AN EFFICIENT STORAGE SYSTEM FOR ADULT ODONATA SPECIMENS, WITH APPLICATION FOR OTHER MUSEUM COLLECTIONS

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Abstract.—A new system of storing adult Odonata (damselfly and dragonfly) specimens is described and compared to existing storage systems. The major design innovation is the use of tongue and groove ("zipper lock") resealable polyethylene envelopes manufactured to fit the standard index card and specimen arrangement currently used in major collections. Other design improvements include low-cost, adhesive-free specimen trays and glass-top drawers built to fit in standard-dimension Cornell insect cabinets. Comparisons of materials and designs with other available systems are presented and discussed. Finally, examples are presented of this new system's applicability to other collections such as Lepidoptera and Archeology.

Key words.—dragonfly, archeology, lepidoptera, envelopes, butterfly, damselfly

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Introduction

Ideally, the storage of specimens should minimize space and material costs while allowing easy access and providing excellent long-term storage conditions. Before the 1960s, most adult Odonata (dragonfly and damselfly) specimens were prepared and preserved, similar to butterflies, as pinned and spread specimens or in triangular envelopes of folded paper (Beatty and Beatty 1963). Pinning specimens allows excellent views of all external characteristics and easy handling, but large collections require substantial space and detached parts are difficult to associate with specimens. Storing specimens in paper envelopes saves space and retains detached parts but does not allow for easy viewing or handling. Furthermore, the triangular shapes and irregular sizes hamper searching, retrieval, and curation of specimens (Beatty and Beatty 1963).

In 1963, Beatty and Beatty presented a method of storing unspread specimens in moisture-proof cellophane envelopes accompanied by a 77 mm × 127 mm index card, on which collection and identification information was recorded (Fig. 1a). Their design was based on one pioneered by J. G. Needham in the 1930s, when cellophane films first became common. Early cellophane films lacked a moisture-proofing layer and were subject to significant shrinkage and shrivelling over time (Beatty and Beatty 1963). Since the Beatty and Beatty (1963) paper was published, most major collections have adopted the technique of storing Odonata in envelopes as a means of reducing space requirements. Although the index card creates a standardized size of specimen, most museums do not have standardized storage trays, drawers or cabinets to house them properly (Beatty and Beatty 1963). Although a number of equipment suppliers produce complete systems for storage of pinned and alcohol collections, none existed for envelope storage.

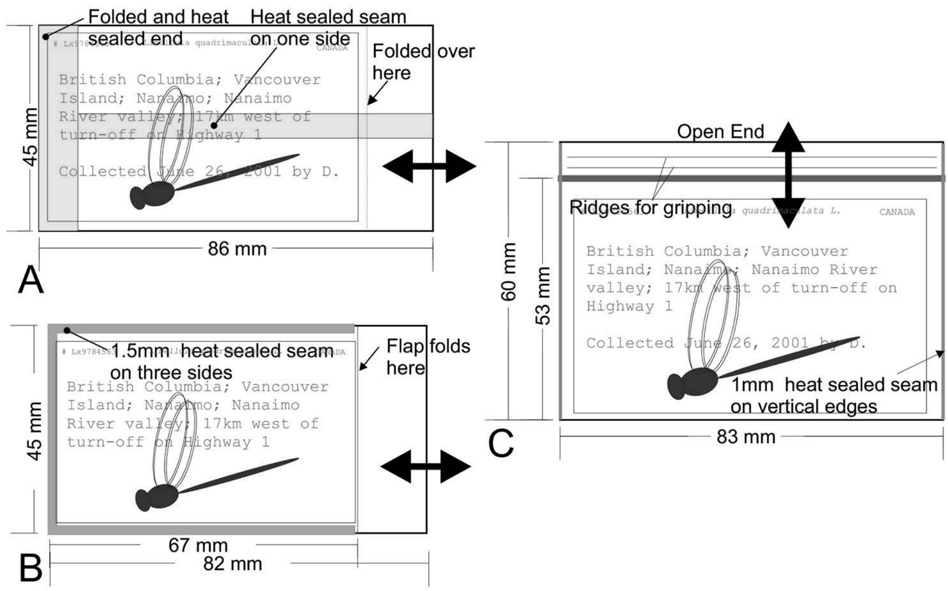

Figure 1. Envelope designs: (A) cellophane or polypropylene by Beatty and Beatty (1963); (B) polyester (Mylar M-30) by C. S. Guppy circa 1988; (C) polyethylene resealable.

In this paper we introduce a complete storage system for Odonata specimens with improvements designed to address the shortcomings of those used in existing collections. We also provide examples of how this system can be utilized in other collections to improve storage and handling in general.

Description and Comparison

The Royal British Columbia Museum (RBCM) in Victoria, Canada, began storing Odonata in envelopes in 1980. Initially, this storage system used cellophane envelopes, a regenerated cellulose polymer (Taylor 1986). Each envelope contained an index card with associated data and a specimen, stored vertically in 135 mm wide × 77 mm deep × 77 mm high specimen trays. These trays were specially manufactured from boxboard with taped seams. Three larger trays, holding six specimen trays each, were installed sideways into an open wooden drawer (Fig. 2a). The drawers were part of a system intended to house alcohol vials in 1.1 m tall melamine cabinets (BioQuip Products, Gardena, CA). In 1987, the RBCM needed a new supply of envelopes, which were no longer available from the original supplier. At that time, odonatologists expressed concerns about the poor archival quality of cellophane because some had noticed shrinking or shrivelling problems. The carbon disulfide and sulfuric acid used in cellophane production can remain in the film and affect adjacent materials (Taylor 1986). Further, cellophane contains a significant amount of water and softeners that can migrate to other specimens with temperature fluctuations (Taylor 1986). After expending considerable effort in locating a supplier, RBCM staff purchased specially manufactured envelopes made of polyethylene terephthalate (PET) film (1.5 mil DuPont Mylar^{TM} M-30) (Fig. 1b). These envelopes opened on the narrow side and were similar in shape to the existing cellophane design, but the seams were glued on three edges and a long flap folded over to close the envelope. Although PET is considered inert and

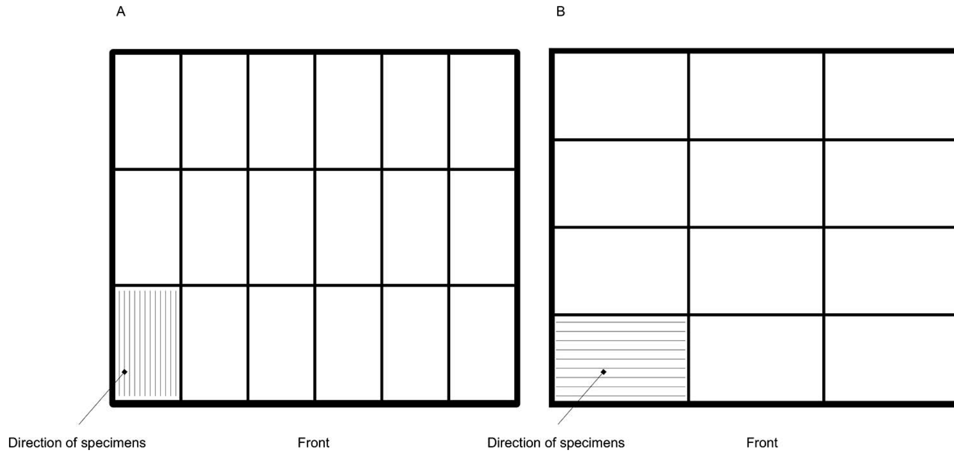

Figure 2. Top views of (A) open top drawer with alignment of boxes and specimens and (B) Cornell-style glass-top drawer and arrangement of boxes and specimens.

suitable for archival purposes (Taylor 1989), it was discovered that the DuPont Mylar M-30 is coated with polyvinylidene chloride (PVDC), like the original Beatty and Beatty cellophane envelopes (DuPont K202/203). This coating provides a layer for heat-sealing, printing, and moisture-proofing, but it eventually decomposes (Taylor 1989). In 1988 a variation on the Beatty and Beatty design, using polypropylene instead of cellophane, became available from suppliers for approximately 50% the cost of the M-30 envelopes.

In 1988, funds became available to upgrade the Odonata cabinets at the RBCM. A new storage cabinet system using full-height (2.19 m) cabinets and sealed, glass-topped, sugar pine drawers, like those used for pinned insects, was designed and specially manufactured for the RBCM Odonata collection by BioQuip (catalogue #2517TAN). The gasketed cabinets are the same dimensions and are made from the same materials as the standard Cornell cabinets from BioQuip (2500 series). However, the cabinet holds deeper drawers (102 mm inside depth) (catalogue #1012OD), that allow envelopes to be stored upright. Each cabinet holds 17 drawers, whereas the standard pinned specimen cabinet holds 25 drawers.

This system, with tight-fitting drawer lids and polypropylene seals on the cabinet door, was an improvement over the previous cabinets with open drawers. However, there were still problems related to envelope and box designs. The original specimen trays were not designed to fit Cornell drawers, and a foam wedge needed to be inserted into each drawer to keep the specimen trays firmly in place. The addition of foam wedges wastes space and creates extra labor and material cost. Both cellophane and uncoated Mylar envelopes also suffered from design flaws—neither envelope type can be sealed without gluing, taping, or heat-sealing the open end. Although sealing is more time consuming and makes the envelopes difficult to reopen, not sealing the envelopes leads to two problems. First, the folded flap does not lie flat, but pushes out against its neighbors, creating a fan shape instead of sitting squarely within each box of specimens. Secondly, unsealed envelopes increase the likelihood that an entire drawer of envelopes is at risk of being infested by dermestid beetles or other pests because a pest would have little problem moving among envelopes. If stored in open-top drawers, the entire cabinet could be damaged by the introduction of one infested envelope. Specimens in unsealed envelopes also face potential damage from liquids, gases, and fluctuations in humidity.

In 1998, the RBCM was again in need of cabinets, specimen trays, and envelopes to house new specimens from ongoing surveys of Odonata. Little had changed in Odonata storage products, except for an increase in price. Given the increased cost and the various shortcomings of the specimen trays and envelopes described above, we chose to design a new envelope and box system to house Odonata. Here we describe our solution, its advantages and disadvantages, and improvement over the designs currently in use in other collections. All quoted prices are in US dollars; Canadian prices were converted using published annual exchange rate for the year the purchase was made.

We made several design changes to the envelope storage box. The material was changed from 1-mm-thick boxboard to cheaper 2 mm corrugated cardboard. Instead of taped seams, we chose a simple folding design with anchor tabs. This was less costly to produce, surplus specimen trays require considerably less storage space when collapsed, and no adhesives are used. The dimensions of the folded box (146 mm $\times$ 95 mm $\times$ 84 mm) allow a snug, but not tight, fit for three columns by four rows of specimen trays per drawer. This arrangement allows a good view of the specimens and a more intuitive ordering of specimens (front to back and left to right) within and between drawers (Fig. 2b). Manual folding along impressed lines is straightforward and requires less than 10 seconds per box. Although 18 original specimen trays fit in a drawer, the "sideways" orientation made it difficult to visually scan the contents without removing the drawer (Fig. 2a).

The production price for the new design, excluding the one-time cost for the initial die of $235, was $0.17 per box for a quantity of 4,500. According to the supplier, the boxboard equivalent is more expensive for a quantity of 4,500 but for 10,000 or more the manufacturing efficiencies of boxboard reduce the cost to below the price for corrugated cardboard. Hence boxboard could be a more cost-effective option than corrugated cardboard for large specimen collections (> 120,000 specimens).

A potential concern with the use of cardboard is off-gassing. We used a risk analysis model for decision-making and found that, in our geographic region, cardboard off-gassing in a closed space was less likely to cause significant loss in collection value than other risks such as pest infestation and seismic activity. Some institutions might choose to optimize their choice of materials to minimize contaminants. If this is the case, then acid-free corrugated and noncorrugated board is available through a variety of sources (e.g. http://www.universityproducts.com/).

The preparation and storage of Odonata specimens was also improved by computer-generated labels printed on stiff, 80-pound, acid-free paper. This eliminated both the manual creation of specimen data labels and the use of acidic index cards. Acid-free paper for labelling Odonata is important because the paper is in direct contact with the specimens. Laser-printed and ink jet-printed labels have been found to exhibit permanence when carbon-black pigment based inks are used (Carter and Walker 1999). An additional benefit is that this paper can be also used for pinned and alcohol-preserved specimen labels. The only drawback is the labor required to cut out the labels.

The most significant innovation was the envelope design. We examined many commercial products packaged in "tongue and groove" or "zipper-lock" type resealable envelopes and used this technology to determine whether these envelopes could replace cellophane or Mylar envelopes. We found a local company that was able to produce resealable polyethylene envelopes to our specifications (Fig. 1c). Our conservators at the RBCM investigated the plastic envelopes and approved them for archival storage. It should be noted that some polyethylene zipper-lock envelopes might contain the antioxidant butylated hydroxytoluene (BHT). This additive can stain light-colored specimens and interfere with some chemical

Table 1. Summary of characteristics of various dragonfly envelope storage options with the preferred state bolded.

Feature/product	Cellophane[a]	Mylar M-30[a]	Polypropylene[b]	Polyethylene
Archival	No	**Yes**	**Yes**	**Yes**
Cost	Medium	High	Medium	**Low**
Static charge	High	High	**Low**	**Low**
Transparency	Good	**Excellent**	Good	Good
Rigidity	**Stiff**	**Stiff**	Low	Low
Durability	Medium	Low	**High**	**High**
Resistance to insect infestation	Low	Low	**High**	**High**
Ease of access to specimen	Low	Low	Low	**High**

[a] folded.
[b] heat sealed.

analyses (Baker 1995). Thus, every effort should be made to ensure that the envelopes used in specimen storage do not contain BHT. In addition to having a resealable tongue and groove seam, another major modification was to move the seam from the height of the envelope to the width of the envelope, which creates a much larger opening for handling the label and specimen. A minimum purchase of 50,000 envelopes was required, and the final price in 1999 for this quantity was $0.007 per envelope. This price was significantly lower than the cellophane ($0.06), polypropylene ($0.06), and the Mylar M-30 ($0.09) designs.

Discussion

The new RBCM system of sealed cabinet, drawer, and specimen envelope for the storage of Odonata has significant advantages over the older system. A summary of these advantages is provided in Table 1.

Most importantly, each specimen now has three levels of protection from damaging agents such as dermestid beetles and relative humidity fluctuations. Specimen retrieval time from the collection is improved by the ability to view drawer contents via the clear envelopes and face-forward trays. Although the potential for mold damage exists when a fresh (moist) specimen is placed into a sealed container, the standard preparation of adult Odonata involves placing specimens into acetone to preserve coloration (Paulson 2016), which dries and sterilizes the specimen quickly. To date, none of the thousands of specimens collected and stored in our resealable envelopes have shown any signs of mold growth, and only one specimen housed in the research collection sustained damage from dermestids, and this damage was contained entirely within the single envelope. It is believed that the specimen was infested and not treated with acetone prior to being placed in the resealable envelope. On the other hand, within 2 years of implementing the resealable envelopes, two separate trays of deaccessioned specimens in the original M-30 envelopes were attacked and totally destroyed by dermestids. Cast skins and frass in the box bottom indicated that the beetles were moving freely among the M-30 envelopes. More recently a drawer of odonate specimens housed in a working cabinet was infested with a dermestid beetle (*Anthrenus verbasci* [L.]). Because the specimens were from various sources, the drawer contained a mix of specimen storage types (Table 2). The findings clearly illustrate the improved specimen protection provided by the resealable envelopes. None of the resealable envelopes showed any signs of infestation, despite the complete loss of some specimens across all of other envelope storage types.

Table 2. Impact of an insect infestation (Dermestidae: *Anthrenus verbasci*) on various types of envelopes stored together in a working drawer of Odonata. Damage is indicated for the extent of the damage as a percent of total for each type. Envelope types are arranged in order from least impacted to most impacted based on damage. Minor damage included some evidence of dermestid activity whereas extensive meant the specimen was unrecoverable.

Envelope type	No damage (%)	Minor damage (%)	Major damage (%)	Total number of envelopes
Resealable polyethylene	100	0	0	21
Cellophane	81	9.5	9.5	42
Paper	62	15	23	92
Mylar	50	32	18	22
Glassine	25	33	42	12
Total				189

Handling of specimens is safer and easier with the opening oriented along the wide side of the envelope. The top opening design also eliminates the possibility that specimen fragments, often legs and abdomens, become detached from the body, and might fall out of the envelope during normal handling. The top strip of the envelope, isolated above the seam, also makes a convenient and safe tab to hold onto the envelope without applying any pressure to the specimen. The Mylar M-30 envelopes carry a high static charge, which often makes it difficult to remove the specimen from the narrow opening and past the partly folded flap without breakage. Although the polypropylene and polyethylene plastics have relatively low static charge, the partly folded flap and narrow side opening still make specimen handling more difficult with the Beatty and Beatty (1963) design. The Mylar M-30 envelopes are very clear and glossy, which allows an excellent view of the contents. The polypropylene and polyester envelopes are not as clear as the Mylar but lack the reflective glare. The rigidity of the Mylar envelopes creates a tight fit for larger bodied specimens and therefore must be handled carefully, because any twisting can place undue stress on the specimen. The polypropylene envelopes are generally less rigid than Mylar, except along the seams. Polyethylene envelopes are quite soft and pliable and rely mainly on the stiff label paper to keep them flat and upright. Even large-bodied dragonflies fit comfortably with minimal pressure on the specimen. The heat-sealed seams on polypropylene and polyethylene envelopes are very strong in contrast to the Mylar envelope seams, which readily split when any tension is applied. Considering all of the advantages and the significant cost differences, the resealable polyethylene design (Fig. 1c) is superior to either of the open-end designs.

Although the cost of the envelopes and cardboard specimen trays is low compared to the alternatives, the sealed glass-topped drawers contribute significantly to the cost of the overall system. Price estimates based on 5,000 specimens stored in (A) two 1.1-m vial cabinets, 17 open wooden drawers, paperboard specimen trays and polypropylene or Mylar envelopes versus (B) one 2.9-m steel cabinet, 17 glass-top drawers, cardboard specimen trays, and polyethylene resealable envelopes were similar for both systems. System A ranged from \$0.42/specimen with polypropylene envelopes to \$0.47/specimen for Mylar, whereas system B was \$0.44/specimen. Although system B has a relatively high initial cost, savings accrue in reduced maintenance requirements (e.g., reducing monitoring, replacing split envelopes, repairing broken specimens, risk to collection) in the long term, thus saving time, money, and specimens. For established collections, already equipped with large numbers of cabinets and drawers, switching to the low-cost resealable envelope design is particularly attractive. Not only are the resealable envelopes inexpensive, but the significant improvement in protection it affords the specimens, especially in open top drawers, makes it worth the conversion.

All adult Odonata stored in envelopes in the entomology collection at the RBCM have been completely rehoused into this new system (approximately 43,000 specimens). Additionally, backlog Lepidoptera collections donated in envelopes have been upgraded into the resealable envelopes (approximately 4,500 specimens), and now freshly collected Lepidoptera are spread and immediately placed in envelopes in the field for future housing in this system because of the incredible space savings achieved.

Other types of collections might also find this system useful for the storage of flat or small items. Recently, the RBCM Archeology collection adopted this storage system for housing small artifacts measuring less than 14 cm × 9 cm × 1 cm to protect them from damage and make retrieval easier. Prior to this change, artifacts were at risk of contact with each other by being housed loosely in drawers with objects of all sizes and materials. The need to check site numbers and/or artifact numbers to find the object of interest required that every object was handled. Now that information and the small artifacts to which the information relates are both inside the resealable envelopes and inside the cardboard storage boxes. Furthermore, the storage system is much more compact, relieving significant space pressure. All submission of archaeological material must now follow these repository requirements if researchers have material for deposition into the RBCM.

The attractive wood and glass construction, the seal, and the increased depth of the envelope drawers has led other disciplines at the RBCM to use empty drawers as display cases for fragile mounts of birds, mammals, skeletons, and other objects. These users have remarked that similar cabinets and drawers would be preferable to those currently used in their collections.

Conclusions

The three levels of sealing and protection inherent in the Royal British Columbia Museum Odonata storage system design are superior to all other commercially available systems. Most other systems rely solely on the cabinet door seal to prevent access by dermestid beetles; once past this barrier, pests are essentially free to exploit the entire contents of the cabinet. The use of standard 2.9-m Cornell cabinets allows the envelope collection to fit side by side with cabinets of pinned specimens, without special requirements or inconsistencies, and allows use of the full height available to the footprint. The most significant improvement in this system is the polyethylene envelope design utilizing a resealable seam. This envelope design minimizes the risk of damage to the specimens and is less expensive than other designs. Training time is minimal because the design is so similar to commercially available "zipper lock" sandwich bags.

Acknowledgments

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