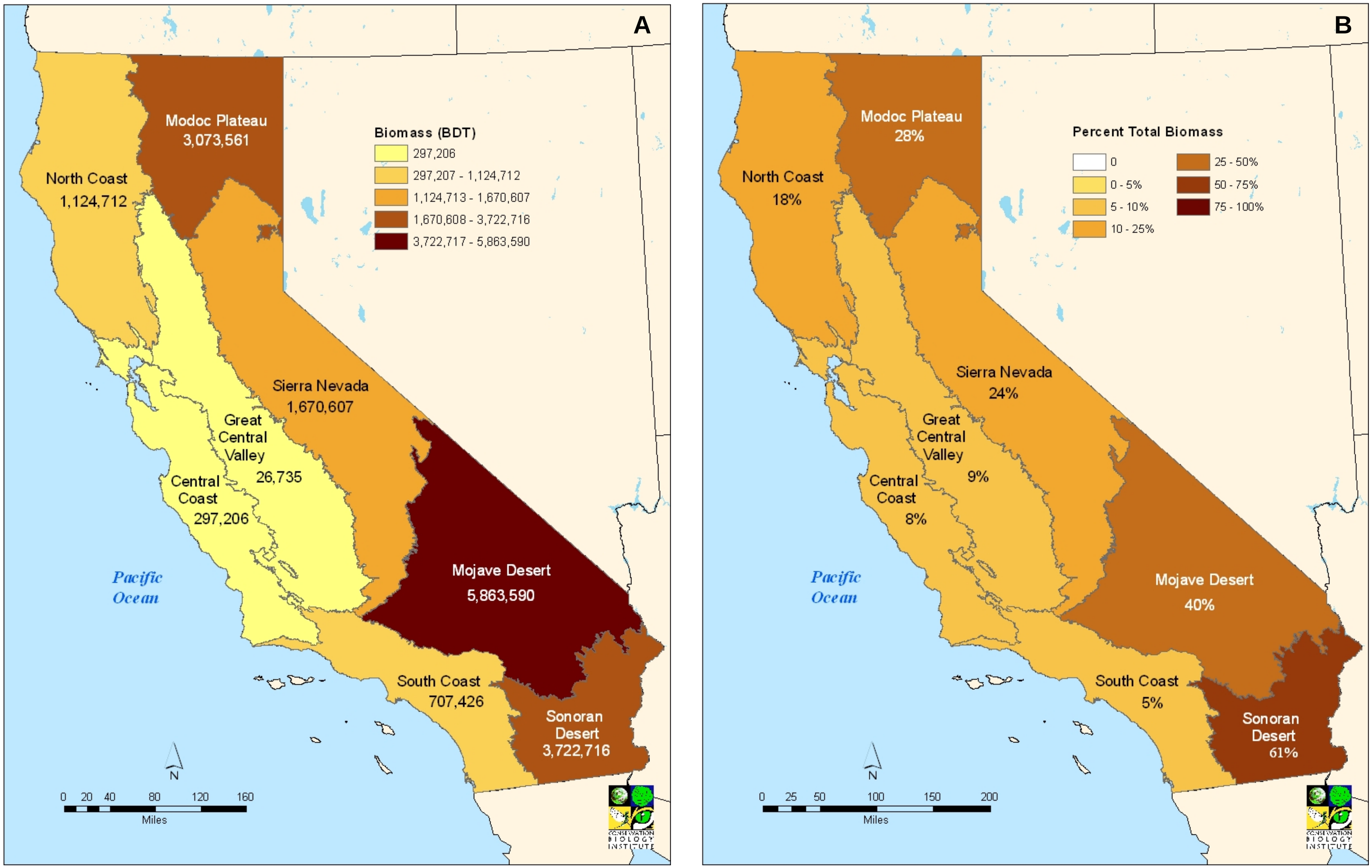


Figure 29. Technical shrubland biomass (bone dry tons) within Bureau of Land Management lands (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.

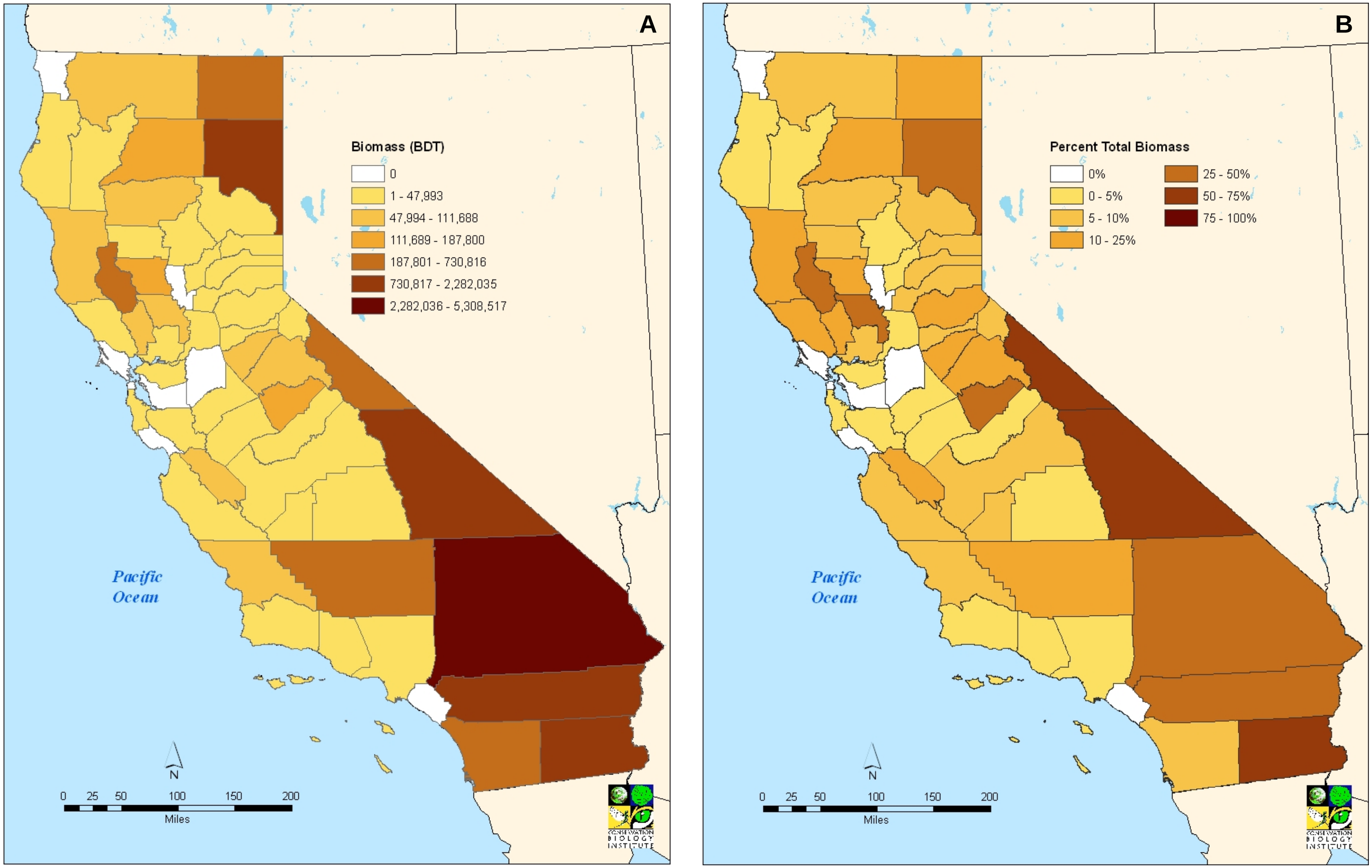


Figure 30. Technical shrubland biomass (bone dry tons) within Bureau of Land Management lands (A) and percent of total technical shrubland biomass (B) by county.

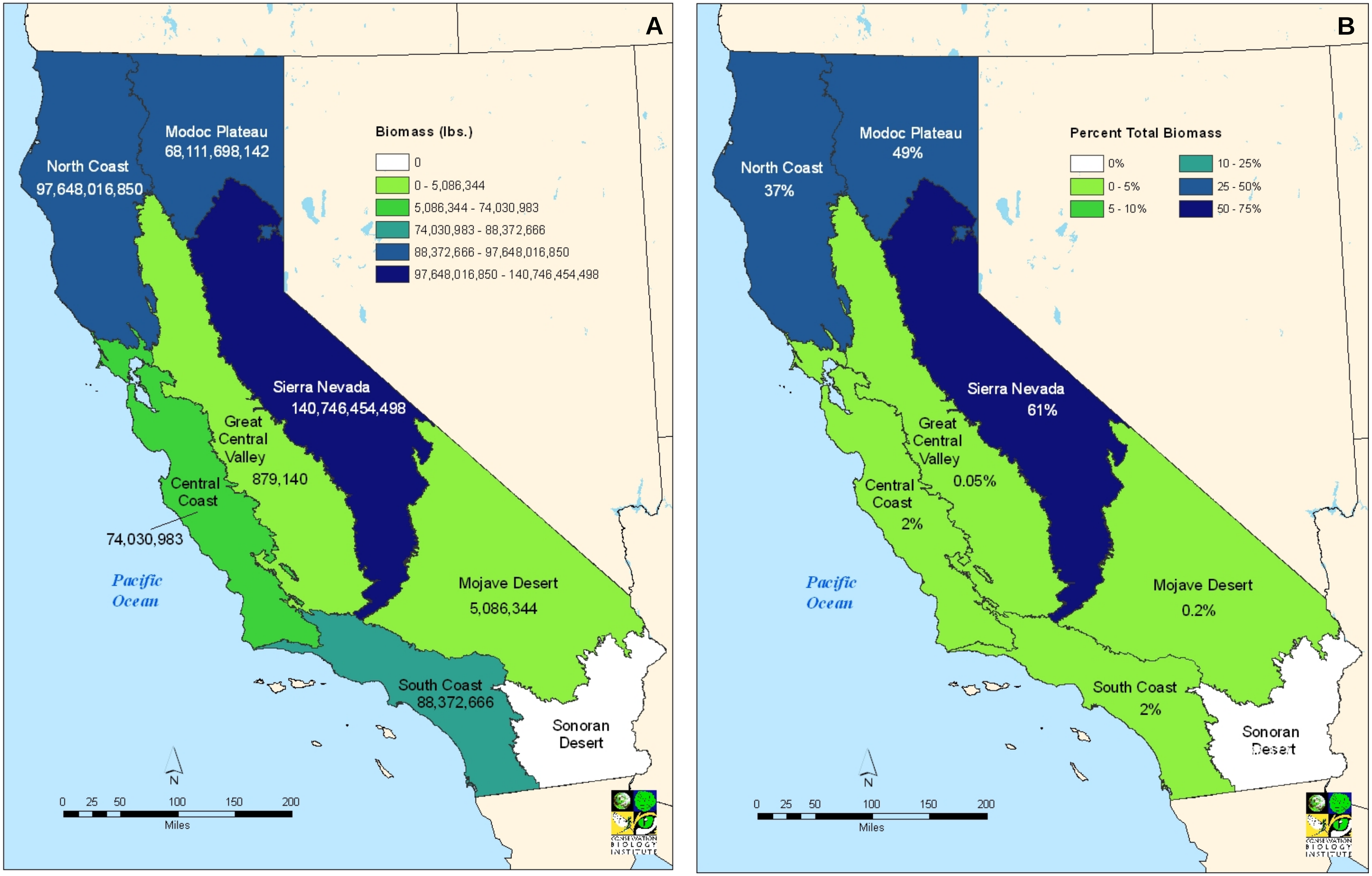


Figure 31. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service lands (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.

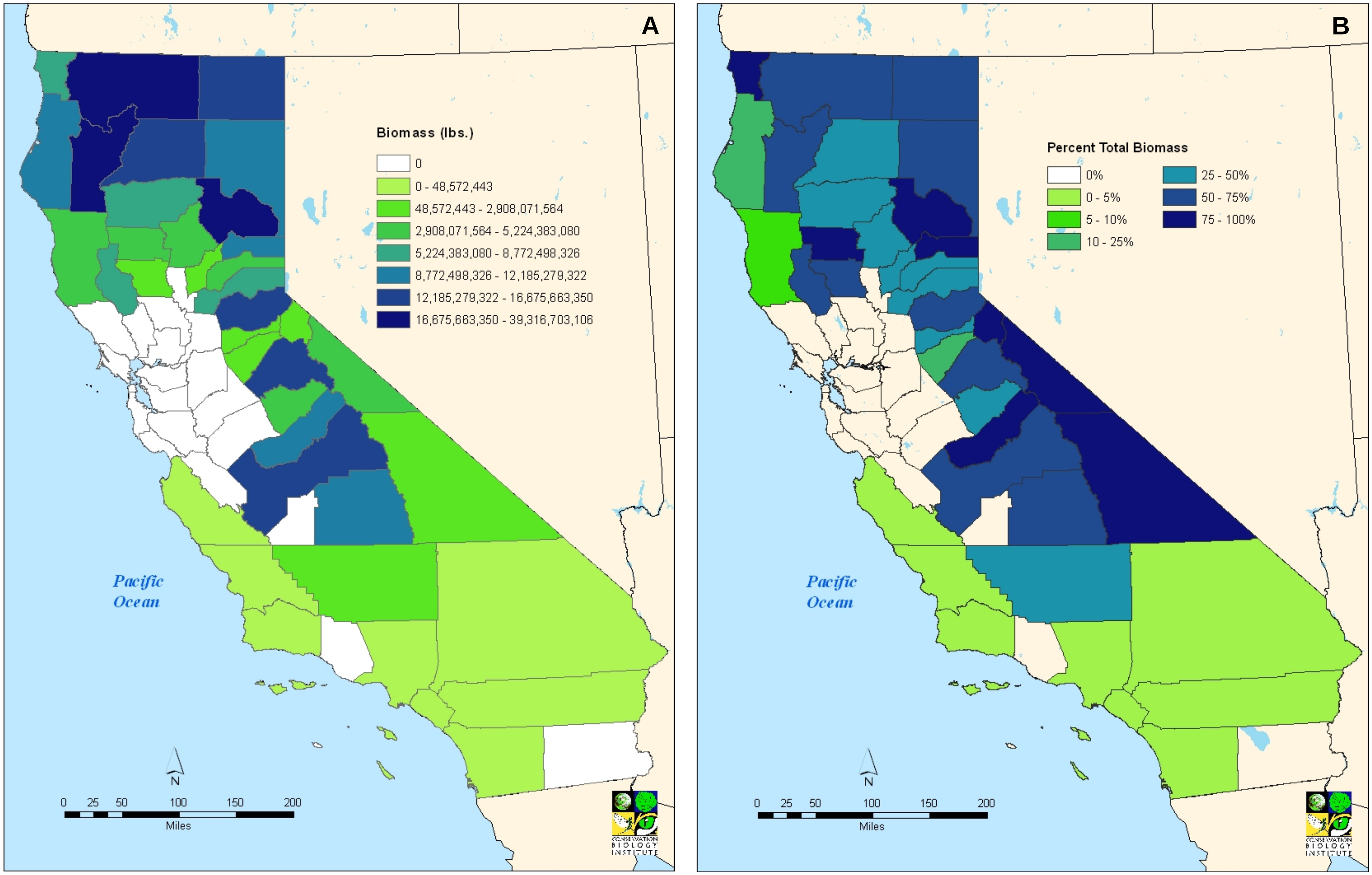


Figure 32. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service lands (A) and percent of total technical non-merchantable forest biomass (B) by county.

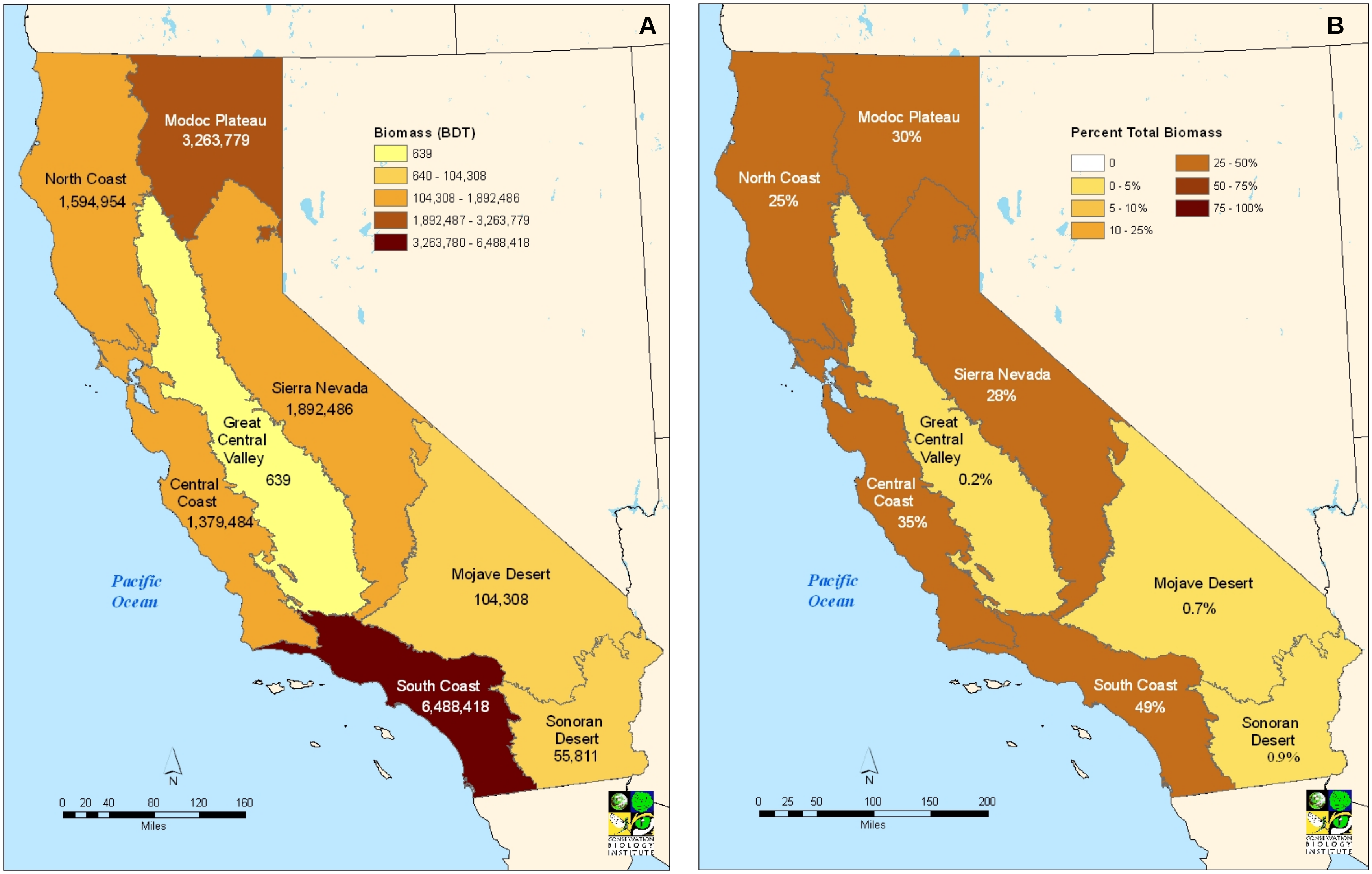
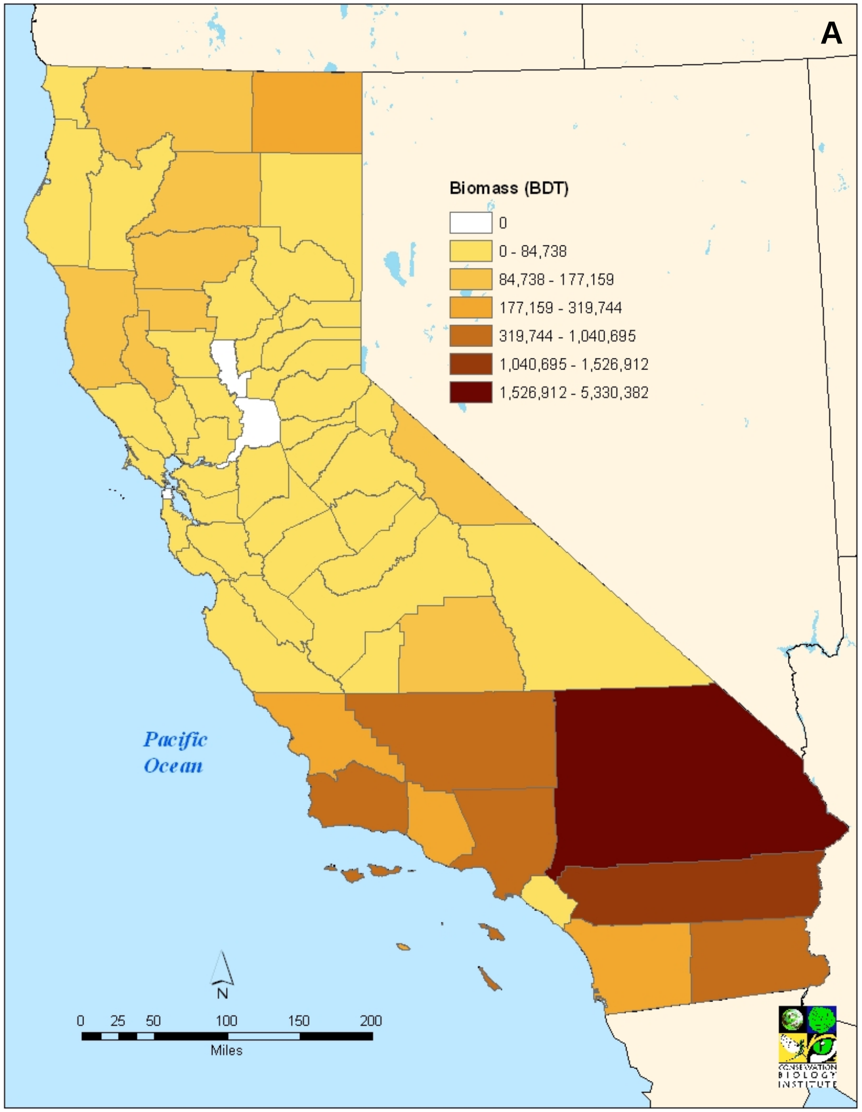


Figure 33. Technical shrubland biomass (bone dry tons) within USDA Forest Service lands (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.



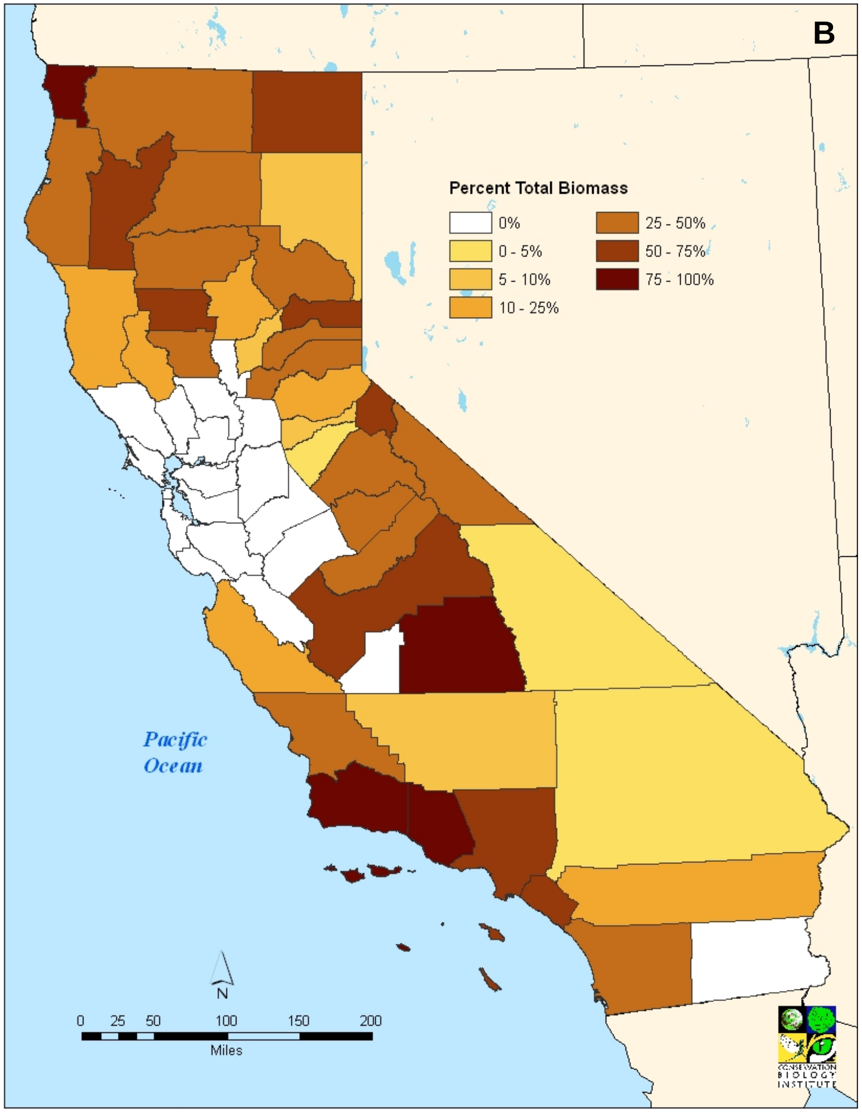


Figure 34. Technical shrubland biomass (bone dry tons) within USDA Forest Service lands (A) and percent of total technical shrubland biomass (B) by county.

Combined Ecological and Administrative Constraints

If the results from the combined ecological constraints are added to the USDA Forest Service and Bureau of Land Management lands, the resulting technical non-merchantable forest biomass amount is reduced by approximately 183 million BDT, or 54% of the original statewide estimate (Table 3). The WUI portion reclaims 5.5 million BDT (1.62%) resulting in a final reduction of 178 million BDT of technical non-merchantable forest biomass (~52%). That leaves approximately 48% of the original estimate available for biomass development.

The reductions were proportionally higher for the shrubland component, with over 35 million BDT removed from the total estimate (or 57%) when Forest Service lands, BLM lands, and other ecological values were combined (Table 4). Some of these lands were reclaimed when the WUI was factored back into the assessment. Nearly 6,000 BDT (0.93%) were placed back into the availability pool making the total technical shrubland biomass reduction of nearly 35 million BDT (56%).

At the ecoregion level, the greatest reductions in technical non-merchantable forest biomass for USDA Forest Service and Bureau of Land Management lands plus the combined ecological constraints was the Sierra Nevada and North Coast (Figure 35A) with greatest percentages observed for the Mojave Desert (84%) and the Sierra Nevada (64%) followed by the Modoc Plateau (57%) and finally the North Coast (51%; Figure 35B). Highest county reductions in overall technical non-merchantable forest biomass were observed in Siskiyou, Trinity, and Plumas (Figure 39A) with the highest percent reductions in Del Norte, Trinity, Plumas, Glenn, Sierra, Alpine, Mono, Inyo, San Bernardino and Madera counties (Figure 36B).

The greatest technical shrubland biomass reductions were observed in the Mojave Desert ecoregion followed closely by the South Coast and Modoc Plateau (Figure 37A). Ecoregions with the greatest percent reductions were the Sonoran Desert (75%) followed by the Great Central Valley (70%) and Mojave Desert (61%; Figure 37B). At the county level, San Bernardino showed the greatest reduction followed by Modoc, Lassen, Riverside, and Los Angeles counties (Figure 38A). Counties showing the highest percent reductions in technical shrubland biomass include Santa Barbara, Ventura, Tulare, Alpine, Mono, and Del Norte (Figure 38B).

Table 3. Summary table of statewide changes in available forest biomass totals (bone dry tons) as estimated by the California Energy Commission (CEC) after considering additional ecological constraints.

	Technically Available Biomass		FTTA Biomass			
	Non-Merchantable (BDT)	**% Total Non-Merchantable**	**Non-Merchantable (BDT)**	**% Total Non-Merchantable**	**Prescription Non-Merchantable (BDT)**	**% Total Prescription Non-Merchantable**
Statewide Total	340,416,978		256,979,284		60,153,299	
Focal Species	1,389,992	0.41	603,592	0.23	1,300	0.002
Critical Habitat	26,530,356	7.79	21,396,826	8.33	5,077,944	8.44
Old-Growth Forests	53,082,476	15.59	42,336,871	16.47	10,387,308	17.27
Combined Values	70,398,320	20.68	55,570,657	21.62	13,448,627	22.36
USDA Forest Service Lands	153,337,278	45.04	111,629,977	43.44	23,095,089	38.39
Bureau of Land Management Lands	8,936,066	2.63	5,746,350	2.24	1,269,255	2.11
Forest Service, BLM, and Combined Values	183,160,208	53.80	135,156,746	52.59	29,863,631	49.65
National WUI portion	5,499,257	1.62	4,610,284	1.79	1,144,751	1.90
Non-WUI portion	177,660,951	52.19	130,546,461	50.80	28,718,881	47.74
Available Biomass	**162,756,027**	**47.81**	**126,432,822**	**49.20**	**31,434,418**	**52.26**

Table 4. Summary table of statewide changes in available shrubland biomass totals (bone dry tons) as estimated by the California Energy Commission (CEC) after considering additional ecological constraints.

	Technically Available Shrubland Biomass	
	biomass (BDT)	**% total biomass**
Statewide Total	62,042,700	
Focal Species	6,200,227	9.99
Critical Habitat	5,622,202	9.06
Old-Growth Forests	297,779	0.48
Combined Values	8,556,503	13.79
USDA Forest Service Lands	14,779,881	23.82
Bureau of Land Management Lands	16,490,285	26.58
Forest Service, BLM, and Combined Values	35,372,250	57.01
National WUI portion	579,160	0.93
Non-WUI portion	34,793,090	56.08
Available Biomass	**27,249,610**	**43.92**

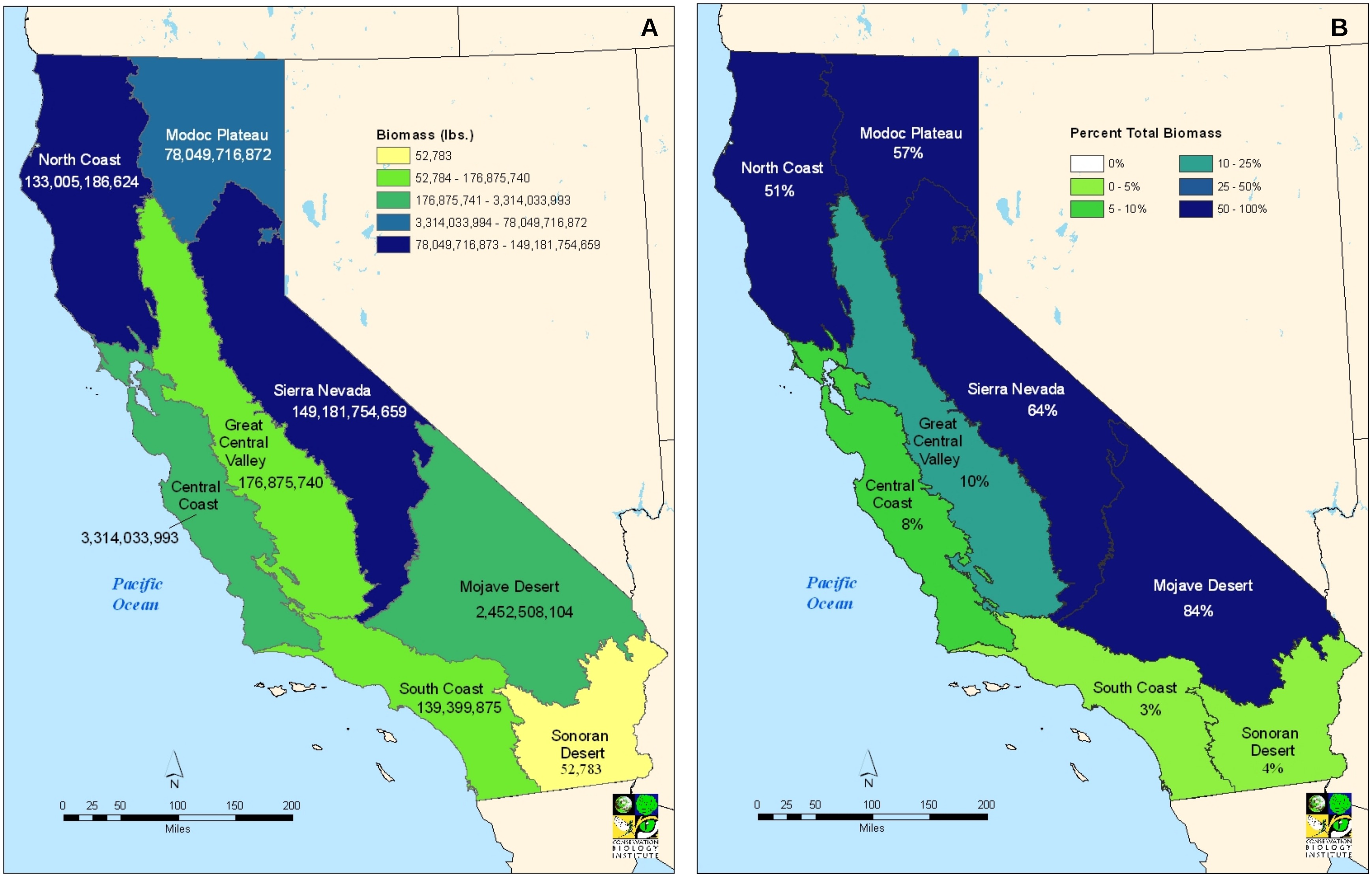


Figure 35. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by Jepson ecoregion.

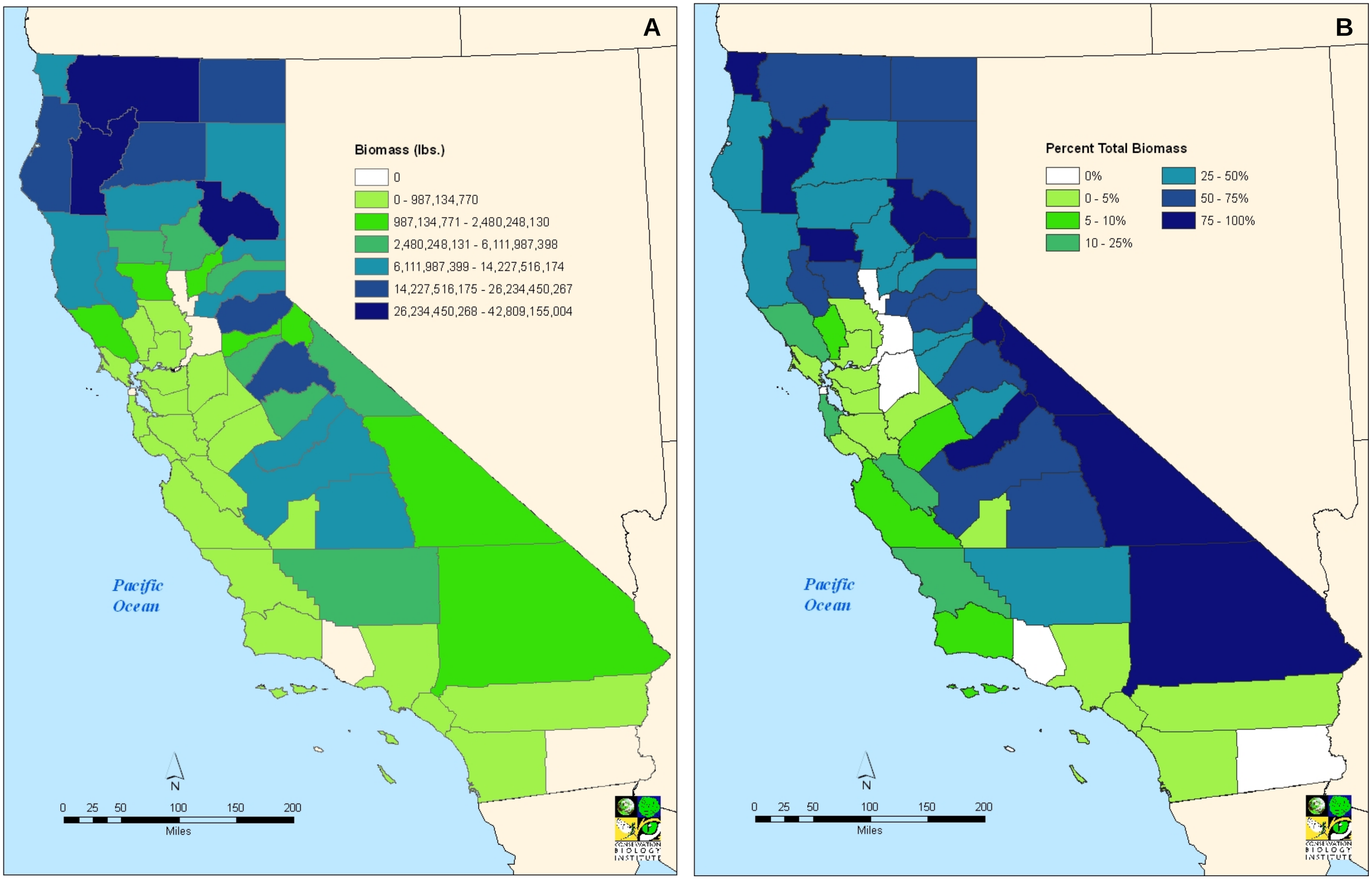


Figure 36. Technical non-merchantable forest biomass bone dry weight (pounds) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical non-merchantable forest biomass (B) by county.

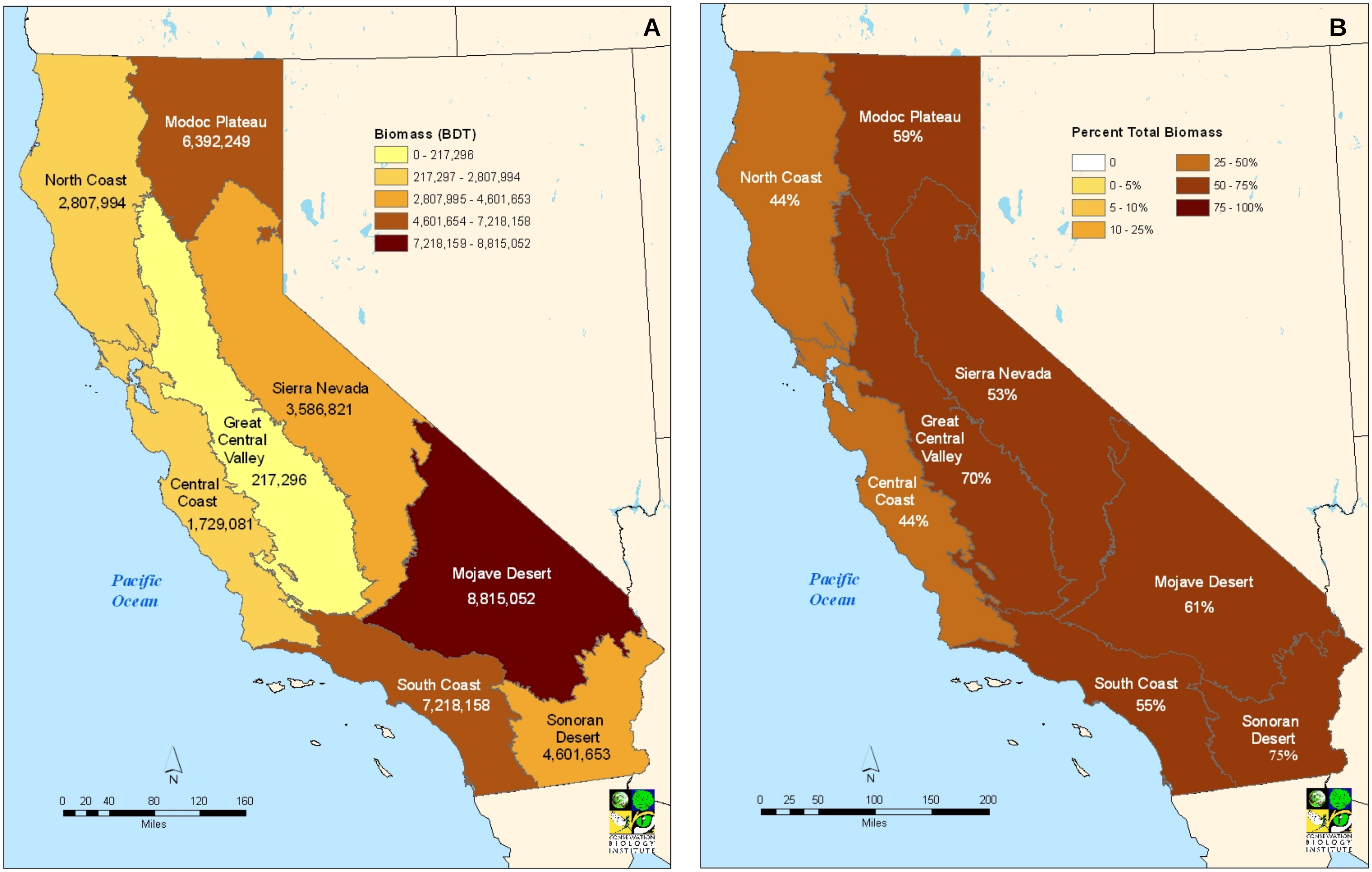


Figure 37. Technical shrubland biomass (bone dry tons) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical shrubland biomass (B) by Jepson ecoregion.

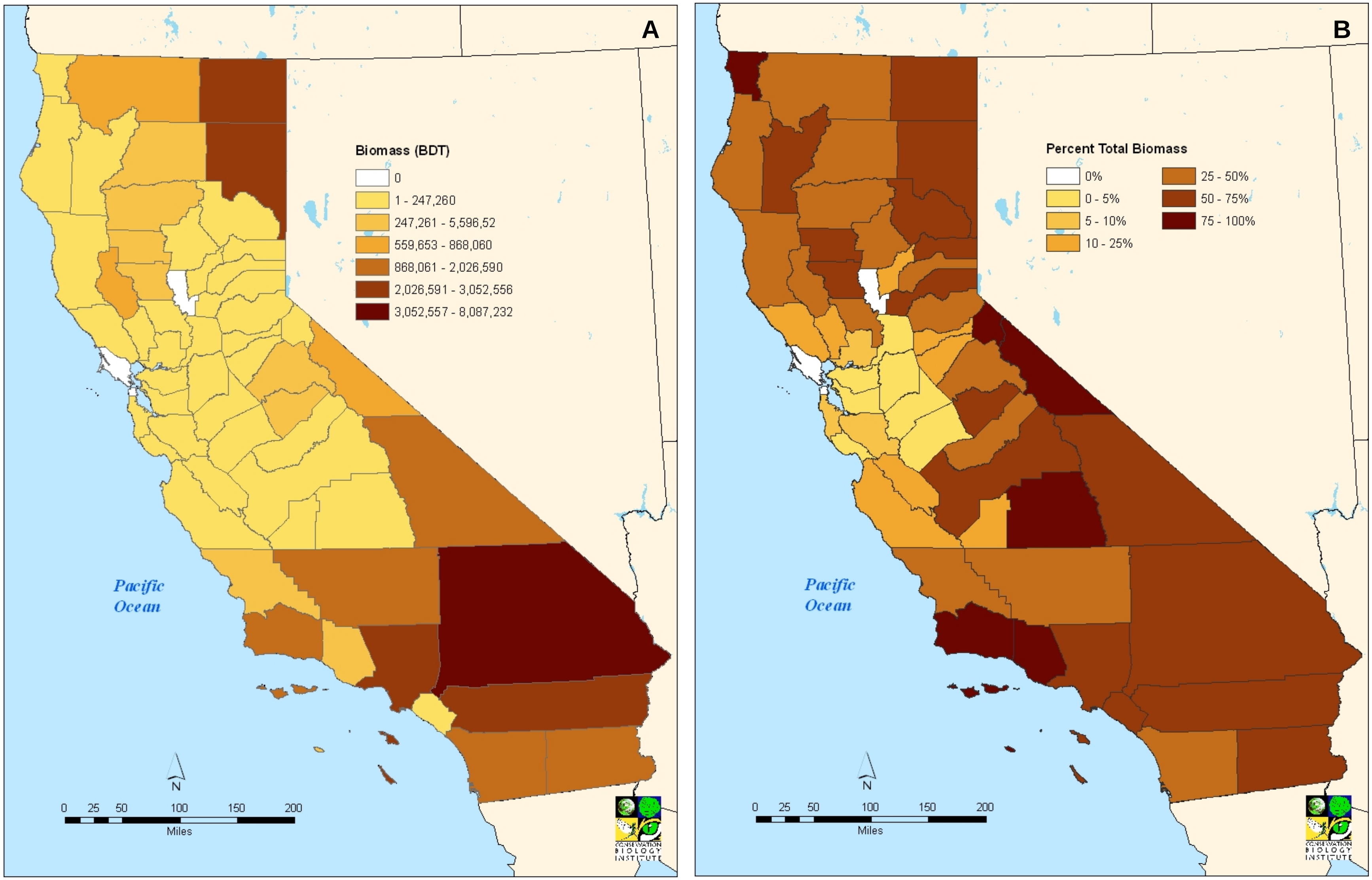


Figure 38. Technical shrubland biomass (bone dry tons) within USDA Forest Service and Bureau of Land Management lands with combined ecological values (A) and percent of total technical shrubland biomass (B) by county.

Other Considerations

We examined three other factors that could affect technical forest and shrubland biomass estimates, but these are much more difficult to show directly and pertain more to the impact of scale on state or regional estimates. For each of these considerations, they would need to be factored in regardless of whether one uses the California Department of Forestry and Fire Protection (CEC 2005) estimates or the reduced amounts presented in this report.

Natural Heritage

The first two pertain to known locations of rare and endangered species. First, we considered northern and California spotted owl records, which totaled 3,121 and 1,742 respectively (Figure 39). In the case of northern spotted owls, this additional criterion would have virtually no impact on biomass estimates, because most, if not all, would be located within designated critical habitat. Likewise, the majority of the California spotted owl sites are located on USDA Forest Service land and would already be accounted for if these lands are removed from biomass development (Figure 40 A&B).

Over 39,000 individual natural heritage records (G1/G2 or S1/S2) occurred throughout California using the most recent Natural Heritage database (Figure 41). The ecoregion with the highest number of records was the Great Central Valley (n=8,715) followed closely by the South Coast (n=8,201). Central Coast was third with 6,576 occurrences, followed by the North Coast and Sierra Nevada, which both had roughly 4,750 records (Figure 42A). The highest numbers of records per county were concentrated in the southern third of the state where the larger counties are located. Top counties included Kern, San Bernardino, Riverside and San Diego (Figure 42B).

These records signify where rare plant and animal species have been recorded, but the records do not represent a complete inventory of the distribution of any species. Biomass development plans would need to evaluate the likely presence and impacts on these species and their habitats, which cannot be done simply using natural heritage records. Occupied habitat areas would need to be largely avoided by any biomass development plan, which could represent a significant constraint that is impossible to quantify with existing data. The amount of overall area affected may be quite small compared to the other values examined in this study, but protection of these species should not be lost when planning for such a widespread resource plan. In some cases, as demonstrated under the focal species section in this report, critical habitat should be mapped and excluded from technical biomass estimates. As data become available, critical habitat for other species should be included as part of ongoing biomass development planning.

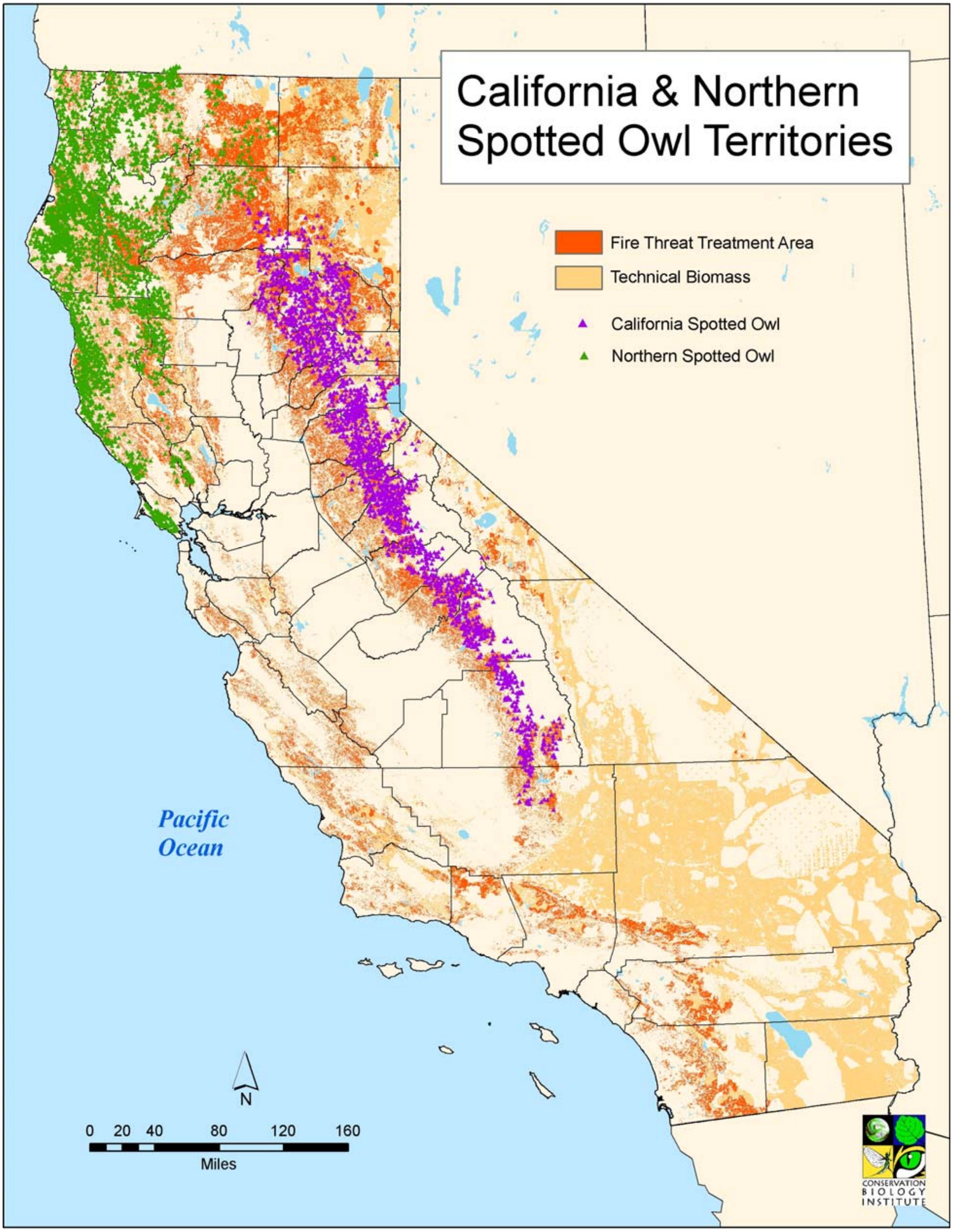


Figure 39. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with recorded occurrences of northern and California spotted owls.

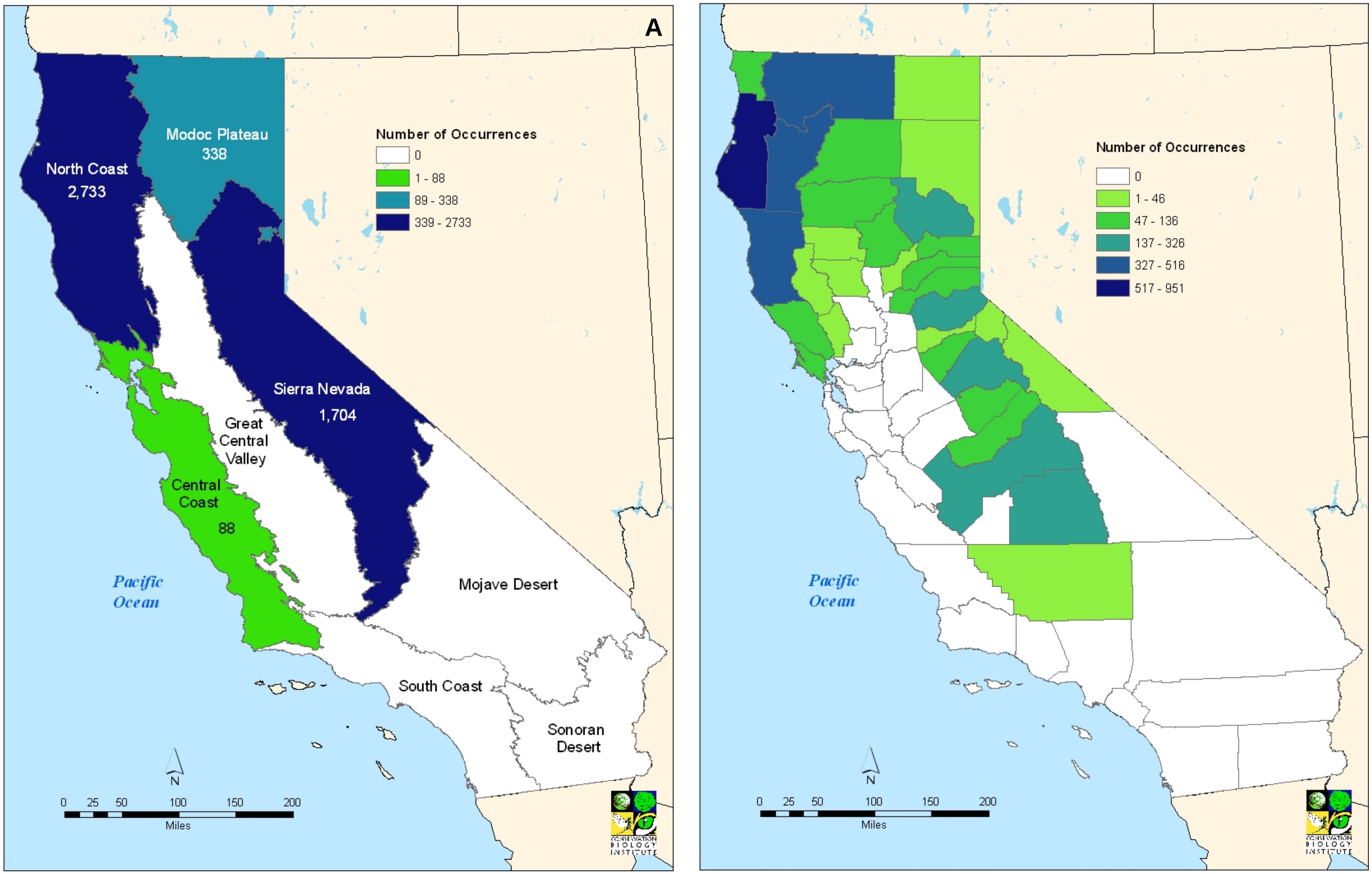


Figure 40. Count of recorded northern and California spotted owl occurrences by Jepson ecoregion (A) and by county (B).

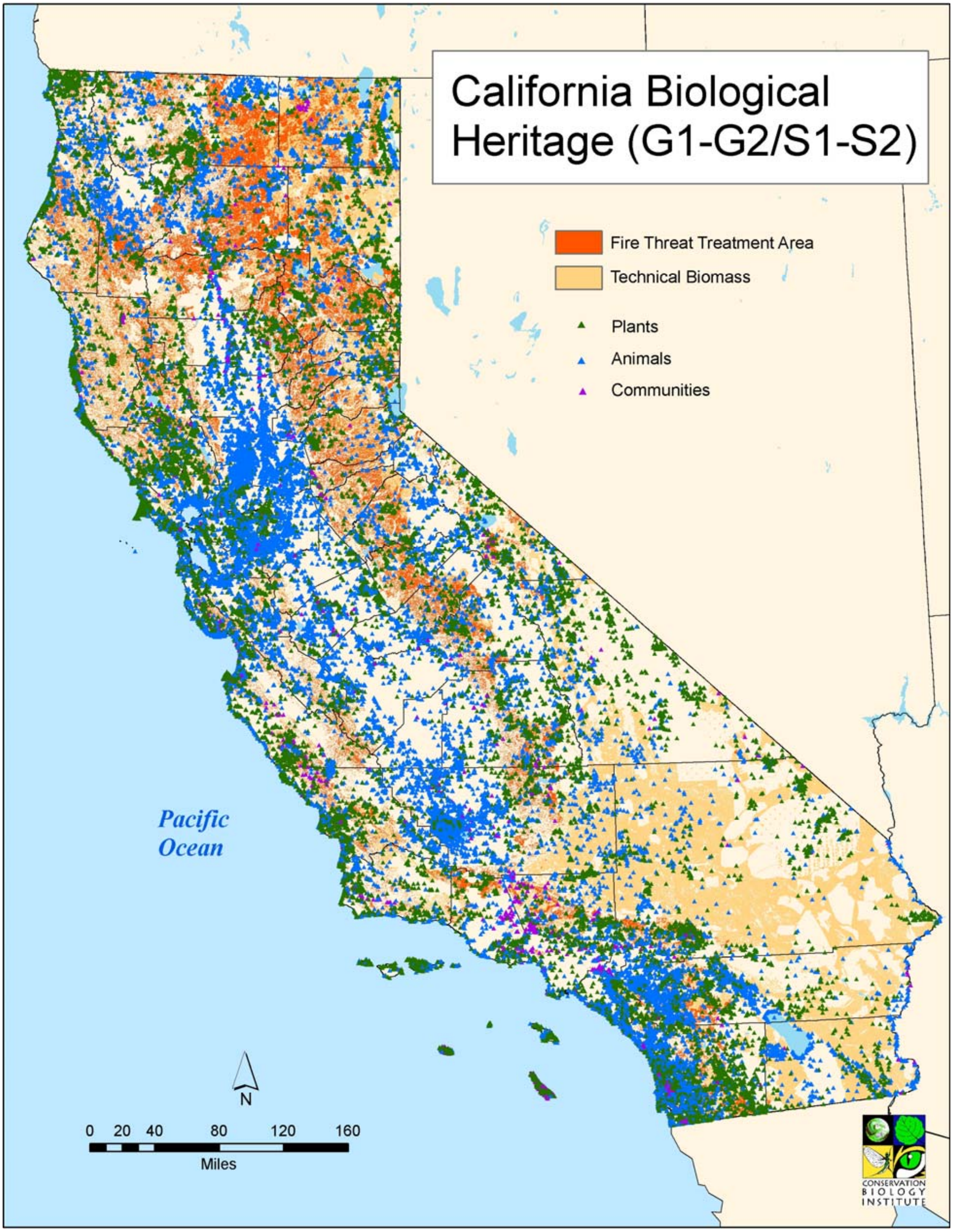


Figure 41. Technical non-merchantable and FTTA forest and technical shrubland biomass in California with recorded occurrences of G1/G2 and S1/S2 species.

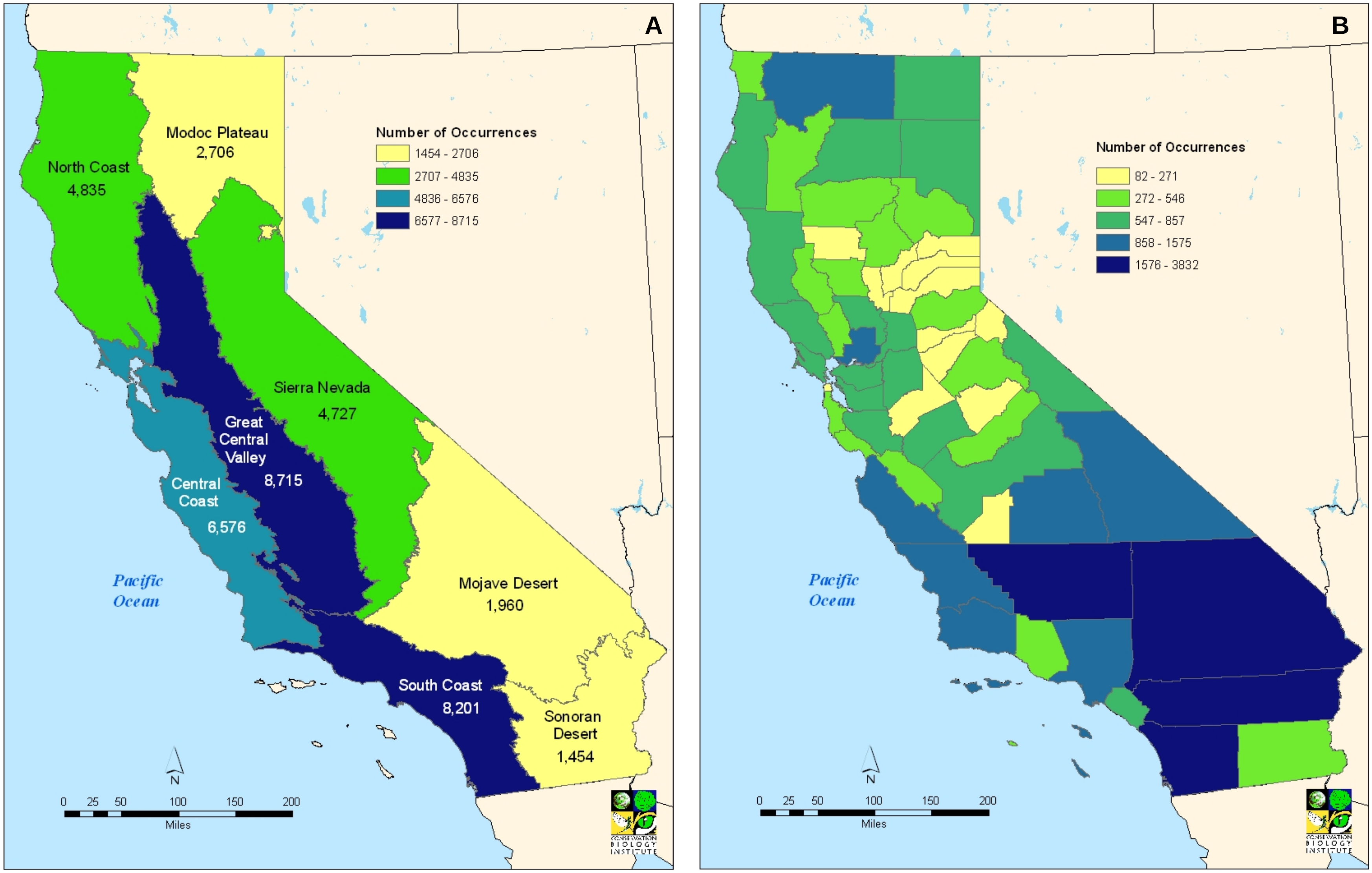


Figure 42. Count of recorded G1/G2 and S1/S2 occurrences by Jepson ecoregion (A) and by county (B).

Riparian Reserves

The method of calculating riparian reserves could potentially have a much larger affect on the state biomass estimate. Precise buffer distances were used in the exclusion of riparian areas in the process carried out by the California Department of Forestry and Fire Protection (CEC 2005) analysis, and the only statewide hydrology theme available was at 1:100,000 spatial scale. This is common in projects that cover large extents and especially when it comes to stream buffers, but it can lead to much lower estimates since the scale of implementation is finer, and therefore more detailed, than the scale used in making the estimates. For example, riparian reserve estimates, based on medium-scale data, used for the Northwest Forest Plan were found to be too low compared to the finer scale of implementation, causing considerable consternation for many trying to implement the plan.

Our hydrologic scale sampling showed the same pattern as observed in the Northwest Forest Plan, which also included a portion of northern California. We sampled hydrologic datasets at a 1:24,000-scale within three national forests in each of the three main forested ecoregions. These three forests were the Mendocino (North Coast), Lassen (Modoc Plateau), and the Eldorado (Sierra Nevada; Figure 43). The results showed a wide range of differences between the 1:24,000 and 1:100,000 scale hydrology data. This is partly due to differences in mapping standards used by each forest. More importantly, it shows real and important differences in the physical drainages based on the variability of geology and terrain between ecoregions (Figure 44). All regions showed considerably more area identified by the 1:24,000-scale analysis versus the 1:100,000-scale data (Figure 45). For example, in Eldorado National Forest in the Sierra Nevada, hydrology data showed a huge difference between the two scales, with the 1:24,000-scale analysis capturing over three and a half times more area than the 1:100,000-scale. It is impossible to fully quantify the biomass impact for this criterion because of the limited geographic extent of the finer data. However, based on the differences observed and the experience in other landscapes looking at the same issue, the impact during the implementation of any biomass development plan will be significant.

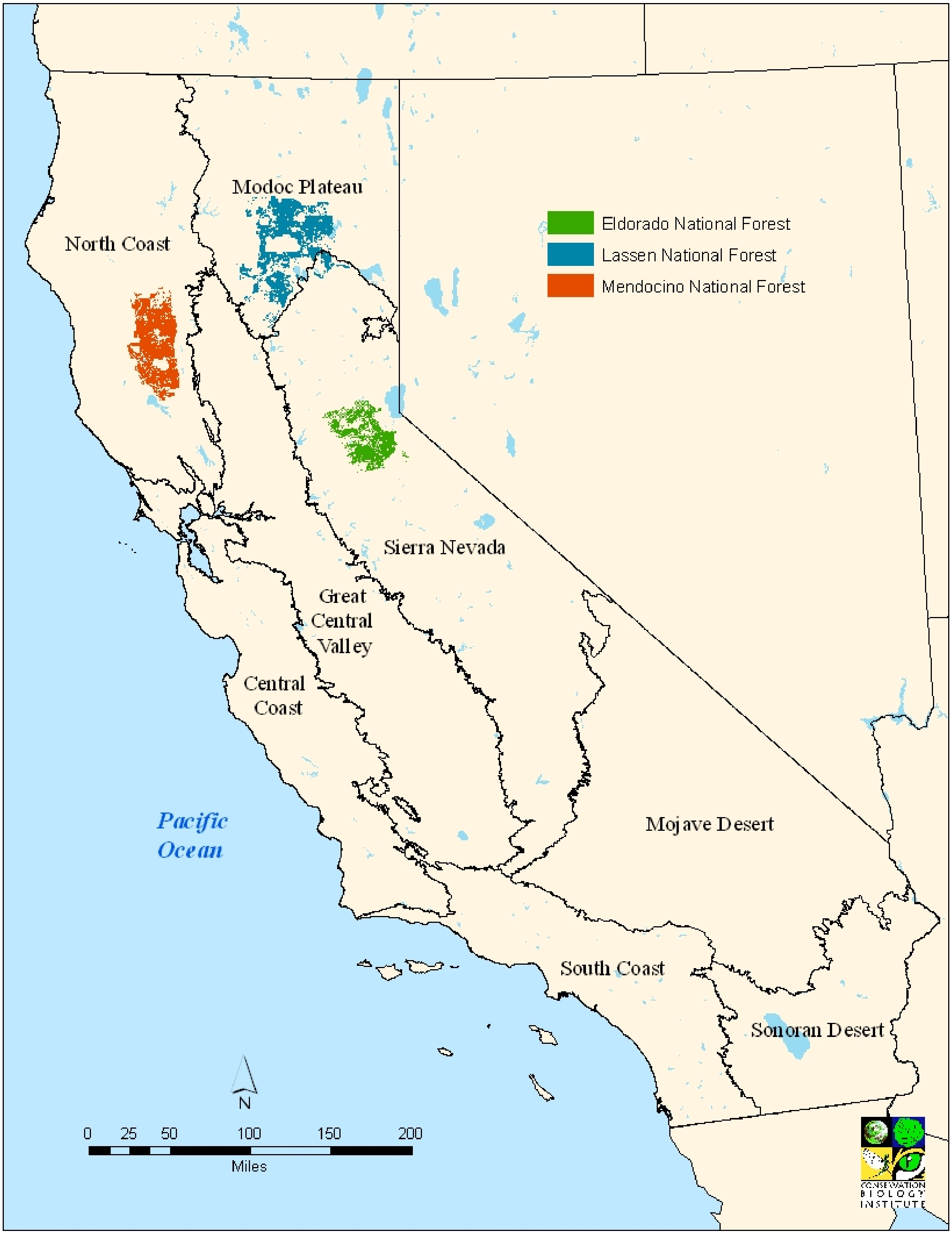
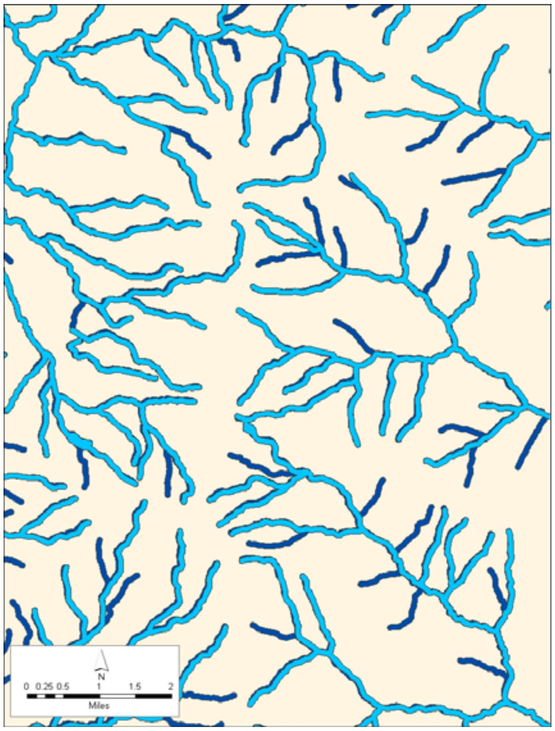
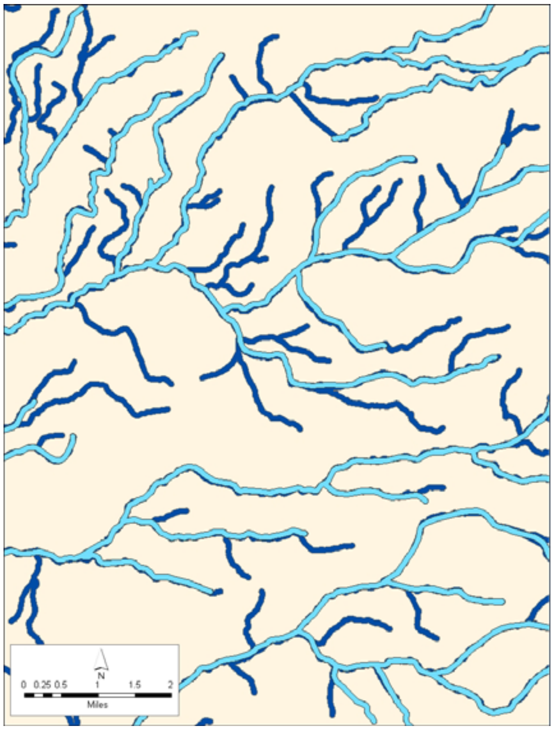


Figure 43. Locations of fine scale (1:24,000) hydrologic datasets used in the riparian area scale comparison.



Mendocino National Forest

Eldorado National Forest



Lassen National Forest

Figure 44. Close-up examples of three comparisons between 1:100,000 (light blue) and 1:24,000 (dark blue) scale hydrologic datasets for each of the three national forests within three different Jepson ecoregions.

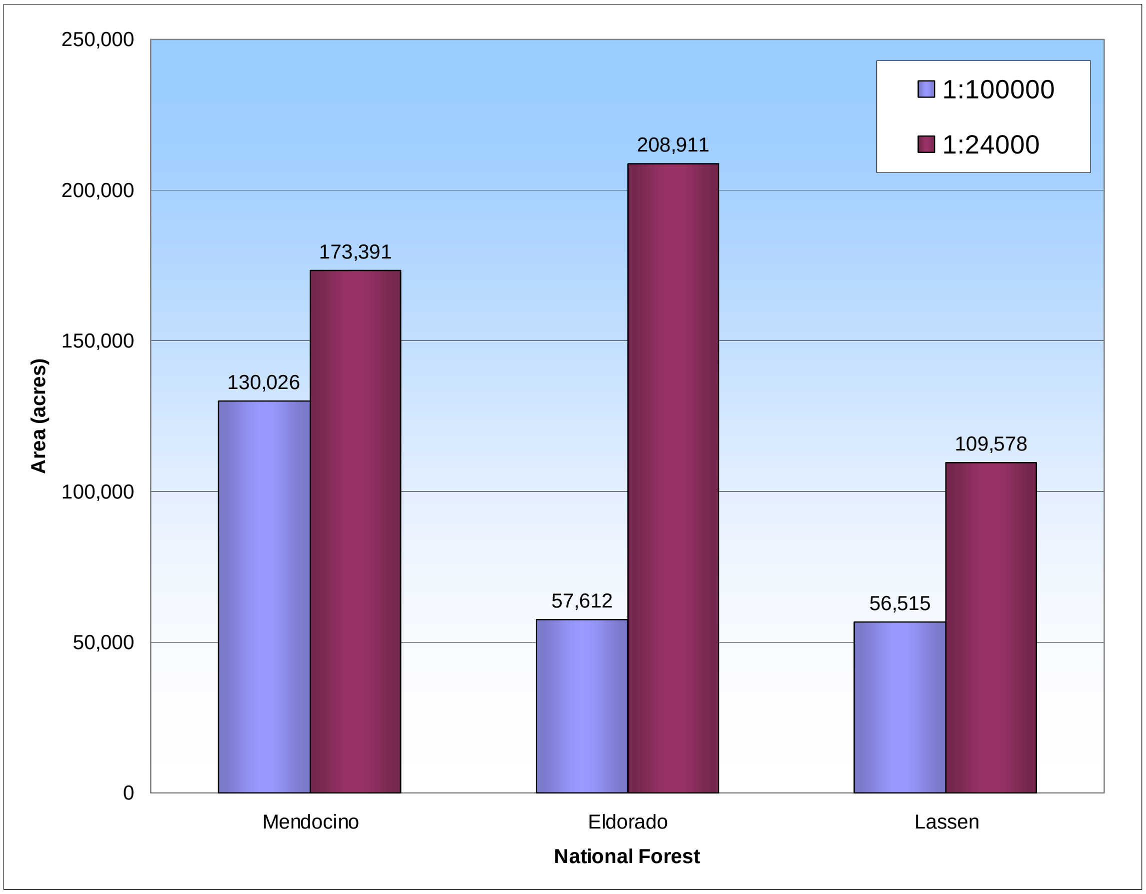


Figure 45. Histogram comparing riparian area using a 100m x 100m resolution derived from 1:100,000 and 1:24,000 scale hydrologic datasets for each of the three national forests within three different Jepson ecoregions.

Discussion and Conclusions

Protecting existing forest and shrubland ecological values is an extremely important consideration as we advance alternative energy policies and develop new energy sources. Energy derived from forest and shrubland biomass is only part of a much larger biomass source pool, which also considers sources such as agricultural and municipal waste as well as dedicated biomass crops. But in order for biomass energy to earn its "green" label, it will have to achieve its energy goals without damaging the natural environment. While some of these safeguards were recognized and included in developing forest and shrubland biomass estimates for California, we contend that there are other values that should not be overlooked.

Based on the available spatial datasets, our analysis explored the potential impact that many of these other considerations would have on the current estimates. Some additional constraints were administrative in nature, such as USDA Forest Service lands. Removing all USDA Forest Service lands is obviously extensive and was evaluated in this assessment because the recent Energy Bill excluded Forest Service lands for biomass development purposes.

Other constraints tested were based on mapable ecological values, including old-growth forests, designated critical habitat, and mapped habitat for focal species. Some important natural communities were already removed from the original state biomass estimates (coastal management zones and coastal sage scrub habitats), but other rare natural communities should be accounted for in other regional and state biomass assessments.

The old-growth forest data available for the state were incomplete and from multiple sources. This value is an important one, but it is extremely difficult to get consensus on what it is and how to map it. A better approach would be to map the remaining most natural and intact forest areas, which would naturally contain a good amount of older forest, but would avoid the need to define "old," which usually distracts people away from what it most important. Rather than fixate on when a forest is classified as "old," we should be mapping and protecting those forests that are in the best ecological condition regardless of their absolute age. This would require additional information about species composition and degree of human development, which is thankfully usually easier to obtain or generate from a variety of means than an old growth theme. The result would be a far better ecological screen than old growth alone, and could be more meaningfully applied to other regions where true old growth is non-existent or extremely rare.

Designated critical habitat is an important constraint. Unfortunately, critical habitat is only mapped for a small proportion of listed federal species, which could result in serious deficiencies depending on the region or state. Based on the current status of this mapping country-wide, our attempt to include this important information as an ecological screen was limited. While it is possible that some species for which critical habitat has been designated could tolerate some biomass development, and in some cases even benefit by it, our assumption was that most of these species are endangered in large part due to the loss and degradation of their native habitats, and further modification (unless restorative) would contribute to further declines.

Adding the mapped habitat for the three focal species was done to illustrate two important points. Two of the three species were also included in the designated critical habitat section. While the two Peninsular bighorn sheep maps were very similar, the two maps for the desert tortoise were different enough to warrant using both maps and by doing so abiding by the precautionary principle – erring on the side of caution from the standpoint of the species. The inclusion of the San Joaquin kit fox was to illustrate how data on another federally listed species could be included if designated critical habitat has not yet been mapped. This species is found in shrublands and could be severely affected by frequent modification of shrubland habitats within its range.

The heritage element occurrence (rare and endangered species) data and hydrologic scale examination were added to highlight the importance of these factors when considering the overall impact of biomass development. In the case of the species location data, current law restricts impact on these species when encountered. Plant species are obviously easier to accommodate than animal species, but some added protections are warranted. However, at the geographic extent of this study, the area impact of these data is minimal. The difference in hydrologic scale has the potential to have a much greater impact, but it is very difficult to quantify. In some regions, it could mean further reductions of as much as 5-7%.

For all of the various constraints added, we assumed that these areas would be off limits to biomass development unless identified inside the WUI. Of course, WUI area can range widely depending on which WUI map is applied. We elected to track the changes using the national standard WUI map. However, the state version of the WUI is almost 4 times greater than the WUI area as mapped following the national standard. Obviously the WUI definition chosen will result in very different estimate outcomes.

For simplicity, we assumed that all mapped constraints would be off limits to biomass development. That is certainly the easiest way to frame this relatively coarse-level assessment, but in reality, complete restriction may not be possible or desirable in all situations. More refinement of the method could easily be achieved with the existing data.

We tracked amounts and percentages at multiple levels – state, ecoregions, and counties – in order to better understand these impacts at scales that matter to any biomass development implementation plan. This report includes numerous maps, allowing the reader to answer many more questions than the general interpretation and discussion we provide regarding biomass potential in any particular region or county, and what ecological values should be considered more carefully.

The need for careful consideration of ecological values is extremely important when examining the potential environmental impacts of a large new initiative such as developing forest and shrubland biomass into an alternative energy source. This study was not intended to be all inclusive. Rather, it was intended to demonstrate how other important values for which we have data could be incorporated into biomass estimates that would provide more realistic numbers in a spatially explicit way prior to any implementation or infrastructure investment. Having a better understanding of what levels of forest and shrubland biomass could be used for this purpose without damaging other important ecological values is extremely valuable.

Acknowledgments

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Literature Cited

Bauen, A., J. Woods, et al. (2003). BioPowerswitch! A biomass blueprint to meet 15% of OECD electricity demand by 2020. Prepared for WWF International and Aebiom**:** Berlin.

California Department of Forestry and Fire Protection Fire and Resource Assessment Program (CDF FRAP) (2005). Existing Forestry Biomass Vegetation Data. Raster dataset. California Department of Forestry and Fire Protection: Sacramento, CA.

California Energy Commission (2004). An Assessment of Biomass Resources in California. Public Interest Energy Research Consultant Report, Contract 500-01-016. California Department of Forestry and Fire Protection: Sacramento, CA.

California Energy Commission (2005). Biomass potentials from California forest and shrublands including fuel reduction potentials to lessen wildfire threat. Public Interest Energy Research Draft Consultant Report, Contract 500-04-004. California Department of Forestry and Fire Protection: Sacramento, CA.

California Energy Commission (2006). An Assessment of Biomass Resources in California 2006. Public Interest Energy Research Draft Collaborative Report, Contract 500-01-016. California Energy Commission: Sacramento, CA.

Energy Information Administration (2001). Annual Energy Outlook 2002. DOE/EIA-0383(2002). U.S. Department of Energy: Washington, DC.

Haq, Z. (2002). Biomass for Electricity Generation. Energy Information Administration, U.S. Department of Energy: Washington, DC.

Scharlemann, J. P. W. and W. F. Laurance (2008). "How green are biofuels?" Science 319(5859): 43-44.

Springsteen, B. (2000). Assessment of California waste resources for gasification. GE-EER, Contract 500-98-037. Irvine, CA.

Turhollow, A. F. and S. M. Cohn (1994). Data and sources of biomass supply, unpublished report. Oak Ridge National Laboratory: Oak Ridge, TN.

Zah, R., H. Böni, et al. (2007). Ökobilanz von Energieprodukten: Ökolangische Bewertung von Biotreibstoffen. Empa**:** Bern.

Appendix A. Reference map of California counties