

Amateur collectors are critical to the study of fossil vertebrates: A case study from two Neogene localities in Northern California (Santa Margarita and Purisima formations)

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ABSTRACT

Vertebrate paleontology was born from the efforts of amateur and commercial fossil collectors in the nineteenth century. Amateur fossil collecting is a popular hobby in the USA, though owing to different ownership laws, American vertebrate paleontologists have less positive attitudes toward amateur collectors than in Europe where amateur and professional collectors work synergistically. Collections-based and literature surveys were conducted to evaluate the scientific contribution of amateurs to vertebrate paleontology near Santa Cruz, California. The first was a survey of museum collections identifying collector status (amateur or professional) of fossils from two formations (Santa Margarita Sandstone, Purisima Formation). The second was a comprehensive literature survey for these two stratigraphic units, documenting whether fossils were collected by amateurs or professionals. The third was a literature survey of all published (2009-2021) Cenozoic marine vertebrate records for the Pacific coast of North America (Alaska to Baja California, Mexico). The first survey indicates that amateurs have contributed the most (75.9%) to Santa Margarita Formation specimens and over a third (38.1%) of Purisima Formation specimens. These contributions are of high quality as they are included in 40% of all publications through time in the study area, and amateur-collected fossils are reported in half (49%) of all publications from the Pacific coast over the past decade. These findings indicate that amateur collectors are not only capable of collecting scientifically significant specimens, but appear to be integral to the study of Cenozoic marine vertebrates on the Pacific coast. Dismissive attitudes towards amateur collectors are clearly unwarranted. Advice for cultivating strong professional-amateur relations is provided.

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INTRODUCTION

Attitudes amongst vertebrate paleontologists toward amateur fossil collectors (hereafter amateur paleontologists) are a spectrum ranging from dismissive or critical (Black, 2013; Sager, 2017) to positive and encouraging (Godfrey, 2018; Munt, 2018; Haug et al., 2020). Many published studies have been conducted on amateur-collected specimens and many professional paleontologists have published positive comments on amateur paleontologists or even considered an integral part of the paleontological community (den Ouden and Pouwer, 2018; Godfrey, 2018; Munt, 2018; Haug et al., 2020). However, the author has been privy to a number of “off the record” conversations with other researchers (from multiple institutions) who privately expressed frustration with or dismissed amateurs altogether. These attitudes are in the author’s opinion a minority, though no surveys evaluating how pervasive elitist or dismissive attitudes persist among professional paleontologists have been conducted. Likewise, few published criticisms of amateur collectors by professionals exist, though conflicts between amateurs and museums or professional paleontologists are common albeit rarely discussed in print (e.g., Miller, 1988; Potera, 1995; Dunne and Middleton, 2018). One incident concerns a fossil bird collector meeting with an academic who angered the collector by informing the collector that “he should not have this material, and [it] should be [handed] over to the resident academic specialist forthwith” (Liston, 2018). Other incidents include mishandling and loss of non-donated amateur collected specimens at museums (Miller, 1988).

Criticism of commercial collectors abounds, focused on the cultivation of a fossil market and private ownership of fossils (Shimada et al., 2014). Some paleontologists have publicly considered specimens collected by commercial collectors scientifically worthless owing to the lack of stratigraphic provenance and taphonomic data (Horner, in Sager, 2017), and even taken an extreme view stating “it would be better to let a *Triceratops* skull fall to pieces than have that specimen mangled by amateurs who ignore basic scientific data collection” (Black, 2013). Even more extreme are calls for the US Federal Government to intervene and

seize fossils through eminent domain (Carr, in Pringle, 2014). Other (anonymous) paleontologists are opposed to any private ownership of fossils altogether (Boessenecker, pers. obs.), and according to one colleague, a (anonymous) museum curator leading a field trip for a regional conference cancelled a field trip at the last minute when they learned amateur collectors had signed up. Many amateurs happen to excavate, buy and sell fossils, and maintain private collections – albeit in the capacity of hobbyists rather than commercial dealers. Because of the ‘soft’ boundary between amateurs and commercial dealers, blanket generalizations can seriously erode the confidence that amateurs hold with professionals – despite being aimed at commercial rather than hobby collectors.

Amateur collectors have the capacity to work with professional paleontologists in a number of settings (field studies, fossil preparation, and even research), and critically discover and recover specimens that professionals may not come across. However, many fossils are difficult or impossible to collect safely without very specific tools and training, and most professionals who have worked with amateurs even in the most positive of contexts are aware of fossils irreparably damaged by inexperience (most professionals are likewise painfully aware of such accidents being caused by students and even professional colleagues; e.g., Maltese, 2018). In other cases, museum excavations have been looted by collectors between visits (e.g., Smith et al., 2021). Many fossil sites are geographically confined and/or ephemeral (e.g., quarries), and tensions can arise when professionals and amateurs compete for the same specimens (Catalani, 1999); further confounding relations are incidents where irresponsible collecting practices, often by amateurs but in some cases by professionals as well, might result in all parties involved losing site access (Catalani, 1999; Boessenecker, pers. obs.). Professional paleontologists are further concerned with the ability of amateurs to collect proper field data. Whereas a few studies have reported positive examples of amateur contributions to paleontology (Catalani, 2014; Godfrey, 2018; Munt, 2018; den Ouden and Pouwer, 2018), none have as of yet quantified the degree to which amateurs have contributed to the science. In com-

parison, a number of publications defending commercial paleontology have been published, ranging from rational (Maltese, 2018) to aggressive (Siber, 2018).

This study aims to answer the following questions: 1) are the collections made by amateur paleontologists scientifically significant? 2) If so, how important are amateur discoveries? 3) How do the discoveries of amateur versus professional paleontologists compare? These questions are addressed by a survey of existing museum collections at two institutions in California from two localities near Santa Cruz, California (Figure 1), as well as reporting the results of two literature surveys: counting amateur v. professionally collected publication records from the study area since the early twentieth century (Literature Review I), and a broader literature search across all Cenozoic marine vertebrate fossils from the eastern North Pacific over the past 12 years (2009-2021; Literature Review II). Finally, some comments for academic paleontologists on interacting with amateur paleontologists are provided.

METHODS

The word amateur is used throughout this text, which in some contexts has a negative connotation as indicating unskilled or incompetent. The original meaning of amateur, derived from the latin *amatorum*, refers to an individual pursuing a particular field out of love or passion for the subject rather than their primary source of income. Sometimes the term avocational is used instead of amateur. The present study prefers the original term, which honors the amateur paleontologist's passion for collecting, preparing, and studying fossils.

To compare the collecting efforts of amateurs and professionals, data were compiled for museum collections of vertebrate fossils from two rock units: the upper Miocene Santa Margarita Sandstone ($n=703$) and the Miocene-Pliocene Purisima Formation ($n=1424$), both in Santa Cruz County, California (Figure 1).

A number of factors led to the choice of this study area. The Santa Cruz area is urban (Santa Cruz County population is 262,382, as of 2010 census), and thus a large number of people live in close proximity to fossil localities – considered to be a critical factor in locality access by amateurs (Uhen and Pyenson 2007). Paleontological research has been actively pursued over the past 40 years in the area (see Study Area and Geologic Background). Vertebrate fossils are readily encountered and frequently collected by amateurs in the field area (Perry, 1977, 1989; 1993). Critically, several localities are private or consist of city or county land that has no protections in place for vertebrate fossils, and amateur collectors can thus legally collect vertebrate fossils from formations at several localities. Lastly, the author has spent over a decade conducting field studies and research on the fossil vertebrates of these strata (Boessenecker, 2016; 2017; Boessenecker and Perry, 2011; Boessenecker et al., 2015; Fallon and Boessenecker, 2019; Racicot et al., 2014) and is familiar with most of the amateurs and professionals who have made scientific contributions from the study area. Both localities are richly fossiliferous and the rate of erosion/fossil destruction is rapid enough to support sustainable fossil collecting by amateur collectors and professional paleontologists (e.g., Underwood and Ward, 2018).

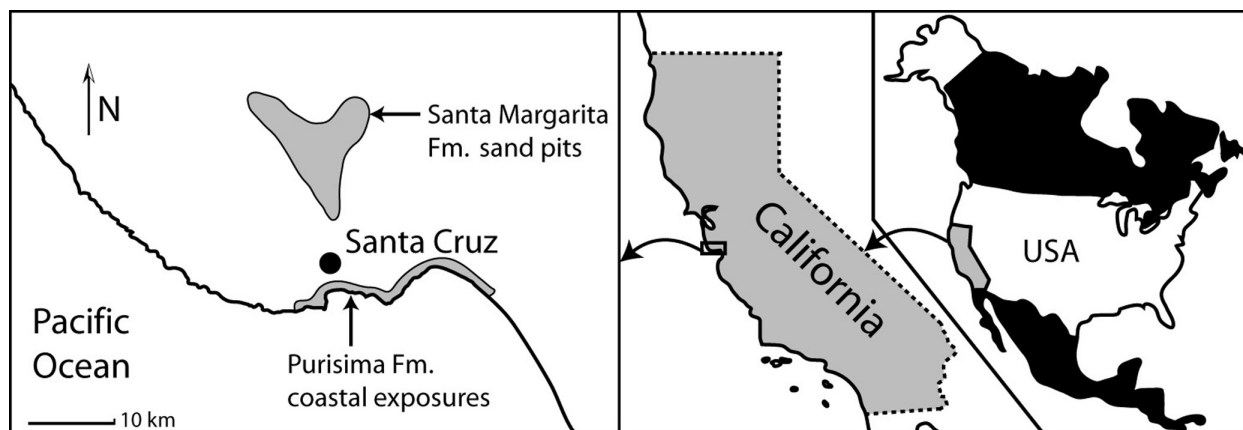


FIGURE 1. Map of the study area showing the location of inland exposures of the Santa Margarita Sandstone and coastal exposures of the Purisima Formation in northern California.

Collector names were pulled (accessed February 2016) from databases of two museums (Appendix): Santa Cruz Museum of Natural History (Santa Cruz, CA; SCMNH; n=828) and University of California Museum of Paleontology (Berkeley, CA; UCMP; n=1296). Specimens were assigned either “amateur” or “professional” depending upon whether any professionals were involved in collecting. Even though some fossils were collected by professionals assisted by amateurs, this study seeks to quantify the independent activities of amateurs, so such specimens were noted as collected by professionals. Collector names were identified as professionals if they were at any time employed as a paleontologist or geologist, or a student in either field. Likewise, amateur collectors were identified if their primary occupation was not related to either field. In order to estimate the quality of contributions produced by amateur paleontologists, the available literature on the fossil vertebrates from these two strata (n=26) were scrutinized in order to determine whether the specimens reported in those studies were collected by amateurs, professionals, or both. If amateur contributions were to consist only of poorly preserved, damaged, and/or scientifically non-significant fossils then they should only appear in a minority of peer-reviewed articles. Collector names are recorded in SCMNH and UCMP databases but withheld here to conform to ethical rules regarding disclosure of employment status. Because this dataset does not include identifying information, a human participant research review was not needed.

Lastly, in order to gauge the broader significance of amateur discoveries, the literature on Cenozoic marine vertebrates from the eastern North Pacific (British Columbia, Washington, Oregon, California, Baja California) was surveyed over the past decade (2009-2021; Appendix) in order to record 1) whether fossils reported within were collected by professionals, amateurs, or both and 2) whether the collectors were acknowledged or thanked by the authors.

STUDY AREA AND GEOLOGIC BACKGROUND

The upper Miocene Santa Margarita Sandstone and Miocene-Pliocene Purisima Formation are exposed in Santa Cruz County, California (Figure 1). The Santa Margarita Sandstone is richly fossiliferous and consists of a basal unconsolidated conglomerate overlain by arkosic sand with giant scale cross-bedding, deposited within a narrow tidally influenced northeast-southwest oriented

channel between landmasses and connecting the Pacific Ocean to an inland sea occupying the San Joaquin basin (Phillips, 1983). On the basis of invertebrate biostratigraphy, the Santa Margarita Sandstone is likely to be 9-12 Ma in age and thus Tortonian-equivalent (Repenning and Tedford, 1977). The Santa Margarita Sandstone yields abundant waterworn shark teeth and marine mammal bone fragments from the lower conglomerates and well-preserved articulated and associated skeletons of cetaceans, pinnipeds, and sirenians within the upper sandstones. The Santa Margarita Sandstone is chiefly exposed in a series of quarries, sand pits, and road cuts in the southern Santa Cruz Mountains (Figure 2A-B) and occasionally in stream cuts (Repenning and Tedford, 1977; Domning, 1978; Perry, 1993). Vertebrate paleontologists have typically sought well preserved and often articulated marine mammal remains (see Repenning and Tedford, 1977; Domning, 1978), whereas amateur collectors typically screen for shark teeth (Figure 2B) or collect echinoids (Perry, 1993).

The Purisima Formation consists of a regressive coarsening upwards sequence of diatomite, siltstone, and sandstones deposited within a coastal embayment. The Purisima Formation has a strong geochronologic framework based upon glauconite K/Ar dates, paleomagnetism, and tephrochronology (see Powell et al., 2007, and references therein). Six phosphatic bonebeds occur throughout the formation and frequent with intermittent storm-deposited and hiatal shell beds and phosphatic bonebeds. Within bonebeds, shark teeth, fish bones, bird bones, marine mammal bones, teeth, and skeletons are common (Boesenecker et al., 2014), and many shell beds yield well-preserved bivalves and gastropods with original coloration (Perry, 1989). Unlike the Santa Margarita Sandstone, virtually all productive exposures of the Purisima Formation are coastal cliffs (Figure 2C-D). Much of the vertebrate assemblage is unpublished, so field efforts by vertebrate paleontologists have targeted any vertebrate specimens that might represent new records for taxa not yet known for the Purisima Formation, more completely preserved specimens of existing taxa, or new taxa. Owing to the rarity of typical vertebrate fossils sought after by amateurs (e.g., shark teeth), these collectors instead often collect mollusks and occasional whale bones. Certain savvy collectors have made surprisingly large collections of fossil bird bones (S. Jarocki, n=192) and collected numerous marine mammal skulls (S. Jarocki, n=5; J. Neubert, n=3; C. Pirrone, n=2; F. Sheperd, n=2).

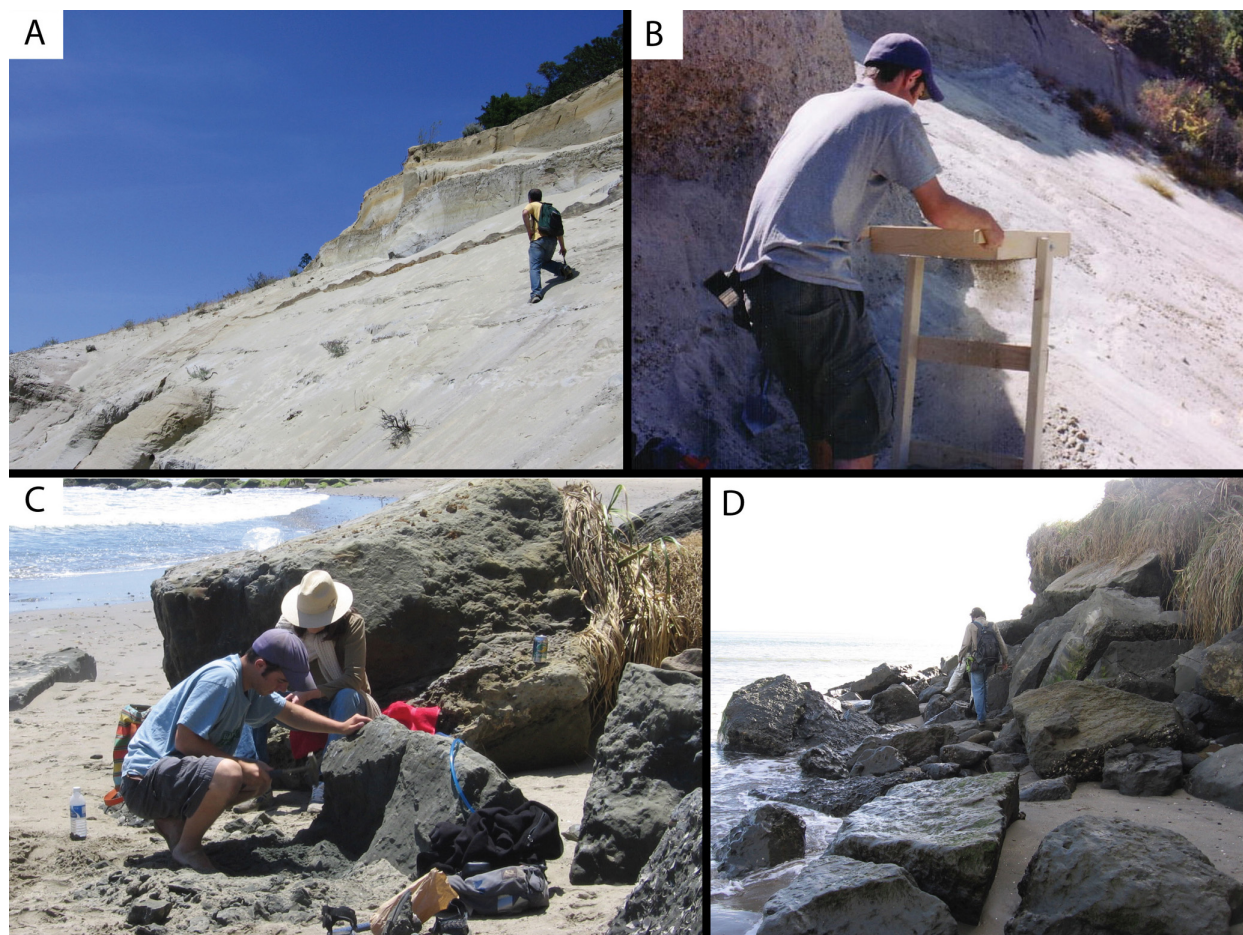


FIGURE 2. Typical localities and collecting in the study area. A) amateur collector Claudio Argento prospecting for marine vertebrates and echinoderms in the upper Santa Margarita Sandstone in Zayante Quarry, near Zayante, California; B) the author dry screening for shark teeth in the former Santa Cruz Aggregates Co. quarry (Bean Creek 1, =UCMP locality V4004), photo by Eric Holt; C) the author excavating an odontocete mandible from a fallen block of Purisima Formation near Capitola (UCMP locality V99868) with playwright Claudia Stevens (photo by S. Michalies); D) prospecting for fossil vertebrates amongst fallen blocks of Purisima Formation near Capitola (UCMP locality V99869) with amateur collector Linda Meneses.

RESULTS

Comparison by Stratigraphic Unit

Just over one-third of Purisima Formation vertebrate fossils in museum collections were collected by amateurs ($n=544$, 38.2%; Figure 3C; Appendix) while nearly two-thirds were collected by professionals ($n=877$, 61.6%); collector status of only three specimens was unknown ($n=3$; 0.2%). Collections from the Santa Margarita Sandstone are dominated by amateur collected specimens ($n=534$, 75.9%; Figure 3C), and a minority were collected by professionals ($n=147$, 18.8%); fewer yet had unknown collector status ($n=37$; 5.2%).

Comparison by Institution

Nearly all SCMNH specimens from both units were collected by amateurs (Figure 3A-B; Appendix); for the Santa Margarita Sandstone, 95.2% of specimens were amateur-collected ($n=512$) versus 4.8% by professionals ($n=26$). Similar figures describe the Purisima Formation (Figure 3A-B), with 95.5% of specimens being collected by amateurs ($n=278$) versus 4.5% by professionals ($n=12$).

UCMP collections are more dominated by professional collections but nevertheless still contain specimens collected by amateurs (Figure 3A-B). Amateur-collected specimens constitute a minority of specimens from the Santa Margarita Sandstone (13.9%; $n=23$) whereas approximately two-thirds

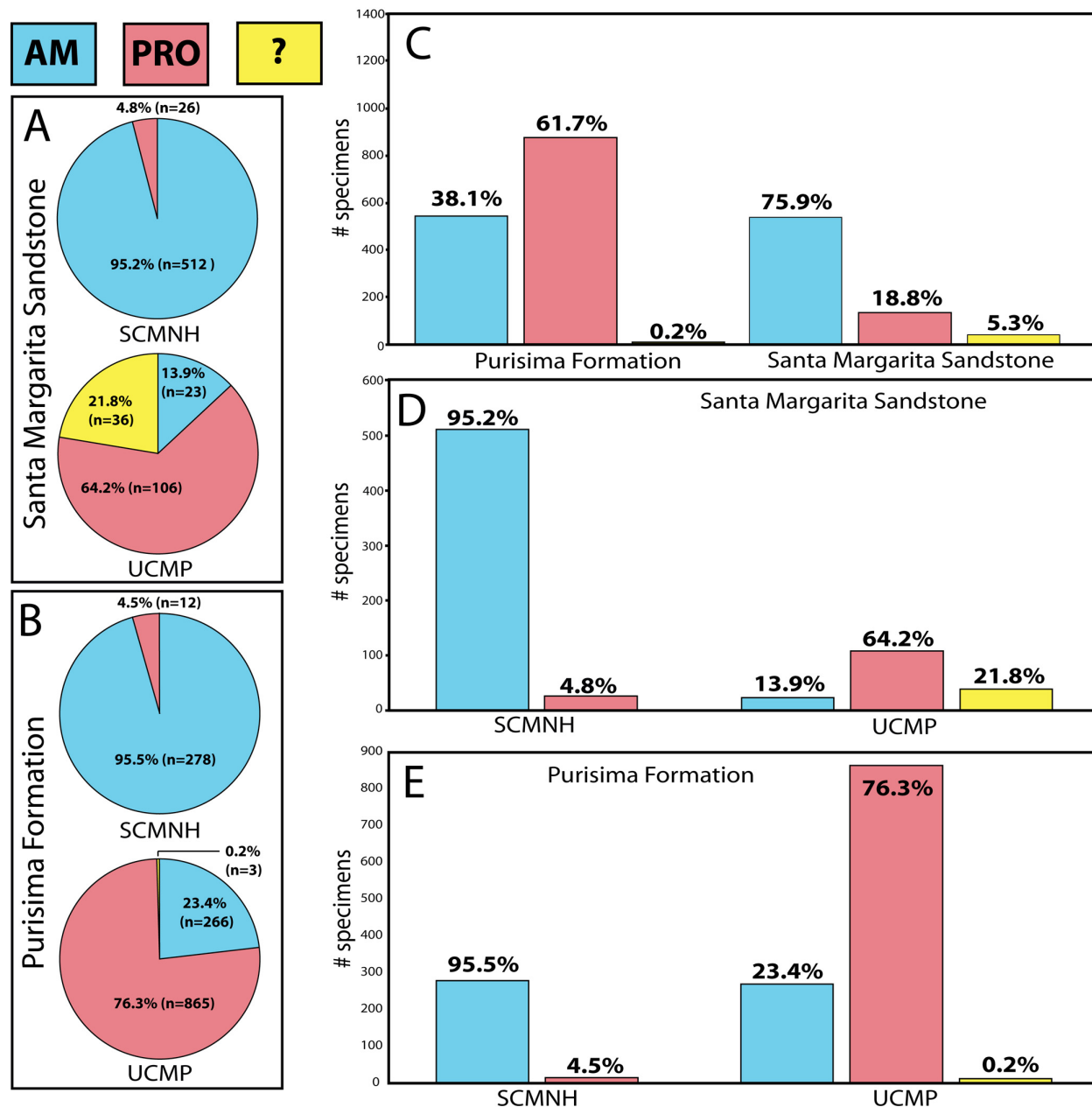


FIGURE 3. Comparison of amateur versus professional collected specimens at SCMNH and UCMP from the Santa Margarita Sandstone and the Purisima Formation. A) Pie charts showing proportion of amateur v. professionally collected fossils from each rock unit and each institution; B) Comparison of the proportion of fossils collected by amateurs and professionals between each rock unit (institutions pooled); C) comparison of the proportion of fossils collected by amateurs and professionals between museums for the Santa Margarita Sandstone; D) comparison of the proportion of fossils collected by amateurs and professionals between museums for the Purisima Formation.

were collected by professionals (64.2%, n=106); just under one quarter (21.8%; n=36) were collected by collectors with unknown status. Approximately one quarter of specimens from the Purisima Formation were collected by amateurs (23.4%, n=266) versus three quarters collected by professionals (76.3%, n=865); only three specimens

were collected by collectors of unknown status (0.2%).

Literature Review I – Amateur Collected Fossils from the Study Area

Out of 26 peer reviewed publications (Appendix) reporting and describing vertebrate fossils from the Santa Margarita Sandstone and Purisima

Formation in Santa Cruz county (three of which report fossils from both units), a slim majority (n=14, 56%) of these report fossils collected by professionals from the study area. Two-fifths of these studies (n=10; 40%) report amateur collected specimens; of these, seven (28%) report a combination of amateur and professionally collected specimens, and three (12%) report specimens collected only by amateurs. One study reported a specimen found by a collector of unknown status (4%), but is likely to represent an amateur collection. If so, this would bring the number of publications reporting any amateur collected fossils to 11 (44%).

Literature Review II – Cenozoic marine vertebrate paleontology in eastern North Pacific, 2009-2021

Out of 102 peer reviewed publications published since January 2009 (Appendix) reporting, describing, naming, or figuring Cenozoic marine vertebrates from the eastern North Pacific, just over one-third (n=35; 34%) were based completely on amateur-collected specimens, while about one quarter (n=28; 27%) were collected by the authors of the study. Somewhat fewer numbers of papers reported fossils reported both specimens collected by amateurs and professionals (n=14; 14%) and fossils collected by other researchers (n=17; 17%); eight of these papers did not mention the names of the collectors (8%). A majority of these studies acknowledged or thanked the collectors (n=91) and the remainder did not (n=11). Of papers reporting fossils collected by individuals other than the authors (n=66; e.g., amateurs, combination, or other paleontologists), most (n=61; 92%) acknowledged the collectors by name (or thanked them in the acknowledgements) and a few (n=5; 8%) did not.

DISCUSSION

Stratigraphic/Locality Comparisons

Both stratigraphic units include large numbers of vertebrate fossils collected by amateur fossil collectors. Whereas the sample from the Santa Margarita Sandstone is dominated by amateur collected specimens (n=535; 76%), even over one-third (n=544; 38%) of the collection from the Purisima Formation is constituted by amateur collections (Figure 3C; Appendix).

Why is the Santa Margarita sample dominated by amateur collections? Vertebrate fossils are typically found by dry sifting (Figure 2B) and, depend-

ing upon the locality, the number of fossils recovered is more or less proportional to the amount of time spent sifting and the volume of sifted sediment. Many specimens from SCMNH collections were also made by quarry operators who quickly pulled specimens off of conveyor belts, saving them from destruction (F.A. Perry, pers. comm.). Shark teeth are commonly sought after by amateur fossil collectors at these localities, and 1cm+ teeth can be found at a rate of 20/hour if digging vigorously (Boessenecker, pers. obs.). Scientifically significant fossils are rare, and most professionally collected specimens from this unit were recovered either as skeletons exposed in outcrop or excavated during quarrying of bonebeds.

In contrast, the Purisima Formation is relatively less fossiliferous with respect to vertebrates. Shark teeth are a major draw for fossil collectors (arguably the draw for the Santa Margarita Sandstone), but are very rare in the Purisima Formation and occur only at discrete horizons (Boessenecker et al., 2014). Furthermore, Purisima shark teeth are discoverable only during surface collection (e.g., Figure 2C) rather than sifting, as sifting is not possible given the combination of cohesiveness from clay minerals and light induration to complete cementation. Approximately 10 shark teeth per year are found, on average one per visit if multiple shark-bearing strata are scoured on the same day (e.g., assuming 10 visits per year; pers. obs.). For example, it took the author six years of visiting the Purisima Formation exposures in the study area 3-10 times per year until a single shark tooth was found. Most vertebrate remains found by amateurs consist of cetacean bone fragments and occasionally complete vertebrae, collected by amateurs seeking well-preserved mollusks; only a few collectors (S. Jarocki, C. Pirrone, F. Shepard) visit Purisima Formation localities with the intention of searching only for scientifically significant vertebrates (e.g., shark/fish teeth, bird bones, marine mammal teeth, skulls, jaws, or other diagnostic elements; Figure 4). Indeed, the rarity of significant vertebrate remains requires extensive patience and repeated site visits including after storms. Examples of scientifically significant marine vertebrate fossils collected by amateur collectors with extensive knowledge of local geology are shown in Figure 4. Lastly, unlike the seemingly homogeneously fossiliferous gravels of the Santa Margarita Sandstone, different fossils occur only in particular horizons within the Purisima Formation, and thus a strong grasp of stratigraphy and lithology is necessary to target particular vertebrates, echinoderms,

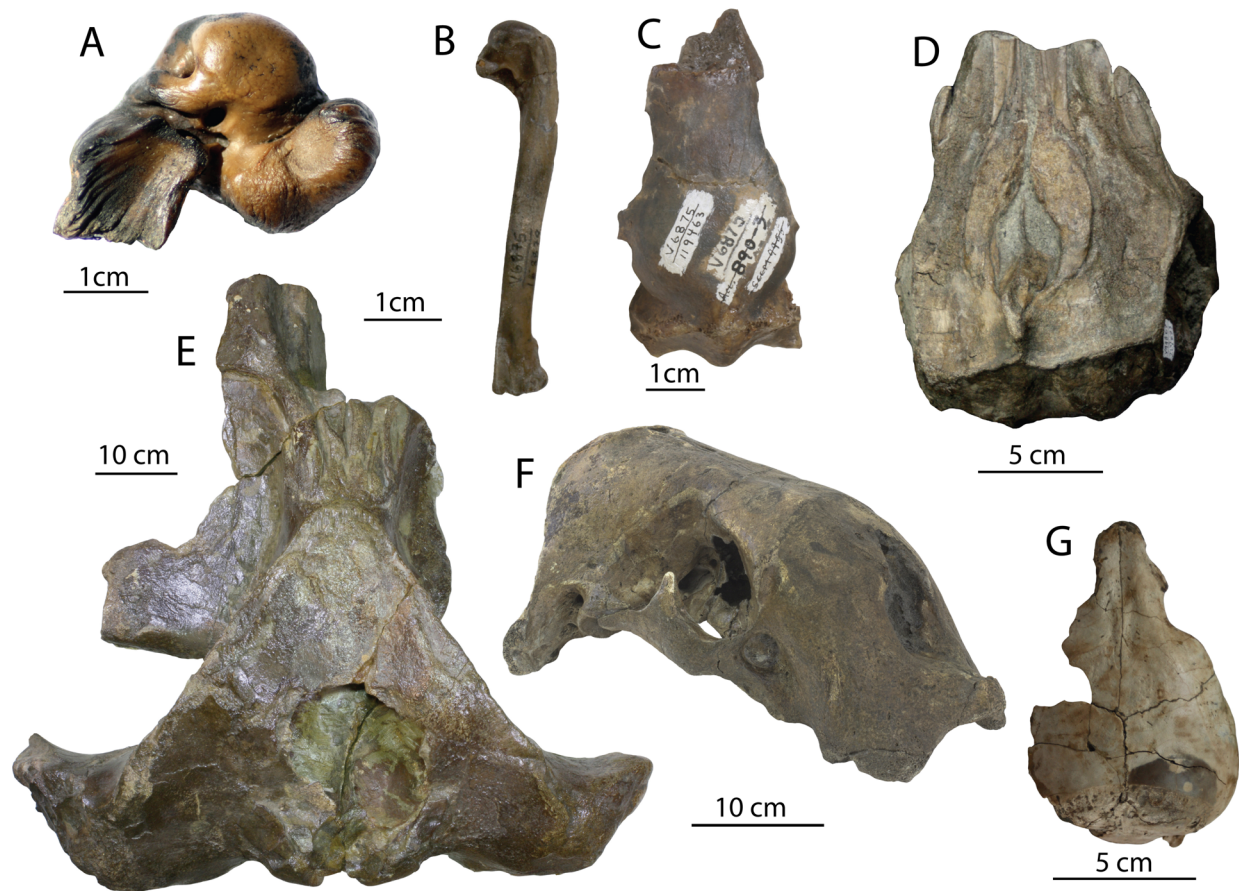


FIGURE 4. Examples of rare, scientifically significant specimens collected from challenging Purisima Formation exposures in Santa Cruz, California, by amateur collectors. A) Globicephaline dolphin periotic, UCMP 219487, collected by S. Jarocki; B) alcid bird humerus, UCMP 168879, collected by S. Jarocki; C) sulid (*Morus* sp.) bird skull, UCMP 119463, collected by G. Macy; D) lipotid dolphin skull (*Parapontoporia* sp.), UCMP 219673, collected by F. Sheperd; E) baleen whale skull (*Parabalaenoptera* sp.), SCMNH 9990.15, collected by W. Miller; F) walrus skull (*Valenictus* sp.), UCMP 219091, collected by F. Sheperd; G) fur seal skull (*Thalassoleon macnallyae*), SCMNH 9975.1, collected by G. Macy.

and mollusks, in addition to identifying which boulders on the beach to examine for whichever fossil type is sought.

Institutional Comparisons

This study examined collection data from two institutions (Figure 3): one is a local, community museum that is geographically close to the localities (SCMNH) and the other is a larger university museum located two hour's drive away from the study area (UCMP). This discussion is not intended to pass judgement on the manner in which each museum interfaces with the public. While SCMNH is a community museum and frequently interfaces with the local amateur community, UCMP is a research institution, and interfacing with the amateur community is not within its mis-

sion as part of the University of California system. As a result, amateur collections dominate those from the study area of SCMNH (95%), and about one-fifth of those from UCMP were collected by amateurs (~22%). Regardless, a large number of amateur discoveries have made their way into UCMP collections any way – which separately demonstrates that amateur collected specimens are of high enough quality to be permanently curated at a large, regional repository.

Quality of Amateur Collections

Results of the literature survey for the study area indicate that amateur-collected fossils have been either the sole focus of (e.g., Kellogg, 1927; Boessenecker et al., 2015; Boessenecker, 2017) or included within (Mitchell and Repenning, 1963;

Mitchell, 1962; Barnes, 1971, 1972, 1978, 1985; Repenning and Tedford, 1977; Domning, 1978) published peer reviewed articles alongside fossils collected by professional paleontologists (or geologists). This demonstrates that amateur collected fossils are not just common, non-informative specimens (e.g., duplicates of existing voucher specimens at best, indeterminate fragments at worst) but include a number of well-preserved specimens of scientific interest. Furthermore, one of the holotype specimens (*Dusignathus santacruzensis*) from the Purisima Formation in the study area was collected by an amateur collector, Porter M. Chaffee (Kellogg, 1927).

Collector Data

In some publications in each literature survey, a number of publications either lacked collector data completely or included it only for a minority of reported specimens. Aside from making studies like this difficult, the collectors and preparators of fossils should always be acknowledged for their efforts. In many cases degreed curators and collections managers were thanked, but not collectors (who may have been amateurs or professionals). Amateur collectors can be frustrated when not recognized for their discoveries or donations – and so can professional paleontologists. Whether intentional or a genuine oversight during the writing process, leaving out collector names from a publication is often interpreted by amateur collectors and professional paleontologists alike as careless or snobbish (Boessenecker, pers. obs.). In some cases where large specimens were collected by a large team, it may be more appropriate to thank an entire field crew. However, this generally does not apply to specimens collected by amateur collectors, nor does it apply to any of the specimens upon which publications in either literature review were derived.

Professional-Amateur Collaboration in Santa Cruz County

Paleontologists are often not paid well, and small museums generally do not have acquisition budgets. However, there are some things that money cannot buy. Creativity is critical, and there are many ways to encourage donations simply by building good will. The amateur collector community in Santa Cruz has been on good terms with the paleontological and museum community, largely owing to the efforts of the Santa Cruz Museum of Natural History and Mr. Frank Perry in particular, who has worked tirelessly to engage the local com-

munity and secure scientifically significant donations for SCMNH, UCMP, and LACM. Some of these efforts included providing local talks, regularly meeting with amateur collectors to identify recent finds, maintaining a fossil club (Monterey Bay Paleontological Society) and its newsletter. Although not affiliated at the time with a local museum, the author continued this trend into the 2000s by starting a fossil club (San Francisco Bay Paleontological Society), leading field trips, and eventually inviting amateur collectors along to help collect scientifically significant specimens for museums. Some collectors became repeat field assistants (e.g., C. Argento, C. Pirrone, and F. Sheperd). Mr. Perry and the author routinely identify fossils for amateur collectors, as well as provide (*pro bono*) collecting, preparation, and curatorial advice to amateurs. When fossils are donated, painted casts have been provided to the collector as a sign of appreciation. In comparison to the east coast (e.g., South Carolina), the situation in Santa Cruz benefits greatly from the lack of a fossil market – driven by a much smaller collecting community and comparably rare fossils that need some skill to locate, collect, and prepare. More recently, in South Carolina, the author has opted for displaying amateur donations in a special exhibit as well as promoting amateur finds and donations on social media. It is astounding what a paleontologist can ‘buy’ with a little bit of good will, plaster, mold- ing compound, patience, and positivity.

Of critical importance is being proactive with the local amateur community. It is easy enough to wait for amateurs to come to an institution with an interesting find; however, the museum professional often finds themselves “behind the curve” when amateurs have the inevitable yet preventable field accidents, damaged fossils during collection, or collected specimens illegally or without any field notes. Proactive interfacing with the community reduces the chances of amateurs unknowingly damaging specimens, recording insufficient data, looting museum excavations (Smith et al., 2022), or even breaking the law (e.g., Dunne and Middleton, 2018). This is easier than ever with the advent of the internet and social media – excellent platforms to educate amateur paleontologists on collecting etiquette. Attending more traditional events like fossil club meetings and hosting museum outreach at public events can also help educate and build future bridges with the amateur community. Other possibilities include installing a special mini-exhibit on local collecting guidelines, or writing and printing a pamphlet with “do’s and don’ts”. Interact-

ing with amateur collectors on social media and fossil collecting web pages, including identifying fossils and answering questions, can build significant good will and help educate local or regional amateur collectors (MacFadden et al., 2016). Educating local amateurs clearly helps establish boundaries, rules, and best practices and can help prevent future misunderstandings (Dunne and Middleton, 2018).

Amateur Collectors and Vertebrate Paleontologists on the Pacific Coast, USA

Vertebrate paleontology was borne out of the efforts by an early commercial paleontologist, Mary Anning, and her collections of marine reptiles made along the shores of Lyme Regis in the southwestern UK (Maltese, 2018). These exposures erode rapidly and fossils are discovered or destroyed within days to hours of being exposed (Underwood and Ward, 2018). Such characteristics are common to other areas where amateur paleontologists have made substantive contributions to vertebrate paleontology like the Isle of Wight, UK (Munt, 2018), Kimmeridge Bay, UK (Underwood and Ward, 2018), and Calvert Cliffs in Maryland, USA (Godfrey, 2018). Coastal cliffs of California, Oregon, and Washington expose a wide variety of Oligocene through Pleistocene marine vertebrate-bearing strata that have been prospected by amateur paleontologists for over a century, quite similar to the collecting history of the British coast. Significant marine vertebrate discoveries have been made at most of these localities by amateur paleontologists including J. Goedert, D. Emlong, G. Pierson (Oregon and Washington) as well as G. Macy, J. Neubert, and S. Jarocki (Santa Cruz region). One in particular, Douglas Emlong, collected hundreds of scientifically significant specimens chiefly from Oregon and Washington (but also including a few specimens from the Purisima Formation) during the 1960s and 1970s. The Smithsonian purchased this collection in 1967 and then paid Emlong to collect significant vertebrates and ship them east in crates (Ray, 1981). The Emlong Collection has produced no less than 16 holotypes as of 2019 – three of which were named since 2015, and many future holotypes are actively being studied and many additional specimens await preparation and/or study. Forty years after acquisition, the bulk of material still awaits preparation.

Marine vertebrate fossils in the eastern North Pacific are geochronologically young and typically encountered in coastal exposures of often un-lith-

ified or lightly indurated marine rocks. Neogene marine strata are prime targets for amateur collecting (Underwood and Ward, 2018). As a result, marine vertebrate paleontology has benefited greatly rather than harmed by the efforts of amateur collectors over the past century. Half of all papers (49/102) reporting Cenozoic marine vertebrates from the eastern North Pacific published in the last decade have been founded (in whole or in part) upon amateur collected fossils. Note that this is a low estimate, as several papers (n=7) include amateur collected specimens found by J. Goedert, who happens to be a coauthor on these studies and thus these were assigned to the “author” category; including these brings the total of publications including amateur collected specimens to 56. Critically, this number outweighs papers reporting fossils collected by the authors reporting them (28/102; but see above). At present marine vertebrate paleontology on the west coast seems dependent upon the generosity of amateurs, and these results suggest that vertebrate paleontologists may not be contributing as much to museum collections.

It is unclear whether this mode of collections use and expansion is sustainable. Many large assemblages of fossils amassed by amateurs from the eastern North Pacific exist in USNM, LACM, and UWBM collections, including G. Pierson, J. Goedert, and especially D. Emlong (Ray, 1977, 1981; Barnes and Goedert, 1996; Goedert, 2020). The vast Emlong collection in particular at the USNM is seemingly bottomless, yet Emlong passed away in 1980 and his collection is thus finite. A majority of the collection has not yet been prepared out of hard concretions, but these efforts apparently ceased, and preparation of the remaining specimens has not re-commenced. Further, unless active amateur collectors are respected, supported, and celebrated by vertebrate paleontologists, amateurs have little to no reason to donate fossils. Snobbish attitudes persist amongst some marine vertebrate paleontologists (including those who have published on amateur discoveries; Boessenecker, pers. obs.) and can easily discourage amateurs from donating or even interacting with academics. Attitudes of entitlement do much to frustrate amateurs (Miller, 1988) and undermine the work of professionals who seek to work synergistically with the amateur community (Liston, 2018). Lack of effort on behalf of scientists (negligence) and outright hostility to donors have caused several donation streams to completely dry up at major museums, which formerly cultivated and enjoyed a warm relationship with amateur collec-

tors (Boessenecker, pers. obs). According to the results of this study, paleontological research on Cenozoic marine vertebrates from the eastern North Pacific is dependent on amateur donations, which outnumber of published fossils collected by the researchers themselves.

Professional paleontologists who feel entitled to possess amateur collected specimens (e.g., Liston, 2018) or dismiss their contributions, lest they be hypocrites, ought to change their opinions (and behavior) regarding amateurs or do the hard field work themselves. Vertebrate paleontologists are encouraged to not frustrate landowners as land access can be revoked in retribution for bad behavior (Leiggi et al., 1994). Similarly, professionals ought to extend the same concern toward amateur collectors. Professional paleontologists who make no time for amateurs, dismiss their talents and discoveries, or are hostile will not cultivate an atmosphere conducive to amateur cooperation (Miller, 1988). Further, a sufficiently disgruntled amateur collector, who lives close to a locality, can easily outcompete more infrequently visiting professional researchers. Positive encouragement, assistance with identification, answering questions, cooperative field trips, museum tours, sharing literature, and providing casts of donated specimens all do much to foster amateur cooperation. "Kill not the goose that lays the golden egg."

CONCLUSION

Museum collections of vertebrate remains from two representative institutions are constituted by a large number of fossils collected and donated by amateur paleontologists from the Miocene-Pliocene Santa Margarita Sandstone and Purisima Formation of Santa Cruz County, California. At one museum (SCMNH), nearly the entire collection was assembled by amateur fossil collectors. A survey of the published literature indicates that nearly all published articles include or were completely focused on fossils collected by amateurs, and all vertebrate holotype specimens were either discovered or collected by amateur fossil collectors. Fossil collections from the study area further have excellent collection data and provenance. Altogether, these results indicate that at localities easily accessed by amateur collectors and characterized by moderate-rapid erosion, there is a real opportunity to engage and partner with ama-

teur paleontologists. Cenozoic marine vertebrate paleontologists working in the eastern North Pacific are currently publishing more rapidly on amateur discoveries than fossils they are contributing to permanent collections through field studies. At present this field appears to rely on the exploitation of amateur collecting without reciprocal contribution via scientific collecting. This practice is unsustainable unless amateurs are respected, treated well, and supported by professional researchers. Positive collaboration between professionals and amateurs is necessary for sustaining donation streams. Lastly, this study clearly indicates that negative connotations of the term amateur are, within the field of paleontology, unwarranted.

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APPENDIX

Fossil collector data from Santa Cruz, California, and literature review results (available as a zipped file at palaeo-electronica.org/content/2022/3517-amateur-paleontology).

ERRATUM

PE Note: the following reference which is cited prominently in the paper was mistakenly left out of the reference list.

Liston, J. 2018. Ivory towers of entitlement? The commercialisation of academic paleontologists. *Geological Curator*, 10:671-680.

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