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A low-cost, scalable solution for automated cutting of entomological labels

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Abstract

The digitization and labelling of historic and new specimens is a time-consuming, error-prone process as labels are still often hand-cut. To improve efficiency and consistency, we developed a low-cost solution for high-throughput environments which employs Cricut Maker 3 to automatically cut precision entomological labels. We optimized digital label templates for use with Cricut software and developed custom accessories for efficient label transfer and organization. Implementation of pre-cut label batches increased workflow efficiency, reduced user strain, and improved label quality. This system is compatible with existing digitization pipelines and supports standardized labelling formats, including those for DNA barcode workflows. With minimal set-up and maintenance costs, Cricut offers an effective suite of tools for generating specimen labels in Natural History Collections. Modernizing entomology labelling workflows supports data standardization, collection digitization, and the scientific value of natural history specimens.

Keywords: collection management, Cricut Maker, entomology, natural history collections, specimen labels

Introduction

The world’s Natural History Collections (NHCs) collectively hold more than a billion specimens and are a critical resource for taxonomic and systematic studies (Bakker et al. 2020; Sigwart et al. 2025; Pinedo-Escatel et al. 2024; Suarez and Tsutsui 2004). Each of these specimens possesses one or more labels, which are central to its scientific value, as they record collection locale and date, collector's name, identifier, and taxonomic assignment. Many NHCs are

currently being digitized (Scoble 2010) to facilitate their incorporation into databases, creating the need for labels that often include unique identifiers. The latter information can be vital for legal purposes (e.g., permits, loans) and for linking the specimen with collaterals such as genitalia slides, tissue samples, and DNA extracts. As digitization efforts expand through efforts such as the Integrated Digitized Biocollections (iDigBio 2025) in support of data access through the Global Biodiversity Information Facility (GBIF 2025), the demand for precise, legible specimen labels is increasing (Evenhuis 2010).

Traditional Natural History Label Standards

To maximize the accessibility and scientific value of label information, NHCs adhere to best practices. Each label typically includes key metadata such as collection locality and date, collector, and sampling method. Increasingly, labels also include taxonomic assignments and/or unique identifiers (UIDs).

To ensure long-term access to information on each label, text is printed in a clear font with fade-resistant ink on archival-quality, acid-free paper (Range et al. 2025). Labels are securely affixed, often directly on the pin which holds the specimen. Labels are compact to conserve space in the archive. Traditionally, labels have been generated on demand and cut by hand or a paper cutter, a labor-intensive and imprecise process.

Before digital printing, labels were handwritten, and the ink and paper quality varied greatly, impacting the legibility of the text. In addition, the data on each label was often limited by space constraints, and sometimes impossible to interpret given the lack of GPS coordinate and the use of archaic place names. Best practices now call for the transcription and relabeling of handwritten labels (while retaining the original) to preserve and augment the historical record (Blagoderov et al. 2012).

Why Automate Labelling?

As NHCs expand, so does the demand for efficient protocols to generate high-quality specimen labels. Aside from new accessions, many institutions are re-labelling legacy specimens to standardize data formats, improve legibility, and incorporate new information (Vollmar et al. 2010). The growth of NHCs has been amplified by the increasing use of DNA barcoding, which has created a rationale to expand collections because sequence recovery is much simpler from fresh material (Puillandre et al. 2012; Wheeler et al. 2012).

New accessions coupled with the re-labelling of historical material have created the need for scalable, cost-effective solutions for generating high-quality labels (Blagoderov et al. 2012). Major collections such as the National Museum of Natural History with 148M objects (Smithsonian 2025) or the Natural History Museum with 80M objects (Natural History Museum 2025), continue to add specimens. While these are the largest NHCs, many other institutions

hold tens of millions of specimens, creating a substantial need for label generation. For example, the Centre for Biodiversity Genomics processes 3M DNA barcode vouchers annually, 10% of which require two physical labels (one with collection data, one with barcode information), creating the need to generate 0.6M labels each year. As each label contains data specific to an individual specimen, it must be linked to its respective voucher.

Manual cutting of labels is labor-intensive, error-prone, and can lead to repetitive strain injury. Finding an ergonomic solution for repetitive tasks reduces injuries and increases productivity (Odebiyi and Okafor 2023). Equally important, it avoids variation in label quality (e.g., misaligned edges, truncated data). For samples with a unique identifier, it is critical to keep labels in logical order, and when a batch of specimens cannot be processed in a single sitting, the labels must be stored in an organized fashion to ensure their connection to the corresponding specimen during later processing.

Motivated by the need to generate hundreds of thousands of specimen labels annually, we explored alternatives to manual cutting. Some options (e.g., rotary, die press, laser) are expensive or complex to implement, but blade-based cutters (e.g., Cricut Inc.) use computer-guided blades to cut complex shapes with precision. Adopting automation reduces human error and enhances data integrity for legal and scientific purposes (Holland and Davies 2020; Holovachov et al. 2014).

We tested the capacity of an inexpensive craft cutter (Cricut Maker 3) to automate the production of high-quality labels. The balance of this paper details costs (capital + operating) and describes best practices for its implementation.

Methods

Automated Cricut Workflow

After evaluating several cutting systems, the Cricut Maker 3 (hereafter CM3) was best suited to high-volume label cutting. This tool has the advantage of working with hundreds of materials, is compatible with inkjet printers, utilizes free design software, and has integrated Bluetooth communication. The latter feature provides flexibility for its deployment in the usual workspace while aiding setup at other stations.

The CM3 has several features that facilitate its use for printing specimen labels. Its software (Cricut Design Space) is compatible with SVG files, allowing design software (e.g., Inkscape 2025) to be used to create custom label templates. In addition, its lightly adhesive cutting mat ensures that labels remain in order once cut. Furthermore, its capacity to cut diverse materials means that it can support other workflows. In trials, the CM3 was able to cut a pre-printed sheet

of 285 labels and place them in sequential order on a foam mat for later attachment to pinned vouchers five times faster than manually (5.7 versus 28.4 minutes) (Table 1).

Table 1. Time required to prepare and cut 285 labels with CM3 versus manual.

Step	CM3	Time (s)	Manual	Time (s)
Preparation	Y	40	Y	120
Cutting/Arraying	N	0	Y	1586
Removal from mat	Y	302	N	0
Total Time (s)		342		1706
Total Time (min)		**5.7**		**28.4**

Cutting Considerations

Printed sheets of entomological labels contain hundreds of individual labels that require a series of horizontal and vertical cuts for their separation. This layout produces many small, disconnected shapes along with intersecting lines. When cuts occur at these intersections, tearing may result, potentially causing damage or detachment of label rows if mat adhesion is inadequate. To minimize tearing and to ensure accurate separation, it is important to select the proper cutting mat and paper type.

Cutting Mats

The cutting mats require periodic replacement. We tested two mats: LightGrip Machine Mats ($8.53 CAD each), and StandardGrip Machine Mats ($3.33 CAD each), with a Cricut Access subscription. StandardGrip Machine Mats were too adhesive on their first use, causing some tearing during label removal, but the adhesion was subsequently acceptable. With the rotation of the mats 180 degrees midway through the use span, each mat can be used to cut roughly 48 pages of labels (48 x 285 = 13,680).

Paper Type

Acid-free cardstock is standard for entomological labels, but it must resist tearing. When two or more labels are required for a specimen, it is best practice to employ different colours for them. For example, in the case of DNA barcoded specimens, one label records collection data, while the other provides the DNA Barcode Voucher data. After evaluating diverse products, two brands of 8.5 x 11-inch cardstock were adopted: Cougar Smooth White 65lb/176 g/m^2 (Domtar, Montreal, QC, CA) for the Collection Label, and Springhill Index Canary 90lb/163 g/m^2 (Sylvamo, Memphis, TN, USA) for the DNA Barcode Label.

Label Generation and Formatting

Label dimensions must be standardized to automate cutting on the CM3. Both Collection and DNA Barcode Labels are 17.3 mm x 8.0 mm (Fig. 1A–B) to facilitate compact archiving. The collection information for each specimen is stored in an SQL database with an Access (Microsoft) interface. All data added to the labels are stored in the Collections database in digital format to facilitate quick retrieval of the information for the generation of labels. To minimize the text on each label, several data standards are employed (Fig. 1A). Countries are designated by the ISO 3166-1 alpha-3 code while their divisions (e.g., states or provinces) are represented by the ISO 3166-2 code. GPS coordinates are recorded in decimal degrees rounded to four digits and the date is presented in dd-Mmm-yyyy format to reduce the length of month while also protecting against accidental swapping of month and day. If required, other locality and collection information can be included in the remaining space (max.136 characters).

An Arial font is employed to balance space constraints with readability. For text spacing and standardization, a controlled system for assigning a unique identifier is employed. The Sample ID (e.g., CBG-A67875-H11) employs Arial Bold 4.2 pt while other information on the Collection Label uses Arial 3 pt to maximize characters (Fig. 1A). To increase accessibility and link to accessory data, a 2D barcode is present on each DNA Barcode Label, allowing a user to scan the label to obtain the unique identifier used for linking to databases (e.g., BOLD) or assembling lists (Fig. 1B). This 2D barcode is generated from data in the CBG Collections database using BarTender software (Seagull Software, Redmond, WA, USA). The DNA Barcode label employs Arial 3 pt for the Sample ID (e.g., CBG-A67875-H11) and Process ID (e.g., CRBTI40788-25) (Fig. 1B). Labels are printed on a Xerox VersaLink C8000 laser printer.

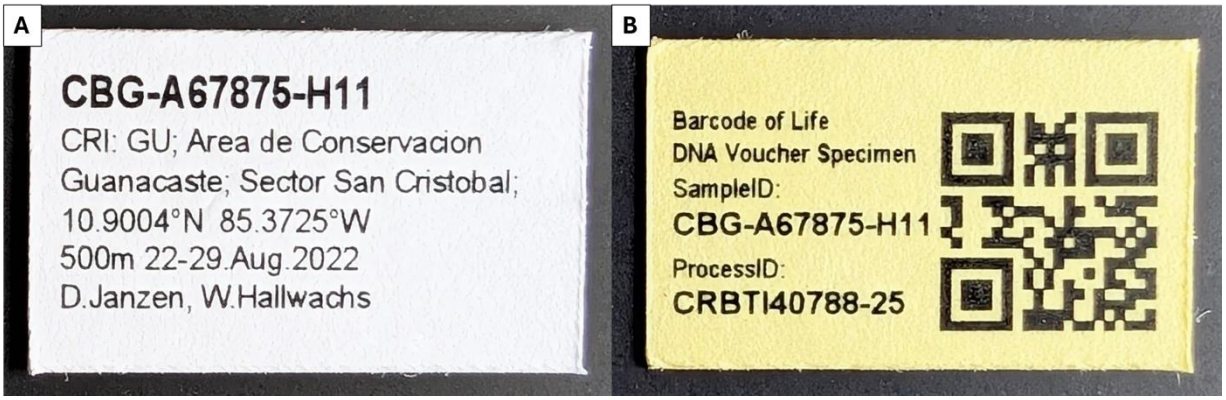

Figure 1. Specimen labels employed at the Centre for Biodiversity Genomics. A) Collection Label; B) DNA Barcode Label.

Cricut templates and alignment

A cutting template was created in Cricut Design Space (See Supplementary File 1) to match the label sheets with basic line cuts attached into a single shape (Fig. 2A) because the Design Space software will otherwise gather all unattached shapes into the most efficient space, regardless of

their positioning on the page. Moreover, the CM3 does not start cuts at the 0,0 corner of the mat but instead maintains a border area which is excluded from the alignment. To properly align label sheets while accommodating this exclusion border, cardstock was attached to blank Cricut Mats at the edges, and a template with basic cut lines at 0,0 in Design Space was made to cut out the true margins (Fig. 2B).

The CM3 has settings for different materials, but the Medium Cardstock setting (a single pass at 350 cut pressure) performs best. Each mat is manually inserted, aligned, and loaded by pressing the load/unload button on the machine. After each page is cut, the finished mat must be manually removed and replaced. The template can also be modified via Design Space to work with other labeling software in common use by NHCs (e.g., EntomoLabels). This flexibility supports broader integration across institutional databases and workflows, allowing seamless generation of labels directly from existing collection management systems.

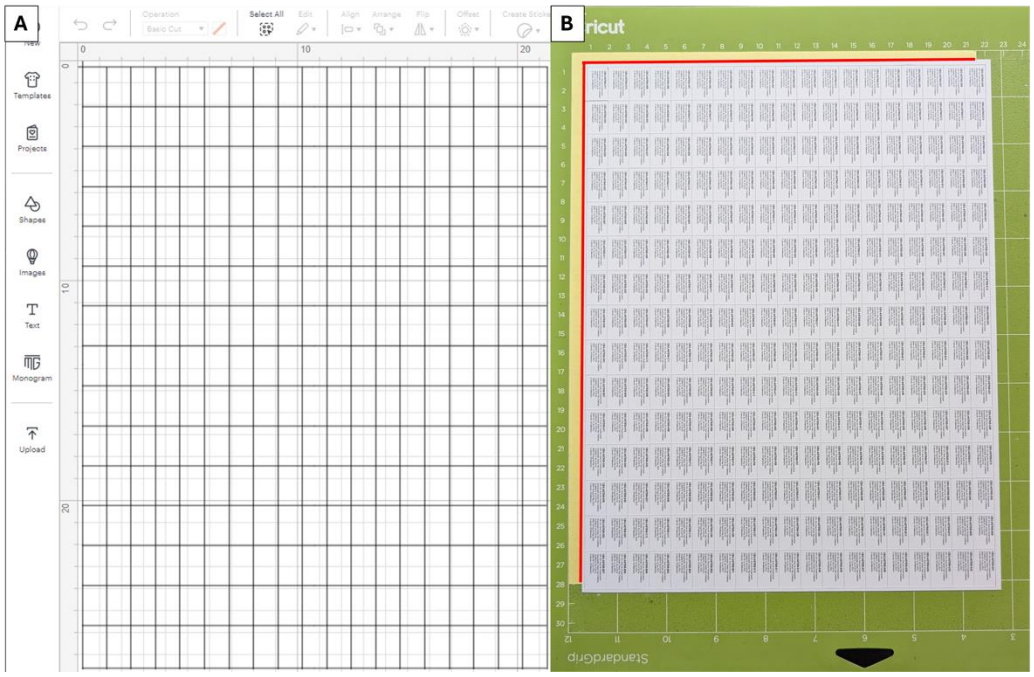

Figure 2. A) CM3 template in Design Space and B) Page of Collection Labels. The red line delineates the exclusion border in yellow cardstock for correct placement of the printed page on the cutting mat.

Cricut Workflow Maintenance

The blade of the CM3 should be replaced after cutting approximately 32 sheets of labels (= 9,120 labels) or when signs of tearing or dragging are observed (e.g., pulling at intersections of cuts). CM3 blades are $10- $20 CAD each, but third-party options which perform just as well are $0.21 CAD each when purchased in bulk (60).

When cutting mats see near daily use, they will pick up debris that limits their adhesiveness which can lead to label detachment or tearing during cutting. Cleaning a mat regularly to remove debris will lengthen its lifespan. This is easily accomplished by scrubbing the adhesive surface with a baby wipe and then patting it dry with a paper towel. Despite such intervention, the adhesiveness of the CM3 mat will ultimately decrease, requiring replacement. Mat lifespan can be increased by rotating 180 degrees once detachment issues arise to utilize space on the mat which was not impacted by its previous template alignment. With this maintenance and twice weekly use, mats remain usable for six months (48 uses) before the adhesive surface is compromised, leading to excessive detachment of labels. We found that the addition of a cardstock bracing strip (approximately ¾ x 8 ½ inches) placed against the terminal edge of the label sheet is effective in securing the rows during vertical cuts (Fig. 3), preventing their detachment, further extending the lifespan of the CM3 cutting mats.

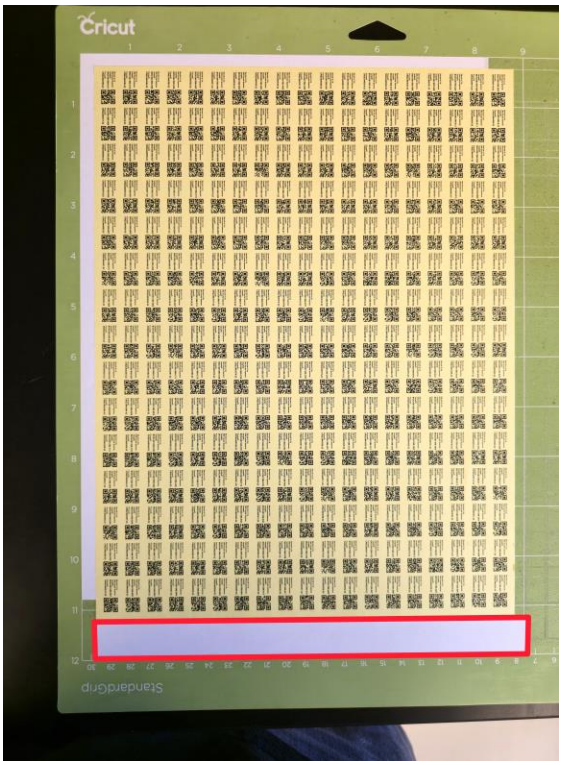

Figure 3. Cardstock bracing strip at terminal edge outlined in red.

Tools for label removal and organization

To maintain an organized array while removing a full column of labels at once, we employ an 8-inch bulldog clamp with two 8-inch polymer clay blades glued with high-strength adhesive to the interior of the clamp, with the dull sides facing outward (Fig. 4). Prior to clamping and removal, the labels should be slightly lifted from the mat along their leading edge with curved forceps (with slightly dull tips to prevent damage to the mat or labels). By lightly dragging the forceps down the far-right edge of a full column of labels, it can be partially detached in one movement,

allowing the blades of the clamp tool to be easily slid underneath, allowing removal of the entire column of labels (Fig. 5A–C). A straight edge, such as a ruler, also provides a simple way to transfer labels from the clamp blades onto a pinning board in a neat, organized column.

Figure 4. Label removal tool made from 8” bulldog clips and two polymer clay blades attached with adhesive.

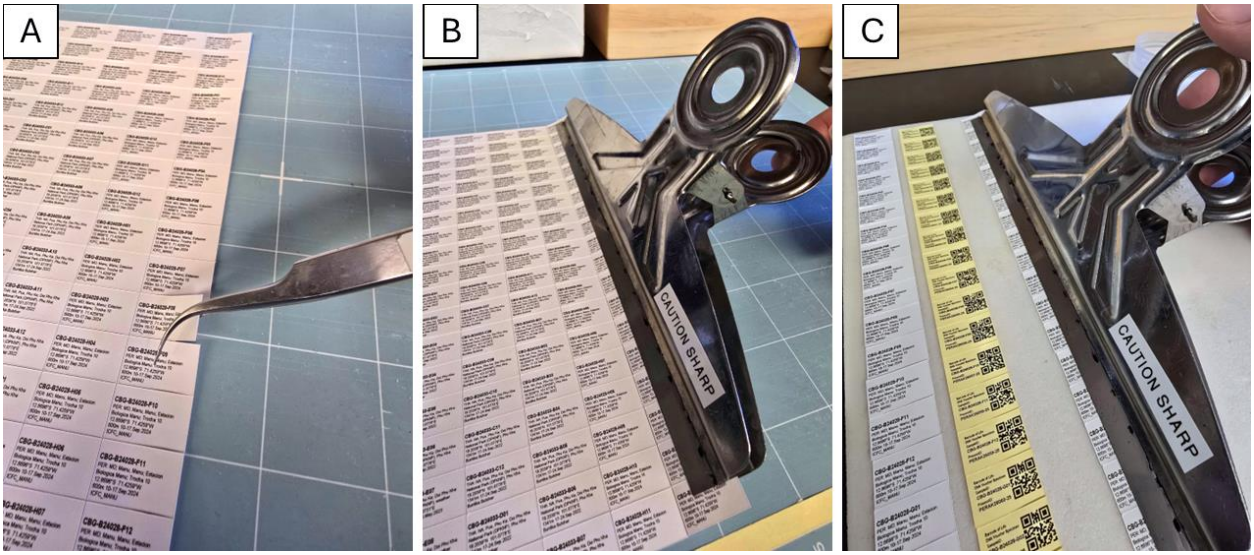

Figure 5. Process for removing a row of labels from the mat and its transfer to labelling foam. A) labels are loosened using curved forceps; B) labels are removed from mat using the label removal tool; and C) labels are transferred to a foam board.

Discussion

Cricut Workflow Costs and Efficiency

With a setup cost of less than $600 CAD and monthly maintenance fee of $20 CAD (Table 2), the CM3 is an inexpensive, efficient solution for generating entomological labels in high-throughput fashion. Each cutting template accommodates up to 285 labels on a standard 8.5 x

11.0-inch sheet, and a full batch of labels can be cut in under three minutes. For a facility generating a million labels annually, this workflow will save roughly 20 person-weeks of labour with the added benefit of reducing the risk of strain injuries and making precision cutting tasks accessible to staff with fine-motor limitations

Other Potential Uses in a Natural History Collection

While this study has considered the benefits of CM3 for generating entomological labels, the device can generate many other types of labels (e.g., drawer, loan) or exhibition signage by making new templates. Beyond labels, the CM3 can cut out inserts to brace enveloped specimens to maintain their integrity or to create prepackaged sampling or field kits. Additionally, the CM3 can be used to design custom brand lab wear or create outreach and promotional materials.

Conclusion

The adoption of CM3 for cutting labels brings multiple benefits in a high-throughput environment (Table 3). It enables users to pre-cut multiple large batches of labels in a single session while maintaining them in a structured order, allowing for their efficient storage and easy retrieval. Its capacity for precision cutting avoids uneven or misaligned cuts often encountered when labels are manually cut. Both features are particularly important for labels with a Unique Identifier as its truncation or misplacement compromises data integrity. CM3 integrates seamlessly with digital label designs generated from databases or spreadsheets, enhancing the efficiency of end-to-end workflows. Time formerly spent on manual cutting can be diverted to other tasks because automated cutting runs independently. In settings where millions of labels need to be generated each year, other cutting machines could be considered (e.g., Silhouette Cameo 4) that possess feeders to automatically load and cut multiple sheets of card stock without manual intervention. Regardless of the system, the shift to automated label-cutters supports standardization and enhances the digitization and long-term preservation of specimens held by NHCs.

Table 2. Costs for CM3 materials.

Initial Set-up				
Item	**Quantity**	**Cost Type**	**Cost (CAD)**	**Notes**
Cricut Maker 3	1	Initial	$469.00	1 blade.
StandardGrip Machine Mats (12”x12”)	30	Initial	$99.99	Discounted with subscription.
8" label removal tool	1	Initial	$12.64	Optional 4" label tool is $8.47
Cricut Access subscription	1	Monthly	$12.99	
Subtotal			$594.62	
Monthly Operating Costs per 100 sheets (28,500 labels)				
Item	**Quantity**	**Cost Type**	**Cost (CAD)**	**Notes**
StandardGrip machine mat	2	Replacement	$6.66	Discounted with subscription.
Replacement blade	3	Replacement	$0.63	
Baby wipe	6	Replacement	$0.60	
Cricut Access subscription	1	Renewal	$12.99	Optional 10% discount and rebates.
Subtotal			$20.88	

Table 3. Manual versus CM3 workflows for cutting labels in a high-throughput setting.

Category	Manual	CM3
Time	Slow	Fast
Cut Accuracy	Inconsistent	Uniform, high accuracy
Labour Requirement	High effort, continuous input	Low effort once cutting is set up
Label Organization	Difficult to keep organized	Labels remain in original layout
Ergonomic Impact	High strain	Low strain
Setup Time	None	Moderate; requires software and hardware preparation
Maintenance Needs	None	Blade/mat replacement and mat cleaning
Scalability	Low	High
Other Functions	Limited	Varied

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