The Reliability of Citizen Science: A Case Study of Oregon White Oak Stand Surveys

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Abstract

*We trained students (grades 3–10) through classroom presentations to survey an Oregon white oak (*Quercus garryana*) stand in Washington, USA, and compared their data to those obtained from professionals. In May and July 2002, 607 students and 8 professionals surveyed 59 and 22 50-m transects, respectively. We enumerated oaks and ponderosa pines (*Pinus ponderosa*), measured diameter at breast height, and rated the crown shape of oaks. Oak diameter at breast height measurements and tree counts were consistent between students and professionals ($\alpha = 0.05$), but subjective crown assessments and live or dead status differed. Students tended to overreport relatively rare pines and larger oaks relative to professionals. This project provided resource managers with data describing oak diameter at breast height and distribution while educating students about the ecology of local wildlife habitat.* (WILDLIFE SOCIETY BULLETIN 34(5):1425–1429; 2006)

Key words

citizen science, data reliability, Oregon white oak, Quercus garryana*, Washington.*

Resource agencies have a mandate to manage resources in a sustainable way for the future (Tudor and Dvornich 2001). It can be difficult for agencies with limited budgets and personnel to collect sufficient data for informed management decisions (Brown et al. 2001). Concomitantly, more agencies are seeking to involve volunteers and students in collecting environmental data (Kerr et al. 1994, Brown et al. 2001), as evidenced by programs such as NatureMapping (Dvornich et al. 1995), Earth Day Forest Watch (Rock and Lauten 1996), Waterwatch (Nicholson et al. 2002), and the Global Learning and Observations to Benefit the Environment (GLOBE) project (Becker et al. 1998, Means 1998).

When resource agencies and educators work together to involve students in data collection, students can fulfill essential academic learning requirements, improve their skills in decision making, and increase their civic involvement (Tudor and Dvornich 2001). Although the benefits to students who participate in data collection or monitoring programs are well established (e.g., Dvornich et al. 1995, Means 1998, Frank 2000, Tudor and Dvornich 2001), the benefits to resource managers are largely related to data reliability. Studies regarding the volunteer or student data quality have reported mixed results. Some report a general consistency between data collected by volunteers and professionals (e.g., Mattson et al. 1994, Rock and Lauten 1996, Becker et al. 1998) and others report mixed or questionable results (e.g., Engel and Voshell 2002, Nicholson et al. 2002). Variation largely depends on the purpose of the monitoring, professional data collection, volunteer skill level, and the scope of projects. Our primary objectives were to involve students in field monitoring efforts, to compare data collected by 2 student age-classes with data collected by professionals using the same protocols, and to describe the structure of an Oregon white oak stand (*Quercus garryana*). In this paper we focus on presenting the methodology and findings related to the first 2 objectives.

Study Area

For this study Washington Department of Fish and Wildlife (WDFW), United States Bureau of Reclamation, and Woodland Park Zoo (WPZ) personnel worked with the Yakima School District to involve students in a survey of Oregon white oak at the Oak Creek Wildlife Area (OCWA), Washington, USA. The Oregon white oak is the only native oak in Washington (Stein 1990), and it provides rare and valuable habitats that make a significant contribution to biodiversity in the state (Larsen and Morgan 1998). Because the distribution of the state-listed "threatened" western gray squirrel (*Sciurus griseus*) is closely associated with that of Oregon white oak (Larsen and Morgan 1998, Washington Department of Wildlife 1993), managers are in need of data characterizing the available oak habitat of the OCWA. Western gray squirrels rely on oaks (Ryan and Carey 1995) and large conifers such as ponderosa pine (*Pinus ponderosa*; Carey 1996) for food, seasonal cover, nest sites, and travel and escape routes. The OCWA is in a unique ecotone (Ryan and Carey 1995) of the eastern Cascades, an area of transition from higher elevation coniferous forest to the grassland and shrub steppe of central Washington below elevation 533 m. The study area, the riparian zone northeast of Oak Creek, was characterized by a mixed stand of Oregon white oak with occasional mature ponderosa pines.

Methods

Student Training and Protocol

We initially contacted the Yakima School District superintendent with our proposal to invite students to join us in a

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portion of our field research. We then worked with local teachers and education professionals to develop field protocols and a 1-hour training program for students, grades 3–10. The training consisted of background information about OCWA ecosystem, oak and pine identification, and methodology for assessing tree-trunk diameter and crown shape. The training described sampling (i.e., why we use a transect with a defined width to monitor OCWA habitat and the importance of following protocols in science). During the 2 weeks prior to fieldwork, WPZ personnel made 23 training presentations at 13 schools throughout the Yakima SD.

To conduct this experiment we set up 59 line transects, 10 m wide, in advance at 100-m intervals along the Oak Creek Road, which runs parallel to Oak Creek. All transects were 50 m in length except 5 25-m transects, due to the close proximity of Oak Creek to the road in some areas. We flagged all transect starting, mid, and endpoints in the field prior to the arrival of the students. We oriented transects perpendicular to the road, with start points 10 m from road edge to avoid biases associated with the road.

We chartered school busses to transport students to the site on 9 days during the fieldwork period, from 13–24 May 2002. The number of students on site ranged from 47–122 each day, totaling 607 participants. Teachers established crews of 10–15 students in advance, led by WDFW staff. Crews were to sample $\geq$1 transect per day and each crew consisted of a rope team to measure transect width and 2 measuring teams to count and measure trees.

Data Collection

The students collected 3 types of data on trees: counts by species, measurements of diameter at breast height (dbh), and classification of the crown shape. We enumerated only Oregon white oak and ponderosa pine trees with a diameter at breast height of $\geq$2.5 cm. We counted trees when at least half of the trunk was within the transect swath. For diameter at breast height measurements, we used a standard elevation of 1.37 m. For the subjective classification of oak crown shape, we used a diagram developed by the United States Forest Service printed on the back of data forms (Fig. 1). We classified trees as "dead" in lieu of a crown code for dead trees.

We selected a sample of 22 transects for quality control (QC) testing by professional biologists and natural resource managers (pros) from WDFW and the WPZ. We stratified the students into 2 classes, grades 6–10 ($\geq$6 grade) and grades 2–5 (<6 grade), and included 2 transects that were assessed by both grade-level groups. The sample procedure ensured that pros would QC check the same proportion of transects reported by the students to have no trees as did students. We excluded problem transects ($n = 16$) from the QC sample-selection pool, leaving 43 of the 59 total available for QC sampling. We defined problem transects as those transects that were 25 m in length ($n = 5$), for which student data forms were missing or data were unclear ($n = 7$), and in which student grade level was unavailable or unclear ($n = 4$). Of the 43 remaining transects, $\geq$6-grade students assessed 44% ($n = 19$) and <6-grade students assessed 56% ($n = 24$). Students determined that 26% ($n = 11$) of the 43 had no trees.

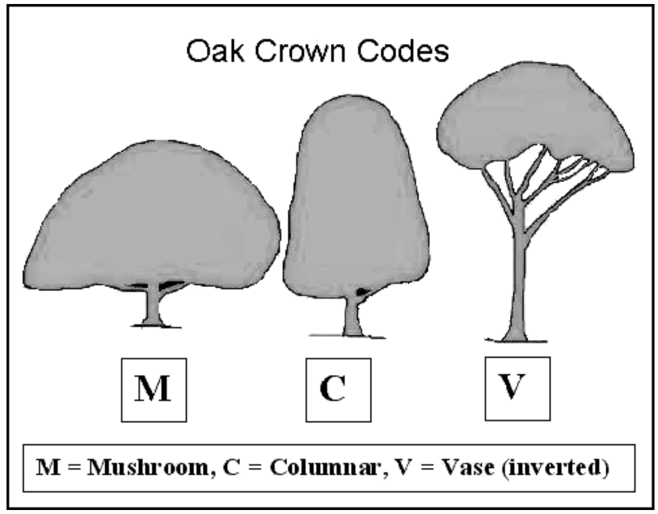

Figure 1. Oregon white oak crown codes. Adapted from diagram created by the United States Forest Service (http://www.fs.fed.us/pnw/olympia/silv/oak-studies/acorn_survey/survey.shtml).

We selected 2 of 22 QC transects because they were surveyed by students in both grade groupings on different days. We randomly selected 8 transects for QC which were originally surveyed by $\geq$6-grade students and 10 transects for QC which were checked by <6-grade students, a total of 16 unique transects with trees, because 2 transects had been surveyed from each of the 2 grade groupings. We selected 6 of the 22 QC transects from the group students classified as having no trees. On 29 July 2002, 8 pros from WDFW and WPZ spent 1 day in the field working in 2 teams to survey the 22 QC transects.

Data Analysis

We compared 3 types of student- and pro-collected oak data: the number of trees enumerated per transect, the diameter at breast height of trees within each transect, and proportions of crown shape measurements and diameter at breast height within crown codes. Because of small sample sizes for count data and normality assumptions that were not met for diameter at breast height data, we used nonparametric tests for data analysis and report median values as measures of central tendency (see Zar 1999). We did not have an adequate sample size for statistical interpretation of the pine data.

We used the Mann–Whitney test (U statistic) for independent groups to compare the number of oaks counted on transects surveyed by $\geq$6-grade students ($n = 8$) and the number of oaks counted on transects surveyed by <6-grade students ($n = 10$) with professional data from the same transects. We also used the U statistic to compare diameter at breast height data between pros versus $\geq$6-grade students (8 transects) and pros versus <6-grade students (10 transects). We used the chi-square (χ^2) goodness-of-fit test to compare frequencies of oak crown code collected by

Table 1. Median oak diameter at breast height (dbh) within 4 crown codes measured by professionals (pros) and ≥6-grade students, at Oak Creek Wildlife Area, Washington, USA, 2002.

	Pros ($N = 131$)			≥6-grade students ($N = 118$)[a]			
Crown code	**Median dbh**	***n***	**% *N***	**Median dbh**	***n***	**% *N***	***P*[b]**
Inverted vase	10.4	54	41.2	19.7	43	36.4	0.33
Columnar	8.3	48	36.6	6.7	39	33.1	0.50
Mushroom	31.5	7	5.3	9.2	9	7.6	<0.01
Dead	8.1	22	16.8	13.4	27	22.9	0.45

[a] Actual *N* of oaks reported by ≥6-grade students = 119. One oak was not included in table because the crown was not classified by the student.

[b] *P* value calculated from *U* test comparing dbh of oaks classified into 1 of 4 crown shapes pooled from 8 transects surveyed by both ≥6-grade students and pros.

students and pros on the same transects. We calculated expected proportions from the professional data and compared expected professional and observed student proportions of crown codes. The χ^2 test also was used for comparing the number of oaks classified as live or dead by students and by pros.

Finally, to determine if pros and students were classifying tree crowns for the same trees in the same way, we used the *U* statistic to compare oak diameter at breast height measurements between pros and students within each of the morphological classifications. If students and pros classified the same trees on the same transects consistently, there would be no difference in the diameter at breast height measures of oaks within the crown classifications. We defined large oaks as >50-cm diameter at breast height, medium oaks as 30–50-cm diameter at breast height, following Larsen and Morgan (1998), and we identified oak saplings as <10-cm diameter at breast height following Thilenius (1968). We set the significance level ($P > 0.05$) a priori.

Results

For tree counts we found the number of oaks per transect to be consistent between pros and students (≥6-grade data [$U_{8,8} = 65.0$, $P = 0.27$], <6-grade data [$U_{10,10} = 36.5$, $P = 0.68$]). We did not find differences in reported oak diameter at breast height values within each transect between both grade classes of students and pros for all except one transect, in which case the number of oaks counted by ≥6-grade students ($n = 2$) was too small for statistical testing. On 22 QC transects, pros counted 4 pines (median dbh = 60.1), and students counted 11 pines (median dbh = 45.0). We found no difference in the proportions of the 3 oak crown codes between pros and students (≥6-grade data [$\chi^2_2 = 1.83$, $P = 0.40$], <6-grade data [$\chi^2_2 = 0.59$, $P = 0.75$]). However, comparing student and professional oak diameter at breast height within specific codes (see Tables 1, 2), we found that students and pros differed in their classification of mushroom (M)-shaped trees (≥6-grade data [$U_{9,7} = 59.0$, $P < 0.01$], <6-grade data [$U_{14,14} = 143.5$, $P = 0.04$]).

We found no difference in proportion between professional and ≥6-grade student live- or dead-coded oaks ($\chi^2_1 = 2.70$, $P = 0.10$), but professional and <6-grade student proportions did differ ($\chi^2_1 = 7.19$, $P = 0.01$). Using measures made by pros only, the oak diameter at breast height interquartile range (encompassing 50% of all measures) was 5.9–17.0 cm. Large oaks made up 1.8% ($n = 5$), medium oaks accounted for 6.1% ($n = 17$), and saplings accounted for 52.5% ($n = 146$) of all oaks measured by pros ($n = 278$). Considering crown code assessments by pros only, we found that M-shaped trees ($n = 19$) comprised 6.8% of oaks measured.

Discussion

Despite consistency in tree counts between students and pros for oaks, students counted more pines ($n = 11$) than did pros ($n = 4$). The small sample size did not allow statistical testing, but we feel the disparity in pine counts is important considering the general scarcity of pines in the study area. We suspect that because of the uniqueness and larger size of pines in the study area, students may have altered the survey transects to include pines. Students may feel it is important to document a unique or rare item, without understanding how this kind of selective sampling can bias a data set. Galloway (2005) found that students exaggerated numbers

Table 2. Median oak diameter at breast height (dbh) within 4 crown codes measured by professionals (pros) and <6-grade students, at Oak Creek Wildlife Area, Washington, USA, 2002.

	Pros ($N = 176$)			<6-grade students ($N = 143$)			
Crown code	**Median dbh**	***n***	**% *N***	**Median dbh**	***n***	**% *N***	***P*[a]**
Inverted vase	10.1	68	38.6	11.1	63	44.1	0.68
Columnar	9.4	70	39.8	9.7	58	40.6	0.26
Mushroom	23.4	14	8.0	12.1	14	9.8	0.04
Dead	4.8	24	13.6	4.8	8	5.6	0.38

[a] *P* value calculated from *U* test comparing dbh of oaks classified into 1 of 4 crown shapes pooled from 10 transects surveyed by both <6-grade students and pros.

of relatively rare ungulates in a survey from school buses. Engel and Voshell (2002) found that volunteers overrated ecological condition in stream macroinvertebrate studies.

Although student and professional oak diameter at breast height data were statistically consistent, the median diameter at breast height values reported by both grade groupings were higher than professional values in 13 of the 18 transects QC checked. Anecdotal observations from pros in the field during student data collection noted that students seemed more eager to count larger trees. Our trainings may have inadvertently influenced students to inflate habitat quality by exaggerating numbers of large oaks and pines because we explained that these trees provide important habitat for wildlife. We therefore recommend that researchers present research implications after data collection and focus training on the importance of surveying a random sample from a population.

We found that morphological assessments of crown shape and determination of live or dead tree status were rarely consistent between pros and students. Although numbers and proportions of trees in each morphological category are similar between students and pros (Tables 1, 2), the diameter at breast height values were significantly different for M-coded oaks; thus, the similar proportions may have been coincidental. The relative percentages of columnar and inverted vase codes were similar enough that we cannot rule out that both students and pros were reporting these two interchangeably. We found greater variation in proportions and median oak diameter at breast height between professional and ≥6-grade student data (Table 1) than between professional and <6-grade data (Table 2). Although the diameter at breast height data for dead oaks between <6-grade students and pros were consistent, <6-grade students counted fewer dead oaks ($n = 8$) than pros ($n = 24$).

The M crown code was designated for well-established, mature oaks with large mushroom-shaped crowns. These trees are of special significance to resource managers because they provide more cavities and habitat for wildlife (Larsen and Morgan 1998). The metrics of both crown shape and diameter at breast height similarly describe the general rarity of large, mature oaks at the OCWA. Pros noted in the field that M-crowned oaks were made identifiable as a unique population by both the mushroom shape of the crown and the noticeably larger diameter at breast height relative to other oaks. For professional data only, M-shaped oaks accounted for 6.8% of the classifications and the pooled diameter at breast height values for medium- to large-sized oaks accounted for 7.9% of all trees measured. Because of this similarity, student data might still be used to evaluate the area for the number and distribution of mature oaks using oaks within the medium and large diameter at breast height categories.

Management Implications

The American Association for the Advancement of Science (1993) has called on schools to involve students in doing science, not just studying it. The Office of the Superintendent of Public Instruction in Washington has now included field investigation as a type of science inquiry that students are required "to know and be able to do" as part of the Essential Academic Learning Requirements or state standards for science (M. Tudor, WDFW, unpublished data). The potential for scientific collaboration between students and resource management agencies is, thus, growing. Although the benefits of participating in scientific studies to students are well documented, resource managers need to know how these partnerships might be of use in meeting their goals. Although this project represents only one example, it can be used as a case study that provides insight for the question of how educators and managers can improve the quality of student data for their projects.

We recommend that managers planning future work 1) visit students both prior to and after fieldwork, with the latter meeting focusing on the results and implications of the findings, 2) meet and work with teachers in advance of the student training to ensure that the field activities contribute to the ongoing classroom curricula, 3) avoid collecting morphological crown-code classifications or other subjective measures, and 4) recognize that student-collected survey data pertaining to relatively rare or charismatic species may be exaggerated in terms of quality or quantity. Resource managers can take public outreach and education beyond scripted classroom presentations. We encourage managers and biologists to initiate communications with statewide Project WILD coordinators and school district community outreach coordinators with ideas to involve K–12 students in actual ecological field research.

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