Attachment 11

Appeal Packet – Bracketed

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NAPA COUNTY
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A Commitment to Service

NAPA COUNTY CLERK OF THE BOARD'S OFFICE
1195 Third Street, Suite 310, Napa, California, 94559 (707) 253-4421

APPEAL PACKET COVER SHEET

(Section 2.88.050 of Napa County Code)

Deadline for filing with the Clerk of the Board's office: no later than 2 p.m. on the 10th working day after the filing of the Notice of Intent to Appeal. (Napa County Code sec. 2.88.050(A).)

TO BE COMPLETED BY APPELLANT
(Please type or print legibly)

Action Being Appealed: Approval of Amendment to Mitigation Measure 6.1 in the Walt Ranch Vineyards Agricultural Erosion Control Plan and EIR documents

Permittee Name: Hall Brambletree Associates, LP

Permittee Address: c/o Mike Reynolds 401 St. Helena Highway South, St. Helena, CA 94574
No. Street City State Zip

Project Site Address/Location (if different from Permittee Address):
Walt Ranch-Napa County Napa CA 94558
No. Street City State Zip

Assessor's Parcel No.: 032-120-028, 032-480-007, -008, -011, -012, -013, -014,-015,-016,-017,-018,-019,-020, -021, -022, -023,-024, -027, -028, 032-490-004, -005, -006, -008, -009, -010, -011, -012, -013, -014, -015, -016, -017,-018,-019,-020

Permit Number: P11-00205-ECPA **Date of Decision:** October 11, 2021

Nature of Permit or Decision: Approval of Amendment to Erosion Control Plan and EIR

Appellant's Name: Center for Biological Diversity

Appellant's legal status (check one): ☐ Individual ☒ Corporation/registered nonprofit
☐ Individual on behalf of unofficial organization (e.g., neighborhood group, special interest group, etc.)
Specify organization name:

Telephone #: (707) 599-2743 **Fax #:** (510) 844-7150

E-Mail Address: rmiddlemiss@biologicaldiversity.org

Mailing Address: 1212 Broadway, Suite 800 Oakland CA 94612
No. Street City State Zip

Appellant's Qualification as Interested Person:
Submitted Comment letter on the Addendum to the EIR–no financial or real interest
project applicant, adjacent property owner, other (describe)

Primary Point(s) of Contact for Appellant: ☒ **Check here if Appellant is sole point of contact and will be the prehearing conference representative**

Contact # 1 Name: Ross Middlemiss
Telephone # (707) 599-2743 **Email:** rmiddlemiss@biologicaldiversity.org
Mailing Address: 1212 Broadway, Suite 800 Oakland CA 94612
No. Street City State Zip

☒ **Check here if this contact will be your representative at the prehearing conference**

Contact # 2 Name: Aruna Prabhala
Telephone # (408) 691-6272 **Email:** aprabhala@biologicaldiversity.org
Mailing Address: 1212 Broadway, Suite 800 Oakland CA 94612
No. Street City State Zip

☐ **Check here if this contact will be your representative at the prehearing conference**

Attach additional sheet(s) for additional contacts if needed.

Reason for Appeal. Be specific – **factual or legal basis for such grounds of appeal must be expressly stated or they are waived.** At a minimum, you must include: (1) identification and description of the specific factual or legal determination(s) made as part of the decision that are the focus of the appeal; and (2) express assertion of all arguments, contentions, and facts that form the grounds for your appeal. If the basis of the appeal will be, in whole or in part, that there was a prejudicial abuse of discretion on the part of the approving authority, or that there was a lack of a fair and impartial hearing, this must be expressly stated. ***(attach additional sheets and/or supporting documentation if necessary)***

Please see attached.

Are you appealing a decision relating to real property? (check one) ☒ Yes ☐ No
If Yes, please ensure that you attach the required Ownership Report, including list of owners and Assessor's map page(s) as indicated on the Checklist.

Evidence of payment of required fees (check one): ☒ **Attached** ☐ **Will be submitted later***

* Pursuant to Napa County Code sec. 2.88.050, evidence of payment **must** be received by the Clerk of the Board no later than the 2 p.m. deadline.

	November 5, 2021	Ross Middlemiss
Signature of Appellant	Date	Print Name

CENTER *for* BIOLOGICAL DIVERSITY

November 5, 2021

Napa County Board of Supervisors
1195 Third Street, Ste. 310
Napa, CA 94559

Re: Appeal of Approval of Addendum to the Environmental Impact Report for the Walt Ranch Vineyards Conversion (No. P11-00205-ECPA).

The Center for Biological Diversity challenges the Napa County Planning, Building and Environmental Services Director's (County) decision to approve the Addendum amending Mitigation Measure 6.1 ("MM 6.1") of the Walt Ranch vineyard (Project) environmental impact report (EIR) and its corresponding Erosion Control Plan (application number P11-00205-ECPA). The County's conclusion that the amendment to the project's greenhouse gas (GHG) mitigation would offset the Project's 27,528 $MTCO_2e$ of GHG emissions is not supported by substantial evidence, and therefore does not comply with the Napa County Superior Court's Peremptory Writ of Mandate and Judgment Granting Peremptory Writ of Mandate (attached as Exhibit 1) or the California Environmental Quality Act (CEQA). For the reasons outlined below, the County's Board of Supervisors should grant this appeal and revoke the County's approval of the amended GHG mitigation measure and revise the measure to take into account the best available science and ensure compliance with CEQA.

The Center is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has over 1.7 million members and online activists throughout California and the United States. The Center and its members have worked for many years to protect imperiled plants and wildlife, open space, air and water quality, and overall quality of life for people in Napa County.

This appeal challenges the County's revision to the Project's GHG mitigation, made in light of the September 30, 2019 Court of Appeal decision that invalidated the EIR's approach to mitigating the Project's extensive GHG emissions. (Court of Appeals Decision at 51-53.) The Court of Appeal invalidated the EIR's conclusion that setting aside 248 acres of unspecified oak woodlands pursuant to MM 6.1 would reduce GHG impacts to a less than significant level. (Court of Appeals Decision at 53.) The Court reasoned that without a demonstration that the preserved acres were under threat of development, or development possible under County regulations, the mitigation measure would not be additive, as required by CEQA. (Court of Appeals Decision at 52.) Following the Court of Appeal's judgment, the Napa County Superior Court issued a Peremptory Writ of Mandate directing the County to vacate and set aside its findings concerning whether the project will have a less-than-significant impact with respect to greenhouse gas ("GHG") emissions." (Exhibit 1.) The Writ prohibits any Project-related activities that cause or contribute to GHG emissions until such time as a revised GHG mitigation measure is presented for their consideration. (Exhibit 1.) In accordance with the Writ, the County can only approve a revised mitigation measure if the findings contained therein are supported by substantial evidence. (Exhibit 1.)

The question before the Board now is whether or not there is substantial evidence demonstrating that the amended mitigation measure will reduce the Project's GHG emissions impacts to a less than significant level. The Board's review is the last chance for the County to assure the public that it has done everything within its discretion to mitigate the Project's impacts. The Applicant's claims of "going above and beyond" are not enough to meet CEQA's legal burden, nor are they sufficient to satisfy the Board's duty to protect the County's natural landscapes and the public trust.

As discussed below, as well as in the comments submitted by the Center on October 1, 2021, incorporated herein by reference, the amended mitigation measure does not meet CEQA's standards for mitigation. (Exhibit 2.) This appeal identifies the legal and factual shortcomings of the County's approval decision, but also recommends actions the County can take to rectify the measure's flaws and ensure on the ground conservation benefits.

First and foremost, the Addendum and supporting documents fail to include enough information on how the revised mitigation measure will be implemented, and whether implementation will successfully mitigate the Project's GHG emissions. The Addendum fails to clearly identify where either the preservation acreage or the planting areas are to be located. The Addendum doesn't demonstrate how the preserved acreage and the planting areas under MM 6.1 will be located in relation to the Project's development footprint and the 525 acres already slated for conservation under County conservation policies. The Addendum lacks any on the ground survey data depicting the actual condition of the Project site, instead relying on generic modeling and unsupported assumptions about fire damage and the carbon sequestration capacity of seedlings planted in the proposed planting program. Critically, the Addendum fails to put forward evidence showing the 80% survival rate of the proposed planting program can be achieved and would sequester the amount of carbon the Applicants purport it will. Lastly, the Addendum allows monitoring to cease far sooner than is required to truly know if planting has been successful and provides the County no oversight and enforcement mechanisms to ensure the Applicants will make good on their planting promises.

In addition to filling the informational gaps described in this letter, the Center urges the Board to revise the mitigation measure based on the following recommendations:

1. Prioritize establishing contiguous conservation easements of 248 acres on-site or alternatively within the watershed.
2. If moving forward with only 124 acres of on-site mitigation lands and the tree planting program, demonstrate that the conservation easements for the 124 acres of woodlands and the tree planting program would be protected from development by providing mapped areas of the revised project footprint, undevelopable lands with >30% slope and within riparian setbacks, and proposed Biological Resources mitigation lands.
3. Provide a live and dead tree inventory and propose specific locations for tree planting based on the inventory and in consultation with wildlife agencies, NGOs, academics, and Native Tribes.
4. Provide a specific plan for propagating and planting tens of thousands of seedlings.
5. Provide a specific timeline for tree plantings and designate milestone markers that outline goals for number of trees planted and number of successful plantings.

6. Require a minimum 7-year monitoring program for plantings with specific, measurable, performance criteria and adaptive management strategies to accommodate climate change conditions (e.g., extended drought, increased wildfire frequency) and ensure an 80% success rate 16,790 of planted seedlings surviving to maturity.
7. Provide a clear definition of how tree planting survival is determined.

I. Preservation of Existing Oak Woodland Must be Prioritized

The County's original approval of the Project required extensive oak woodland preservation as mitigation for both biological resources and GHG impacts. (Addendum at 2.) The Court of Appeals did not invalidate the practice of preserving existing oak woodlands as a viable means of mitigation, it simply held that the County's failure to identify the areas to be preserved made it impossible to determine whether or not the mitigation was additive. (Court of Appeals Decision at 52.) The logical fix for the EIR's shortcoming would be to identify 248 acres of oak woodland that would otherwise be developable, because the areas have slopes under 30% and are outside stream setbacks and permanently protect those lands through a conservation easement. County policy demonstrates a preference for preserving existing habitat, and the Board should not depart from this scientifically-backed approach now.

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Instead of the preservation route set forth in the EIR, Applicants proposed, and the County approved, a revised measure that halves the preserved acreage and commits to planting 16,790 oak seedlings. (Addendum at 3.) There is no discussion of why this approach is favored now, nor is there discussion of why preserving 248 developable acres within the project site is infeasible. The Center urges the County to reconsider this approach, and instead follow the science and prioritize the preservation of existing oak woodland, either within or outside the Project site, over the uncertain and risky tree planting proposal. As discussed more fully below, unless the County can provide substantial evidence demonstrating the effectiveness and adequacy of the tree planting program, the County should require the conservation of existing habitats to mitigate the Project's GHG emissions as required by CEQA. (*Sacramento Old City Assn. v. City Council* (1991) 229 Cal.App.3d 1011, 1027.)

The amendment is also unclear regarding the locations of the different land uses planned for the Project in relation to the GHG mitigation lands. The failure to include the revised project footprint and the areas of undevelopable land (including the 525 acres the letters refer to) precludes a determination of whether or not development will occur within the proposed easement area or the available acceptable woodland area, or that 124 acres of oak woodland that is outside riparian setbacks on slopes less than 30% will be protected. The original project footprint provided in the FEIR appears to show a substantial amount of project footprint within and adjacent to the proposed easement area (FEIR at Figure 3-4), which would have direct and indirect impacts to the proposed mitigation. The amendment should be revised to provide more information so that the public can determine that at least 124 acres of oak woodlands outside riparian setbacks on slopes under 30% will be avoided for the purposes of GHG mitigation. 2

II. The Effectiveness of the Amended Mitigation Measure is not Supported by Substantial Evidence

The approval of revised MM 6.1 was not based on substantial evidence demonstrating the measure will effectively reduce the impact of the project's GHG emissions to a less than significant level. CEQA requires that feasible mitigation measures be adopted (CEQA Guidelines § 15126.4(a)), and that the effectiveness of those measures is supported by substantial evidence. *(See Gray v. County of Madera* (2008) 167 Cal.App.4th 1099, 1116-17 [An agency's finding that a mitigation measure will be effective will not be granted deference if the finding is not supported by substantial evidence]; *see also Tracy First v. City of Tracy* (2009) 177 Cal.Ap.4th 912, 937.) Successful tree planting programs require careful planning with "a multiyear commitment to maintaining trees, monitoring whether project goals have been achieved, and providing funding for corrective actions if they are not." (Holl & Brancalion, 2020). The Addendum is lacking critical details about where the mitigation actions will be implemented and how the existing conditions of the Project site affect that process; and fails to demonstrate the seedling planting plan will be effective over the lifespan of the Project. For these reasons, explained more fully below, this appeal should be granted so that the County can address these shortcomings and prepare a mitigation measure that fully complies with CEQA. (Cal. Pub. Res. Code § 21002; § 21081.6(b); Guidelines § 15126.4(a)(2).)

As a preliminary matter, it's important to clarify what the revised mitigation measure must do, and the lens through which the Board will review the measure when considering this appeal. The revised mitigation must offset the GHG emissions that were estimated in the EIR. That is what the County certified, and what each reviewing court considered. The Applicant summed it up well in its October 4th letter, "[t]he estimate is therefore settled and cannot be challenged." (October 2021 Hall Letter at 4.) Any speculation about how much carbon was released during the 2017 and 2020 fires and how it would lower the Applicant's mitigation obligation, is a distraction. The Applicant's attempts to portray the revised mitigation as an altruistic endeavor should be ignored. The Applicant must mitigate for the GHG emissions calculated in the EIR, "[t]here is no reduction in the Applicant's mitigation obligation because of the fire damage." (Notice of Decision at 2.)

A. The effectiveness of planting oak seedlings is undermined by the lack of information of where planting will occur and the existing conditions in those areas

The revised mitigation was approved despite failing to include information critical to understanding how MM 6.1 would be implemented and whether or not it would be successful, in violation of CEQA. (*See Preserve Wild Santee v. City of Santee* (2012) 210 Cal.App.4th 260.) The addendum fails to clearly and adequately provide specific locations of where 16,790 to 33,580 trees would be planted. The Ascent Report states that there are 1,023 acres of eligible planting area, of which 901 acres were originally oak woodland. The October 2021 Hall Letter asserts that "Ascent has identified specific locations on the property where a tree replanting program can be successfully implemented" (October 2021 Hall Letter at 5), but these specific areas are not provided to the public. If it was infeasible to delineate specific planting areas at the time the Addendum was approved, CEQA requires such an explanation. (*See San Joaquin Raptor Rescue Center v. County of Merced* (2007) 149 Cal.App.4th 645, 671.)

The uncertainty around specific planting areas is compounded by the amendment's failure to provide sufficient, science-based information concerning the current state of the project site following the 2017 and 2020 fires. This lack of detail is exemplified by the unsupported assumption in the Ascent GHG Mitigation Report ("Ascent Report") that all trees in the burn areas were lost. (Ascent Report Table 3, at 6.) As discussed in the Center's October 1, 2021 letter ("Center Letter"), oaks are fire-adapted and much of the Project area likely survived the wildfires. (See Center Letter at 3-5, attached as Exhibit 2.) Figure 1 below demonstrates that areas with the 2020 burn area, identified as an eligible planting area, either survived the fire or are likely regenerating.

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Figure 1: An aerial view of a portion of the proposed eligible planting area from October 2020, after the Hennessey Fire was contained. Photo credit: Bryant Baker

Therefore, much of the area in the proposed eligible planting areas are likely naturally regenerating and will continue to sequester large amounts of carbon on their own. Planting seedlings in these areas will likely fail or result in the destruction of existing, intact, carbon-storing habitat with little to no gains. The County must revise the mitigation measure to include on-the-ground vegetation inventories of the proposed planting areas.

The informational shortcomings of the amended MM 6.1 undermine the validity of the County's approval. MM 6.1 must be revised to include, at a minimum, the specific locations of where tree planting will occur, and survey data concerning the current condition of those areas.

Without such information, the Addendum as approved fails to ensure that the tree planting portion of the MM 6-1 is effective, adequate and meets CEQA's requirements. (*Sierra Club v. County of San Diego* (2014) 231 Cal.App.4th 1152; *POET, LLC v. State Air Resources Bd.* (2013) 218 Cal.App.4th 681.)

B. The amended mitigation relies on flawed sequestration calculations

The approved MM 6.1 undercounts the number of trees that would need to be planted in order to sequester the necessary amount of carbon. Based on the numbers provided in Table 4 of the Ascent Report, the calculation of 16,790 trees for the planting program is incorrect because it does not take the 80% survival (i.e., 20% death) rate into account. Using the average carbon sequestration rate per tree provided in Table 4 of the Ascent Report and assuming an 80% success rate, 20,965 trees are required to meet the 27,528 MTCO2e total over 30 years, as the Applicant asserts. (May 2021 Hall Letter at 3.)

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$$\text{X trees} = \frac{27{,}528{,}000 \text{ kg carbon}}{54.7 \text{ kg carbon/tree/year} * 30 \text{ year} * 0.8}$$

X trees = 20,965 trees

The 16,790 trees would result in the sequestration of 27,552 MTCO2e only if there is 100% survival. But when accounting for an 80% survival rate, 16,790 planted trees would only result in sequestering 22,042 MTCO2e by the surviving 13,432 trees. The addendum provides incorrect information that both undercuts and oversells the mitigation measure. The Notice of Decision's conclusion "that planting 16,790 trees, with an 80% survival rate after five years, will, over the Project horizon of 30 years, achieve the required GHG offset to reduce the impact of the project to a less-than-significant level[.]" is not supported by substantial evidence. (Notice of Decision at 2-3.)

C. The Ascent Report overestimates how much sequestration the planted trees achieve over the 30-year planning horizon

To make matters worse, beyond misapplying the average yearly sequestration of each tree, the actual sequestration averages themselves were improperly calculated. The inappropriate use of the i-Tree model resulted in an overestimation of how much carbon the planted trees would sequester over the project's 30-year lifetime. According to the Ascent Report, the average carbon sequestration rates per tree per year provided in Table 4 were calculated using a project lifetime of 99 years. (Ascent Report at 6; see also Appendix A i-Tree report at 1.) Oaks have varying growth rates, but they are generally slow-growing. Therefore, accumulating biomass takes time, and early years of growth have relatively little carbon gains. Including trees 31 to 99 years old to estimate the amount of carbon stored within 30 years of planting seedlings will result in skewed and misleading results because the seedlings and saplings store much less carbon compared to mature trees. The age/size[1] of the trees is critical to calculating an accurate prediction of how much carbon will be stored within 30 years of planting a seedling. Trees store carbon in their biomass (above-ground trees and below-ground roots) by taking in carbon dioxide and using it to photosynthesize. As trees get older and bigger they store more carbon. Not only are trees able to remove more carbon from the atmosphere as they get bigger, but their storage capacity/accumulation of carbon also increases over time (Stephenson et al., 2014). Therefore, including trees up to 99 years old when calculating the average carbon sequestration of trees between 1 and 30 years old is inappropriate and will result in substantially inflating the carbon sequestration predictions. 5

This issue is clear in Napa RCD's Acorns to Oaks program. After planting 5,525 acorns over 8 years, they recorded 936 surviving seedlings. Based on calculations following the U.S. Department of Energy's method for calculating carbon sequestration by trees in urban and suburban settings,[2] 936 seedlings sequestered 1,498 lbs (679 kg) of carbon, compared to 2814 lbs (1276 kg) of stored carbon in one 100-year-old oak tree (See Jim Wilson Comments, October 1, 2021; Stilwell 2021 [Exhibit 3].). According to the U.S. Department of Energy (1998), one-year-old seedlings sequester carbon at a rate of 1.6 to 4.0 lbs/tree/year (0.73 to 1.8 kg/tree/year), which is vastly different from the 54.7 kg average provided in the Ascent Report, In fact, trees with slow and moderate growth rates are estimated to take longer than 60 years to reach a point when they are sequestering at least 54 kg/tree/year, and fast-growing trees don't reach sequestering 54 kg/tree/year until about 49 years (U.S. Department of Energy 1998). Therefore, including carbon storage potential of trees 31 to 99 years old in the model skews the average carbon sequestration rate to be much higher compared to what the average would be if only 1- to 30-year-old trees were included in the calculation. This puts into question whether an average annual sequestration rate is what should be used to predict carbon storage potential of planted trees. Instead, a calculation that incorporates the dynamic and cumulative nature of tree growth and carbon sequestration should be implemented. The flawed sequestration calculations undermine the Notice of Decision's conclusion that the tree planting plan will offset the required 27,528 MTCO2e over the 30-year life of the project.

D. Achievement of the 80% survival performance standard is not supported by substantial evidence

The conclusion that 80% survival of planted oak seedlings will be achieved is not supported by substantial evidence. Nowhere in the Addendum or the Ascent Report is there an explanation of why the 80% survival rate was selected, nor is there evidence that such a standard

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[1] Tree age is often used as a proxy for size even though growth rates can vary depending on the available resources (e.g., water, sunlight) and grazing pressure. For example, a 2007 study found that 21 years after blue oak seedlings were planted, individuals ranged from 6 to 112 cm in height and 0.6 to 2.8 cm in diameter (Koenig & Knops, 2007). And 41 years after blue oak seedlings were planted, individuals ranged from 28 to 200 cm in height and 0.7 to 7.7 cm in diameter (Koenig & Knops, 2007). This demonstrates the slow growth of some oaks and that, even after decades of planting, they may not sequester as much carbon as predicted.

[2] https://www3.epa.gov/climatechange/Downloads/method-calculating-carbon-sequestration-trees-urban-and-suburban-settings.pdf

can realistically be met. (*See Cleveland National Forest Foundation v. San Diego Assn. of Governments* (2017) 17 Cal.App.5th 413, 433 ["Unrealistic mitigation measures, similar to unrealistic project alternatives, do not contribute to a useful CEQA analysis" (citations omitted)].) The only evidence as to the effectiveness of oak planting programs that was before the County when it approved the amended mitigation was data from the recent Acorns to Oaks program. (See Jim Wilson Comments; Exhibit 3.) That program experienced a survival rate of 17% for the 5,525 acorns planted over the course of 8years. (*Ibid.*) While the survival rate of seedlings is likely higher than acorns, the gap between 80% and 17% is significant, and requires at the very least a demonstration of how the 80% standard was selected. While the Applicant's October 4th letter claims that "a recommendation by an acknowledged expert [Ascent] constitutes substantial evidence that the program will be successful[.]" CEQA requires more. (*See North Coast Rivers Alliance v. Marin Municipal Water Dist. Bd. Of Directors (*2013) 216 Cal.App.4th 614, 639-40 [An EIR must contain sufficient information and analysis to enable the public to discern the analytic[al] route the agency traveled from evidence to action" (citations omitted)].) 6

E. The planting plan's monitoring period is inadequate.

7 The amendment should include, at a minimum, the Public Resources Code §21083.4 requirement of a seven-year monitoring period. That provision, titled "Conversion of oak woodlands," requires that any planting effort to mitigate a project's impacts to oak woodland must be monitored for no less than 7 years from planting. (Pub. Res. Code § 21083.4(b)(2)(B).) The Applicant's attempt to dismiss the applicability of section 21083.4 is nonsensical. (See Hall Letter, October 4, 2021.) The goal of section 21083.4 is to provide mitigation for the removal of oak trees; and to constitute mitigation trees planted pursuant to this provision must survive. Section 21083.4 requires a 7-year monitoring period so that the goal of the mitigation, survival of planted trees to replace those lost to development, can be achieved. The planting program here seeks to achieve the same goal, plant trees that will survive and replace the trees destroyed by the vineyard conversion. The 7-year monitoring period should act as a minimum, since, as discussed above, seedlings and saplings have a much lower survival rate than the Applicant assumes, and they sequester relatively small quantities of carbon compared to mature oaks that sequester the majority of carbon in woodlands. More substantial carbon sequestration might not occur for decades; longer monitoring with specific, measurable performance criteria and adaptive management would help to ensure the planted trees are able to survive in the long-term and reach the size required to sequester large amounts of carbon (Holl & Brancalion, 2020). Scientists recommend 15-20 years or more of monitoring with adaptive management to determine the success, or lack thereof, of enhanced, restored, or created habitat. (See Exhibit 2 at 7.) In addition, simply taking a photo of plantings every year without active care of the plantings is insufficient to ensure an 80% survival rate of the new plantings (FEIR BRMP at 80). The amended mitigation measure provides no evidence to support the effectiveness of the 5-year monitoring period, and as noted above, the undocumented "recommendation" of the Applicant's consultant does not constitute substantial evidence.

F. The planting plan is vague and lacks adequate enforcement measures

The approved mitigation is vague as to how monitoring of the planting plan will be carried out, and ultimately lacks key details concerning recourse if the performance standards are

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not met. (*See Preserve Wild Santee v City of Santee* (2012) 210 CA4th 260, 281.) The Ascent Report states that "replanting can occur over a period of a few years, or shorter depending on the level of participation from partners." (Ascent Report at 9.) There is no definition or guidance for what constitutes "a few years." It does not give a timeline for the GHG mitigation to be completed and seemingly passes accountability of implementing the planting program to "partners." The measure must be revised to provide a specific timeline for tree plantings and designate milestone markers that outline goals for number of trees planted and number of successful plantings and provide a clear definition of how tree planting survival is determined. In its current form, the planting program's lack of detail and vague language provides an unacceptable amount of post-approval discretion to whomever it is that will implement the program, in violation of CEQA. (*See Communities for a Better Environment v. City of Richmond* (2010) 184 Cal.App.4th 70, 93 [success criteria based on the post-approval, subjective judgment of agency violates CEQA]; *see also Golden Door Props. v. County of San Diego* (2020) 50 Cal.App.5th 467, 520-24 [invalidating measure lacking standards governing director's discretion].)

Critically, MM 6.1, as amended, is silent on what happens after 5 years of monitoring. If less than 80% of the 16,790 seedlings (20,965 seedlings if calculated accurately, see above) survive after 5 years, there are no mechanisms in place for the County to hold the Applicant accountable for the unrealized GHG mitigation. The measure must be revised to include concrete, evidence-based and enforceable performance standards so that the public is assured the project's significant GHG emissions will in fact be mitigated.

III. Conclusion

Taken together, MM 6.1 in its current form inspires more questions than it answers and fails to meet CEQA's standards for acceptable mitigation. The stakes are too high for speculative and undefined measures to be accepted in return for the destruction of carbon-sequestering oak woodlands and other native habitats. We urge the Board to grant this appeal and reject the amended mitigation measure in its current form. The Board has authority to demand a scientifically-sound, effective and enforceable mitigation measure to account for the project's significant GHG emissions. The Board should use its authority to require mitigation that prioritizes preservation of existing habitats via contiguous conservation easements, includes clear mapping of the Project's components and how they overlap with land cover types and the development footprint, and provides an account of existing trees and their condition within the Project site. If the Board decides to allow seedling planting as part of the mitigation, a planting plan must include specific details for implementation, such as a timeline for planting and preestablished milestone markers and adaptive strategies if milestones are not met and a clear definition of "survival" by which success is measured. Lastly, the planting plan should include monitoring of no less than 7 years and include adaptive management strategies that account for the impacts of climate change, while providing the County with enforcement mechanisms to ensure that the Applicant is held responsible for any failure to meet its sequestration obligations under the mitigation measure.

The County is not bound by the Applicant's preferences or motives, it must instead follow the law and act on behalf of Napa residents that demand action to combat the escalating effects of climate change. The recommendations provided in this letter provide a roadmap to legally and scientifically sound mitigation, and we hope the Board does all in its power to fully mitigate the Project's negative impacts. The effects of the climate crisis are already being felt in Napa, and the Board must take urgent action to halt rising temperatures and avert a climate catastrophe. This monumental struggle will not be won with a business as usual approach. Protecting Napa's ecological wonders and ensuring a livable future for its residents requires immediate and resolute action, and a half-baked tree planting plan simply won't cut it.

Sincerely,

Ross Middlemiss
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References

Holl, K. D., & Brancalion, P. H. S. (2020). Tree planting is not a simple solution. *Science, 368*(6491), 580–581.

Koenig, W. D., & Knops, J. M. H. (2007). Long-term Growth and Persistence of Blue Oak (*Quercus douglasii*) Seedlings in a California Oak Savanna. *Madroño, 54*(4), 269–274.

Stephenson, N. L., Das, A. J., Condit, R., Russo, S. E., Baker, P. J., Beckman, N. G., Coomes, D. A., Lines, E. R., Morris, W. K., Rüger, N., Álvarez, E., Blundo, C., Bunyavejchewin, S., Chuyong, G., Davies, S. J., Duque, Á., Ewango, C. N., Flores, O., Franklin, J. F., … Zavala, M. A. (2014). Rate of tree carbon accumulation increases continuously with tree size. *Nature, 507*(7490), 90–93.

Exhibits

Exhibit 1 – Napa Superior Court Peremptory Writ of Mandate and Judgment Granting Peremptory Writ of Mandate, May 8, 2020.

Exhibit 2 – Center for Biological Diversity comments on Walt Ranch Notice of Tentative Decision, October 1, 2021

Exhibit 3 - Jim Wilson comments on Walt Ranch Notice of Tentative Decision, October 1, 2021

Exhibit 1

NAPA SUPERIOR COURT
825 BROWN STREET • NAPA, CALIFORNIA 94559-3031

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U.S. POSTAGE PITNEY BOWES
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FILED

MAY 06 2020

CLERK OF THE NAPA SUPERIOR COURT
BY J. Olivier
DEPUTY

SUPERIOR COURT FOR THE STATE OF CALIFORNIA,
COUNTY OF NAPA

CENTER FOR BIOLOGICAL DIVERSITY, and SIERRA CLUB, Petitioners, vs. NAPA COUNTY, NAPA COUNTY BOARD OF SUPERVISORS, NAPA COUNTY DEPARTMENT OF PLANNING BUILDING AND ENVIRONMENTAL SERVICES; and DOES 1 through 20, inclusive, Respondents. HALL BRAMBLETREE ASSOCIATES, LP, and Does 21 through 40, inclusive, Real Parties in Interest.	Case No.: 17CV000060 PEREMPTORY WRIT OF MANDATE

TO RESPONDENTS NAPA COUNTY, NAPA COUNTY BOARD OF SUPERVISORS AND NAPA COUNTY DEPARTMENT OF PLANNING, BUILDING AND ENVIRONMENTAL SERVICES:

The Court having entered judgment in this proceeding ordering that a peremptory writ of mandate issue under seal of this Court:

YOU ARE HEREBY COMMANDED, on receipt of this writ, as follows:

1. Within 60 days of service of this writ, Respondents shall vacate and set aside their findings concerning whether the project will have a less-than-significant impact with respect to greenhouse gas ("GHG") emissions.

2. Respondents shall not reconsider whether to adopt such findings unless and until those findings are supported by substantial evidence in the record without making substantive changes to other aspects of the Project and/or EIR that have already been approved and are not subject to this partial writ of mandate.

3. Respondents shall not approve, and Real Party in Interest Hall Brambletree Associates LP shall not commence, Project-related activities that cause or contribute to GHG emissions, unless and until the Court discharges this peremptory writ of mandate.

4. Respondents shall file the following returns to this peremptory writ of mandate:

a. Respondents shall file an initial return to the writ of mandate within 90 days of service of this writ setting forth the steps taken to comply with paragraph 1 of this writ.

b. Respondents shall file a supplemental return to the writ of mandate within 30 days of completing the activities, if any, mandated by paragraph 2 of this writ setting forth those actions.

5. This Court retains jurisdiction over Respondents' proceedings by way of the returns to the peremptory writ of mandate until the Court has determined that Respondents have complied with CEQA as specified herein or that Respondents have determined not to approve the Project.

6. Nothing in this writ shall be understood to direct Respondents to exercise their discretion in any particular way. (Pub. Resources Code, § 21168.9, subd. (c).)

Dated: 05/06/2020

Victoria Wood, Judge

Superior Court of California

County of Napa
825 Brown Street
Napa. CA 94559

Case #: 17CV000060 **Center for Biological Diversity and Sierra Club vs Napa County et al**

John P Rose	1212 Broadway STE 800 OAKLAND, CA 94612
Elizabeth Rachel Pollock	555 Capitol Mall STE 800 SACRAMENTO, CA 95814
Jeffrey Michael Brax	1195 Third Street Suite 301 Napa, CA 94559

Certificate of Mailing/Service

I hereby certify that I am not a party to this cause and that a copy of the foregoing document was:

☒ **mailed** (first class postage pre-paid) in a sealed envelope
☐ **certified copy faxed** to Napa Sheriff's Department at (707) 253-4193
☐ **personal service** – personally delivered to the party listed above
☐ **placed in attorney/agency folders** in the ☒ Criminal Courthouse ☐ Historic Courthouse

at Napa, California on this date and that this certificate is executed at Napa, California this Date. I am readily familiar with the Court's standard practice for collection and processing of correspondence for mailing within the United States Postal Service and, in the ordinary course of business, the correspondence would be deposited with the United States Postal Service on the day on which it is collected at the Courthouse.

Date: 5/6/2020 **Robert E Fleshman, Court Executive Officer**

J. Oliver

Julie Oliver, Deputy Court Executive Officer

FILED

MAY 06 2020

CLERK OF THE NAPA SUPERIOR COURT
BY
DEPUTY

SUPERIOR COURT FOR THE STATE OF CALIFORNIA,
COUNTY OF NAPA

CENTER FOR BIOLOGICAL DIVERSITY, and SIERRA CLUB,

Petitioners,

vs.

NAPA COUNTY, NAPA COUNTY BOARD OF SUPERVISORS, NAPA COUNTY DEPARTMENT OF PLANNING BUILDING AND ENVIRONMENTAL SERVICES; and DOES 1 through 20, inclusive,

Respondents.

HALL BRAMBLETREE ASSOCIATES, LP, and Does 21 through 40, inclusive,

Real Parties in Interest.

Case No.: 17CV000060

JUDGMENT GRANTING PEREMPTORY WRIT OF MANDATE

I. PROCEDURAL HISTORY

The Petition of Center for Biological Diversity (CBD) and Sierra Club (each a Petitioner and collectively Petitioners) came on for hearing February 13, 2018, and March 1, 2018, before the Honorable Thomas E. Warriner in Department G of this Court. Aruna Prabhala of the Center for Biological Diversity appeared on behalf of Petitioners. Jason Dooley appeared on behalf of Respondents County of Napa, Napa County Board of Supervisors, and Napa County Department of Planning, Building and Environmental Services ("Entity Respondents"). Whitman Manley appeared on behalf of Real Parties in Interest Hall Brambletree Associates, LP ("Real Party")(Entity Respondents and Real Party will hereinafter be referred to collectively as "Respondents"). On April 5, 2018, the Court entered judgment in favor of Respondents and Real Parties (Original Judgment).

Petitioners appealed the Original Judgment to the Court of Appeal, First Appellate District. On September 30, 2019, the Court of Appeal affirmed the Original Judgment in part and reversed in part. (See *Living Rivers Council v. County of Napa*, 2019 Cal. App. Unpub. LEXIS 6612 (*Opinion*).) Specifically, the Court of Appeal found that Petitioner CBD demonstrated a lack of substantial evidence supporting the inference that the trees to be permanently conserved would not reasonably have remained on the property. (*Id.* at 87.) "CBD has accordingly satisfied its burden of showing that substantial evidence does not support the EIR's conclusion that the project would have a less-than-significant GHG emission impact." (*Ibid.*) On all other claims, the Court of Appeal affirmed the Original Judgment of this Court. Accordingly, the Court of Appeal reversed the judgment denying Petitioners' petition for a writ of mandate and remanded the matter to this Court to grant the petition as to the EIR's failure "to ensure that the GHG emissions associated with the Project, as mitigated, constitute a less-than-significant-impact, as set forth in [this Opinion]." (Opinion at 87-88.)

On February 11, 2020, this Court invited the parties to submit additional briefing regarding the appropriate nature and scope of the writ of mandate and judgment, consistent with the Opinion of the Court of Appeal. Hearing on the matter was held on March 4, 2020, with the following attorneys appearing: Jason Dooley on behalf of the entity Respondents; Aruna Prabhala and Ross Middlemiss on behalf of Petitioner; and Whitman Manley on behalf of Real Party. Following the hearing, the matter was submitted.

Having read and considered the parties' briefs and arguments at hearing, the Court now orders as follows.

II. LEGAL ANALYSIS

When a public agency's decision, determination, or finding does not comply with CEQA, a peremptory writ of mandate must be issued. (Pub. Resources Code § 21168.9, subd. (a).) As noted above, pursuant to the *Opinion* of the Court of Appeal, "substantial evidence does not support the EIR's conclusion that the project would have a less-than-significant GHG emission impact." (*Opinion* at p. 87.)

Respondents urge the Court to issue a so-called "partial writ" and judgment directing the County to reconsider its finding of substantial evidence on this single issue. (See Memorandum of Points and Authorities in Support of Proposed Judgment (Respondent's Memo) at 5:4-7.) Respondents further argue that "the judgment and writ need not direct the County to decertify the EIR. (*Id.* at 5:9-10.)

Respondents' position appears to find support in the following language of the *Opinion*. "We remand the CBD matter to the trial court to grant the petition *as to the following EIR issue*: to ensure that the GHG emissions associated with the Project, as mitigated, constitute a less-than-significant impact, as set forth in Section II.F of this opinion." (*Opinion* at 87-88. Emphasis added.)

Partial writs are authorized under Public Resources Code section 21168.9. Subsection (b) of the statute specifically requires that a mandate order under subsection (a) "shall be limited to that portion of a determination, finding, or decision or the specific project activity or activities found to be in noncompliance only if a court finds that (1) the portion or specific project activity or activities are severable, (2) severance will not prejudice complete and full compliance with this division, and (3) the court has not found the remainder of the project to be in noncompliance with this division. The trial court shall retain jurisdiction over the public agency's proceedings by way of a return to the peremptory writ until the court has determined that the public agency has complied with this division."

As to the first finding of the three that cumulative necessitate issuance of only a partial writ, Petitioner contends that a severability finding cannot be made in this case, because the Project itself is not severable. For this contention, Petitioner relies heavily on the Fifth Appellate District's decision in *Landvalue 77, LLC v. Board of Trustees of California State University* (*Landvalue 77*) (2011) 193 Cal.App.4th 675. Implementing plain language interpretation of section 21168.9, this Court disagrees with Petitioner, as well as with the Fifth District in *Landvalue 77*. When section 21168.9 subsection (b)(1) requires a finding that the "the portion *or* specific activity or activities" are severable, the Court interprets this language to allow for the severability finding to be as to a portion not only of project activity/ies, but alternatively to a portion of the "determination, finding, or decision," as indicated in the prefatory language of the sentence identifying the three requisite findings. This Court's interpretation seems to be supported by the Second Appellate District in *Preserve Wild Santee v. City of Santee* (2012) 210 Cal.App.4th 260, at page 287, when it critiqued the *Landvalue* 77 Court's "perfunctory" conclusion that the "in part" language in subdivision (a)(1) does not apply to EIR certification decisions. Applying this interpretation of severability under section 21168.9, the Court easily concludes the portion of the County's decision pertaining to mitigation for GHG emissions is severable from the remainder of the Project decisions, as the First District seemed to contemplate in its *Opinion* as well.

The Court also believes it should make the second and third findings that require it to issue only a partial writ in this case. Obviously, the court has not found the remainder of the Project to be in noncompliance with CEQA, since the First District has upheld all other aspects of the Project approval. Whether the Court can make the second finding that severance of this portion of the County's approval would not prejudice complete and full compliance with CEQA is a closer question for consideration.

The First District found deficient the County's approval of the EIR's GHG mitigation measure, number 6-1, because there was insufficient evidence that the unspecified 248 acres of trees to be preserved as mitigation would not reasonably have remained on the property under "business as usual circumstances," i.e. without the proposed Project. (*Opinion* at 87.) It is possible Respondent will be able to approve the same mitigation measure, by simply identifying 248 acres of the 524 to be preserved and finding sufficient evidence in the record that those acres would not reasonably have remained without the preservation contemplated by the Project. Petitioner's concern that a partial writ could result in modifications to the mitigation measure that may require "changes to the scope and scale of the Project" can be alleviated by a mandate that the County shall not readopt findings of a less than significant GHG emissions impact, unless and until such findings are supported by substantial evidence in the record *without making substantive changes to other aspects of the Project and/or EIR that have already been approved and are not subject to the partial writ of mandate.* Petitioner's concern that Respondent may be required to adopt a Statement of Overriding Considerations, is alleviated by the fact that such a statement would be subject to separate CEQA compliance. Under these circumstances, the Court concludes that severance of the County's decision [that mitigation measure 6-1 sufficiently supported approval of the Project] will not prejudice complete and full compliance with CEQA.

III. JUDGMENT

IT IS THEREFORE ORDERED that:

1. As set forth in the *Opinion*, the Petition for Writ of Mandate, filed by Petitioners is granted in part as to the following EIR issue: to ensure that the greenhouse gas ("GHG") emissions associated with the project, as mitigated, constitute a less-than-significant impact. As set forth in Section II.F of the *Opinion*, substantial evidence does not support the County of Napa's (the "County's") conclusion that the conservation easement that the Project must provide will provide sufficient mitigation to reduce the Project's GHG emissions to less-than-significant levels.

2. In all other respects, the petition is denied.

3. A peremptory writ of mandate shall issue under the seal of the Court commanding:

a. The County shall vacate and set aside its findings concerning whether the Project, as mitigated, will have a less-than-significant impact with respect to GHG emissions.

b. The County shall not reconsider whether to adopt such findings unless and until they are supported by substantial evidence in the record without making substantive changes to other aspects of the Project and/or EIR that have already been approved and are not subject to the partial writ of mandate.

c. The County shall not approve, and Real Party in Interest Hall Brambletree Associates LP ("Real Party") shall not commence, Project-related activities that cause or contribute to GHG emissions.

4. The Court retains jurisdiction to ensure compliance with the writ issued pursuant to this judgment. If the County responds to the writ by re-adopting its finding concerning GHG emissions, then the County shall file a return to the peremptory writ of mandate issued pursuant to this judgment setting forth the steps taken by the County to respond to the writ.

5. Nothing in this judgment shall be understood to direct the County to exercise its discretion in any particular way. (Pub. Resources Code, § 21168.9, subd. (c).)

6. Unless and until this Court has determined that the County has taken the actions specified herein to bring the Project approvals into compliance with CEQA, the County and Real Party shall not undertake, and are enjoined from undertaking, any Project-related activities that may cause or contribute to GHG emissions.

7. The portion of the Project decision affected by this judgment is severable under Public Resources Code section 21168.9, subdivision (b). Paragraph (6) of this judgment ensures that no GHG emissions will occur as a result of the project, unless and until the County has addressed, to the Court's satisfaction, the adequacy of the steps taken to offset the project's GHG emissions. The EIR's analysis of GHG emissions has been found to be otherwise adequate. The EIR has also been found be to adequate with respect to its analysis of all other issues. Issuing this partial writ will not prejudice complete and full compliance with CEQA.

8. Each party shall bear its own costs.

Dated: 05/06/2020

Victoria Wood, Judge

Superior Court of California

County of Napa
825 Brown Street
Napa. CA 94559

Case #: 17CV000060 **Center for Biological Diversity and Sierra Club vs Napa County et al**

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Certificate of Mailing/Service

I hereby certify that I am not a party to this cause and that a copy of the foregoing document was:

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Date: 5/6/2020 **Robert E Fleshman, Court Executive Officer**

J. Oliver
Julie Oliver, Deputy Court Executive Officer

Exhibit 2

CENTER for BIOLOGICAL DIVERSITY

October 1, 2021

Sent via email and FedEx

David Morrison
Director
Napa County Planning, Building, and Environmental Services
1195 Third Street, 2nd Floor
Napa, CA 94559

Re: Comments on the Addendum to the Environmental Impact Report for the Walt Ranch Vineyards Conversion (No. P11-00205-ECPA).

Dear David Morrison,

On behalf of the Center for Biological Diversity ("Center"), we are writing to express our concerns regarding the Addendum to the Environmental Impact Report for the Walt Ranch Vineyard Conservation ("Addendum") addressing the greenhouse gas ("GHG") emissions mitigation for the Walt Ranch Vineyards Conversion (No. P11-00205-ECPA) ("Project"). The proposed revisions to Mitigation Measures 6-1 ("MM 6-1") fail to use the best available science and fall short of the California Environmental Quality Act's ("CEQA") requirements to adequately mitigate the GHG impacts of the project. As detailed further below, the proposed mitigation is inadequate in part, because of the following:

- The Addendum fails to demonstrate that the Project's GHG emissions will be adequately mitigated with effective and enforceable measures. As proposed, the revised Mitigation Measure 6-1 does not comply with CEQA.
- The Addendum lacks substantial evidence that the proposed tree planting program is viable and would adequately mitigate the project's impacts. The Addendum needs to provide more information on the current Project site condition to analyze the adequacy and effectiveness of the proposed tree planting program.
- The proposed conservation easements are insufficient and are not clearly presented.
- The Addendum's carbon calculations are unclear and uncertain.

The Center is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has over 1.7 million members and online activists throughout California and the United States. The Center and its members have worked for many years to protect imperiled plants and wildlife, open space, air and water quality, and overall quality of life for people in Napa County.

I. CEQA requires a project's significant environmental impacts to be mitigated with effective and enforceable measures.

CEQA was enacted for the state to "take all action necessary to protect, rehabilitate, and enhance the environmental quality of the state" and to "[e]nsure that the long-term protection of the environment . . . shall be the guiding criterion in public decisions." (Cal. Pub. Res. Code § 21001.) Mitigation of a project's environmental impacts is one of the "most important" functions of CEQA. (*Sierra Club v. Gilroy City Council* (1990) 222 Cal.App.3d 30, 41.) Therefore, it is the "policy of the state that public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures which will avoid or substantially lessen the significant environmental effects of such projects." (Pub. Res. Code § 21002.) Ultimately, "the public agency bears the burden of affirmatively demonstrating that, notwithstanding a project's impact on the environment, the agency's approval of the proposed project followed meaningful consideration of alternatives and mitigation measures." (*Mountain Lion Foundation v. Fish & Game Com.* (1997) 16 Cal.4th 105, 134.) Here, if the County chooses to approve the Addendum and Mitigation Measure 6.1 as drafted, the County will not have fully met that burden.

The Environmental Impact Report ("EIR") for the Project concluded Walt Ranch will result in 105,849 metric tons of greenhouse gas emissions (GHG), largely due to the removal of trees to plant vineyards. At the time of Project approval, the County required the Project proponent Hall-Brambletree to mitigate for a little more than a quarter of those emissions, or approximately 27,528 MTCO$_2$e, through the preservation of 248 acres of oak woodland. Now, many years later and as the climate crisis only continues to worsen, the County has failed to ensure that the Project proponent will fully mitigate even those emissions by allowing a scientifically unsupported tree planting proposal and reducing the total number of preserved oak woodlands to 124 acres. Any substantive carbon gains from planting seedlings as part of the proposed tree planting program will not be seen for decades (Dybala et al., 2019), and as detailed further below, the gains are not guaranteed. The Addendum contains significant information gaps and uncertainties raising questions about the adequacy and effectiveness of the revised mitigation plan for the Project's significant GHG emissions. The CEQA Guidelines and relevant case law requires the County to make substantive revisions to the proposed MM 6-1 before adopting the Addendum. (Cal. Pub. Res. Code § 21002; § 21081.6(b); Guidelines § 15126.4(a)(2).)

II. The Addendum lacks substantial evidence that the proposed tree planting program is viable and would adequately mitigate the project's impacts.

According to the Addendum, the amended mitigation would include a tree planting program that would plant 16,790 oak trees as mitigation for the project's GHG impacts (from chopping down 14,281 trees) as well as an additional 16,790 oak trees to discourage an administrative appeal of the Project. (Hall Letter at 4) This would add up to a total of 33,580 replanted oak trees. However, there are a number of concerns regarding the validity and adequacy of the proposed tree planting program.

A. The Addendum lacks necessary information on the current Project site condition to analyze the adequacy and effectiveness of the proposed tree-planting program.

As an initial matter, the Addendum does not include vital information on the current conditions of the Project site, but instead makes unsupported assumptions and conclusions to support the inclusion of tree planting in MM 6-1. This approach violates CEQA and calls into question the reliability and adequacy of tree planting as a mitigation measure. (*City of Long Beach v. City of Los Angeles* (2018) 19 Cal.App.5th 465, 487.) The May 5, 2021 letter from Hall Brambletree Associates to Napa County in Attachment A of the Addendum ("Hall Letter") states that "[m]ost of the sequestered carbon that would be emitted by clearing trees and planting vines is already in the atmosphere" because 97% of the property burned either in the 2017 Atlas Fire and/or the 2020 Hennessey Fire. (Hall Letter at 1.) This is an unsubstantiated representation of the conditions of the Project area. This inaccurately assumes that the fires burned everything to the ground, no trees (or other vegetation) survived, no ecosystems that are either resilient to or dependent on wildfire, and that no carbon is stored in the soils or remaining tree trunks or other vegetation types. Neither the Addendum nor Hall Letter provide evidence to support this conclusion, nor could they. Nonetheless, this assumption is echoed throughout the Hall Letter and is used to bolsters the benefits and efficacy of the tree planting component of MM 6-1. (See Table 3 of the April 28, 2021 Walt Ranch Erosion Control Plan: Greenhouse Gas Mitigation Report in Attachment A of the Hall Letter ["Ascent Memo"].)

The Hall Letter assumes that fires burned uniformly throughout the area, which is inaccurate and not substantiated with any meaningful evidence. Fires are not uniform across a landscape. They have many different properties that affect their impacts on the environment. The frequency, intensity, severity, spatial complexity, and seasonality of wildfires all play a role in how ecosystems respond. Complete annihilation of oak woodlands in wildfires rarely happens, and the Project proponent provides no substantive analyses or evidence to support their assertions that most of the sequestered carbon has been emitted into the atmosphere already. Oak woodlands have evolved with wildfire due to lightning strikes and Indigenous cultural burning for millennia. For example, even when oaks are completely burned or topkilled, much of the stored carbon remains in dead tree trunks, and they can resprout basally (from the base of the tree) or epicormically (from the remaining tree trunk or branches) (see Figure 1 below). They are well adapted to wildfire, with trees and saplings often surviving wildfires, though survival rates can vary with fire severity and fire frequency (Ackerly et al., 2019; Holmes et al., 2008; Nemens et al., 2018).

Analysis of the 2017 Tubbs Fire provides an example of the varying wildfire characteristics and impacts to oak woodlands (Ackerly et al., 2019). According to the study, the Tubbs Fire was a mixed severity fire that burned 14,895 ha, of which 13,351 ha were in Sonoma County. Of the area burned in Sonoma County, 13.2% was unchanged, 22.1% experienced low-severity fire, 35.8% experienced medium-severity fire, and 28.9% experienced high-severity fire. Based on data from plots within Pepperwood Preserve, 73% of trees (diameter at breast height [DBH] > 1cm) and 50% of saplings (height > 50cm, DBH < 1cm) survived the fire, with higher survival in the low- and medium-severity fire patches (Ackerly et al., 2019). Many of the trees had crown survival, meaning the trunks and top branches outlasted the fire and green foliage was observed during surveys conducted a year later in the summer of 2018, while those that were burned more severely or top-killed often had basal resprouting, which means they survived the fire and were regrowing within a year of burning (Ackerly et al., 2019). Other studies have also shown the resilience of oak species to wildfire; a review found that wildfire mortality rates were 1-11% for mature oaks, 2-10% for saplings (with 75-90% top-killed and resprouting), and 17-52% for seedlings (Holmes et al., 2008), and after multiple fires 97% of top-killed oaks resprouted (Nemens et al., 2018).

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Figure 1. Basal resprouting of topkilled coast live oak sapling (top left) and black oak mature trees (top right). Epicormic sprouting of the same coast live oak tree 4 and 17 months after fire (bottom left and bottom right, respectively). Photos: Bryant Baker.

Therefore, not only is there carbon still being stored in the remaining tree trunks or boles that did not burn to ash in the fire, but many of the trees may still be alive and continuing to capture carbon (in their above-ground biomass as regrowth and in their roots and soils). In addition, the soils and other vegetation types are also carbon sinks, and digging them up to plant vines would release even more carbon. Stating that the Project would not have any impacts on carbon emissions because the recent fires already released most of the sequestered carbon in the Project area is an inaccurate representation of the conditions at the site as well as the Project's impacts to GHG emissions and climate change. The assertion fails to account for the fire resilience of oak woodlands and other habitat types and the fire severity throughout the site. Such assertions have the potential to overestimate the benefits of and over-credit the proposed tree planting mitigation.

According to the "Ascent Memo," areas that were burned solely by the Atlas Fire are already regrowing. But oaks in areas burned in the Hennessey Fire are likely also recovering. And although the condition of the areas burned by both fires is unclear, fire return intervals in oak woodlands are estimated to be less than 20 years (Van de Water & Safford, 2011) and a recent study found that 97% of top-killed oaks resprouted in an area that had burned twice in a short timeframe (Nemens et al., 2018). The areas that burned in the Hennessey Fire or both the Hennessey and Atlas fires should not be immediately written off as a dead zone of oaks or other fire-resilient vegetation. The oak woodlands in these areas will likely recover on their own.

Therefore, the assertions in the Hall Letter and Table 3 of Ascent Memo that such plantings would have additive carbon storage value are based on the assumption that no trees or other vegetation survived the recent fires. This assumption is not substantiated or grounded in the best available science. More analyses regarding fire severity and tree survival in the Project area are needed to more accurately estimate the number of individual oaks that did not survive in the burned areas. Without knowing the severity of the fires that burned through the Project area or the number of trees that survived (by remaining standing and/or resprouting), the public is unable to determine if the proposed tree planting program will truly be additive or effectively mitigate the Project's GHG impacts and if the Addendum meets CEQA's mandates.*(City of Long Beach v. City of Los Angeles* (2018) 19 Cal.App.5th 465.)

Additionally, the estimated oak woodland tree densities and number of trees lost provided in Table 3 of the Ascent Memo are unsubstantiated in science and lack evidentiary support. The Ascent Memo calculates the tree densities and trees lost without differentiating between mature trees, saplings and seedlings. (Ascent Memo at 6). But the carbon in these ecosystems is stored mostly in large, mature oak trees that have massive trunks and branches, and those trees likely survived the wildfire(s). Smaller saplings and seedlings make up a small proportion of the stored carbon and could be lost to wildfire, herbivory, or competition, with little impact on the amount of carbon storage in the ecosystem. Therefore, these calculations should have been more refined with mature trees, saplings, and seedlings separated out so that a more accurate estimate of carbon gains from the tree planting program could be provided. The County should take into account that, due to the proposed Project, carbon loss of tree removal will be immediate, while any gains from mitigation is slow and uncertain. The effectiveness and adequacy of the mitigation from the proposed tree planting program is questionable, and any substantive carbon gains from planting seedlings will not be seen for decades (Dybala et al., 2019). Carbon storage gains need to be more immediate to combat the climate crisis. Therefore, unless the County can provide substantial evidence demonstrating the effectiveness and adequacy of the tree planting 10 program, the County should require the conservation of existing habitats to mitigate the Project's GHG emissions as required by CEQA. (*Sacramento Old City Assn. v. City Council* (1991) 229 Cal.App.3d 1011, 1027.)

B. The tree planting mitigation is inconsistent, flawed and inadequate.

In addition to the significant information gaps in the Addendum, the proposed revision to MM 6-1 to replace oak woodland preservation with tree planting is inconsistent, flawed and inadequate for a number of reasons.

First, according to the Ascent Memo, "[o]ak woodlands accounted for … 68% of the burned area eligible for planting," (Ascent Memo at 6) which suggests 32% consisted of other habitat types. However, this is inconsistent with the concluding paragraph of the Ascent Memo, which states that "the total area of eligible planting areas is 1,025 acres, 901 acres of which were originally oak woodlands prior to the recent wildfires" (Ascent Memo at 9), which would be 88% of the burned area eligible for planting. This is inconsistent and should be clarified.

Second, if we consider 12-32% of the eligible planting area, there is a substantial portion of the eligible planting area that did not support oak woodlands at the pre-2016 baseline. Planting oak trees in areas that are comprised of grasslands and shrublands and did not historically have oaks could involve removing other carbon-sequestering vegetation that we know can grow there and replacing it with oak trees that may or may not survive there. Other areas where planting oaks would have added benefits to carbon storage and biodiversity, including fallowed agricultural lands, previously logged lands, or urban areas, could be considered as potential planting areas. Replanting and restoration of oaks require thoughtful planning to ensure the appropriate conditions are present to increase the chances of successful mitigation. As proposed, the Addendum fails to meet CEQA's requirement that the efficacy of an adopted mitigation measure must be supported by substantial evidence. (*Tracy First v. City of Tracy* (2009) 177 Cal.App.4th 912, 937.) 11

Third, the Project proponent's threat to reduce the number of trees that will be planted based on whether a challenge is filed against the Addendum raises significant concerns. According to the Addendum, "the applicant is proposing to reduce the number of trees to be planted from 33,580 to 16,790 trees in the event the County's decision to approve the revised GHG mitigation is appealed or challenged in court." (Addendum at 2-3.) Courts have rejected attempts by government agencies to discourage citizens from initiating legal remedies because such actions violate an individual's First Amendment rights. (*See BE&K Constr. Co. v. NLRB* (2002) 536 U.S. 516, 524-525; *Western Nat'l Mut. Ins. Co. v. Lennes [In re Workers' Compensation Refund]* (8th Cir. 1995) 46 F.3d 813, 823.) The Project proponent's attempt and the County's apparent acquiescence to hold hostage environmental mitigation and conservation benefits to the community in exchange for silence from concerned citizens is undemocratic. The Project proponent's apparent ability to plant an additional 16,790 trees also raises concerns whether all feasible mitigation measures to address the Project's significant GHG emissions were 12 adopted. Regardless of whether an appeal is filed, the Addendum should require the planting of 33,580 trees and any alternative approach would be contrary to public policy and case law.

13 And finally, the Addendum's requirement that monitoring for survival of seedlings last only five years is wholly inadequate. Oak mitigation plantings must be maintained for a minimum of seven years per Public Resources Code §21083.4. Scientists recommend 15-20 years or more of monitoring to determine the success, or lack thereof, of enhanced, restored, or created habitat (Mitsch & Wilson, 1996; Zedler & Callaway, 1999). Higher mitigation ratios coupled with extended years of effective monitoring and adaptive management strategies are needed to improve chances of successfully mitigating impacts (Ambrose et al., 2006; Moilanen et al., 2009; Sudol & Ambrose, 2002). We urge the County to revise the Addendum to address these concerns to ensure that the tree planting portion of the MM 6-1 is effective, adequate and meets CEQA's requirements. (*Sierra Club v. County of San Diego* (2014) 231 Cal.App.4th 1152; *POET, LLC v. State Air Resources Bd.* (2013) 218 Cal.App.4th 681.)

III. The proposed conservation easements are insufficient and are not clearly presented.

14 The Addendum includes a reduction in required mitigation in MM 6-1 from 248 acres to 124 acres of woodland habitat, arguing that the 124 acres "would be in addition to the 525 acres required to be permanently protected offset impacts related to biological resources, ultimately resulting in the protection of no less than 649 acres." (Addendum at 2.) The Hall Letter attempts to further justify this approach by claiming that that the acreage protected is "well over double the size of the project footprint of 316 acres." (Hall Letter at 2). However, the preservation of 525 acres to address the Project's significant impacts to wildlife and other biological resources should not be used to downplay the Project's significant GHG emissions or that much of the Project site is not suitable for vineyard development. The fact remains that the revised MM 6-1 reduces the acres of oak woodland the project proponent will be required to permanently protect, raising significant concerns about the efficacy of the MM 6-1 to reduce the Project's GHG emissions.

15 For example, it is not clear from the Addendum or the Hall Letter how the Project proponent will fully meet the now reduced requirement to preserve 124 acres. The Hall Letter "estimate[s] there will be at least 110 acres of woodland habitat" within the proposed conservation easement provided in Figure 1, which is 14 acres less than the proposed 124 acres. (Hall Letter at 2). The Hall Letter then goes on to state that the Project proponent has identified "a total of over 35 acres of suitable woodland habitat" as available outside of the proposed 110-acre easement. (Hall Letter at 2). However, Figures 1 and 2 of the Letter do not support these statements. First, the figures show 124.2 acres of "Available Acceptable Woodland in Easement" in dark green within the proposed easement area. But according to the text, that area only covers 110 acres. Second, the light green areas identified as "Available Woodland Outside of Easement" seem to cover much more than 35 acres. Third, the hatched purple polygons in Figure 2 are labeled as "Acceptable Woodland Habitat in Mitigation Easement (35.1 acres)," but many

of those polygons do not appear to include the light green polygons that indicate the "Acceptable Woodland Outside of Easement."

Therefore, the figures and the text do not match, making it difficult to understand what or where the mitigation will actually be. This lack of clarity and uncertainty violates CEQA's requirements for mitigation. (See *Cleveland Nat'l Forest Found. v San Diego Ass'n of Gov'ts* (2017) 17 Cal.App.5th 413, 433.) The location of the remaining 35 acres is important because disconnected small patches of land will be subject to edge effects and degradation, which will make them less effective at carbon storage compared to healthy woodlands. The public would be better able to understand the effectiveness of the proposed mitigation if the development footprint and the undevelopable areas were included in the maps. As currently presented, this information is insufficient to determine if this mitigation is adequate or meets CEQA requirements. (*San Joaquin Raptor* Rescue *Center v. County of Merced* (2007) 149 Cal.App.4th 645.) To the extent feasible, large, contiguous conservation areas and connectivity among the heterogeneous habitats should be prioritized to minimize habitat degradation that could negatively affect carbon storage capacity. That could include preserving appropriate mitigation lands adjacent to undevelopable lands. However, in contravention of CEQA's requirements, the public cannot ascertain the adequacy, certainty or effectiveness of the proposed mitigation as it is currently presented. (See *Preserve Wild Santee v. City of Santee* (2012) 210 Cal.App.4th 260.)

The Hall Letter also argues that "[i]dentifying 248 acres of woodland habitat that is not otherwise restricted due to steep slopes, watersheds, or the existing easement…would result in a patchwork of small "blobs" scattered throughout the property," which led them to "focus[] primarily on a large contiguous area that can be better-preserved, monitored and enforced through conservation easements" and "arrive[] at the not-less-than-124-acre proposal." While the preservation of more contiguous and connected conservation lands is a laudable goal, it is unclear why a contiguous 110-acre easement combined with other smaller areas throughout the Project site could not have been used to meet the original 248-acre mitigation requirement. As originally drafted and adopted, MM 6-1's requirement to conserve 248 acres to mitigate impacts to 316 acres of habitat was only a 0.78:1 mitigation ratio, and the proposed amendment of 124 mitigation acres is a 0.39:1 mitigation ratio. Both of these ratios are severely insufficient in light of the on-going climate crisis and extinction crisis. 16

The Addendum and proposed revisions to MM 6-1 requirements to preserve oak woodlands are inadequate, unclear and potentially ineffective. CEQA requires the Addendum be revised to address these outstanding concerns with the proposed revisions to MM 6-1. (*See* CA Pub. Res. Code § 21002, Guidelines § 15364; *Gray v. County of Madera* (2008) 167 Cal.App.4th 1099.)

IV. The Addendum's carbon calculations are inconsistent, unclear, and confusing.

According to the Ascent Memo, GHG emissions due to tree removal were calculated using the CalEEMod emissions factor for sequestration loss of 0.0367 $MTCO_2e$/tree over 100 years for 28,616 trees, which came out to 105,021 (Report, Table 1, at 2). But the preservation of

248 acres of woodland carbon sequestration was calculated using the CalEEMod emissions factor for land use change of 111 MTCO$_2$e/acre for an estimated 248 acres, which came out to 27,528 (26% of the calculated carbon emissions from construction). It is unclear why the calculation methods differ between calculating losses and gains. Why is one calculation based on trees and the other calculation based on acres? The calculation for loss of carbon sequestration from tree removal and gains in carbon sequestration from preservation should be calculated consistently so that the public can fully assess the adequacy of the mitigation for the Project's GHG emissions. (*City of Long Beach v. City of Los Angeles* (2018) 19 Cal.App.5th 465, 487.) 17

V. Conclusion

We urge the County to reject, or at a minimum substantially revise, the proposed Addendum until the issues discussed above are adequately addressed. The County is not limited to measures proposed by the Applicant but must instead adopt an addendum that reflects the best available science and fully complies with the requirements of CEQA. Given the recent IPCC report emphasizing the severity of the climate crisis and predicting that global warming will reach or exceed 1.5C if we do not take immediate, rapid, and large-scale action to reduce GHG emissions (IPCC, 2021), the County can and should do more to address, reduce, and mitigate the GHG emissions from the Project.

Thank you for the opportunity to submit comments on the proposed Addendum.

Sincerely,

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Exhibit 3

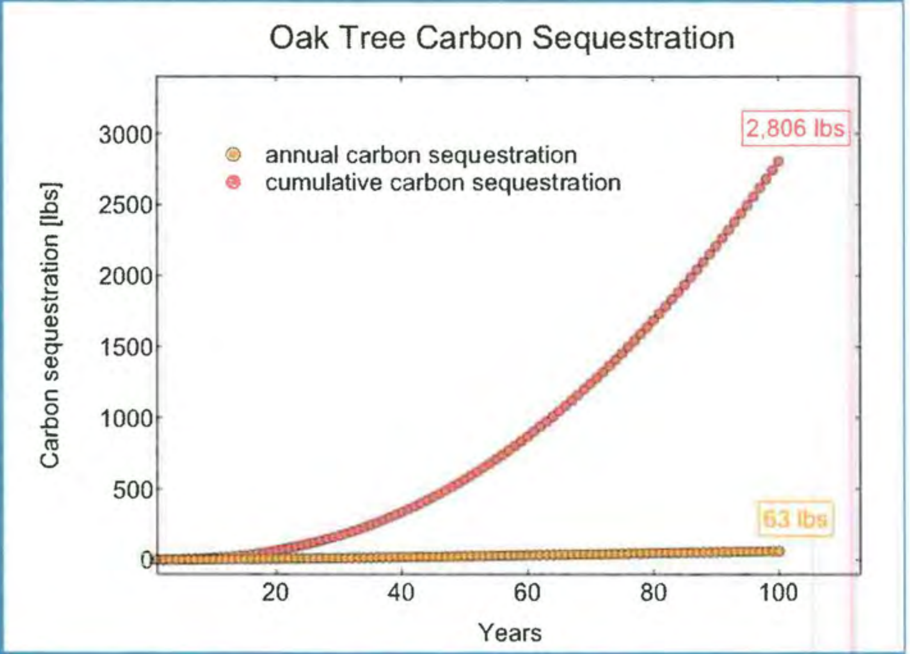
Are We Losing Faster Than We're Gaining?

Katie Stilwell
with Napa Climate NOW!

In Napa County, we're losing faster than we're gaining!

We are losing the ability to sequester carbon <u>faster</u> than we're gaining sequestration potential with newly planted trees.

Because we need to get to net zero emissions by/before 2030, we can no longer cut down forests and take decades to regrow that lost carbon sequestration and stocking.

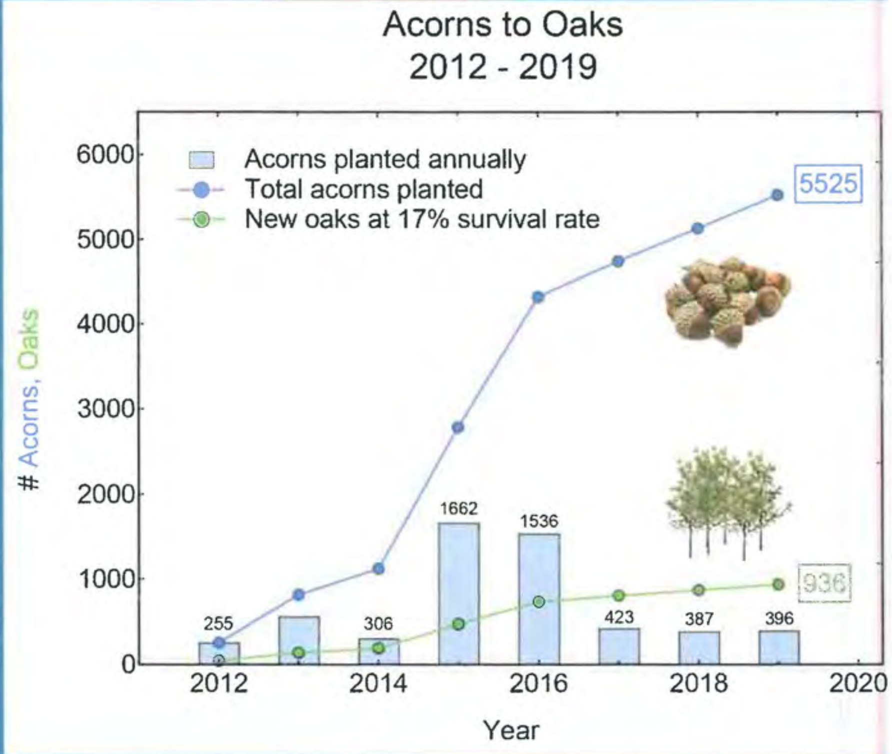


Placing responsibility on our youth

Acorns to Oaks Program 2012-2019[1]

Instilling a conservation ethic in youth
5,525 acorns planted
17% survival rate -- 936 surviving oaks
4 years average seedling age

All of the surviving seedlings have sequestered roughly half the CO2 that a mature oak has sequestered.



WHY IT'S A PROBLEM

Rational/Emotional connection to home

Increasing anxiety among youth regarding climate crisis

Politicized science > Env crisis and COVID

It's become about ethics: **short-term private gain vs. long-term health of the commons** (air, environment)

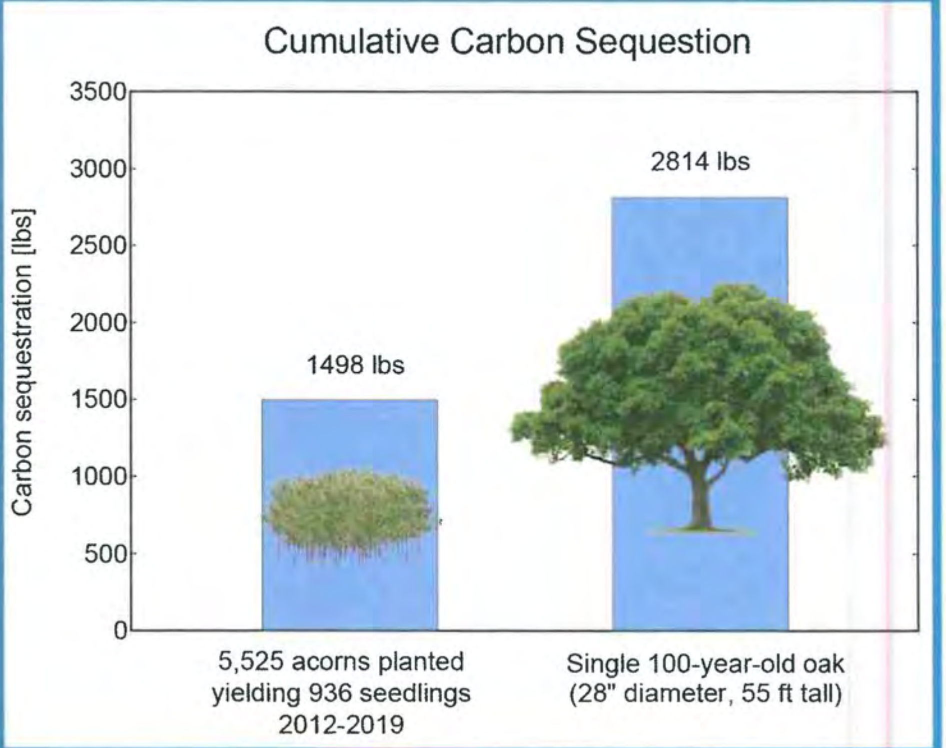
WE URGENTLY NEED TO:

Practice proforestation

Proforestation: "growing existing forests intact to their ecological potential" [5]

Stop deforestation of Napa Valley

Deforestation causes a loss of sequestration potential and also re-releases carbon

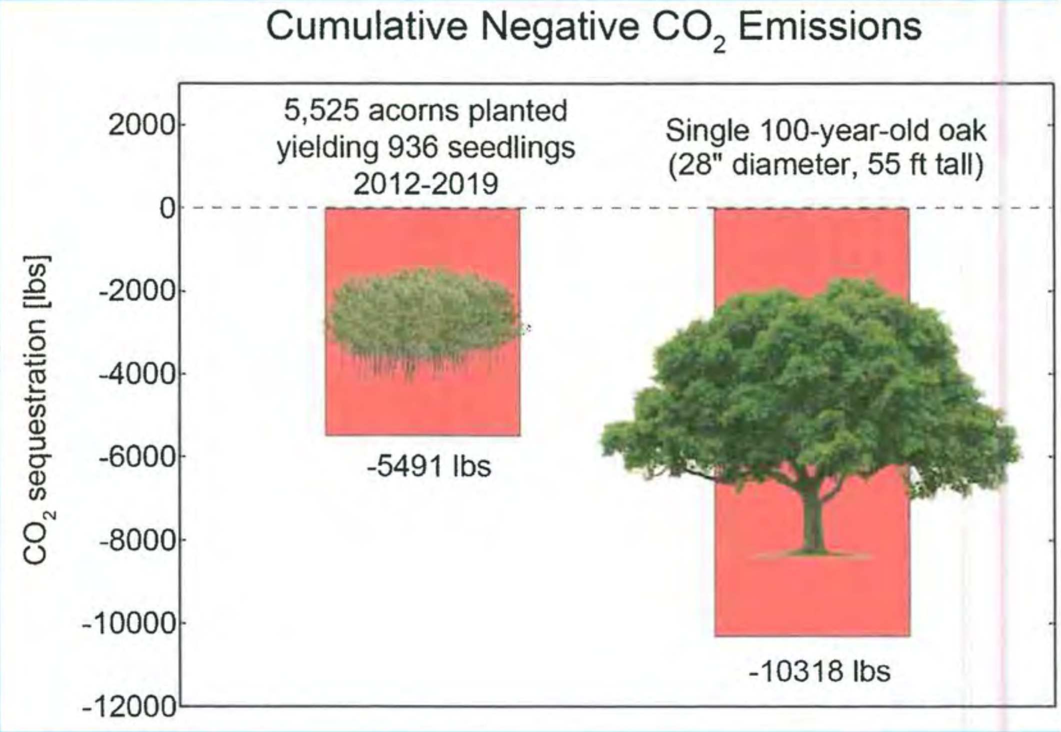


WE URGENTLY NEED TO:

You can also think of it like this!

-negative emissions: trees taking carbon dioxide out of the air

Bottom line: there's a difference of about half the environmental benefit between a single mature oak and all the surviving seedlings.



WE URGENTLY NEED TO:

Respect Napa County's Policy CON-65:

> "the County shall ...strive to maintain and enhance the County's current level of carbon sequestration functions" [4]

Appendix:

1: https://naparcd.org/

2: https://naparcd.org/wp-content/uploads/2017/10/8-Calculating-CO2-Sequestration.pdf

3: http://www.unm.edu/~jbrink/365/Documents/Calculating_tree_carbon.pdf

4: https://www.countyofnapa.org/DocumentCenter/View/3334/Napa-County-General-Plan---Complete-Document-PDF

5: https://www.frontiersin.org/articles/10.3389/ffgc.2019.00027/full

Photo Credits: Hardy Wilson (slide 4); Duane Cronk (slide 7)

References

PERSPECTIVES

ECOLOGY

Tree planting is not a simple solution

Tree planting must be carefully planned and implemented to achieve desired outcomes

By **Karen D. Holl**[1] and **Pedro H. S. Brancalion**[2]

This mixed-species tree-planting project is part of a larger-scale initiative to restore 15 million hectares of Brazil's Atlantic Forest.

PHOTO: HOLL ET AL.

A plethora of articles suggest that tree planting can overcome a host of environmental problems, including climate change, water shortages, and the sixth mass extinction (*1*–*3*). Business leaders and politicians have jumped on the tree-planting bandwagon, and numerous nonprofit organizations and governments worldwide have started initiatives to plant billions or even trillions of trees for a host of social, ecological, and aesthetic reasons. Well-planned tree-planting projects are an important component of global efforts to improve ecological and human well-being. But tree planting becomes problematic when it is promoted as a simple, silver bullet solution and overshadows other actions that have greater potential for addressing the drivers of specific environmental problems, such as taking bold and rapid steps to reduce deforestation and greenhouse gas emissions.

These ambitious tree-planting efforts (examples in supplementary table S1) are mostly well intentioned and have numerous potential benefits, such as conserving biodiversity, improving water quality, providing shade in urban areas, and sequestering carbon (*1*, *3*). Nonetheless, the widespread obsession over planting trees can lead to negative consequences, which depend strongly on both how and where trees are planted (see the table). For example, whereas tree planting often enhances floral and faunal diversity, planting trees in historic grasslands and savannas can harm native ecosystems and species (*4*). Likewise, trees are often suggested as an important income source for small landholders but may increase social inequity and dispossess local people from land if tree-planting programs are imposed by governments and external investors without stakeholder engagement (*5*). Repeatedly, top-down reforestation projects have failed because the planted trees are not maintained, farmers use the land for livestock grazing, or the land is recleared.

The massive Chinese government Grain-for-Green tree-planting program, which cost an estimated $66 billion, illustrates a number of these trade-offs. The program is credited with increasing tree cover by 32% and reducing soil erosion by 45% in southwestern China over a 10- to 15-year period (*6*). But like many large-scale reforestation programs, most new tree cover is composed of one or a few non-native species that have much lower biodiversity than native forests (*6*). Moreover, large-scale tree planting in the semiarid Loess Plateau in central China has reduced river runoff and in turn the amount of water available for human activities, owing to the large amount of water transpired by rapidly growing trees (*7*). Most of the trees for this program were planted in former agricultural land, resulting in a 24% decrease in cropland. During the same time period, native forest cover decreased by 7% (*6*). This illustrates a major overarching concern about tree planting, which is the displacement of agriculture from the land being reforested to areas occupied by native forests, thus resulting in further deforestation (*8*).

Reforestation projects can be an important component of ensuring the well-being of the planet in coming decades, but only if they are tailored to the local socioecological context and consider potential trade-offs. To achieve the desired outcomes, tree-planting efforts must be integrated as one piece of a multifaceted approach to address complex environmental problems; be carefully planned to consider where and how to most effectively realize specific project goals; and include a long-term commitment to land protection, management, and funding.

The first priority to increase the overall number of trees on the planet must be to reduce the current rapid rate of forest clearing and degradation in many areas of the world. The immediate response of the G7 nations to the 2019 Amazon fires was to offer funding to reforest these areas, rather than to address the core issues of enforcing laws, protecting lands of indigenous people,

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and providing incentives to landowners to maintain forest cover. The simplistic assumption that tree planting can immediately compensate for clearing intact forest is not uncommon. Nonetheless, a large body of literature shows that even the best-planned restoration projects rarely fully recover the biodiversity of intact forest, owing to a lack of sources of forest-dependent flora and fauna in deforested landscapes, as well as degraded abiotic conditions resulting from anthropogenic activities (*9*).

Tree planting is not a substitute for taking rapid and drastic actions to reduce greenhouse gas emissions. Certainly, planting trees in formerly forested lands is one of the best options to offset a portion of anthropogenic carbon emissions, but increasing global tree cover will only constitute a fraction of the carbon reductions needed to keep temperature increases below 1.5° to 2°C (*4*). Potential carbon sequestration estimates of increasing tree cover range more than 10-fold, depending on assumptions about the rate of carbon uptake, the amount of land considered appropriate for reforestation, and how long those trees remain on the land (*2*, *3*, *10*). Moreover, much uncertainty remains about how much carbon trees will sequester in the future, given that increasing drought and temperatures from climate change can lead to substantial tree mortality either directly or indirectly through feedback loops involving fire and insect outbreaks (*11*). Conversely, some high-latitude areas that were unsuitable for trees may become favorable in the future.

Contrasting tree-planting outcomes

Tree-planting efforts can have both negative and positive ecological and social outcomes depending on whether the location-specific pros and cons of different alternatives are rigorously evaluated, and projects are comprehensively planned in consultation with all stakeholders.

Unintended negative effects

- Reduced water supply
- Destruction of native grasslands and spread of invasive tree species
- Increased social inequity
- Displacement of farmland
- Increased deforestation

Potential beneficial outcomes

- Greater carbon and water storage
- Reduced soil erosion
- Increased landscape connectivity and native biodiversity
- Provision of food, wood, and shade
- Income generation

Maximizing the benefits of tree planting requires balancing multiple ecological and social goals to prioritize where to increase tree cover regionally and globally. Some global maps estimate potential land area for reforestation without factoring in that people need places to live, produce food, and extract natural resources (*12*). Large-scale reforestation may be feasible in some areas, particularly those in public ownership, but reforestation will mostly occur in multiuse landscapes. Several recent studies suggest that prioritizing forest restoration on the basis of criteria, such as past land use, potential for natural regrowth of forest, conservation value, and opportunity cost from other land uses, can increase feasibility and improve reforestation success (*13*). For example, choosing appropriate locations for tree planting in the Brazilian Atlantic Forest biome can triple conservation gains and halve costs (*14*). Large-scale planning is more likely to result in successful reforestation projects over the long term and prevent deforestation elsewhere. But recognizing competing land uses means that the actual land area feasible for reforestation is much lower than the amount proposed by some ambitious global reforestation maps and national commitments (*12*).

Successful tree planting requires careful planning at the project level, which starts by working with all stakeholders to clearly identify project goals. People plant trees for many different reasons, such as restoring forest, sequestering carbon, providing income from timber harvesting, or improving water quality. A single tree-planting project may achieve multiple goals, but it is rarely possible to simultaneously maximize them all, because goals often conflict, and prioritizing one goal may result in other undesirable outcomes. Clear goals are key to being able to evaluate whether the project was successful and to selecting the most cost-effective way to increase the number of trees. For example, if a primary project goal is to restore historically forested habitat, simply allowing the forest to regrow naturally often results in the establishment of more trees at a much lower cost than actively planting trees, particularly in locations with nearby seed sources and less-intensive previous land use. By contrast, if the goal is to provide landowners with fruit trees or species with valuable timber, then plantations of non-native species may be the most suitable approach. Many additional questions must be addressed prior to project implementation, such as potential unintended consequences of tree planting, which species to plant, how landowners will be compensated for lost income, and who is responsible for maintaining trees over the long term.

Most projects set targets of how many trees to plant (table S1), rather than how many survive over time or, more importantly, whether the desired benefits are achieved. By contrast, most tree-planting goals, such as carbon sequestration and providing timber and nontimber forest products to landowners, require decades to achieve. This short-term view has resulted in large expenditures on tree-planting efforts that have failed. For example, approximately $13 million were spent to plant mangrove trees in Sri Lanka following the Indian Ocean tsunami in 2004, yet monitoring of 23 restoration planting sites five or more years later found that more than 75% of the sites had <10% tree survival because of poor project planning and lack of seedling maintenance (*15*).

Hence, successful tree-planting projects require a multiyear commitment to maintaining trees, monitoring whether project goals have been achieved, and providing funding for corrective actions if they are not. Using this adaptive management approach will certainly increase the price tag of tree planting, but it is money better spent than simply planting trees that mostly do not survive.

To realize the potential benefits of increasing tree cover, it is essential that tree-planting projects include thorough goal setting, community involvement, planning, and implementation, and that the time scale for maintenance and monitoring is sufficient. Otherwise the extensive human energy and financial resources invested in tree planting are likely to be wasted and have undesirable consequences, thus undermining the potential of this activity to deliver the expected environmental benefits that are critically needed for humans and nature in this time of rapid global change. ■

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SUPPLEMENTARY MATERIALS

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Science

Tree planting is not a simple solution

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LONG-TERM GROWTH AND PERSISTENCE OF BLUE OAK (*QUERCUS DOUGLASII*) SEEDLINGS IN A CALIFORNIA OAK SAVANNA

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ABSTRACT

We report on growth and survivorship of two cohorts of blue oaks *Quercus douglasii* Hook. & Arn. (Fagaceae) monitored at Hastings Reservation in Monterey County, California, the first growing in an unprotected old field and measured as seedlings in 1965 and the second planted as acorns in 1985 in several sites differing in their degree of protection from grazing. Growth of all individuals was extremely slow: among those surviving in the first cohort, mean (± SD) height in 2006 was only 76.7 ± 45.0 cm for an average growth rate of 1.8 cm yr $^{-1}$, and only one of the original 73 oaks had grown taller than 1.5 m while one was still a seedling 28 cm in height 41 yr after being first marked. Of the second cohort, mean height 21 yr after planting was 54.3 ± 31.4 cm. None of these latter individuals had grown out of the sapling stage while 25% were still seedlings < 30 cm in height. Growth of this second cohort was significantly greater when protected from grazing and when growing in the open rather than in the shade. Although growth was slow, survivorship of oaks first measured in 1965 was high, indicting that individuals can live for decades despite significant grazing pressure. Our results confirm the difficulties of inferring age from size of blue oaks, since individuals just achieving the height at which they are typically cored may be 50 or more years old. They also indicate that regeneration, although very slow, can occur in open oak savannas in California despite significant grazing pressure. Whether the observed amount of regeneration is sufficient for long-term sustainability will require continued monitoring and modeling of oak demography.

Key Words: blue oak, *Quercus douglasii*, regeneration, seedling growth, survivorship.

The health and status of California's vast oak woodlands is one of the more vexing questions currently facing the state's ecologists and rangeland managers. Are they declining, and if so, is it due to grazing, competition from exotic grasses, fire suppression, climate change, or some combination of factors (Griffin 1981; Muick and Bartolome 1987; Gordon and Rice 2000; Kueppers et al. 2005; Tyler et al. 2006)? In the case of the blue oak *Quercus douglasii* Hook. & Arn. (Fagaceae), a species dominating nearly 2×10^6 ha in the state (Standiford 2002), the evidence is mixed, as demographic surveys almost uniformly reveal limited recruitment but long-term studies have generally shown no decline in tree density (Tyler et al. 2006).

Resolving this problem lies in obtaining more extensive data on the demography of the species in question. Unfortunately this has not proved to be easy, since individuals can live hundreds of years and are logistically difficult to age, making it virtually impossible to estimate when prior regeneration events occurred, much less the extent to which such events are episodic and dependent on particular ecological circumstances.

Here we report on the persistence and growth of blue oaks planted as acorns or first marked as natural seedling recruits as part of studies going back to 1965. Our results indicate that the relationship between size and age in this species may be even more problematical than previously suspected. They also confirm the remarkable degree to which blue oak saplings can cling to what appears to be a precarious existence over many years until such time that they are able to achieve sufficient height to escape browsing.

METHODS

The study was conducted at Hastings Reservation, Monterey County, California, established in 1937. Thus, although cattle grazing, clearing, and various agricultural activities occurred historically, no such disturbances took place during the time period covered by this study. Hastings is located approximately 50 km from the coast and averages 53.3 cm of rain year^{-1} (mean of 67 yr between 1 July 1939–30 June 1940 and 1 July 2005–30 June 2006; records from Reserve headquarters). Individual oaks followed were either planted or monitored in two areas of the Reserve. The first, North Field, was an old field cleared around 1900 and used until 1937 for hay and grapes. North Field was left open the entire time and was thus regularly grazed by mule deer (*Odocoileus hemionus*) as well as smaller mammals including gophers and mice. The second area (Arnold Road Flat) was within a large exclosure built in 1983 for a separate study and thus was not grazed by large herbivores during the study, but was open to smaller mammals.

Two sets of oaks were examined. The first, called the "White" cohort, consisted of 73 naturally-recruiting blue oak seedlings in North Field that were tagged and measured (height only) in April 1965 by K. L. White. Three of the seedlings were new in spring 1965. All others were pre-1965 seedlings when tagged. Their ages were not known, but all were short (mean ± SD = 6.5 ± 3.2 cm, range 2–18 cm) and were presumably thought to have been from acorns produced in fall of 1963 that sprouted in spring 1964. It was not possible to identify the original 1965 vs. pre-1965 seedlings, and thus all individuals in the White cohort are assumed to have been at least 42 yr old in 2006.

Subsequent to marking, seedlings and saplings were monitored and measured by J. R. Griffin on 10 occasions (June 1969, January 1976, September 1979, January 1984, June 1986, June 1987, August 1988, June 1989, June 1990, and February 1991). With some exceptions, at each sampling period the height of tallest sprout from each remaining seedling was measured, while starting in 1988, the greatest width of each seedling was measured. Finally, on 5 October 2006, we examined all individuals whose identity we could be confident of and measured their height, width, and the basal diameter of stems > 0.5 cm at 5 cm above the ground. When multiple stems were present, they were combined to yield a single value for the overall diameter that matched the total basal area of all stems. Size and growth rates are based on the 14 individuals we identified and measured in 2006.

The second set of oaks used in the study, called the "Menke" cohort, consisted of individuals from a study of water relations of California oaks by J. W. Menke initiated in 1985. Blue oak acorns were planted in several 5 × 5 blocks varying in their degree of protection from grazing and openness. Block 1 (not protected; shaded) was planted adjacent to several blue oak trees near North Field, but otherwise not protected from grazing in any way. Block 2 (protected; open), also near North Field, consisted of acorns planted in the open, but protected by wire mesh baskets up to 40 cm in height that were opened up in 1992 to allow free growth of saplings that had in some cases had grown out of or up to the top of the baskets. Two additional sets of acorns were planted within a deer exclosure on Arnold Road Flat. Block 3 (protected; open) was planted in an open area within the plot, while block 4 (protected; shaded) was planted under partial cover of a mature blue oak within the plot; seedlings in both these blocks were also protected by wire mesh baskets 40 cm in height. For analysis, we divided individuals into those that were not protected (block 1) vs. protected (blocks 2–4)(variable "protection"), and those that were growing in the open (blocks 2 and 3) vs. those that were shaded (blocks 1 and 4)(variable "shade").

We measured the maximum height, maximum width, and basal diameter at 5 cm above ground on 5 October 2006 of all individuals we could unambiguously identify as having been from the original set of acorns based on remaining wooden stakes and their location within the original grid on which acorns were originally planted (Fig. 1). All individuals were thus known to be 21 yr old at the time they were measured. No data from prior years was available. We used the two categories of "protection" and "shade" to quantify the effects of these variables on growth of the saplings using general linear models. Survivorship could not be measured in these oaks, as we could not be certain how many had been planted initially.

Following Phillips et al. (1997), we classify individuals as "seedlings" (<30 cm in height), "saplings" (30–150 cm in height), "poles" (150–300 cm in height), and "adults" (taller than 3 m). Significant browsing by deer, where present, is expected up until individuals reach the pole size class (McCreary 2001). Values presented are means ± SD.

RESULTS

White Cohort

Of the original 73 seedlings marked in 1965, J. R. Griffin found 64 (88%) in June 1969 and 18 (24.7%) in February 1991, while we successfully located 14 (19.2%) in 2006 (Fig. 2). These values represent minimum survivorship of the original seedlings, since other seedlings and saplings were present in the plot and it is possible that some lost their tags during the course of the study and could no longer be identified.

Growth of the seedlings varied considerably, with individuals at the end of the study an average of 76.7 ± 45.0 cm (range 28 to 200 cm) in height (Fig. 3), 90.6 ± 43.8 cm (range 13 to 174 cm) in width, and 4.3 ± 2.0 cm (range 0.7 to 7.7 cm) in basal diameter. The rate of growth was < 1 cm yr^{-1} in height during the first three decades (Fig. 4), and in one case (7% of surviving individuals) the oak was still in the seedling category (28 cm in height) in 2006, 41 yr after being initially marked. Of the remaining 13 oaks, 12 (86%) graduated to the sapling size class by 2006 and one (7%) achieved pole status, thereby being the only one of the original 73 seedlings to

FIG. 1. One of the Menke plots in December 2006. The wire mesh exclosures are approximately 40 cm in height. Note the wooden stakes and grid spacing of the seedlings used to identify them in 2006.

have completely escaped likely grazing by deer after (at least) 42 yr. Overall, the mean increase in height over the 42 yr was 1.83 cm yr^{-1} (range 0.67–4.76 cm yr^{-1}) and the mean increase in basal diameter of the 14 oaks (conservatively assuming that their original diameter was 0) was 0.10 cm yr^{-1} (range 0.05–0.18 cm yr^{-1}).

Although overall growth was slow, growth rate increased considerably near the end of the study (Fig. 4), presumably as height or width finally became sufficiently large to provide some protection against grazing. Overall, height was relatively well predicted by models including age as either a squared or exponential term (quadratic model: height $= -0.866 * \text{age} + 0.054 * \text{age}^2 + 15.1$, $F_{2,160} = 81.7$, $R^2 = 0.50$, $P < 0.0001$; exponential model: height $= 9.27 * e^{0.0399*\text{age}}$, $F_{1,161} = 140.8$, $R^2 = 0.46$, $P < 0.0001$).

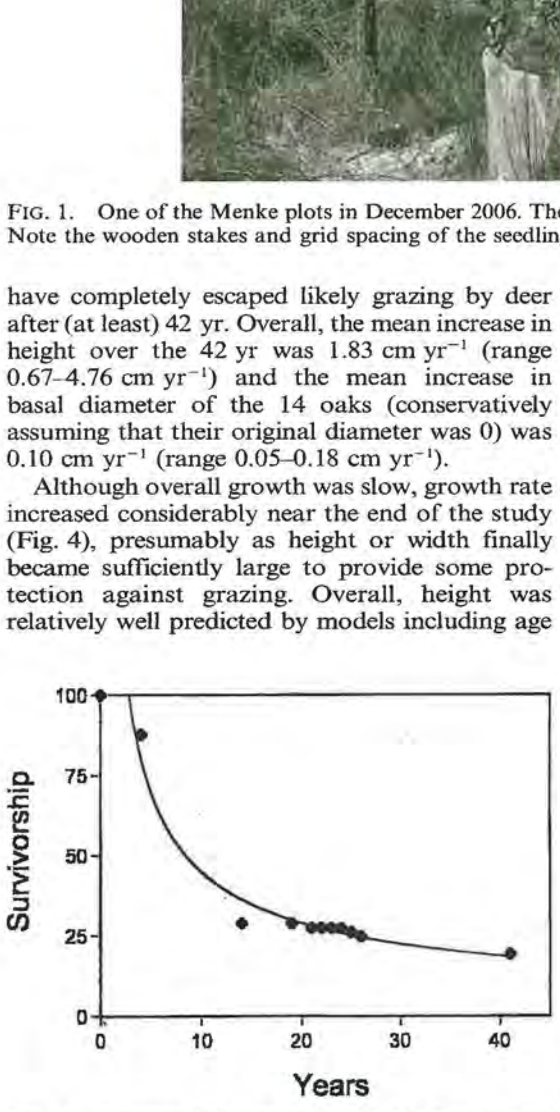

FIG. 2. Survivorship curve for the 73 White cohort first marked in 1965 as seedlings. The overall annual survivorship between 1965 and 2006 based on this sample is 96.1% year ^{1}. Line drawn is fit by a power curve: percent survivorship = 193.3 × (years) $^{0.634}$.

Menke Cohort

We identified and measured a total of 32 oaks in the four Menke plots (Fig. 4). Overall, the mean height of the individuals in 2006 was 54.3 ± 31.4 cm (range 6–112 cm), while the mean diameter was 1.6 ± 0.5 cm (range 0.6–2.8) cm. After 21 yr, 8 of 32 (25%) were still seedlings < 30 cm in height, while the majority were saplings < 150 cm in height. Mean increase in height was 2.59 cm yr^{-1} (range 0.29–5.33 cm yr^{-1}) and mean increase in diameter was 0.074 cm yr^{-1} (range 0.029–0.133 cm yr^{-1}). Both protection (positively) and shade (negatively) affected height of the oaks, while only shade (negatively) influenced diameter (Table 1). At 21 yr of age, the height of these individuals was generally within the range expected from the White cohort, given that none of the latter had been protected from grazing in any way (Fig. 4).

DISCUSSION

Because of low survivorship, there have been few prior studies of growth by blue oaks seedlings and none that have covered as long a time period as that reported on here. Previous work by Phillips et al. (1997, 2007a, b) is the most extensive, demonstrating that up to 18% of blue

FIG. 3. The authors at two of the White individuals in October 2006. Left: tree 767, 7 cm in height in 1965, 112 cm (6.7 cm diam.) in 2006, by which time it was third-tallest tree of the 14 found. Right: tree 772, also 7 cm in height in 1965, 34 cm (1.9 cm diam.) in 2006, at which time it was the second-shortest tree still extant.

oak seedlings are 26 or more years old, that surviving seedlings grow very slowly and remain for a long time in the seedling size class, and that fencing significantly increases seedling growth. Our results confirm and extend these conclusions. Of 14 oaks known to have survived 41 yr after being marked, one (7%) was still a seedling 28 cm in height and only one successfully outgrew the sapling stage (>150 cm) during the course of the study.

Comparably slow growth was observed in a second set of oaks planted as acorns in 1985, one-fourth of which were still seedlings < 30 cm in height when 21 yr old. Growth in this second set was significantly greater among those that were protected from grazing by wire mesh baskets and (in some cases) deer fencing and among acorns that were planted in the open rather than in the shade. The latter of these findings matches the reduced photosynthetic capacity and root elongation rates among blue oak seedlings grown in the shade by Callaway (1992a, b), although Callaway's studies also found blue oak seedlings to be relatively shade tolerant and to survive better when cover was present.

In contrast, the first of these findings, that growth of seedlings was greater among those protected from grazing, is not surprising, as grazing by deer and rodents is well known to inhibit seedling growth (White 1966; Griffin 1981; Muick and Bartolome 1987; Tyler et al. 2002; Phillips et al. 2007a). However, growth rates were still low, even among individuals protected from grazing by large herbivores and, at least to some extent, by rodents as well. Of nine oaks growing within deer exclosures and protected by 40 cm wire mesh baskets, mean height after 21 yr was still only 65.6 cm (range 32–112 cm) and mean increase in height only 3.12 cm yr^{-1} (range 1.48–5.33 cm yr^{-1}).

Thus, under natural conditions, blue oaks at Hastings Reservation grow very slowly and may require several decades or more to outgrow the sapling stage even when protected from most sources of grazing pressure. Only after decades, once both the above-ground size of saplings is sufficient to provide some protection against uninhibited grazing by deer and other large herbivores and (perhaps in some cases) the below-ground roots are deep enough to access a more reliable water source, does the growth rate increase (Fig. 4).

Although growth was slow, even among protected seedlings, survivorship of seedlings was relatively high even when unprotected. Of 73 unprotected seedlings originally marked in 1965, 64 (88%) were alive four years later (Griffin 1981), for an annual survivorship of 96.8%, far higher than reported in other studies (Davis et al. 1991; Allen-Diaz and Bartolome 1992; Phillips et al. 2007b). Survivorship subsequently declined, but at least 18 (24.7%) were still alive 26 yr after marking in 1991 and 14 (19.2%) were alive in

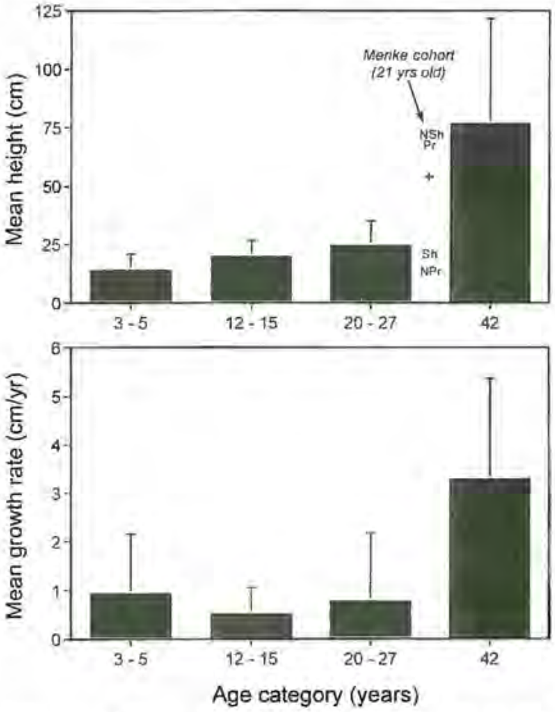

FIG. 4. Mean ± SD height (top) and mean ± SD annual increase in height (bottom) of the White cohort during the four decades of the study. Also marked in the top panel in between the last two categories are the mean heights of the 21-year-old Menke cohort, including the overall mean (+) and the means for seedlings that were not shaded (NSh), protected from grazing (Pr), shaded (Sh), and not protected from grazing (NPr).

2006, 41 yr after the start of the study. Thus, the overall survivorship of the 73 seedlings over the course of the study was at least 96.1% year^{-1}, and survivorship during the 15 yr between 1991 and 2006 was an impressive 98.3% year^{-1}. Possibly these high values are in part a result of having followed a cohort of seedlings that had already undergone considerable mortality by the time they were marked in 1965. Nonetheless, the ability of the seedlings to persist despite repeated and apparently intense browsing over decades is impressive.

Previous studies have found significant differences between the actual age structure of blue oaks stands based on tree-rings and the predicted age structure based on diameter (McClaran and Bartolome 1990; Phillips et al. 1997). Our results suggest that in at least some cases there may be even greater discord between age and size of blue oaks than previously thought because of the length of time some individuals require to achieve the height necessary to escape significant browsing damage. Of the oaks in the White cohort, only one (1.4% of the original sample) had achieved a height of over 150 cm in 41 yr, making it into the "pole" stage at which browsing by large herbivores was no longer likely to significantly inhibit further growth. Conversely, one individual remained a seedling 28 cm in height 41 yr after being first marked. In the Menke cohort, only a small proportion of individuals (3 of 32, 9.4%) had achieved 1 m in height by age 21, and none had successfully grown out of the sapling stage. Clearly by the time many of these oaks graduate into the adult population they will be well over half a century old, and in some cases possibly much older, assuming they survive. At that point, measuring their diameter at breast height (DBH) will clearly yield a gross underestimate of their age. More problematically, even coring them will not provide a good estimate of their actual age, since individuals may have been 50 or more years old by the time they reach the height at which coring is generally performed.

A recent review of recruitment in blue oaks concludes that resolving the current controversy over the sustainability of California oak woodlands will require long-term monitoring, age-structure analysis, and population modeling (Tyler et al. 2006). Our results add to previous concerns that the second of these, age-structure analysis, will have to be conducted with caution and that even with extensive coring or clearing (Mensing 1992) it may not be possible to accurately pinpoint the years or even the general time periods when regeneration has taken place in the past in established stands.

With respect to the regeneration of blue oaks, our sample is clearly too small to draw many

TABLE 1. RESULTS OF TWO-WAY ANOVAS ANALYZING THE VARIABLES "PROTECTION FROM GRAZING" (PROTECTED, NOT PROTECTED) AND "SHADE" (SHADED, NOT SHADED) ON HEIGHT AND DIAMETER OF THE MENKE COHORT IN 2006, WHEN THEY WERE 21 YRS OLD.

	Mean ± SD (N)			
	Yes	No	*F*-value	*P*-value
Height (cm)				
Protection	68.4 ± 23.1 (24)	13.0 ± 4.8 (8)	4.49	0.043
Shade	20.1 ± 13.1 (11)	72.2 ± 21.6 (21)	8.80	0.006
Diameter (cm)				
Protection	1.67 ± 0.57 (24)	1.26 ± 0.39 (8)	2.67	0.11
Shade	1.13 ± 0.40 (11)	1.80 ± 0.49 (21)	13.8	0.001

conclusions. However, it is noteworthy that survivorship of naturally recruiting seedlings was relatively high, at least subsequent to when they were first marked. Furthermore, although only one of the original 73 seedlings had successfully grown out of the sapling stage after 41 yr, other individuals in this sample may eventually join it. Thus, regeneration is occurring, albeit at a painstakingly slow rate. Whether such a slow rate of regeneration is sufficient to maintain California's blue oak woodlands over the long term remains to be determined.

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LETTER

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Rate of tree carbon accumulation increases continuously with tree size

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Forests are major components of the global carbon cycle, providing substantial feedback to atmospheric greenhouse gas concentrations[1]. Our ability to understand and predict changes in the forest carbon cycle—particularly net primary productivity and carbon storage—increasingly relies on models that represent biological processes across several scales of biological organization, from tree leaves to forest stands[2,3]. Yet, despite advances in our understanding of productivity at the scales of leaves and stands, no consensus exists about the nature of productivity at the scale of the individual tree[4–7], in part because we lack a broad empirical assessment of whether rates of absolute tree mass growth (and thus carbon accumulation) decrease, remain constant, or increase as trees increase in size and age. Here we present a global analysis of 403 tropical and temperate tree species, showing that for most species mass growth rate increases continuously with tree size. Thus, large, old trees do not act simply as senescent carbon reservoirs but actively fix large amounts of carbon compared to smaller trees; at the extreme, a single big tree can add the same amount of carbon to the forest within a year as is contained in an entire mid-sized tree. The apparent paradoxes of individual tree growth increasing with tree size despite declining leaf-level[8–10] and stand-level[10] productivity can be explained, respectively, by increases in a tree's total leaf area that outpace declines in productivity per unit of leaf area and, among other factors, age-related reductions in population density. Our results resolve conflicting assumptions about the nature of tree growth, inform efforts to understand and model forest carbon dynamics, and have additional implications for theories of resource allocation[11] and plant senescence[12].

A widely held assumption is that after an initial period of increasing growth, the mass growth rate of individual trees declines with increasing tree size[4,5,13–16]. Although the results of a few single-species studies have been consistent with this assumption[15], the bulk of evidence cited in support of declining growth is not based on measurements of individual tree mass growth. Instead, much of the cited evidence documents either the well-known age-related decline in net primary productivity (hereafter 'productivity') of even-aged forest stands[10] (in which the trees are all of a similar age) or size-related declines in the rate of mass gain per unit leaf area (or unit leaf mass)[8–10], with the implicit assumption that declines at these scales must also apply at the scale of the individual tree. Declining tree growth is also sometimes inferred from life-history theory to be a necessary corollary of increasing resource allocation to reproduction[11,16]. On the other hand, metabolic scaling theory predicts that mass growth rate should increase continuously with tree size[6], and this prediction has also received empirical support from a few site-specific studies[6,7]. Thus, we are confronted with two conflicting generalizations about the fundamental nature of tree growth, but lack a global assessment that would allow us to distinguish clearly between them.

To fill this gap, we conducted a global analysis in which we directly estimated mass growth rates from repeated measurements of 673,046 trees belonging to 403 tropical, subtropical and temperate tree species, spanning every forested continent. Tree growth rate was modelled as a function of log(tree mass) using piecewise regression, where the independent variable was divided into one to four bins. Conjoined line segments were fitted across the bins (Fig. 1).

For all continents, aboveground tree mass growth rates (and, hence, rates of carbon gain) for most species increased continuously with tree mass (size) (Fig. 2). The rate of mass gain increased with tree mass in each model bin for 87% of species, and increased in the bin that included the largest trees for 97% of species; the majority of increases were statistically significant (Table 1, Extended Data Fig. 1 and Supplementary Table 1). Even when we restricted our analysis to species achieving the largest sizes (maximum trunk diameter >100 cm; 33% of species), 94% had increasing mass growth rates in the bin that included the largest trees. We found no clear taxonomic or geographic patterns among the 3% of species with declining growth rates in their largest trees, although the small number of these species (thirteen) hampers inference. Declining species included both angiosperms and gymnosperms in seven of the 76 families in our study; most of the seven families had only one or two declining species and no family was dominated by declining species (Supplementary Table 1).

When we log-transformed mass growth rate in addition to tree mass, the resulting model fits were generally linear, as predicted by metabolic scaling theory[6] (Extended Data Fig. 2). Similar to the results of our main

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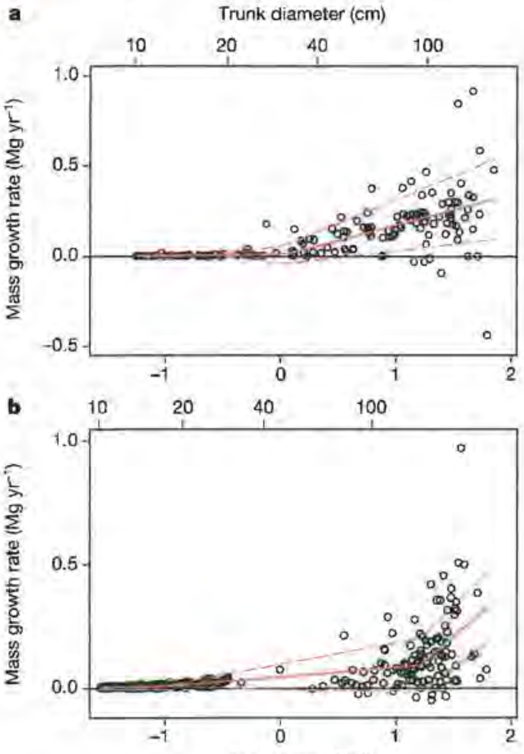

Figure 1 | Example model fits for tree mass growth rates. The species shown are the angiosperm species (*Lecomtedoxa klaineana*, Cameroon, 142 trees) (**a**) and gymnosperm species (*Picea sitchensis*, USA, 409 trees) (**b**) in our data set that had the most massive trees (defined as those with the greatest cumulative aboveground dry mass in their five most massive trees). Each point represents a single tree; the solid red lines represent best fits selected by our model; and the dashed red lines indicate one standard deviation around the predicted values.

analysis using untransformed growth, of the 381 log-transformed species analysed (see Methods), the log-transformed growth rate increased in the bin containing the largest trees for 96% of species.

In absolute terms, trees 100 cm in trunk diameter typically add from 10 kg to 200 kg of aboveground dry mass each year (depending on species), averaging 103 kg per year. This is nearly three times the rate for trees of the same species at 50 cm in diameter, and is the mass equivalent to adding an entirely new tree of 10–20 cm in diameter to the forest each year. Our findings further indicate that the extraordinary growth recently reported in an intensive study of large *Eucalyptus regnans* and *Sequoia sempervirens*[7], which included some of the world's most massive individual trees, is not a phenomenon limited to a few unusual species. Rather, rapid growth in giant trees is the global norm, and can exceed 600 kg per year in the largest individuals (Fig. 3).

Our data set included many natural and unmanaged forests in which the growth of smaller trees was probably reduced by asymmetric competition with larger trees. To explore the effects of competition, we calculated mass growth rates for 41 North American and European species that had published equations for diameter growth rate in the absence of competition. We found that, even in the absence of competition, 85% of the species had mass growth rates that increased continuously with tree size (Extended Data Fig. 3), with growth curves closely resembling those in Fig. 2. Thus, our finding of increasing growth not only has broad generality across species, continents and forest biomes (tropical, subtropical and temperate), it appears to hold regardless of competitive environment.

Importantly, our finding of continuously increasing growth is compatible with the two classes of observations most often cited as evidence of declining, rather than increasing, individual tree growth: with increasing tree size and age, productivity usually declines at the scales of both tree organs (leaves) and tree populations (even-aged forest stands).

First, although growth efficiency (tree mass growth per unit leaf area or leaf mass) often declines with increasing tree size[8–10], empirical observations and metabolic scaling theory both indicate that, on average, total tree leaf mass increases as the square of trunk diameter[17,18]. A typical tree that experiences a tenfold increase in diameter will therefore undergo a roughly 100-fold increase in total leaf mass and a 50–100-fold

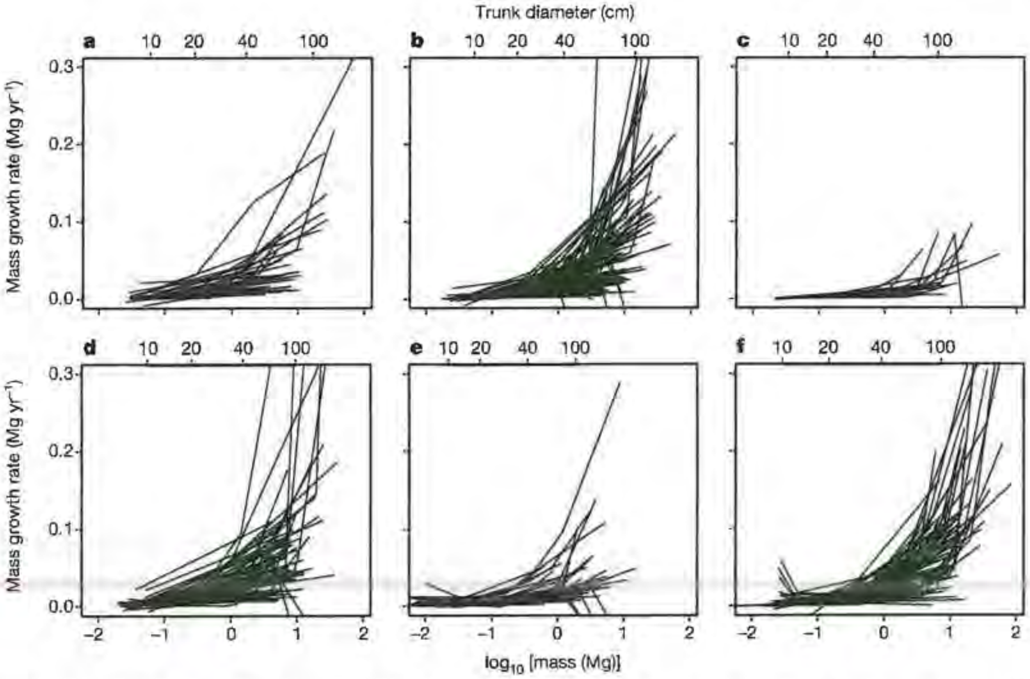

Figure 2 | Aboveground mass growth rates for the 403 tree species, by continent. **a**, Africa (Cameroon, Democratic Republic of the Congo); **b**, Asia (China, Malaysia, Taiwan, Thailand); **c**, Australasia (New Zealand); **d**, Central and South America (Argentina, Colombia, Panama); **e**, Europe (Spain); and **f**, North America (USA). Numbers of trees, numbers of species and percentages with increasing growth are given in Table 1. Trunk diameters are approximate values for reference, based on the average diameters of trees of a given mass.

Table 1 | Sample sizes and tree growth trends by continent

Continent	Number of trees	Number of species	Percentage of species with increasing mass growth rate in the largest trees (percentage significant at $P \leq 0.05$)
Africa	15,366	37	100.0 (86.5)
Asia	43,690	136	96.3 (89.0)
Australasia	45,418	22	95.5 (95.5)
Central and South America	18,530	77	97.4 (92.2)
Europe	439,889	42	90.5 (78.6)
North America	110,153	89	98.9 (94.4)
Total	673,046	403	96.8 (89.8)

The largest trees are those in the last bin fitted by the model. Countries are listed in the legend for Fig. 2.

increase in total leaf area (depending on size-related increases in leaf mass per unit leaf area[19,20]). Parallel changes in growth efficiency can range from a modest increase (such as in stands where small trees are suppressed by large trees)[21] to as much as a tenfold decline[22], with most changes falling in between[8,9,19,22]. At one extreme, the net effect of a low (50-fold) increase in leaf area combined with a large (tenfold) decline in growth efficiency would still yield a fivefold increase in individual tree mass growth rate; the opposite extreme would yield roughly a 100-fold increase. Our calculated 52-fold greater average mass growth rate of trees 100 cm in diameter compared to those 10 cm in diameter falls within this range. Thus, although growth efficiency often declines with increasing tree size, increases in a tree's total leaf area are sufficient to overcome this decline and cause whole-tree carbon accumulation rate to increase.

Second, our findings are similarly compatible with the well-known age-related decline in productivity at the scale of even-aged forest stands. Although a review of mechanisms is beyond the scope of this paper[10,23], several factors (including the interplay of changing growth efficiency and tree dominance hierarchies[24]) can contribute to declining productivity at the stand scale. We highlight the fact that increasing individual tree growth rate does not automatically result in increasing stand productivity because tree mortality can drive orders-of-magnitude reductions in population density[25,26]. That is, even though the large trees in older, even-aged stands may be growing more rapidly, such stands have fewer trees. Tree population dynamics, especially mortality, can thus be a significant contributor to declining productivity at the scale of the forest stand[23].

For a large majority of species, our findings support metabolic scaling theory's qualitative prediction of continuously increasing growth at the scale of individual trees[6], with several implications. For example, life-history theory often assumes that tradeoffs between plant growth and reproduction are substantial[11]. Contrary to some expectations[11,16], our results indicate that for most tree species size-related changes in reproductive allocation are insufficient to drive long-term declines in growth rates[6]. Additionally, declining growth is sometimes considered to be a defining feature of plant senescence[12]. Our findings are thus relevant to understanding the nature and prevalence of senescence in the life history of perennial plants[27].

Finally, our results are relevant to understanding and predicting forest feedbacks to the terrestrial carbon cycle and global climate system[1–3]. These feedbacks will be influenced by the effects of climatic, land-use and other environmental changes on the size-specific growth rates and size structure of tree populations—effects that are already being observed in forests[28,29]. The rapid growth of large trees indicates that, relative to their numbers, they could play a disproportionately important role in these feedbacks[30]. For example, in our western USA old-growth forest plots, trees >100 cm in diameter comprised 6% of trees, yet contributed 33% of the annual forest mass growth. Mechanistic models of the forest carbon cycle will depend on accurate representation of productivity across several scales of biological organization, including calibration and validation against continuously increasing carbon accumulation rates at the scale of individual trees.

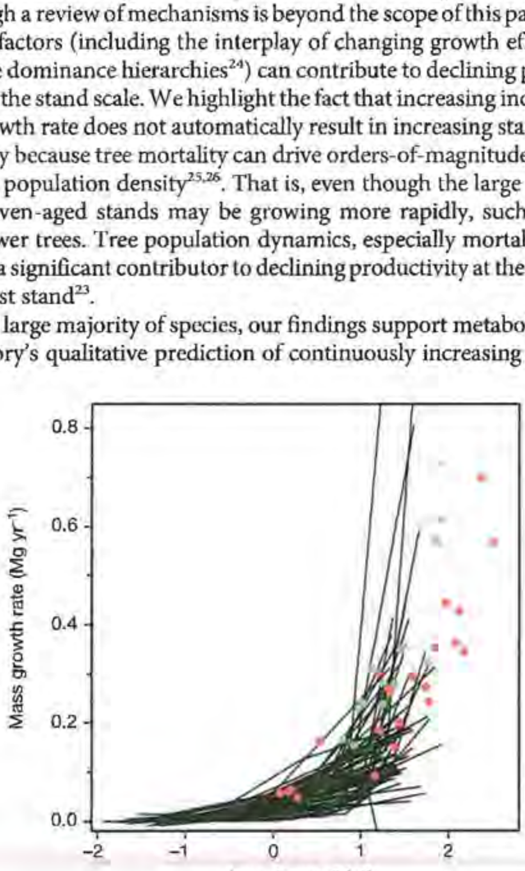

Figure 3 | Aboveground mass growth rates of species in our data set compared with *E. regnans* and *S. sempervirens*. For clarity, only the 58 species in our data set having at least one tree exceeding 20 Mg are shown (lines). Data for *E. regnans* (green dots, 15 trees) and *S. sempervirens* (red dots, 21 trees) are from an intensive study that included some of the most massive individual trees on Earth[7]. Both axes are expanded relative to those of Fig. 2.

METHODS SUMMARY

We estimated aboveground dry mass growth rates from consecutive diameter measurements of tree trunks—typically measured every five to ten years—from long-term monitoring plots. Analyses were restricted to trees with trunk diameter ≥ 10 cm, and to species having ≥ 40 trees in total and ≥ 15 trees with trunk diameter ≥ 30 cm. Maximum trunk diameters ranged from 38 cm to 270 cm among species, averaging 92 cm. We converted each diameter measurement (plus an accompanying height measurement for 16% of species) to aboveground dry mass, M, using published allometric equations. We estimated tree growth rate as $G = \Delta M/\Delta t$ and modelled G as a function of $\log(M)$ for each species using piecewise regression. The independent variable $\log(M)$ was divided into bins and a separate line segment was fitted to G versus $\log(M)$ in each bin so that the line segments met at the bin divisions. Bin divisions were not assigned a priori, but were fitted by the model separately for each species. We fitted models with 1, 2, 3 and 4 bins, and selected the model receiving the most support by Akaike's Information Criterion for each species. Our approach thus makes no assumptions about the shape of the relationship between G and $\log(M)$, and can accommodate increasing, decreasing or hump-shaped relationships. Parameters were fitted with a Gibbs sampler based on Metropolis updates, producing credible intervals for model parameters and growth rates at any diameter; uninformative priors were used for all parameters. We tested extensively for bias, and found no evidence that our results were influenced by model fits failing to detect a final growth decline in the largest trees, possible biases introduced by the 47% of species for which we combined data from several plots, or possible biases introduced by allometric equations (Extended Data Figs 4 and 5).

Online Content Any additional Methods, Extended Data display items and Source Data are available in the online version of the paper; references unique to these sections appear only in the online paper.

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Supplementary Information is available in the online version of the paper.

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Author Contributions N.L.S. and A.J.D. conceived the study with feedback from R.C. and D.A.C., N.L.S., A.J.D., R.C. and S.E.R. wrote the manuscript. R.C. devised the main analytical approach and wrote the computer code. N.L.S., A.J.D., R.C., S.E.R., P.J.B., N.G.B., D.A.C., E.R.L., W.K.M. and N.R. performed analyses. N.L.S., A.J.D., R.C., S.E.R., P.J.B., D.A.C., E.R.L., W.K.M., E.Á., C.B., S.B., G.C., S.J.D., A.D., C.N.E., O.F., J.F.F., H.R.G., Z.H., M.E.H., S.P.H., D.K., Y.L., J.-R.M., A.M., L.R.M., R.J.P., N.P., S.-H.S., I-F.S., S.T., D.T., P.J.v.M., X.W., S.K.W. and M.A.Z. supplied data and sources of allometric equations appropriate to their data.

Author Information Fitted model parameters for each species have been deposited in USGS's ScienceBase at http://dx.doi.org/10.5066/F7JS9NFM. Reprints and permissions information is available at www.nature.com/reprints. The authors declare no competing financial interests. Readers are welcome to comment on the online version of the paper. Correspondence and requests for materials should be addressed to N.L.S. (nstephenson@usgs.gov).

METHODS

Data. We required that forest monitoring plots provided unbiased samples of all living trees within the plot boundaries, and that the trees had undergone two trunk diameter measurements separated by at least one year. Some plots sampled minimally disturbed old (all-aged) forest, whereas others, particularly those associated with national inventories, sampled forest stands regardless of past management history. Plots are described in the references cited in Supplementary Table 1.

Our raw data were consecutive measurements of trunk diameter, D, with most measurements taken 5 to 10 years apart (range, 1–29 years). D was measured at a standard height on the trunk (usually 1.3–1.4 m above ground level), consistent across measurements for a tree. Allometric equations for 16% of species required, in addition to consecutive measurements of D, consecutive measurements of tree height.

We excluded trees exhibiting extreme diameter growth, defined as trunks where D increased by $\geq 40\,\mathrm{mm\,yr^{-1}}$ or that shrank by $\geq 12s$, where s is the standard deviation of the D measurement error, $s = 0.9036 + 0.006214D$ (refs 31, 32); outliers of these magnitudes were almost certainly due to error. By being so liberal in allowing negative growth anomalies, we erred on the side of reducing our ability to detect increases in tree mass growth rate. Using other exclusion values yielded similar results, as did a second approach to handling error in which we reanalysed a subset of our models using a Bayesian method that estimates growth rates after accounting for error, based on independent plot-specific data quantifying measurement error[33].

To standardize minimum D among data sets, we analysed only trees with $D \geq 10$ cm at the first census. To ensure adequate samples of trees spanning a broad range of sizes, we restricted analyses to species having both ≥ 40 trees in total and also ≥ 15 trees with $D \geq 30$ cm at the first census. This left us with 673,046 trees belonging to 403 tropical and temperate species in 76 families, spanning twelve countries and all forested continents (Supplementary Table 1). Maximum trunk diameters ranged from 38 cm to 270 cm among species, and averaged 92 cm.

Estimating tree mass. To estimate each tree's aboveground dry mass, M, we used published allometric equations relating M to D (or for 16% of species, relating M to D and tree height). Some equations were species-specific and others were specific to higher taxonomic levels or forest types, described in the references in Supplementary Table 1. The single tropical moist forest equation of ref. 34 was applied to most tropical species, whereas most temperate species had unique species-specific equations. Most allometric equations are broadly similar, relating $\log(M)$ to $\log(D)$ linearly, or nearly linearly—a familiar relationship in allometric scaling of both animals and plants[35]. Equations can show a variety of differences in detail, however, with some adding $\log(D)$ squared and cubed terms. All equations make use of the wood density of individual species, but when wood density was not available for a given species we used mean wood density for a genus or family[36].

Using a single, average allometry for most tropical species, and mean wood density for a genus or family for several species, limits the accuracy of our estimates of M. However, because we treat each species separately, it makes no difference whether our absolute M estimates are more accurate in some species than in others, only that they are consistent within a species and therefore accurately reveal whether mass growth rates increase or decrease with tree size.

For two regions—Spain and the western USA—allometric equations estimated mass only for a tree's main stem rather than all aboveground parts, including branches and leaves. But because leaf and stem masses are positively correlated and their growth rates are expected to scale isometrically both within and among species[18,37,38], results from these two regions should not alter our qualitative conclusions. Confirming this, the percentage of species with increasing stem mass growth rate in the last bin for Spain and the western USA (93.4% of 61 species) was similar to that from the remainder of regions (97.4% of 342 species) ($P = 0.12$, Fisher's exact test).

Modelling mass growth rate. We sought a modelling approach that made no assumptions about the shape of the relationship between aboveground dry mass growth rate, G, and aboveground dry mass, M, and that could accommodate monotonically increasing, monotonically decreasing, or hump-shaped relationships. We therefore chose to model G as a function of $\log(M)$ using piecewise linear regression. The range of the x axis, $X = \log(M)$, is divided into a series of bins, and within each bin G is fitted as a function of X by linear regression. The position of the bins is adaptive: it is fitted along with the regression terms. Regression lines are required to meet at the boundary between bins. For a single model-fitting run the number of bins, B, is fixed. For example, if $B = 2$, there are four parameters to be fitted for a single species: the location of the boundary between bins, X_1; the slope of the regression in the first bin, S_1; the slope in the second bin, S_2; and an intercept term. Those four parameters completely define the model. In general, there are $2B$ parameters for B bins.

Growth rates, while approximately normally distributed, were heteroskedastic, with the variance increasing with mass (Fig. 1), so an additional model was needed for the standard deviation of G, σ_G, as a function of $\log(M)$. The increase of σ_G with $\log(M)$ was clearly not linear, so we used a three-parameter model:

$$\sigma_G = k \qquad (\text{for } \log(M) < d)$$

$$\sigma_G = a + b\log(M) \qquad (\text{for } \log(M) \geq d)$$

where the intercept a is determined by the values of k, d and b. Thus σ_G was constant for smaller values of $\log(M)$ (below the cutoff d), then increased linearly for larger $\log(M)$ (Fig. 1). The parameters k, d and b were estimated along with the parameters of the growth model.

Parameters of both the growth and standard deviation models were estimated in a Bayesian framework using the likelihood of observing growth rates given model predictions and the estimated standard deviation of the Gaussian error function. A Markov chain Monte Carlo chain of parameter estimates was created using a Gibbs sampler with a Metropolis update[39,40] written in the programming language R (ref. 41) (a tutorial and the computer code are available through http://ctfs.arnarb.harvard.edu/Public/CTFSRPackage/files/tutorials/growthfitAnalysis). The sampler works by updating each of the parameters in sequence, holding other parameters fixed while the relevant likelihood function is used to locate the target parameter's next value. The step size used in the updates was adjusted adaptively through the runs, allowing more rapid convergence[40]. The final Markov chain Monte Carlo chain describes the posterior distribution for each model parameter, the error, and was then used to estimate the posterior distribution of growth rates as estimated from the model. Priors on model parameters were uniform over an unlimited range, whereas the parameters describing the standard deviation were restricted to >0. Bin boundaries, X_i, were constrained as follows: (1) boundaries could only fall within the range of X, (2) each bin contained at least five trees, and (3) no bin spanned less than 10% of the range of X. The last two restrictions prevented the bins from collapsing to very narrow ranges of X in which the fitted slope might take absurd extremes.

We chose piecewise regression over other alternatives for modelling G as a function of M for two main reasons. First, the linear regression slopes within each bin provide precise statistical tests of whether G increases or decreases with X, based on credible intervals of the slope parameters. Second, with adaptive bin positions, the function is completely flexible in allowing changes in slope at any point in the X range, with no influence of any one bin on the others. In contrast, in parametric models where a single function defines the relationship across all X, the shape of the curve at low X can (and indeed must) influence the shape at high X, hindering statistical inference about changes in tree growth at large size.

We used $\log(M)$ as our predictor because within a species M has a highly non-Gaussian distribution, with many small trees and only a few very large trees, including some large outliers. In contrast, we did not log-transform our dependent variable G so that we could retain values of $G \leq 0$ that are often recorded in very slowly growing trees, for which diameter change over a short measurement interval can be on a par with diameter measurement error.

For each species, models with 1, 2, 3 and 4 bins were fitted. Of these four models, the model receiving the greatest weight of evidence by Akaike Information Criterion (AIC) was selected. AIC is defined as the log-likelihood of the best-fitting model, penalized by twice the number of parameters. Given that adding one more bin to a model meant two more parameters, the model with an extra bin had to improve the log-likelihood by 4 to be considered a better model[42].

Assessing model fits. To determine whether our approach might have failed to reveal a final growth decline within the few largest trees of the various species, we calculated mass growth rate residuals for the single most massive individual tree of each species. For 52% of the 403 species, growth of the most massive tree was underestimated by our model fits (for example, Fig. 1a); for 48% it was overestimated (for example, Fig. 1b). These proportions were indistinguishable from 50% ($P = 0.55$, binomial test), as would be expected for unbiased model fits. Furthermore, the mean residual (observed minus predicted) mass growth rate of these most massive trees, $+0.006\,\mathrm{Mg\,yr^{-1}}$, was statistically indistinguishable from zero ($P = 0.29$, two-tailed t-test). We conclude that our model fits accurately represent growth trends up through, and including, the most massive trees.

Effects of combined data. To achieve sample sizes adequate for analysis, for some species we combined data from several different forest plots, potentially introducing a source of bias: if the largest trees of a species disproportionately occur on productive sites, the increase in mass growth rate with tree size could be exaggerated. This might occur because trees on less-productive sites—presumably the sites having the slowest-growing trees within any given size class—could be under-represented in the largest size classes. We assessed this possibility in two ways.

First, our conclusions remained unchanged when we compared results for the 53% of species that came uniquely from single large plots with those of the 47% of species whose data were combined across several plots. Proportions of species with increasing mass growth rates in the last bin were indistinguishable between the two groups (97.6% and 95.8%, respectively; $P = 0.40$, Fisher's exact test). Additionally, the shapes and magnitudes of the growth curves for Africa and Asia, where data for each species came uniquely from single large plots, were similar to those of Australasia, Europe and North America, where data for each species were combined across several plots (Table 1, Fig. 2 and Extended Data Fig. 2). (Data from Central and South America were from both single and combined plots, depending on species.)

Second, for a subset of combined-data species we compared two sets of model fits: (1) using all available plots (that is, the analyses we present in the main text), and (2) using only plots that contained massive trees—those in the top 5% of mass for a species. To maximize our ability to detect differences, we limited these analyses to species with large numbers of trees found in a large number of plots, dispersed widely across a broad geographic region. We therefore analysed the twelve Spanish species that each had more than 10,000 individual trees (Supplementary Table 1), found in 34,580 plots distributed across Spain. Massive trees occurred in 6,588 (19%) of the 34,580 plots. We found no substantial differences between the two analyses. When all 34,580 plots were analysed, ten of the twelve species showed increasing growth in the last bin, and seven showed increasing growth across all bins; when only the 6,588 plots containing the most massive trees were analysed, the corresponding numbers were eleven and nine. Model fits for the two groups were nearly indistinguishable in shape and magnitude across the range of tree masses. We thus found no evidence that the potential for growth differences among plots influenced our conclusions.

Effects of possible allometric biases. For some species, the maximum trunk diameter D in our data sets exceeded the maximum used to calibrate the species' allometric equation. In such cases our estimates of M extrapolate beyond the fitted allometry and could therefore be subject to bias. For 336 of our 403 species we were able to determine D of the largest tree that had been used in calibrating the associated allometric equations. Of those 336 species, 74% (dominated by tropical species) had no trees in our data set with D exceeding that used in calibrating the allometric equations, with the remaining 26% (dominated by temperate species) having at least one tree with D exceeding that used in calibration. The percentage of species with increasing G in the last bin for the first group (98.0%) was indistinguishable from that of the second group (96.6%) ($P = 0.44$, Fisher's exact test). Thus, our finding of increasing G with tree size is not affected by the minority of species that have at least one tree exceeding the maximum value of D used to calibrate their associated allometric equations.

A bias that could inflate the rate at which G increases with tree size could arise if allometric equations systematically underestimate M for small trees or overestimate M for large trees[43]. For a subset of our study species we obtained the raw data—consisting of measured values of D and M for individual trees—needed to calibrate allometric equations, allowing us to determine whether the particular form of those species' allometric equations was prone to bias, and if so, the potential consequences of that bias.

To assess the potential for allometric bias for the majority (58%) of species in our data set—those that used the empirical moist tropical forest equation of ref. 34—we reanalysed the data provided by ref. 34. The data were from 1,504 harvested trees representing 60 families and 184 genera, with D ranging from 5 cm to 156 cm; the associated allometric equation relates $\log(M)$ to a third-order polynomial of $\log(D)$. Because the regression of M on D was fitted on a log–log scale, this and subsequent equations include a correction of $\exp[(\mathrm{RSE})^2/2]$ for the error in back-transformation, where RSE is the residual standard error from the statistical model[44]. Residuals of M for the equation revealed no evident biases (Extended Data Fig. 4a), suggesting that we should expect little (if any) systematic size-related biases in our estimates of G for the 58% of our species that used this equation.

Our simplest form of allometric equation—applied to 22% of our species—was $\log(M) = a + b\log(D)$, where a and b are taxon-specific constants. For nine of our species that used equations of this form (all from the temperate western USA: *Abies amabilis, A. concolor, A. procera, Pinus lambertiana, Pinus ponderosa, Picea sitchensis, Pseudotsuga menziesii, Tsuga heterophylla* and *T. mertensiana*) we had values of both D and M for a total of 1,358 individual trees, allowing us to fit species-specific allometric equations of the form $\log(M) = a + b\log(D)$ and then assess them for bias. Residual plots showed a tendency to overestimate M for the largest trees (Extended Data Fig. 4b), with the possible consequence of inflating estimates of G for the largest relative to the smallest trees of these species.

To determine whether this bias was likely to alter our qualitative conclusion that G increases with tree size, we created a new set of allometric relations between D and M—one for each of the nine species—using the same piecewise linear regression approach we used to model G as a function of M. However, because our goal was to eliminate bias rather than seek the most parsimonious model, we fixed the number of bins at four, with the locations of boundaries between the bins being fitted by the model. Our new allometry using piecewise regressions led to predictions of M with no apparent bias relative to D (Extended Data Fig. 4c). This new, unbiased allometry gave the same qualitative results as our original, simple allometry regarding the relationship between G and M: for all nine species, G increased in the bin containing the largest trees, regardless of the allometry used (Extended Data Fig. 5). We conclude that any bias associated with the minority of our species that used the simple allometric equation form was unlikely to affect our broad conclusion that G increases with tree size in a majority of tree species.

As a final assessment, we compared our results to those of a recent study of *E. regnans* and *S. sempervirens*, in which M and G had been calculated from intensive measurements of aboveground portions of trees without the use of standard allometric equations[7]. Specifically, in two consecutive years 36 trees of different sizes and ages were climbed, trunk diameters were systematically measured at several heights, branch diameters and lengths were measured (with subsets of foliage and branches destructively sampled to determine mass relationships), wood densities were determined and ring widths from increment cores were used to supplement measured diameter growth increments. The authors used these measurements to calculate M for each of the trees in each of the two consecutive years, and G as the difference in M between the two years[7]. *E. regnans* and *S. sempervirens* are the world's tallest angiosperm and gymnosperm species, respectively, so the data set was dominated by exceptionally large trees; most had $M \geq 20$ Mg, and M of some individuals exceeded that of the most massive trees in our own data set (which lacked *E. regnans* and *S. sempervirens*). We therefore compared *E. regnans* and *S. sempervirens* to the 58 species in our data set that had at least one individual with $M \geq 20$ Mg. Sample sizes for *E. regnans* and *S. sempervirens*—15 and 21 trees, respectively—fell below our required ≥40 trees for fitting piecewise linear regressions, so we simply plotted data points for individual *E. regnans* and *S. sempervirens* along with the piecewise regressions that we had already fitted for our 58 comparison species (Fig. 3).

As reported by ref. 7, G increased with M for both *E. regnans* and *S. sempervirens*, up to and including some of the most massive individual trees on the Earth (Fig. 3). Within the zone of overlapping M between the two data sets, G values for individual *E. regnans* and *S. sempervirens* trees fell almost entirely within the ranges of the piecewise regressions we had fitted for our 58 comparison species. We take these observations as a further indication that our results, produced using standard allometric equations, accurately reflect broad relationships between M and G.

Fitting log–log models. To model $\log(G)$ as a function of $\log(M)$, we used the binning approach that we used in our primary analysis of mass growth rate (described earlier). However, in log-transforming growth we dropped trees with $G \leq 0$. Because negative growth rates become more extreme with increasing tree size, dropping them could introduce a bias towards increasing growth rates. Log-transformation additionally resulted in skewed growth rate residuals. Dropping trees with $G \leq 0$ caused several species to fall below our threshold sample size, reducing the total number of species analysed to 381 (Extended Data Fig. 2).

Growth in the absence of competition. We obtained published equations for 41 North American and European species, in 46 species-site combinations, relating species-specific tree diameter growth rates to trunk diameter D and to neighbourhood competition[45–49]. Setting neighbourhood competition to zero gave us equations describing estimated annual D growth as a function of D in the absence of competition. Starting at $D_0 = 10$ cm, we sequentially (1) calculated annual D growth for a tree of size D_t, (2) added this amount to D_t to determine D_{t+1}, (3) used an appropriate taxon-specific allometric equation to calculate the associated tree masses M_t and M_{t+1}, and (iv) calculated tree mass growth rate G_t of a tree of mass M_t in the absence of competition as $M_{t+1} - M_t$. For each of the five species that had separate growth analyses available from two different sites, we required that mass growth rate increased continuously with tree size at both sites for the species to be considered to have a continuously increasing mass growth rate. North American and European allometries were taken from refs 17 and 50, respectively, with preference given to allometric equations based on power functions of tree diameter, large numbers of sampled trees, and trees spanning a broad range of diameters. For the 47% of European species for which ref. 50 had no equations meeting our criteria, we used the best-matched (by species or genus) equations from ref. 17.

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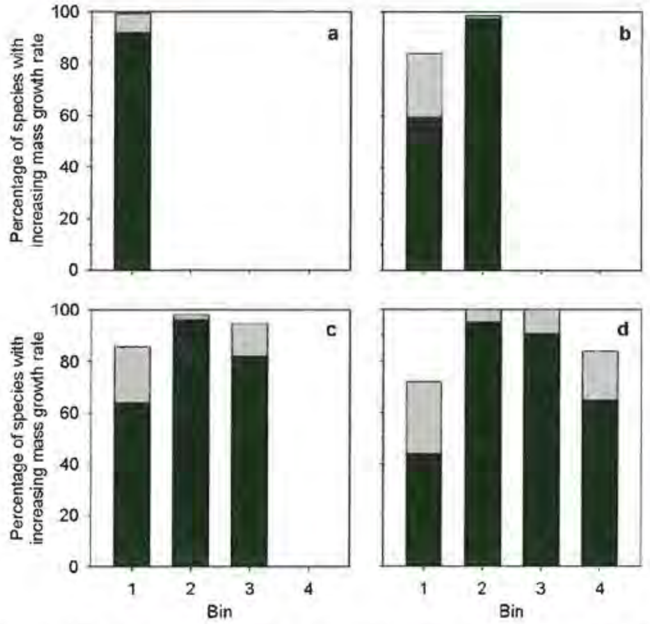
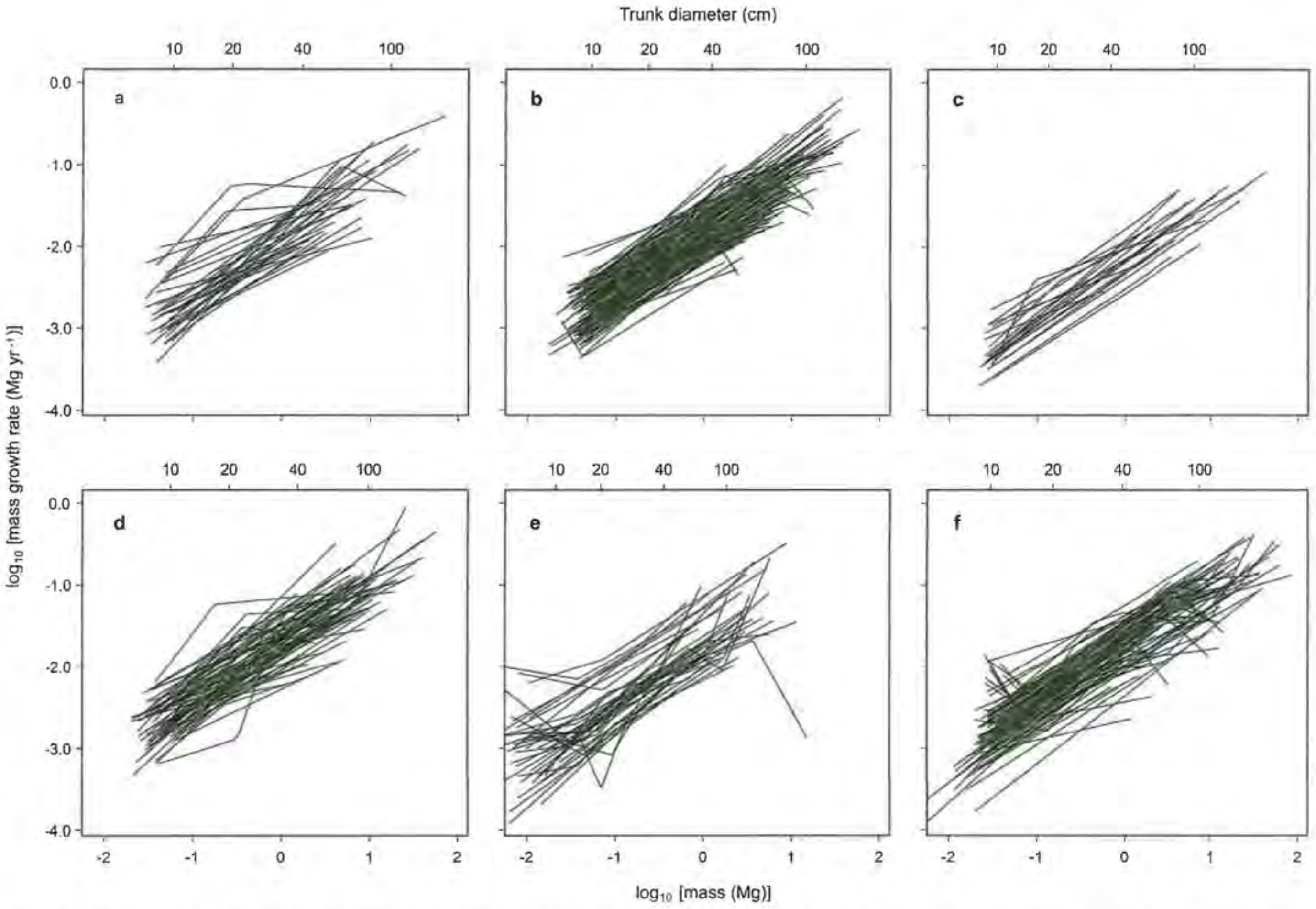
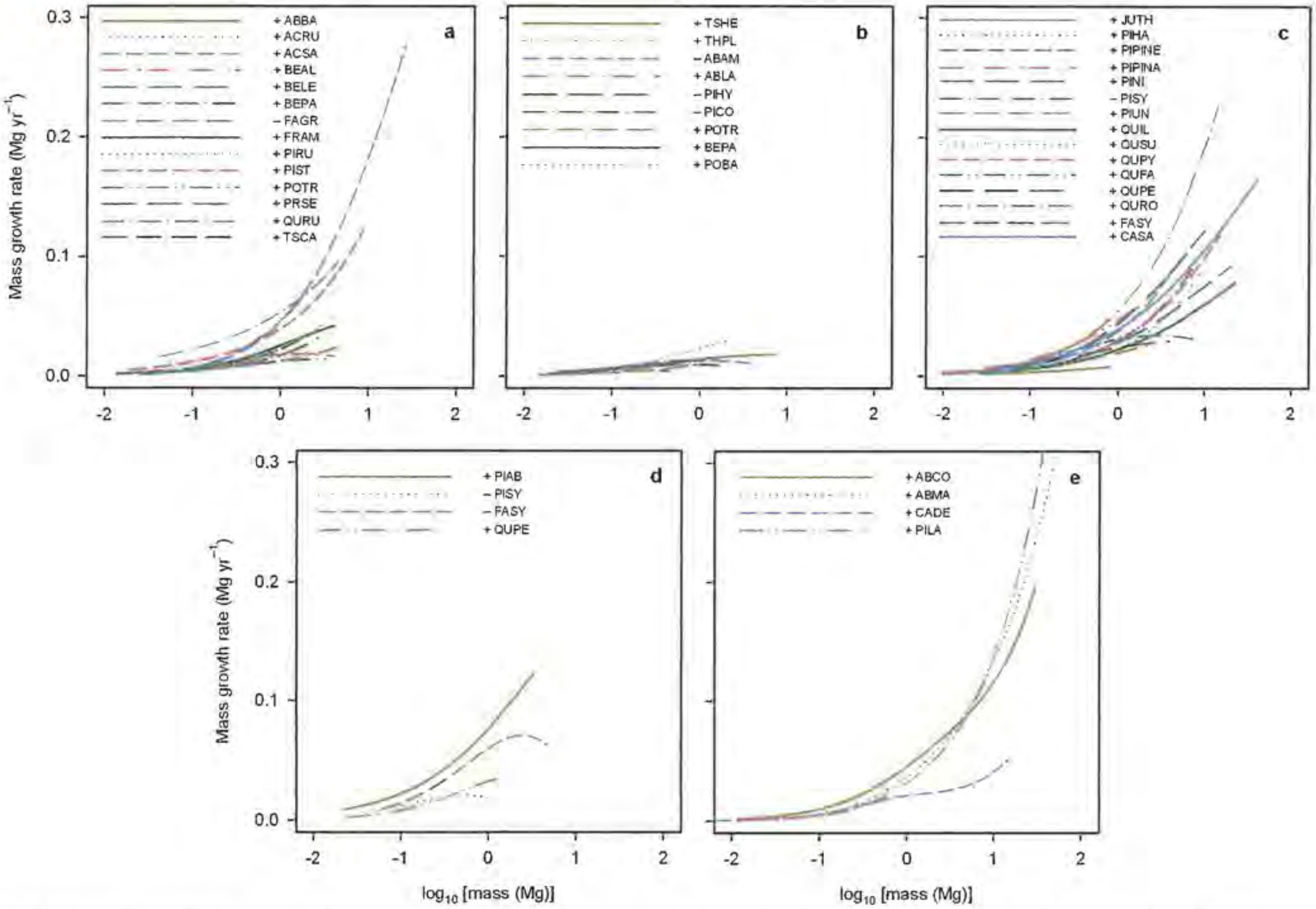


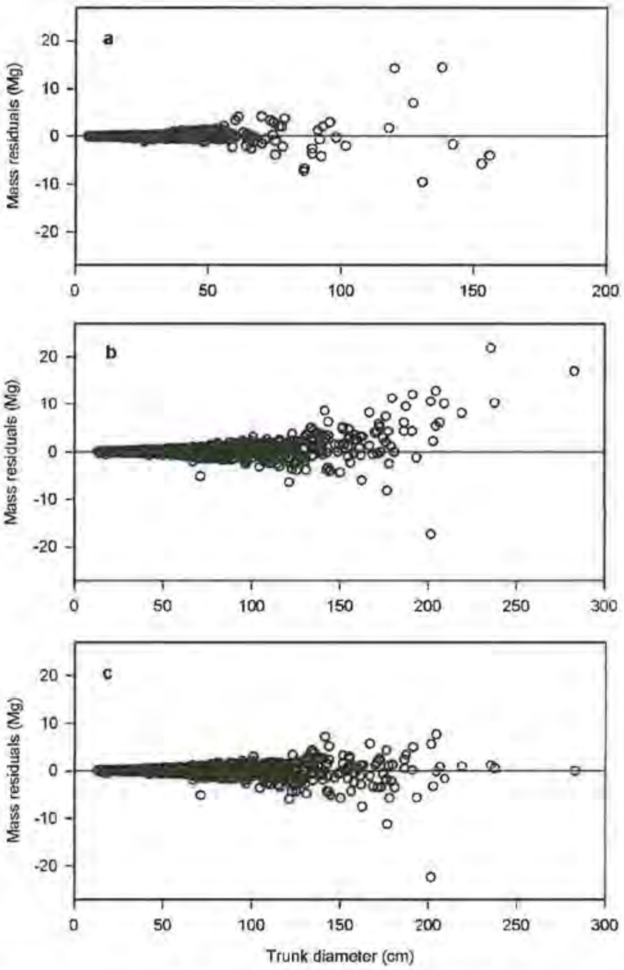
Extended Data Figure 1 | Summary of model fits for tree mass growth rates. Bars show the percentage of species with mass growth rates that increase with tree mass for each bin; black shading indicates percentage significant at $P \leq 0.05$. Tree masses increase with bin number. **a**, Species fitted with one bin (165 species); **b**, Species fitted with two bins (139 species); **c**, Species fitted with three bins (56 species); and **d**, Species fitted with four bins (43 species).



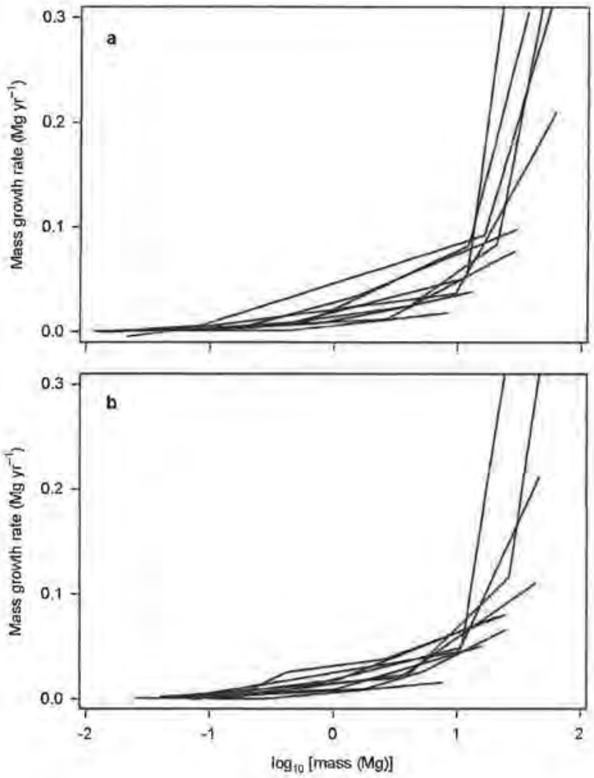
Extended Data Figure 2 | Log–log model fits of mass growth rates for 381 tree species, by continent. Trees with growth rates ≤ 0 were dropped from the analysis, reducing the number of species meeting our threshold sample size for analysis. **a**, Africa (33 species); **b**, Asia (123 species); **c**, Australasia (22 species); **d**, Central and South America (73 species); **e**, Europe (41 species); and **f**, North America (89 species). Trunk diameters are approximate values for reference, based on the average diameters of trees of a given mass.



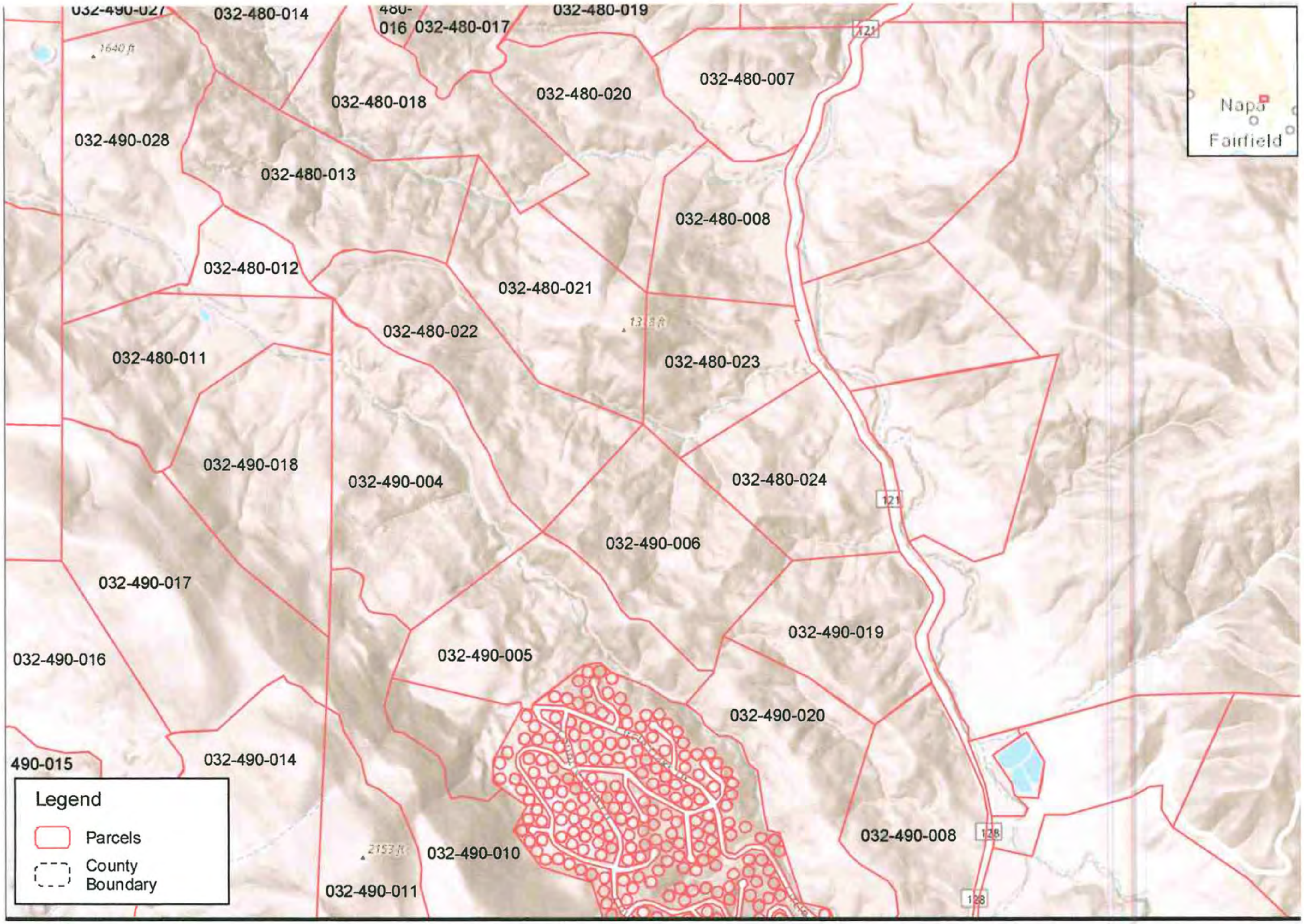
Extended Data Figure 3 | Aboveground mass growth rates for 41 tree species in the absence of competition. The '+' or '−' symbol preceding each species code indicates, respectively, species with mass growth rates that increased continuously with tree size or species with mass growth rates that declined in the largest trees. Sources of the diameter growth equations used to calculate mass growth were: **a**, ref. 45; **b**, ref. 46; **c**, ref. 48; **d**, ref. 47; and **e**, ref. 49. ABAM, *Abies amabilis*; ABBA, *Abies balsamea*; ABCO, *Abies concolor*; ABLA, *Abies lasiocarpa*; ABMA, *Abies magnifica*; ACRU, *Acer rubrum*; ACSA, *Acer saccharum*; BEAL, *Betula alleghaniensis*; BELE, *Betula lenta*; BEPA, *Betula papyrifera*; CADE, *Calocedrus decurrens*; CASA, *Castanea sativa*; FAGR, *Fagus grandifolia*; FASY, *Fagus sylvatica*; FRAM, *Fraxinus americana*; JUTH, *Juniperus thurifera*; PIAB, *Picea abies*; PICO, *Pinus contorta*; PIHA, *Pinus halepensis*; PIHY, *Picea* hybrid (a complex of *Picea glauca*, *P. sitchensis* and *P. engelmannii*); PILA, *Pinus lambertiana*; PINI, *Pinus nigra*; PIPINA, *Pinus pinaster*; PIPINE, *Pinus pinea*; PIRU, *Picea rubens*; PIST, *Pinus strobus*; PISY, *Pinus sylvestris*; PIUN, *Pinus uncinata*; POBA, *Populus balsamifera* ssp. *trichocarpa*; POTR, *Populus tremuloides*; PRSE, *Prunus serotina*; QUFA, *Quercus faginea*; QUIL, *Quercus ilex*; QUPE, *Quercus petraea*; QUPY, *Quercus pyrenaica*; QURO, *Quercus robar*; QURU, *Quercus rubra*; QUSU, *Quercus suber*; THPL, *Thuja plicata*; TSCA, *Tsuga canadensis*; and TSHE, *Tsuga heterophylla*.



Extended Data Figure 4 | Residuals of predicted minus observed tree mass. **a**, The allometric equation for moist tropical forests[34]—used for the majority of tree species—shows no evident systematic bias in predicted aboveground dry mass, *M*, relative to trunk diameter ($n = 1{,}504$ trees). **b**, In contrast, our simplest form of allometric equation—used for 22% of our species and here applied to nine temperate species—shows an apparent bias towards overestimating *M* for large trees ($n = 1{,}358$ trees). **c**, New allometries that we created for the nine temperate species removed the apparent bias in predicted *M*.



Extended Data Figure 5 | Estimated mass growth rates of the nine temperate species of Extended Data Fig. 4. Growth was estimated using the simplest form of allometric model [$\log(M) = a + b\log(D)$] (**a**) and our allometric models fitted with piecewise linear regression (**b**). Regardless of the allometric model form, all nine species show increasing G in the largest trees.



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Labeled parcels show the general location of "Walt Ranch". 2 parcels are above those shown and 3 more are below the labeled parcels on the map above.

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0 0.075 0.15 0.3 mi

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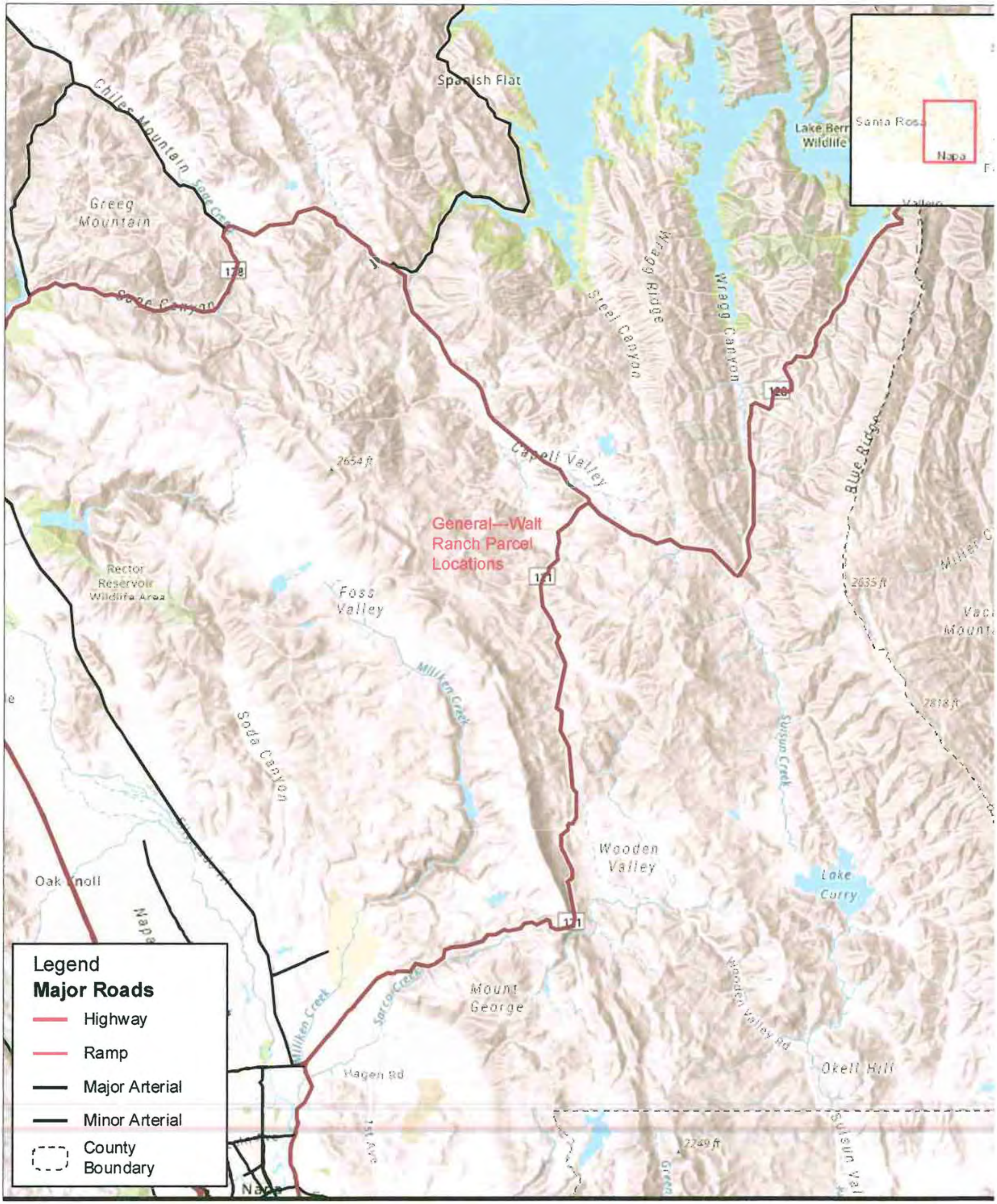

County of Napa

The General location of the Walt Ranch parcels are under the "red text" added to the map above. Please refer to Napa County Parcel maps for specific location

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0 0.75 1.5 3 mi

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