Revista Mexicana de Biodiversidad

Rev.Mex.Biodivers. 89 (2018): 402-411

Taxonomy and systematics

Health level of a mammal collection

Nivel de salud de una colección de mamíferos

Vania E. Rivera-León, Yolanda Hortelano-Moncada *, Fernando A. Cervantes

Colección Nacional de Mamíferos, Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México, Tercer Circuito s/n, Ciudad Universitaria, 04510 Ciudad de México, Mexico

*Corresponding author: yolahm@ib.unam.mx (Y. Hortelano-Moncada)

Received: 2 June 2017; accepted: 16 January 2018

Abstract

The specimens deposited in a scientific collection are the physical evidence of living, as well as extinct, life forms. The physical state and the accuracy of the data and of the specimens stored in a collection may be assessed by the health level of the collection, which is represented by the collection profile and a health index. This paper presents a practical method for assessing a mammal collection health level. This method was designed and standardized following previous works and includes 8 levels. The method was applied to the Colección Nacional de Mamíferos (CNMA), housed at the Instituto de Biología, Universidad Nacional Autónoma de México, in 2011 and in 2015. The cataloged specimens were selected by a stratified random sampling in 2011 and a simple random sampling in 2015. Specimens that had not been cataloged were also assessed and selected by a stratified sampling in both years. A total of 336 specimens were evaluated in 2011 and 331 in 2015. The health index in the CNMA was 0.70 in 2015.

Keywords: Biodiversity; Certification; Biological collections; Curatorial standards; Health index; Handling; Maintenance

Resumen

Los ejemplares albergados en las colecciones científicas constituyen evidencias físicas de formas de vida presentes así como extintas. El estado físico y la precisión de los datos de los ejemplares depositados en las colecciones científicas se pueden evaluar con un método conocido como nivel de salud, que está representado por el perfil de la colección y el índice de salud. Este artículo presenta un método práctico para evaluar el nivel de salud de una colección de mamíferos. El método fue diseñado siguiendo trabajos previos e incluye 8 niveles. El método se aplicó a la Colección Nacional de Mamíferos (CNMA) del Instituto de Biología, UNAM, en 2011 y en 2015. Los ejemplares catalogados fueron seleccionados por muestreo aleatorio estratificado en el 2011 y por un muestreo aleatorio simple en el 2015. Los ejemplares que no habían sido catalogados también se evaluaron y se seleccionaron mediante un muestreo sistemático. Se evaluaron 336 ejemplares en 2011 y 331 en 2015. El índice de salud en la CNMA fue de 0.70 en 2015.

Palabras clave: Biodiversidad; Certificación; Colecciones biológicas; Estándares curatoriales; Índice de salud; Manejo; Mantenimiento

ISSN versión electrónica: 2007-8706; Universidad Nacional Autónoma de México, Instituto de Biología. https://doi.org/10.22201/ib.20078706e.2018.2.2339

Introduction

A biological collection is a place where specimens, as well as their parts or derivatives, are stored. The specimens in a collection are preserved using a variety of techniques, suitably organized and safeguarded along with their associated information. The specimens can be used as reference material for various scientific studies, help us to learn about and understand the present and historical environment, and serve as elements for consultation by present and future generations (Cervantes, 2016; Golden, 2000; Martínez-Meyer, 2005; Simmons & Muñoz Saba, 2005). Collections are centers for documenting and recording historical, natural, and permanent records of flora and fauna. This is particularly important for ecosystems that have been diminished or destroyed due to natural catastrophes or by human activities. Further, they represent a testimony of the vast natural wealth of our planet (Lieberman & Kaesler, 2000; Simmons & Muñoz Saba, 2005). The biological material stored in biological collections constitutes an available source of information, such as books in a library (Mayr & Ashlock, 1991). The specimens critically support scientific knowledge, reduce inconsistencies, and help build verifiable knowledge (Cotterill, 1997). By studying specimens, we can identify the morphological characteristics of species and determine their representation by ecoregion (Vallejo & Acosta, 2005).

With the aim of improving management and maintenance of collections, and to optimize resources, different proposals for evaluation have been put forth to analyze the conditions in which a collection is kept. There are different types of evaluations that can be applied to scientific collections: economic, cultural or assessments of social impact, agents of deterioration and risks, and evaluations of infrastructure and compliance with regulations (ASM, 2004; Kovacic, 2009; O´Dwyer et al., 2004; Price & Fitzgerald, 1996; Waller, 2002). In addition, there are those that assess the effectiveness of curatorial procedures, as reflected in the specimens. The term "health level" by McGinley (1993), refers to the curatorial state of specimens or storage units in a collection. Specifically, it describes spaces where 1 or more specimens are kept, such as a cabinet, shelf, jar, box, or a fixed preparation. The health level of a scientific collection can be represented numerically by the collection health index (CHI) and graphically with the collection profile. The health index is a numerical coding system used to identify the curation level of specimens or storage units. This number indicates the percentage of specimens well curated and available to be used, whereas the collection profile is a graph which shows the number of specimens or storage units by health level (McGinley, 1993).

Based on prior work (Fernández et al., 2005; McGinley, 1993), the ideal profile (Fig. 1) is represented by a bimodal bar graph, where 70 to 80% of the specimens are at or above level 6, 15 to 20% of the specimens at level 3, and 5 to 10% at level 2. Specimens that are at level 6 or higher indicate a constant curatorial revision, whereas specimens at levels

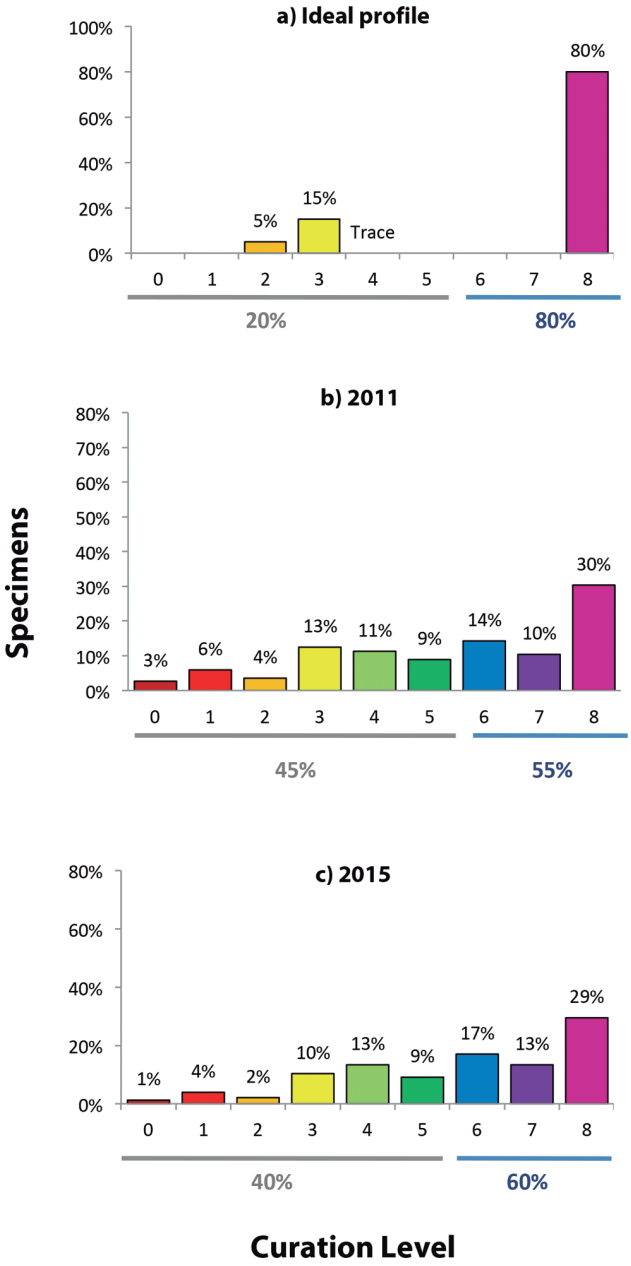

Figure 1. Ideal profile of the health level and the profile obtained for the Colección Nacional de Mamíferos (CNMA), Instituto de Biología, Universidad Nacional Autónoma de México in 2011 and 2015.

https://doi.org/10.22201/ib.20078706e.2018.2.2339

2 and 3 represent the constant acquisition of specimens by the collection through collecting, loan, donation, trade, or seizure (Cato & Williams, 1993; Fernández et al., 2005; McGinley, 1993; Williams et al., 1996). These proposals originated in the United States (Favret et al., 2007; McGinley, 1993; Moser et al., 2001; Williams et al., 1996) and were subsequently promoted in South America, where they were applied to entomological, ichthyological, herpetological, ornithological, mammalian, and botanical collections (Camacho & Burneo, 2009; Fernández et al., 2005).

In some cases, the health level assessment was done considering the entire collection; however, such an undertaking requires major investment of money, time, and qualified personnel. Others evaluated only a taxonomic group, obtaining only a partial view. Another study (Cristín, 2007) made a selection of specimens of the main collection to evaluate by adapting 2 sampling techniques used in ecology: 2-dimensional distribution and stratified sampling (Greenwood, 1996). The selection of specimens from the ancillary collections was done using a systematic sampling (O´Dwyer et al., 2004), which consisted of selecting 1 specimen per 10 shelves. Therefore, the aim of this study was to design and standardize a method to assess the health level of a biological collection. The method should be objective, accessible, reliable, and low-cost in order to conduct periodic assessments. In addition, it should be completed in a short time period, so that it can be used as a curatorial management tool.

Materials and methods

The assessment was applied to the Colección Nacional de Mamíferos (CNMA) of the Instituto de Biología of the Universidad Nacional Autónoma de México in Mexico City. The CNMA was chosen because it is an old and well established collection, one of the largest in Mexico and Latin America, and hosts an extensive representation of Mexican species. The collection is also officially registered with the Mexican government (Cervantes et al., 2016) and has maintained the recognition of the "American Society of Mammalogists" (ASM) for over 40 years because of its compliance with international curatorial procedures.

The sample size was calculated using Cochran (1980) formula:

$$n_0 = Z^2 (p) (1\text{-}p) / d^2$$

where: n_0 = sample size; p = expected proportion; d^2 = accuracy or margin of error allowed; z = 1.96 (normal distribution table for 95% reliability and 5% error).

A 95% confidence level was used for estimating the sample size, with an expected proportion of 0.7 and a margin of error of 5%. The factor was applied to the sample size using the following formula (Cochran, 1980):

$$n_{\text{mas}} = n_{\text{o}} / 1 + [(n_0 - 1) / N]$$

where: n_{mas} = sample size with finitude factor; N = population size (total of cataloged and uncatalogued specimens; n_0 = sample size.

In any collection specimens may be missing for various reasons and therefore the sample size obtained was divided by 0.97 to account for this. This value was obtained from a pilot evaluation. After obtaining the sample size, we proceeded to select cataloged and uncataloged specimens (those that are in various processes of preparation and will be incorporated in the collection) for inclusion in the assessment. The cataloged specimens were selected using a random number generator (http://nosetup.org/php_on_line/numero_aleatorio_2) and uncataloged specimens were selected by a systematic sampling. The number of uncataloged specimens was estimated by multiplying the number of storage units (cardboard trays, boxes, or jars) by the average number of specimens per unit. Then, the total number of uncataloged specimens was divided by the number of specimens obtained from the sample. The resulting number is the interval at which specimens are to be taken until the sample is completed. The first specimen was selected at random.

The criteria used for the health level assessment are based on predefined criteria (ASM, 2004; Camacho & Burneo, 2009; Cristín, 2007; Favret et al., 2007; Fernández et al., 2005; Lorenzo et al., 2006; McGinley, 1993; Moser et al., 2001; Williams et al., 1996) and some were incorporated with changes while some new ones were also added (Table 1).

Evaluations of the CNMA's health level were conducted twice, once in 2011 and again in 2015. In the first evaluation, specimens were selected using a stratified random sampling with proportional allocation to the size of the stratum, and accordingly the sample size was divided proportionately among strata. The strata correspond to the distinguishable zones in the CNMA: A, shelves holding small and medium-size specimens, conventionally prepared as stuffed skins; B, shelves holding medium-size specimens also stuffed or not; C, shelves holding large specimens such as species belonging to the orders Carnivora, Sirenia, Cetartiodactyla, and Perissodactyla; D, shelves holding jars with specimens preserved in alcohol; E, area of tanned skins; F, shelves holding type specimens; and G, shelves with uncataloged specimens (Fig. 2). However, because such sampling is considered somewhat biased and does not

Table 1

Description of the criteria established in this study for the evaluation of the health level (HL) in the Colección Nacional de Mamíferos (CNMA). The criteria were defined following previous studies (ASM, 2004; McGinley, 1993; Williams et al., 1996; Moser et al., 2001; Fernández et al., 2005; Lorenzo et al., 2006; Cristín, 2007; Favret et al., 2007; Camacho & Burneo, 2009). The specimen was assigned a value of "1" (presence), when it met the requirement specified in the criterion and could move to the next level. The value "0" (absence) was assigned when it did not comply and remained at that level.

HL	Criteria	Description
0	Missing specimen	If the specimen or part of it is not physically located in the collection.
1	Preservation	a) Properly prepared specimen. b) Specimen without plague problems. c) Specimen without physical damage and adequate level of alcohol. d) Specimen with legible label and complete information.
2	Stabilization of specimens to be incorporated into the collection	e) Specimen with some sort of arrangement. f) Specimen with complete and correct information. h) Specimen determined at the genus level.
3	Specimens in the process of being cataloged	i) Specimen determined at species or subspecies level, depending on whether the species is monotypic or polytypic. j) Label with complete information, legible, written in permanent ink.
4	Cataloged specimens	k) Catalog number written on the label(s). l) Specimen with all the bone material labeled (skull, jaw and skeleton).
5	Curation of specimens	m) Specimens incorporated according to the established protocols in the collection. n) Specimens organized according to the specific plan of the collection, which must be visible. o) Specimens must be stored in suitable containers.
6	Maintenance	p) Specimen with updated nomenclature on the label or in the database. q) Storage units with adequate and updated labels to avoid unnecessary handling of the specimens. r) Specimens accommodated with sufficient space between them so that they do not get damaged.
7	Updates and databases	s) Information in a database. t) Complete locality with geographic coordinates.
8	Voucher and type specimens	v) Information of the specimen available on internet. w) Type specimens properly marked and sheltered in separate storage units from the rest of the collection.
	Additional criteria	g) Specimen information recorded in either the original, or a copy of the collector's journal, which must be kept in the collection. u) Loan, exchange and donation activities (additional labels corresponding to another institution). x) Type of preservation recorded on the label or in the database. y) Specimens with frozen tissues.

accurately represent the contents of the collection, in 2015 a simple random sampling was conducted on cataloged specimens in order to make the method more objective and easier to apply to other collections (Table 2).

The information was entered in a presence-absence data matrix, in which "1" was assigned for each criterion met and "0" when the criterion was not met; the level was assigned as soon as a criterion was not met as established in the "Curatorial continuum" and other approaches (Table 3; Camacho & Burneo, 2009; Hughes et al., 2000; McGinley, 1993). The collection profile was made by plotting the percentage of specimens by level. The collection's health index (CHI) was calculated by adding the specimens on levels 3, 6, 7, and 8 and dividing it by the total number of specimens evaluated.

Results

In 2011, the CNMA had 47,700 specimens, of which 45,634 were cataloged and 2,070 were in the process

https://doi.org/10.22201/ib.20078706e.2018.2.2339

Figure 2. Distinguishable areas in the Colección Nacional de Mamíferos (CNMA) of the Instituto de Biología, Universidad Nacional Autónoma de México: *1)* shelves holding small and medium-sized specimens conventionally prepared as stuffed skins, *2)* shelves holding medium-size specimens, *3)* shelves holding large mammal specimens of the orders Carnivora, Sirenia, Cetartiodactyla, and Perissodactyla, *4)* shelves holding jars with specimens in alcohol, *5)* area of tanned skins, *6)* shelf holding type specimens, and *7)* shelves with uncataloged specimens under various preparation processes.

of being cataloged. The resulting sample size was 336 specimens, 321 cataloged and 15 uncataloged. In 2015 there were 48,526 specimens, 47,386 cataloged and 1,140 uncataloged. The sample size was 331 specimens, 323 cataloged and 8 uncataloged (Fig. 3; Table 2).

Based on the results, a description was given of the

Table 2

Number of specimens and sample size per each region or stratum in the Colección Nacional de Mamíferos (CNMA).

Strata	Total	Sample size
2011 Sampling		
1) Drawers with small and medium specimens	38,476	267
2) Shelves with specimens in alcohol	5,386	38
3) Shelves with large specimens	746	6
4) Drawers with medium specimens	655	5
5) Tanned skin section	336	3
6) Drawer of type specimens	34	2
7) Uncataloged specimens	2,070	15
Total	47,703	336
2015 Sampling		
Cataloged specimens	47,386	323
Uncataloged specimens	1,140	8
Total	48,526	331

level of health of specimens in the CNMA, number of specimens by level, the percentage they represent, and the confidence interval for the 2 evaluations conducted (Table 4).

In 2011 ≈30% of the specimens were at level 8, 14% at level 6; 12.5% at level 3 and 11.31%, at level 4. In 2015, 30% of the specimens were at level 8; 17% at level 6 and 13.37% at level 4. The levels with the lowest percentage of specimens in both years were level 0, with 3 specimens (1%) and level 2, with 4 specimens (2%). In 2011, 45% of specimens were at levels 0 to 5 and 55% at levels 6 to 8. In 2015, 40% of specimens were at levels 0 to 5 and 60% of specimens at levels 6 to 8.

The health index was estimated at 0.68 for 2011, and 0.70 in 2015, which indicates that 68% and 71% of specimens were at levels 3, 6, 7, and 8 (Fig. 4).

Discussion

The 2011 assessment helped reveal the main curation problems, most of which were addressed. In 2015 new shelves were installed in the collection, thus the almost 48,000 specimens were redistributed, making space for medium-term growth. Additionally, nomenclatural changes have occurred in recent years. As a result, it was considered appropriate to repeat the assessment to check that the arrangement adhered to the specifications established in the CNMA, and the associated information was re-entered in a database.

The health level reported for the CNMA was contrasted with 3 prior studies: the mastozoological collection of the Museum of Zoology of the Pontifical Catholic University of Ecuador (QCAZ; Camacho & Burneo, 2009), the Mammalian collection of the Humboldt Institute (IAvH), and the Hymenoptera collection of the Colombian Institute of Natural Sciences (ICN; Fernández et al., 2005).

Level 0.- Missing specimens. The values obtained in the CNMA (2.68% in 2011, 1.22% in 2015) are below

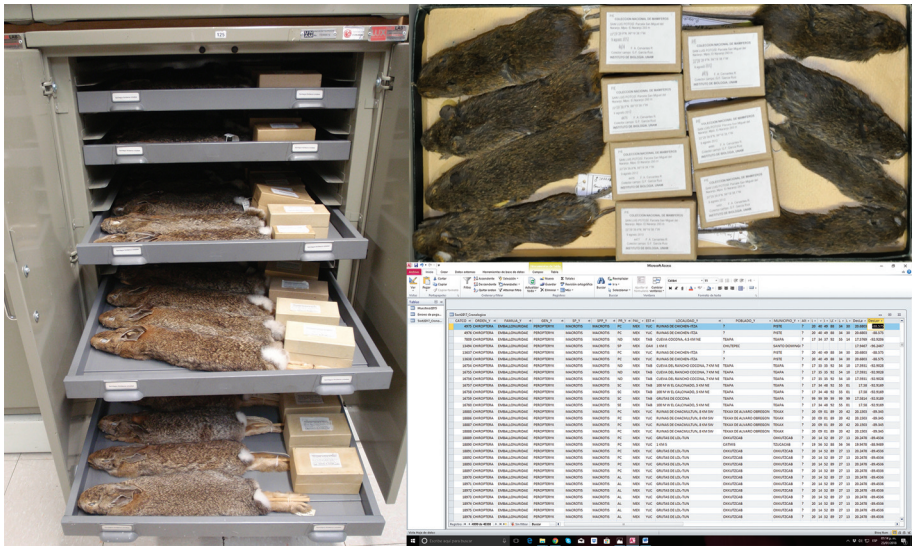

Figure 3. Cataloged mammal specimens and in process to be cataloged and databased, in the Colección Nacional de Mamíferos (CNMA), of the Instituto de Biología, Universidad Nacional Autónoma de México.

https://doi.org/10.22201/ib.20078706e.2018.2.2339

Table 3

Example of the assessment matrix of the specimens sampled at the Colección Nacional de Mamíferos (CNMA). Abbreviations: n = the catalog number of the specimen; Pr= preservation type (ss= skin and skull, sk= skin and skeleton, al=alcohol, so= skull only, and na= not applicable). 1= criterion met. The first criterion not fulfilled is marked with the value "0" and it is the level assigned to each specimen.

Level		1				2			3		4		5			6			7		8		Additional criteria			
n	Pr	a	b	c	d	e	f	h	i	J	k	l	m	n	o	p	q	r	s	t	v	w	g	u	x	y
178	so	1	1	1	1	1	1	1	1	0																
304	ss	1	1	1	1	1	1	1	1	1	1	1	1	0												
534	ss	1	1	1	1	1	1	1	1	1	1	1	1	1	0											
938	ss	1	1	1	1	1	0																			
7150	sk	Missing specimen																								
1086	ss	1	1	1	1	1	1	1	0																	
1770	al	1	1	1	1	1	1	1	1	1	1	na	1	1	1	0										
2261	ss	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0									
2703	al	1	1	1	0																					
8669	ss	1	1	1	1	1	1	1	1	1	1	0														
9735	ss	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0					
10019	ss	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0

those obtained by the ICN and QCAZ collections, with values of 8.3% and 4%, respectively.

Level 1.- Preservation. The percentage of specimens at this level in 2011 was 5.95%, which was similar to that obtained in the IAvH and QCAZ collections, with values of 5.9 and 6.26%, respectively, but higher than the percentage obtained in 2015 with 3.95%. The reduction in the number of specimens at this level in the CNMA occurred because many of the curatorial problems detected in 2011 were corrected. Similar results were obtained for the QCAZ collection, where the original percentage was reduced 12.5% by checking and filling jars with preserving fluid, replacing containers in poor condition, distributing stacked specimens, treating specimens infested with fungi, and printing new labels (Camacho & Burneo, 2009).

Level 2.- Stabilization of specimens to be incorporated in the collection. The values obtained in 2011 (3.57%) and 2015 (2.13%) were below the range proposed in the ideal

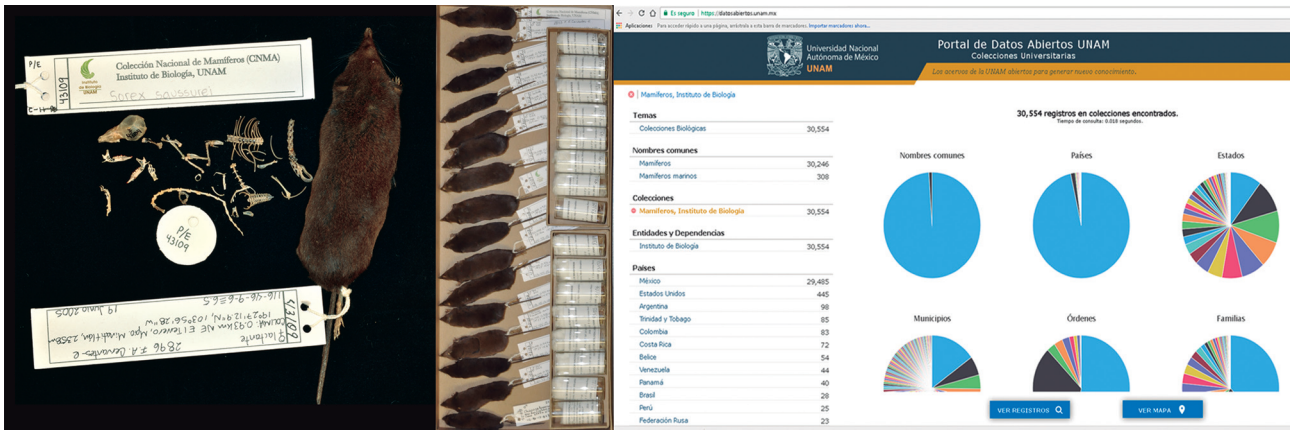

Figure 4. Cataloged museum specimens and website of mammals in the Colección Nacional de Mamíferos (CNMA), of the Instituto de Biología, Universidad Nacional Autónoma de México, which were assigned to level 8 as a result of meeting the aforementioned requirements.

Table 4

Description of the health level (HL) of the specimens of the Colección Nacional de Mamíferos (CNMA), showing the number of sampled specimens in each level (n), the percentage they represent (%) and their confidence intervals (95% CI) for both evaluations.

		2011		2015	
HL	Characteristics	n	% (CI)	n	% (CI)
0	Missing specimens.	9	2.68 (0.95-4.40)	4	1.22 (0.03-2.40)
1	Specimens with preservation problems. Labels with incomplete or illegible information, individuals with notable physical damage, improper preparation, alcohol levels not adequate and damaged by pests.	20	5.95 (3.42-8.48)	13	3.95 (1.85-6.06)
2	Stabilization of specimens to be registered in the collection. Specimens with incomplete or non gender-specific information.	12	3.57 (1.59-5.55)	7	2.13 (0.57-3.69)
3	Specimen in the process of being cataloged. No determination at species or subspecies level, poorly determined, with mistreated labels or information that is blurred but legible.	42	12.5 (8.96-16.04)	34	10.33 (7.04-13.62)
4	Registration or cataloging of the specimen. Predominantly unlabeled skeleton.	38	11.31 (7.92-14.7)	44	13.37 (9.7-17.05)
5	Curation of the specimens. Specimens misplaced in drawers, trays or cardboard boxes battered, or in jars with damaged lids.	30	8.93 (5.88-11.98)	30	9.12 (6.01-12.23)
6	Maintenance. Updated scientific nomenclature not updated on the label, in the database or stacked.	48	14.29 (10.54-18.03)	56	17.02 (12.96-21.08)
7	Update and databases. The information for the specimens is in a database, they have geographical coordinates (obtained during the collecting or calculated later). Were found, constant maintenance, loan, exchange and donation activities.	35	10.42 (7.15-13.68)	44	13.37 (10.01-17.93)
8	Vouchers and type specimens. They meet all the criteria of the previous levels and their information is available. In the 2011 sampling, 2 specimens (lectotype and 1 paratype) were evaluated, while in 2015 no specimens were selected.	102	30.36 25.44-35.27	97	29.48 (24.56-34.41)
	Health index	0.68		0.70	

profile of 5 to 10%. Specimens encountered at this level were donated or confiscated, and arrived with incomplete taxonomic or geographic information.

*Level 3.- Specimens in the process of being cataloged***.** The percentage of specimens at this level, 12.5% and 10.33% in both years 2011 and 2015, respectively, was below the proposed ideal profile of 15 to 20% (McGinley, 1993), but it was above that reported for QCAZ (7%) and IAvH (7.9%). The main problems with these specimens were damage or illegible labels.

Level 4.- Cataloged specimens. The percentage obtained in 2011 was 11.31% and increased to 13.37% in 2015; this was because in many specimens the catalog number was marked only on the skull and the jaw, but not on the rest of the skeleton. It was not possible to compare these values with other collections because the parameters are different.

Level 5.- Curation of specimens. The values obtained were 8.93% in 2011 and 9.12% in 2015, similar to the values obtained in the IAvH of 10.6%, and QCAZ of approximately 11%. In the Ecuadorian collection, improperly positioned specimens were rearranged and in the next evaluation no specimen was at this level (Camacho & Burneo, 2009). In larger and older collections, there are many specimens with outdated curation**,** as a result of standards changing over time (McGinley, 1993).

Level 6.- Maintenance. The percentages obtained in both evaluations (14 and 17%) were higher than in the QCAZ (2.5%), IAvH (1.3%), and ICN (10%). Keeping the nomenclature updated on specimen labels, storage units, and in the database is not easy because taxonomic updates occur frequently. Storage units should be well labeled (trays, shelves, etc.), personnel should avoid unnecessary handling of specimens, and there should be

https://doi.org/10.22201/ib.20078706e.2018.2.2339

a minimum exposure to factors of deterioration such as light, contaminants, temperature, and humidity (Simmons & Muñoz-Saba, 2005).

Level 7.- Updates and databases. The percentages obtained for CNMA were 10.42% in 2011 and 13.37% in 2015, compared to 59% at QCAZ. In contrast, the Colombian collection reported no specimens at this level. At this level, loan, exchange, and donation are assessed, as well as the maintenance and preventive measures against pests. At the CNMA fumigation is performed twice a year and cryofumigation and visual inspections are carried out frequently. Some authors recomend the use of adhesive insect traps and trays are aspirated (Story, 1986).

Level 8.- Voucher and type specimens. The percentages obtained at the CNMA (30.36% in 2011, and 29.48 in 2015), were much higher than that reported for the QCAZ (9%). This may be, in part, because CNMA considers all their specimens. This information is available in free online databases such as the Portal de Datos Abiertos UNAM, Colecciones Universitarias (https:datosabiertos.unam.mx), the Global Biodiversity Information Facility (GBIF; http://www.gbif.or), the Mammal Network Information System (MANIS; http://manisnet.org), and IREKANI (http://unibio.unam.mx). Online availability streamlines access, raises the possibility of conducting numerous scientific studies, and supports teaching and related activities. Some authors consider it risky to disclose the location of endangered or commercially valuable species (Knell, 1996), which could be used for unethical purposes. However, the benefits of accessing a larger quantity of data rapidly and efficiently outweigh the risks (Martínez-Meyer & Sánchez-Cordero, 2006). A substantial investment of time, qualified staff, constant curatorial work, and economic resources are needed to keep the specimens at this level (Fig. 4).

The profile of the CNMA obtained in both years (Fig. 1) was not similar to the ideal profile, but levels 3, 6, 7, and 8 in both profiles include a larger number of specimens, which indicate constant growth and an effective curation, such as specimens in process of being cataloged, maintenance, updates, and voucher and type specimens (Fernández et al., 2005; McGinley, 1993). Therefore, biological collections benefit if they are recognized in the regulations of their host institutions, because it raises awareness of the considerable economic and logistical support they require (Cervantes et al., 2016). By implementing this method, a collection can gradually raise its level. In 2011, 55% of specimens housed at CNMA were at levels 6 to 8 and the figure increased to 60% in 2015.

The value obtained for the health index was 0.68 in 2011 and 0.7 in 2015, a high index compared with those obtained in other mammal collections, of 0.014 to 0.54 (Fernández et al., 2005). The value of the CNMA was lower than that reported for the Ornithological collection of the Humboldt Institute, Colombia (0.93), which has 277 storage units. It was also lower than that obtained by the Ecuador-QCAZ mammalian collection, which attained a 0.79 index after addressing the curatorial problems detected in a prior evaluation (Camacho & Burneo, 2009). The CNMA is a highly valuable collection due to the quality and quantity of its holdings. In conclusion, the method presented is functional and consistent with the curatorial process and can be completed in short time. The evaluation and its results can facilitate management and maintenance of scientific biological collections, help optimize available resources, solicit funding, orient decision making, and plan for growth. It is recommended that other scientific biological collections employ this, or similar methods, to help maintaining the collection in good conditions.

Acknowledgements

To Guillermina Eslava, Departamento de Matemáticas, UNAM, for her help in the design of the sampling. To Alejandro Cristín Ponciano and Joaquín Arroyo-Cabrales, for their comments on the development of the project, to Adam Leiterman, for his help with the edition of the manuscript, and to Julio C. Montero for editing the figures.

References

ASM (American Society of Mammalogists). (2004). Basic curatorial standards for systematic collections of mammals. *Journal of Mammalogy*, *85*, 180–181.

Camacho, M. A., & Burneo, S. F. (2009). Assessment of the mammal collection at the Museo de Zoología of the Pontificia Universidad Católica del Ecuador - QCAZ. *Museology*, *12*, 1–11.

Cato P. S., & Williams, S. L. (1993). Guidelines for developing policies for the management and care of natural history collections. *Collection Forum*, *9*, 84–107.

Cervantes, F. A. (2016). Uso y mantenimiento de colecciones biológicas, IB, UNAM. *Revista Digital Universitaria*, *17*, 1–12.

Cervantes, F. A., Vargas-Cuenca, J., & Hortelano-Moncada, Y. (2016). An overview of the Mammal Collection of Instituto de Biología, Universidad Nacional Autónoma de México. *Journal of Natural Sciences Collections Association*, *4*, 4–11.

Cochran, W. G. (1980). *Técnicas de muestreo*. México D.F.: Compañía Editorial Continental, S.A.

Cotterill, F. (1997). The second Alexandrian tragedy and the fundamental relationship between biological collections and scientific knowledge. In J. R. Nudds & C. R. Pettitt (Eds.). *The value and valuation of Natural Science Collections,*

Proceedings of the International Conference, Manchester, 1995 (pp. 227–241). Oxford: The Alden Press/ Osney Mead/ The Geological Society.

Cristín, A. (2007). *Evaluación científica de la colección de tipos, Colección Nacional de Paleontología del Instituto de Geología, Universidad Nacional Autónoma de México (Tesis)*. Instituto de Geología, Universidad Nacional Autónoma de México. México, D.F.

Favret, C., Cummings, K. S., McGinley, R. J., Heske, E. J., Johnson, K. P., Phillips, C. A.et al. (2007). Profiling natural history collections: a method for quantitative and comparative health assessment. *Collection Forum*, *22*, 53–65.

Fernández, F., Muñoz-Saba, Y., Simmons, J. E., & Samper, C. (2005). La gestión en la administración de las colecciones biológicas. In J. E. Simmons & Y. Muñoz-Saba (Eds.), *Cuidado, manejo y conservación de las Colecciones Biológicas* (pp.189–206). Bogotá: Universidad Nacional de Colombia.

Golden, J. (2000). Institutional and individual orphaned collections. In R. D. White & W. D. Allmon (Eds.), *Guidelines for the management and curation of invertebrate fossil collections: including a data model and standards for computerization* (pp. 37–41). Washington, D.C.: The Paleontological Society.

Greenwood, J. D. (1996). Basic techniques. In W. J. Sutherland (Ed.), *Ecological census techniques: a handbook* (pp. 10–111). Cambridge: Cambridge University Press.

Hughes, N. C., Colllier, F. J., Kluessendorf, J., Lipps, J. H., Taylor, W. L., & White R. D. (2000). Fossil invertebrate and microfossil collections: kinds, uses and users. *Paleontological Society Special Publication*, *10*, 25–35.

Knell, S. J. (1996). What is important? In J. R. Nudds, & C. R. Pettitt (Eds.). *The values and valuation of natural science collections* (pp. 11–16). Proceedings of Conference at the Manchester Museum, Manchester, United Kindom19th-21st April 1995, Geological Society, London.

Kovacic, M. (2009). Is the scientific value of a biological collection measurable? *Natura Croatica*, *18*, 169–174.

Lieberman, B. S., & Kaesler, R. L. (2000). Scientific value of collections of natural history museums: the concept of completeness. *Paleontological Society (Special Publication)*, *10*, 109–117.

Lorenzo, C., Espinoza, E., Briones, M., & Cervantes, F. A. (2006). *Colecciones mastozoológicas de México*. México D.F.: Instituto de Biología, UNAM/ Asociación Mexicana de Mastozoología, A.C.

Martínez-Meyer, E. (2005). Las colecciones científicas: eje del conocimiento de la biodiversidad. *Revista Mexicana de Mastozoología*, *9*, 4–5.

Martínez-Meyer, E., & Sánchez-Cordero, V. (2006). Uso de datos en colecciones mastozoológicas. In C. Lorenzo, E. Espinoza, M. Briones, & F. A. Cervantes (Eds.), *Colecciones mastozoológicas de México* (pp. 301–310). México: Instituto de Biología, UNAM/ Asociación Mexicana de Mastozoología, A.C.

Mayr, E., & Ashlock, P. D. (1991). *Principles of systematic zoology, 2nd Edition*. New York: McGraw-Hill.

McGinley, R. J. (1993). Where's the management in collections management: planning for the improved care, greater use, and growth of collections. In C. L. Rose, S. L. Williams, & J. Gisbert (Eds.). *Temas de actualidad, iniciativas y direcciones futuras sobre preservación y conservación de colecciones de historia natural* (pp. 309–338). Madrid: Congreso Mundial Sobre Preservación y Conservación de Colecciones de Historia Natural. Dirección General de Bellas Artes y Archivos.

Moser, W., Redd, K., & Bright, C. (2001). Collections profiling - the process. Retrieved from: http://www.mnh.si.edu/highlight/profiling/profile_p1.html

O´Dwyer, D., Ratcliffe, P. R., Comerford, G., & Bolton, F. (2004). The collection survey: linking observation to cause across disparate collections. *Natural Science Collections Association Newsletter*, *4*, 20–24.

Price, J. C., & Fitzgerald. G. R. (1996). Categories of specimens: a collection management tool. *Collection Forum*, *12*, 8–13.

Simmons, J. E., & Muñoz-Saba, Y. (2005). *Cuidado, manejo y conservación de las colecciones biológicas.* Bogotá: Universidad Nacional de Colombia.

Story, K. O. (1986). *Approaches to pest management in museums*. Conservation Analytical Laboratory. Washington, DC: Smithsonian Institution.

Vallejo, M. Y., & Acosta, A. (2005). Aplicación de indicadores de conocimiento sobre biodiversidad para el diagnóstico y comparación de colecciones biológicas. *Nova, Publicación Científica*, *3*, 48–57.

Waller, R. (2002). *A risk model for collection preservation*. Prepreprints of the 13th Triennial meeting Rio De Janeiro (pp. 102–107), International Council of Museums, Committee for Conservation. Retrieved from: http://www http://www.museum-sos.org/docs/WallerICOMCC2002.pdf

Williams, S. L., Monk, R. R., & Arroyo-Cabrales, J. (1996). Applying McGinley´s model for collection assessment to collections of recent vertebrates. *Collection Forum*, *12*, 21–35.