

# Collection Forum

**Spring 1990**  
**Volume 6**  
**Number 1**

*Society for the Preservation of Natural History Collections*

1989-1990 COUNCIL  
SOCIETY FOR THE PRESERVATION OF NATURAL HISTORY COLLECTIONS

Cesar A. Romero-Sierra, *President*  
Stephen L. Williams, *President-elect*  
Daniel J. Faber, *Past President*  
Suzanne B. McLaren, *Treasurer*

Shirley S. Albright, *Secretary*  
Joan M. Kaylor, *Secretary-elect*  
Paisley S. Cato, *Managing Editor*

*Members-at-Large*

*Term ending 1990*  
Julia Golden  
Janet B. Waddington

*Term ending 1991*  
Ingrid U. Birker  
Carolyn L. Rose

*Term ending 1992*  
J. Phillip Angle  
Gerald R. Fitzgerald

STANDING COMMITTEES

- Archival Committee:** J. P. Angle (Chair), L. Gordon, J. M. Kaylor  
**Bylaws Committee:** D. J. Faber (Chair), S. S. Albright, C. A. Romero-Sierra  
**Conference Committee:** S. L. Williams (Chair), J. C. Danis, G. R. Fitzgerald, J. Gisbert, D. Willard  
**Conservation Committee:** C. L. Rose (Chair), P. S. Cato, C. Collins, J. E. Deisler, J. Fenn, G. R. Fitzgerald, M. L. Florian, C. A. Hawks, J. M. Kaylor, J. H. Reynolds, C. A. Romero-Sierra, S. Shelton, J. B. Waddington, R. R. Waller, E. A. Webb  
**Election Committee:** F. J. Collier (Chair), W. G. Lyons, B. Seldon  
**Executive Committee:** C. A. Romero-Sierra (Chair), S. S. Albright, D. J. Faber, J. M. Kaylor, S. B. McLaren, S. L. Williams  
**Finance Committee:** H. H. Genoways (Chair), S. L. McLaren  
**Membership Committee:** D. S. Chaney (Chair), J. E. Deisler, W. G. Lyons, A. Pinzl, D. A. Schlitter, J. B. Waddington, R. R. Waller, S. L. Williams  
**Publications Committee:** P. S. Cato (Chair), J. Golden, C. Patterson, A. Pinzl, C. Sease, J. E. Simmons, J. B. Waddington  
**Publicity and Liaison Committee:** J. Golden (Chair), E. Benamy, I. Birker, F. J. Collier, C. A. Hawks, M. Massaro, F. Rafi, J. E. Simmons  
**Resources Committee:** C. A. Hawks (Chair), P. Beelitz, M. A. Dancey, R. C. Dowler, S. Gabe, K. L. Garrett, I. A. Hardy, J. M. Kaylor, C. H. Kishinami, L. Lepage, N. Pliml, A. Y. Suzumoto, J. B. Waddington, S. Woodward

EDITORIAL STAFF

- Paisley S. Cato, *Managing Editor, Collection Forum*, Virginia Museum of Natural History, 1001 Douglas Ave., Martinsville, Virginia 24112  
Julia Golden, *Associate Editor, SPNHC Newsletter*, Department of Geology, University of Iowa, Iowa City, Iowa 52242  
Carl Patterson, *Associate Editor for Book Reviews*, Denver Museum of Natural History, City Park, Denver, Colorado 30205  
Ann Pinzl, *Associate Editor for Advertising*, Nevada State Museum, Capitol Complex, Carson City, Nevada 89710  
Catherine Sease, *Associate Editor for Anthropology*, Field Museum of Natural History, Roosevelt Road at Lake Shore Drive, Chicago, Illinois 60605-2496  
John E. Simmons, *Associate Editor for Life Sciences*, Museum of Natural History, Dyche Hall, University of Kansas, Lawrence, Kansas 66045-2454  
Janet B. Waddington, *Associate Editor for Earth Sciences*, Department of Invertebrate Paleontology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

---

*Collection Forum*, the official journal of the Society for the Preservation of Natural History Collections (SPNHC), is published twice a year to disseminate substantive information concerning the development and preservation of natural history collections. The journal is available by subscription (\$20US per year) and as a benefit of membership in SPNHC (\$15US per year for individuals; \$40US per year for associate members). Address all communications involving membership dues and subscriptions to the SPNHC Treasurer.

*Collection Forum* (ISSN 0831-4985) is published by SPNHC, 5800 Baum Blvd., Pittsburgh, Pennsylvania 15206. POSTMASTER: Send address changes to SPNHC % Suzanne B. McLaren, Treasurer, 5800 Baum Blvd., Pittsburgh, PA 15206. Copyright 1990 by the Society for the Preservation of Natural History Collections.

# FREEZING FOR MUSEUM INSECT PEST ERADICATION

MARY-LOU FLORIAN

*Conservation Services Section, Royal British Columbia Museum,  
675 Belleville Street, Victoria, British Columbia V8V 1X4, Canada*

*Abstract.*—Insect pests may be eradicated by freezing as an alternative to the use of fumigants and pesticides. To avoid damage from the freezing process, specimens must be sealed in polyethylene bags at room temperature, cooled steadily to  $-20^{\circ}\text{C}$ , and held at this temperature for at least 48 hr. The bag must not be opened until the contents have thawed to room temperature (at least 24 hr). Repeated freeze-thaw cycles are recommended to assure insect eradication. Freezing to control insect pests in museum specimens will be most effective when it is used as a component of an integrated pest management program.

Freezing objects composed of dry adsorbent organic material (herbarium specimens, dried skins, taxidermy specimens, mounted insects, skeletons, etc.) for insect pest eradication is recommended as an alternative to chemical treatment. Health hazards, legal aspects of using insecticides and fumigants, the lack of appropriate monitoring equipment in most collections, potential chemical reactions with the materials in museum specimens and the resulting toxic byproducts limit the practicality of chemical pest control. Freezing is a viable alternative, especially when incorporated into a system of integrated pest management (Floriant, 1988, 1989).

## INSECTS AND DIAPAUSE

In freezing museum insects for eradication, care must be taken not to put the insects into diapause (a freeze-resistant state). Insects may be categorized as freeze-tolerant, freeze-sensitive, and freeze-resistant (Zachariassen, 1985). Freeze-tolerant insects are able to withstand the formation of ice in the body fluid at temperatures equal to or below supercooling capacity. Freeze-sensitive insects lack tolerance to the formation of ice in body fluid. Freeze-resistant insects use avoidance mechanisms (acclimation, dehydration, production of alcohols, etc.) to prevent freezing.

Mullen and Arbogast (1984), in discussing the problem of freezing insects in stored foods, grouped insects as those killed at temperatures above freezing; those killed as soon as tissue freezes at  $0^{\circ}\text{C}$ ; and those that are freeze-tolerant.

Salt (1961) maintained that household pests do not normally encounter cold temperatures and thus should not be able to tolerate freezing temperatures. However, there are specific cases reported in the literature of household insect pests which survive freezing temperatures, i.e., cigarette beetle eggs (Mullen and Arbogast, 1984) and hide beetle larvae (Ketcham-Troszak, 1984), both of which are of concern in museums.

The reasons for the time-dependent effects of cold have not been well defined, but from physiological experiments on oxygen consumption and rate of development, it is probable that the rate of metabolic activity is greatly reduced and may not be tolerated over a long period of time (Wigglesworth, 1972).

## THE EFFECTS OF FREEZING ON INSECTS

There are two main questions about the effects of freezing temperatures on live insects: why are the insects killed; and why are some insects freeze-resistant?

When living cells (which have 90% water content) are subjected to low temperatures, specific physical and chemical changes occur, some of which may be lethal. Whether death by freezing is the result of a combination of events or a single event has not been conclusively shown. The possible lethal events are dehydration effects, osmotic swelling, changes in enzyme reaction rates, and ice crystal formation.

Dehydration effects (Loveloch, 1953; Zachariassen, 1985) include the concentration of solutes in the cell due to the loss of free water. Free water diffuses out of the cells and forms ice crystals between the cells in the intercellular fluid. Water loss (dehydration) in insect cells should increase their electrolyte concentration and lower their freezing or supercooling temperature, but there is as yet no clear evidence to support this theory. Salt (1950) reported that relative humidity (RH) does not influence the freezing temperature of insects. In theory the moisture content of rapidly cooled insects will increase because the adjacent air, as it cools, will increase in humidity.

Freezing of the body fluids in intracellular or intrainestinal compartments may lead to osmotic swelling in the unfrozen compartments and an eventual lethal rupture of confining membranes (Zachariassen, 1985).

The rate of enzyme reactions decreases at lower temperatures, but enzyme activity is not usually inhibited even at very low temperatures (Joslyn, 1952; Sizer, 1943). The rate of enzyme reactions may increase with freezing because of the increase in concentration of the enzyme and substrate (Lindelv, 1976).

Water in cells and tissues may take one of three different states—molecularly bound; bound to other water layers; or free water. Molecularly bound water is bonded to polar sites of molecules and does not freeze at  $-20^{\circ}\text{C}$  (Meryman, 1966; Sinanoglu and Abdulnor, 1965; Zachariassen, 1985). Although easily lost and regained with changes of humidity, it rarely freezes. Free water may be located inside capillaries, inside and between cells, in vacuoles and between large fibers. It readily freezes, is quickly lost on drying, and is active in osmosis.

The formation of free ice crystals will vary according to the velocity of freezing (Luyet, 1960, 1970). The slower the rate of freezing, the larger the resulting crystals. In slow cooling of living tissue, a few large ice crystals are formed first in the intercellular fluid. These crystals are not considered lethal or damaging, but may act as nucleation particles or sites for intracellular ice crystal formation. The intracellular ice crystals physically rupture cell and organelle membranes (Karow and Webb, 1965).

If ice crystals have not formed on freezing, they may form during slow thawing. Luyet (1970) reported that ice crystallization may resume upon warming because ice crystal growth is temperature and time dependent.

Uvarov (1931) showed that the effects of low but above freezing temperatures are time-dependent. The importance of the time of exposure to moderately low temperatures ( $2^{\circ}\text{C}$ ) was illustrated in experiments on bedbug eggs. After 10 hr at this temperature, 80% hatched normal larvae, but after 39 hr, no larvae hatched. Uvarov (1931) also reported on the variation of the fatal time of exposure between two species of grain insects. For *Sitophilus oryzae*, at  $7.2^{\circ}\text{C}$ , the fatal time was 60

hr, and at  $-17.7^{\circ}\text{C}$ , it was 1.5 hr. With *Sitophilus granarius*, the fatal times were 75 hr and 2.5 hr, respectively.

### *Supercooling and Cold Acclimation*

Supercooling may prevent freezing from being lethal. Some insects which are freeze-resistant or cold-hardy produce glycerol in their body fluids, which allows them to supercool to  $-15^{\circ}\text{C}$ . During glycerol supercooling, the water forms a vitreous sheet (Pryde and Jones, 1952; Kauzmann, 1948). If ice crystals do form inside the cell during supercooling, they are small and diffuse and do not cause physical damage.

Salt (1956) noted that, in hibernating insects, at  $-10^{\circ}\text{C}$ , about 75–80% of the body water is frozen; at  $-15^{\circ}\text{C}$ , about 85–90% is frozen; and at  $-20^{\circ}\text{C}$ , close to 90% or more is frozen. At  $-15^{\circ}\text{C}$ , only a small group of freeze-tolerant insects can survive. Zachariassen (1985) reported that freeze-tolerant insects become injured when 65% of their body water freezes and stated that “the temperature range from  $-7$  to  $-12^{\circ}\text{C}$  is considered as the general supercooling limit of active insects, regardless of season and geographical distribution.”

Insects held at the lower limits of the supercooling point will freeze after a passage of time. Salt (1950, 1961) illustrated this with *Cephus cinctus*.

Salt (1961) also showed that hibernating insects improve their tolerance to low temperature by acclimation, or “cold-hardening,” so that they can supercool. He showed that with the wheatstem sawfly, *Cephus cinctus*, the slower the rate of cooling, the higher the supercooling point.

It is important to realize that this physiological change is very rapid. Acclimation can occur in 4–18 hr as long as the insect is at a temperature at which it can still move. Insects which cannot move are unable to acclimate (Wigglesworth, 1972).

Insects also undergo heat acclimation, so that, if they are placed in unusually warm temperatures, their tolerance to low temperatures is greatly reduced (Wigglesworth, 1972).

Wigglesworth (1972) reported that after repeated freeze and thaw cycles, the supercooling ability is eliminated and freezing occurs as soon as freezing temperatures are reached. Florian (1978, 1986) suggested that repeated freeze-thaw cycles should be used for insect control in artifacts to ensure that lethal conditions for eradication are obtained.

Thus, to make insects most vulnerable to freezing they should be acclimated at a high temperature (room temperature) before freezing. They should be cooled to approximately  $5^{\circ}\text{C}$  in at least four hr, so that they cannot move. Materials in a chest freezer with adequate air movement will reach this temperature in less than four hr.

The question also arises of whether different stages in the life cycle of the insect are equally vulnerable to freezing. Asahina (1966) listed the freeze-resistance of eggs, larvae, pupae and adults of several insect species. No general conclusions can be drawn from this study because, like similar tests reported in the literature, the rate of freezing and thawing and the previous environmental acclimation of the insects were not recorded. We would expect that such structures as the cocoon would have some insulation advantage, but Asahina (1966) suggested that the egg shells, hibernacula, cocoons, and puparia prevent ice seeding but do not affect the rate or degree of cooling. This does imply that stages with these coverings may

be more resistant. Salt (1961) reported that ice nucleation readily occurred in actively feeding insects both in the feces and in their digestive tracts. Thus, actively feeding insects may be less resistant to freezing than inactive stages.

Ketcham-Troszak (1984) showed that all stages of the life cycle of the hide beetle (*Dermestes maculatus* Degeer) were killed by exposures of 48 hr at  $-12^{\circ}\text{C}$ , 24 hr at  $-15^{\circ}\text{C}$ , and 4 hr at  $-20^{\circ}\text{C}$ .

To be lethal to insects, the freezing procedure should result in cellular damage from dehydration effects, intracellular ice formation, the loss of bound water, or the reduction of enzyme activity. Supercooling should not be allowed to occur during the freezing procedure. The rate of freezing and thawing must allow cell damage to occur. The minimum temperature must be below the supercooling limit. The time held at freezing temperatures must be sufficient to allow intracellular ice crystal growth. Thus, flash freezing and thawing must be avoided. If possible, specimens should be thawed slowly in a refrigerator.

#### *Freeze-Resistance and Insect Eradication*

Because it is not known if museum insect pests can become freeze-resistant, we must be sure that the procedures we use do not mimic those that naturally develop freeze-resistance. The two most important physiological states to guard against are cold acclimation and supercooling ability. Cold acclimation could occur if infested material is exposed to a cool environment before freezing or if the temperature lowers too slowly during the freezing process.

Repeated freeze-thaw cycles break down the supercooling ability of insects and should be used as a component of the freezing procedure.

Because the lethal action of low temperature is both time and temperature dependent, the length of exposure to minimum temperature in the freezing procedure is critical.

If high RH enhances the vulnerability of insects to freezing, placing infested material in a sealed, airtight bag with ambient air of 50% RH should bring the desirable increase in humidity as the closed container cools down.

#### EFFECTS OF FREEZING ON DRY ADSORBENT ORGANIC MATERIALS

The effects of freezing on dry organic materials and museum insect pests have been thoroughly reviewed (Florian, 1986). The following conclusions were reached concerning freezing dry organic materials:

1. Water in dry museum specimens composed of adsorbent materials (equilibrium moisture content of up to 28%) will not freeze at  $-20^{\circ}\text{C}$ ; thus ice damage will not occur. (Adsorption here refers to the adhesion of an extremely thin layer of molecules to a surface.)

2. Sealing the specimen in a clear polyethylene bag (for visibility and low permeability) before placing it in the freezer prevents any dramatic moisture content changes which would cause dimensional changes due to swelling or shrinkage. It also prevents condensation from forming on the specimen while it is in the freezer. After the bag has been removed from the freezer, it should not be opened or the contents removed until the specimen inside has reached room temperature (at least 24 hr). This procedure prevents condensation on the object.

3. Water vapor in the air in the bag with a specimen will not freeze at  $-20^{\circ}\text{C}$ , the established temperature for the freezing procedure.

4. If the specimens are composed of adsorbent materials, they will adsorb the excess water (released by the cooling air in the partially evacuated bag) according to their regain ability, and condensation will not occur. The moisture content of the adsorbent materials will increase. The amount of water available for adsorption is small in reference to the amount that can be adsorbed. Museum objects composed of non-adsorbent materials should not be subjected to freezing because they cannot adsorb the excess water vapor which will condense to form frost on the surface.

5. If the moisture regain of the material is in doubt, condensation can be prevented by eliminating the air in the bag by partial evacuation or vacuum-packing if the object is stable, or by controlling the RH of the cooling air with buffering adsorbent materials.

6. Research is needed to determine the regain ability (the amount and rate of adsorbency of materials) at below freezing temperatures. It is known that regain occurs at  $-20^{\circ}\text{C}$  and the rate is determined by the vapor pressure of the water in the materials (Darling and Belding, 1946).

7. Strength changes of wood, wood adhesives, and polymers generally increase with a decrease in temperature. The strength change is reversible on warming. The strength change increase may be due to the increase in strength properties which results from an increase in moisture content. Minor isodiametric thermal shrinkage and swelling (less than 1%) of wood may occur during the freezing process.

8. Non-adsorbent materials may become brittle at extreme freezing temperatures, but  $-20^{\circ}\text{C}$  is not sufficiently cold to cause a permanent change. The brittleness is immediately reversible on warming.

9. Seed germination rates and viability are influenced by freezing. The freezing of herbarium materials where the viability of seeds is a concern needs to be assessed.

10. The cooling rates of the material must be determined in order to ensure that the insects are held at the minimum lethal temperature for the right length of time ( $-20^{\circ}\text{C}$  for 48 hr). Thermocouples or thermistor probes are recommended to monitor the temperature reduction of the specimen. Most materials, if spaced well, will reach  $0^{\circ}\text{C}$  in less than 1 hr.

If these procedures are followed, no deleterious effects on dry adsorbent material should occur.

#### PROCEDURES FOR FREEZING DRY ORGANIC MATERIALS FOR INSECT ERADICATION

Specimens composed of *non-adsorbent* materials should not be processed in a constant temperature chest freezer.

1. Use a chest freezer, since there will be less loss of cold air when the freezer is opened to place the bagged specimens inside. Do not use frost-free type freezers, as these do not maintain a steady low temperature, but regularly warm up and cool down to clear frost formation.

2. The infested specimen should be sealed in a bag composed of airtight, clear polyethylene film. The air in the bag should be partially evacuated. The amount of air evacuated will depend on the stability of the specimen and its tolerance to the pressure of the film against it. Seal the bag immediately, because, as soon as the specimen is in the bag, insects will respond to the environmental change and try to escape. If the specimen is very large, pretreated silica gel or adsorbent materials can be included with the specimen in the bag to absorb the excess water which results from the reduced holding capacity of the cooled air.

3. Bagged infested specimens should be kept at room temperature (above 18°C) until placed in the freezer. In an emergency, they may be placed in a refrigerator (5°C) until freezer space is available, but should not be temporarily stored in a cold basement or cold storage with temperatures above 5°C.

4. There should be adequate air circulation around the bagged specimen in the freezer to allow for as rapid cooling as possible.

5. Thermocouples or thermistor probes should be used to record the temperature, rate of cooling, time at minimum temperature, and rate of thawing.

6. The minimum temperature of the specimen in the freezer must be  $-20^{\circ}\text{C}$ .

7. The time at the minimum temperature must be 48 hr.

8. A slow rate of thawing is desirable. If possible, place specimens directly from the freezer into a refrigerator or cold storage until thawed.

9. It is desirable to repeat the freeze-thaw cycle immediately.

10. Do not break the seal or remove the specimen from the polyethylene bag until it has reached room temperature and there is no condensed water on the outside of the bag. If possible, leave the specimen in the polyethylene bag for storage. All insect remains should be removed.

11. A record of the freezing procedure should be made and included with the treatment or condition report for the specimen. Ideally the record should include the insect pest identification, stages, and activity; bagging materials and methods; rates of cooling and thawing; time held at minimum temperature; physical changes observed; and the date of cleaning the insect remains from the bag. This last step is important because it establishes a zero point at which no insect remains were present.

#### SUMMARY

From the literature and experiences of museums who are using freezing for eradication of insects, it is apparent that the procedures described above are lethal to museum insect pests. Situations in which there was an apparent failure can be traced to a lack of monitoring of the temperature to  $-20^{\circ}\text{C}$  and not holding the specimen at this temperature for the required 48 hr. The procedures described here prevent possible freeze-resistant insects from undergoing cold acclimation and surviving the freezing temperatures.

There should be no damage to materials if they are adsorbent and are not wet. No damage has been reported using the procedures as described above. Thermal shrinkage is minimal and dimensional changes will not occur because the equilibrium moisture content should not change.

This review is not intended to give specific advice. Relevant information is presented to assist in making logical decisions, for each specific situation, on the use of reduced temperature for museum insect pest eradication.

## LITERATURE CITED

- Asahina, E. 1966. Freezing and frost resistance in insects. Pp. 451–486 in *Cryobiology* (H. T. Meryman, ed.). Academic Press, New York, 775 pp.
- Darling, R. C., and H. S. Belding. 1946. Moisture adsorption of textile yarns at low temperatures. *Industrial and Engineering Chemistry*, 38(5):524–529.
- Florian, M.-L. E. 1978. Biodeterioration of museum objects. *Dawson and Hind*, 9(43):35–43.
- . 1986. The freezing process—effects on insects and artifact materials. *Leather Conservation Newsletter*, 3(1):1–13.
- . 1988. Methodology used in insect pest survey in museum buildings, a case history. Pp. 1169–1174 in *8th Triennial ICOM Meeting, Biodeterioration Working Group, Sydney, Australia, Sept.*
- . 1989. Integrated insect pest control, an alternative to fumigation. Pp. 253–262 in *Proceedings of Conservation in Archives, International Symposium, Ottawa, Canada, May 10–12, 1988*. International Council of Archives, Ottawa, 310 pp.
- Joslyn, M. A. 1952. The action of enzymes in the dried state and in concentrated solution. Pp. 331–334 in *Proceedings of the 8th International Congress of Refrigeration*, London.
- Karow, A. M., and W. R. Webb. 1965. Tissue freezing. *Cryobiology*, 2(3):99–108.
- Kauzmann, W. 1948. The nature of the glassy state and behaviour of liquids at low temperatures. *Chem. Review*, 43:219–256.
- Ketcham-Troszak, J. K. 1984. Investigation into freezing as an alternative method of disinfesting proteinaceous artifacts: The effects of subfreezing temperatures on *Dermestes maculatus* Degeer. M.A. Thesis, Queen's University, Kingston, Ontario, 53 pp.
- Lindeløv, F. 1976. Reactions in frozen foods. Pp. 181–188 in *Towards an Ideal Refrigerated Food Chain*. Inst. Intern. of Refrig., Paris.
- Lovelock, J. E. 1953. The haemolysis of human red blood-cells by freezing and thawing. *Biochimica et Biophysica Acta*, 10:414–426.
- Luyet, B. J. 1960. Anatomy of the freezing process in physical systems. *Annals of the New York Academy of Sciences*, 85(2):115–138.
- . 1970. Physical changes occurring in frozen solutions during rewarming and melting. Pp. 27–43 in *The Frozen Cell* (G. E. W. Wolstenholme and M. O'Connor, eds.). J. A. Churchill, London, 316 pp.
- Meryman, H. T. 1966. Review of biological freezing. Pp. 2–114 in *Cryobiology* (H. T. Meryman, ed.). Academic Press, New York, 775 pp.
- Mullen, M. A., and R. T. Arbogast. 1984. Low temperature to control stored-product insects. Pp. 257–265 in *Insect Management for Food Storage and Processing* (F. J. Bauer, ed.). American Association of Cereal Chemists, St. Paul, 384 pp.
- Pryde, J. A., and G. O. Jones. 1952. Properties of vitreous water. *Nature*, 170(4330):685–688.
- Salt, R. W. 1950. Time as a factor in the freezing of undercooled insects. *Canadian Journal of Research. Section D. Zoological Sciences*, 28(D):285–291.
- . 1956. Freezing and melting points of insect tissues. *Can. J. Zoology*, 34(1):1–5.
- . 1961. Principles of insect cold-hardiness. *Ann. Review of Entomology*, 6:55–74.
- Sinanoglu, O., and S. Abdunor. 1965. Effect of water and other solvents on the structure of biopolymers. *Fed. of Amer. Soc. for Exper. Bio. Proceedings*, 24:512–523.
- Sizer, I. W. 1943. The effect of temperature on enzyme kinetics. *Advances in Enzymology and Related Subjects of Biochemistry*, 3:35–62.
- Uvarov, B. P. 1931. Insects and climate. *Trans. Entom. Soc. London*, 79:1–247.
- Wigglesworth, V. B. 1972. *The Principles of Insect Physiology*. Chapman and Hall, London, 827 pp.
- Zachariassen, K. E. 1985. Physiology of cold tolerance in insects. *Physiological Reviews*, 64(Oct.): 799–832.

# A LOW-COST RADIOACTIVITY TEST FOR GEOLOGIC SPECIMENS

ALICE M. BLOUNT

*The Newark Museum, P.O. Box 540, Newark, New Jersey 07101*

*Abstract.*—Fogging of black-and-white photographic film exposed in light-tight packets to geological samples containing unknown quantities of natural radioactivity is an inexpensive guide to screen collections for radioactive samples.

Radioactive minerals are frequently present in mineral, rock and fossil collections. Minerals containing uranium and thorium can be very highly radioactive, but fossils, particularly those containing carbon, can also have appreciable uranium content (Woodmansee, 1975). In recent years, there has been an increased awareness of the dangers associated with radioactivity. As a curator of earth science collections, I am frequently asked how one can determine radioactivity without a geiger or scintillation counter. I generally recommend the following photographic technique. This procedure involves placing the specimen on top of black-and-white film in a light-tight packet. After several days the film is processed. Radioactive samples will be indicated by a fogging of the film.

This note describes the photographic method for detection of radioactivity. This method is simple and inexpensive. It should be emphasized that the method is intended only to demonstrate which specimens contain radioactive elements and to give a *relative* idea of the intensity of this radioactivity.

## FILM AND EXPOSURE

The film used was Kodak T max 400 black-and-white film. For this type of film all manipulation and processing must be done in total darkness (as indicated on the instructions accompanying the film). To make the test, a short length of film must be enclosed in a light-tight packet. I make packets from the black plastic that had previously enclosed photographic print paper. However, a heavy black plastic garbage bag will work equally well. The selected plastic material is formed into an envelope before going into the dark so that a few inches of film can be cut from the roll of film, inserted in the envelope and the edge folded over and clipped shut easily (Fig. 1).

The specimen of interest is placed on the film packet (Fig. 2). A paper clip is placed between the specimen and film so that an image will appear on the film fogged by radiation. For this paper, I left T max 400 film under a specimen of uranothorite for three days.

The film used has an ASA number of 400 indicating a fast film. Several speeds of T max and other black-and-white films can be used. The exposure time varies according to the ASA number. For example, a film with ASA 200 should be exposed twice as long as ASA 400, and ASA 100 four times as long. If several lengths of films are to be processed at one time, each length can be identified by notching the edge with scissors before placing in the packet.

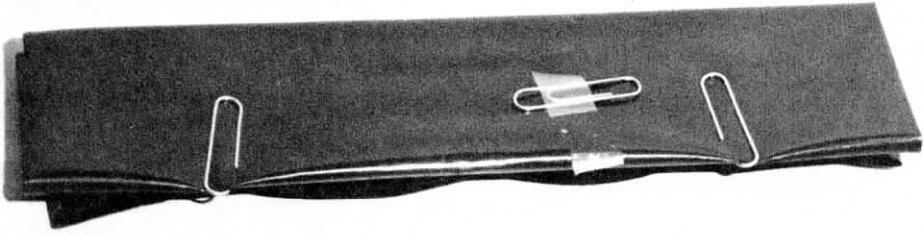


Figure 1. Packet with black-and-white film enclosed.

#### PROCESSING OF FILM

Processing of the film must be done in-house since commercial processors will not deal with short pieces of film. The processing is not difficult. Three solutions are needed: (1) developer, (2) rinse bath and (3) fixer. The rinse bath can be pure water or water mixed with a milliliter (teaspoon) or so of vinegar or acetic acid. The developer and fixer may be purchased as packets of dry chemicals from a camera store.

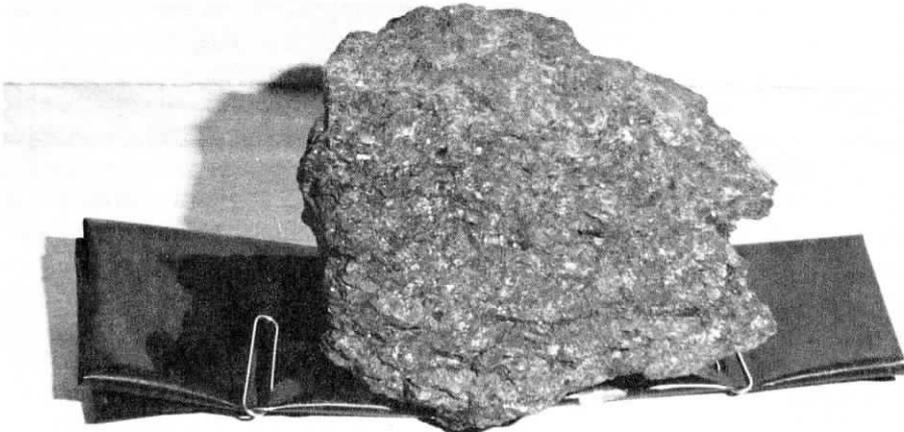


Figure 2. Specimen on film packet. This specimen showed 17,000 counts per second (cps) when measured with a scintillation counter as compared with 33,000 cps for the most highly radioactive minerals.

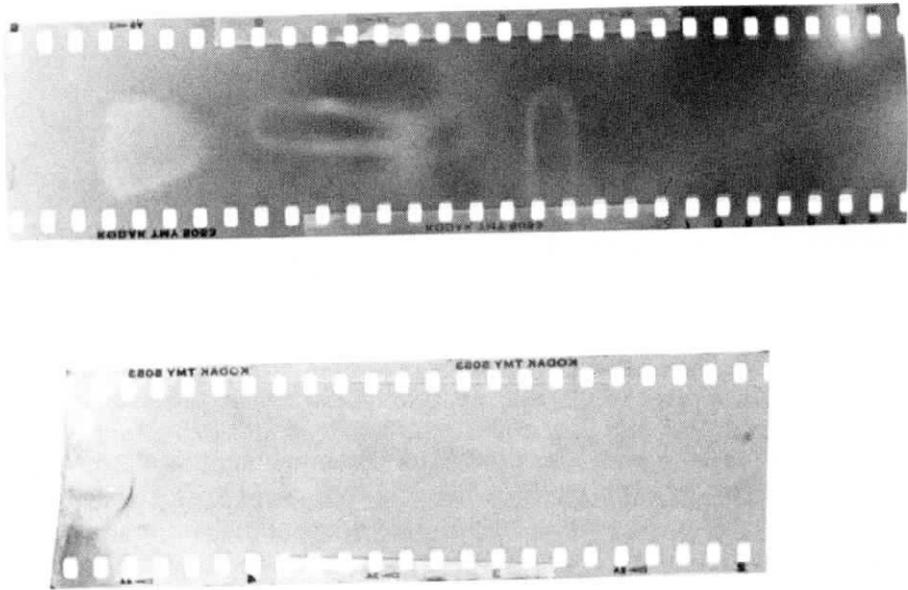


Figure 3. The top film shows the results of three days of exposure to the specimen shown in Figure 2. The lower film is the control, which was not exposed to radioactivity.

The developer used for T max 400 was D-76. The film instructions will indicate which developers are appropriate for the film used. Salespersons at any good camera store also should be able to offer advice, and publications, such as "Black and White Processing Using Kodak Chemicals" (Kodak Technical Publication J-1), can be obtained at a modest price by those wishing more detailed information.

The fixer is the same for all films and print papers. The mixing instructions are printed on the packages and all measurements are given in metric and English units. The mixing involves combining the dry chemicals with tap water, and, although water temperatures are indicated for each solution, the temperature is not critical. The developer should be mixed with slightly warm water and the fixer with cool water. The solutions can be kept for several months. It is best to keep them in a dark place or to store in dark bottles. The bottles should be labeled and dated.

For processing, three bowls or developing trays are needed. Bowls can easily be made by cutting the bottoms from large plastic bottles. The bowls should be filled with about one inch of solution and placed in the following order: developer, rinse bath and fixer.

The time that the film should remain in each solution is indicated on the instructions with the film. For T max 400 the time in the developer is nine minutes. After nine minutes in the developer, the film is rinsed in the rinse bath and placed in the fixer. The room light can be turned on after the film has been in the fixer for about one minute, at which point the film will have an opaque pink appearance. Total fixing time is about five minutes.

The film must be washed after the fixing is complete. Place the bowl or tray with the film strips under the tap and permit a gentle flow of running water to wash over the film for 10 minutes. Finally, the film should be permitted to dry.

### RESULTS

Figure 3 shows two pieces of processed film. One had been placed under a moderately radioactive sample and the other in the same type of packet in the same room but away from anything radioactive. One can clearly see the effect of the radiation on the film.

A scale to determine the degree of radioactivity can be made by exposing film pieces to a highly radioactive sample for various intervals of time. For example, films can be exposed for  $\frac{1}{2}$ , 1,  $1\frac{1}{2}$ , 2,  $2\frac{1}{2}$  and 3 days. If a film exposed to a specimen of unknown radioactive content for three days matches in darkness that of the film exposed for  $1\frac{1}{2}$  days, then one would deduce that the specimen being tested is about half as radioactive as the standard specimen. Since film response is not exactly linear and, in addition, processing conditions will not be exactly the same each time, these results provide an estimate only.

The test described is inexpensive. Black-and-white film can be purchased for about \$3.50 per roll. Ten to twenty specimens can be tested with each roll of film depending upon the length of film piece used. Packages of developer and fixer, one quart size at about \$2.00 each, will be enough for 12 rolls of film. On a per specimen basis, the cost of a test will be between 20 and 40 cents.

### DISCUSSION

The technique described in this paper is not new. The photographic principle finds daily application in the typical film badge worn by personnel to determine exposure in laboratories dealing with radioactive isotopes and X-ray equipment (Rosumny, 1967). Film badges are, however, of less use in the museum setting because of the cost involved. They are supplied and read by commercial laboratories. To obtain actual exposure information, I am presently running an experiment with stationary film badges inside and outside mineral cabinets and in the storeroom. A similar experiment is described in Dixon (1983). It is not my intention to imply that the same level of information can be obtained with the do-it-yourself photographic technique, but that the technique is useful for a screening of specimens in low-budget situations.

### LITERATURE CITED

- Dixon, D. W. 1983. *Radiation Hazards to Collectors of Geological Specimens Containing Natural Radioactivity*. National Radiological Protection Board Report 131 (UK), 23 pp.
- Rosumny, M. R. 1967. Health and safety. Pp. 6-1-6-14 in *Handbook of X-rays* (E. F. Kaelble, ed.). McGraw-Hill, New York, 1,025 pp.
- Woodmansee, W. C. 1975. Uranium. Pp. 1177-1200 in *Mineral Facts and Problems*. U.S. Bureau of Mines Bulletin 667, 1,259 pp.

## A NEW MEANS OF CONTROLLING RELATIVE HUMIDITY IN EXHIBIT CASES

CATHERINE SEASE

*Division of Conservation, Field Museum of Natural History,  
Roosevelt Road at Lake Shore Drive, Chicago, Illinois 60605*

*Abstract.*—Instead of attempting to control the relative humidity in exhibit halls to the levels necessary for the preservation of moisture-sensitive materials, the Field Museum is now using modules to control the humidity within exhibit cases. These modules provide a flexible, relatively simple, and cost-effective means of humidity control. Although modules have only been used for cases containing anthropological artifacts, they have potential for use with natural history specimens as well.

The problem of controlling relative humidity in exhibit halls at the Field Museum is a difficult one. The present building opened in 1921. Like other large museums of this period, Field Museum contains an expansive central hall of approximately one million cubic feet stretching the entire length and height of the building. Large exhibition halls open off this main hall on two levels. All of these public areas are interconnected; only two of the thirty-four exhibit halls are discrete spaces.

Over the past decade, a variety of air conditioning systems have been installed in different parts of the museum. This has made the building much more comfortable for staff and visitors, but has had slight effect on the stability of the collections on display. Even with climate control, the exhibit areas of the museum are much too large for the relative humidity to be controlled to the standards set by the Division of Conservation for the protection of moisture-sensitive artifacts. For example, in the Webber Resource Center, a study hall on the first floor of the museum, the yearly fluctuation of relative humidity ranges between 23% and 77% (Fig. 1). The weekly fluctuation is minimally 4% and has been as great as 25%. Relative humidity levels in other halls, while not exactly the same as in the Webber Resource Center, show similar weekly and yearly fluctuations. Such fluctuations in relative humidity have contributed to the warping, cracking, and splitting of anthropological and biological specimens on display throughout the museum. Skins on mounted bird specimens, for example, are cracked and many teeth on mounted mammals and ethnographic necklaces are split.

In 1986, the Field Museum embarked on a program of major renovation of its exhibition areas. The majority of these projects involved the Department of Anthropology's collections of ethnographic and archaeological materials, a large proportion of which are composed of moisture-sensitive materials, including leather, skin, wood, bone, ivory, and fibers of all kinds. These exhibits involved moving artifacts from the stable environment of a storeroom to a fluctuating environment in an exhibit hall. To solve this problem, the Division of Conservation assisted in the development of a module to control the relative humidity in exhibit cases. To date, the module has only been used in exhibits involving anthropological collections. There is no reason why they cannot be used to control cases containing moisture-sensitive natural history specimens, such as mounted animals, botanical, and some geological materials. The use of these modules

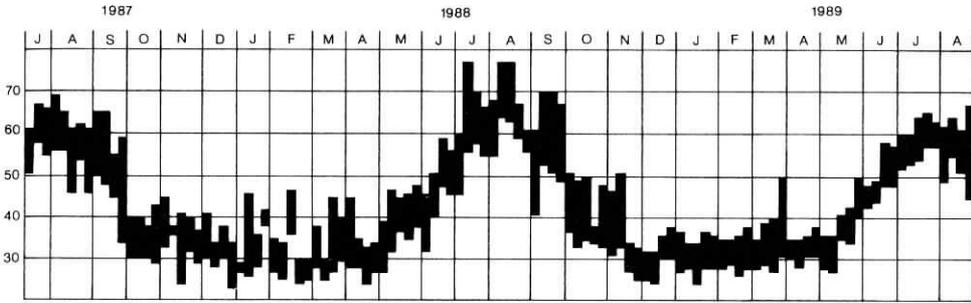


Figure 1. Ambient relative humidity (%) in Webber Resource Center. Each black rectangle represents the weekly fluctuation in the relative humidity.

should become more widespread in natural history museums. These modules can also be used to control relatively small, discrete storage areas.

#### THE RELATIVE HUMIDITY MODULE

The prototype of Field Museum's relative humidity module was designed by Stefan Michalski of the Environment and Deterioration Research Division of the Canadian Conservation Institute (CCI) in Ottawa (Michalski, 1982). Instead of trying to condition the museum as a whole or individual exhibit halls as discrete spaces, this module allows humidity control of just those cases containing moisture-sensitive artifacts.

The relative humidity module is a small, compact, and simple machine that provides low-cost, low-maintenance control of relative humidity in enclosed spaces (Fig. 2). It is a small-scale mechanical control system, featuring a blower, a heat exchanger to keep the conditioned air at room temperature, and a silica gel column to reduce the range of fluctuation in the humidity output of the humidifier or dehumidifier.

Each module measures 20.5 × 22 × 59.5 in. and requires a standard electrical outlet, a plumbed-in source of water, and a drain. The module is easily connected to each case with plastic tubing. A two-inch main supply tube extends from the module with half-inch to one-inch supply tubes branching off it to enter each case. These smaller tubes are sized individually for each case to control the airflow to that case. Exhaust is provided simply by natural leakage through seams in the case.

A single module can be used to control more than one display case. The total volume and the seal of the cases are the deciding factors in determining the number of cases a single module can control. Michalski calculated that one module can control approximately 2,700 cubic feet of air if the cases are reasonably well sealed (Michalski, 1985). This figure was later revised to 3,500 cubic feet (personal communication, Michalski).

Since connecting the module to a case is simply a matter of drilling a small hole and inserting the plastic tubing, installation is not a major job involving significant costs. As a result, the module allows for extreme flexibility in designing and changing exhibition areas. If the contents of a case are changed and no longer require humidity control, the tubing can be pulled out. Existing display cases can

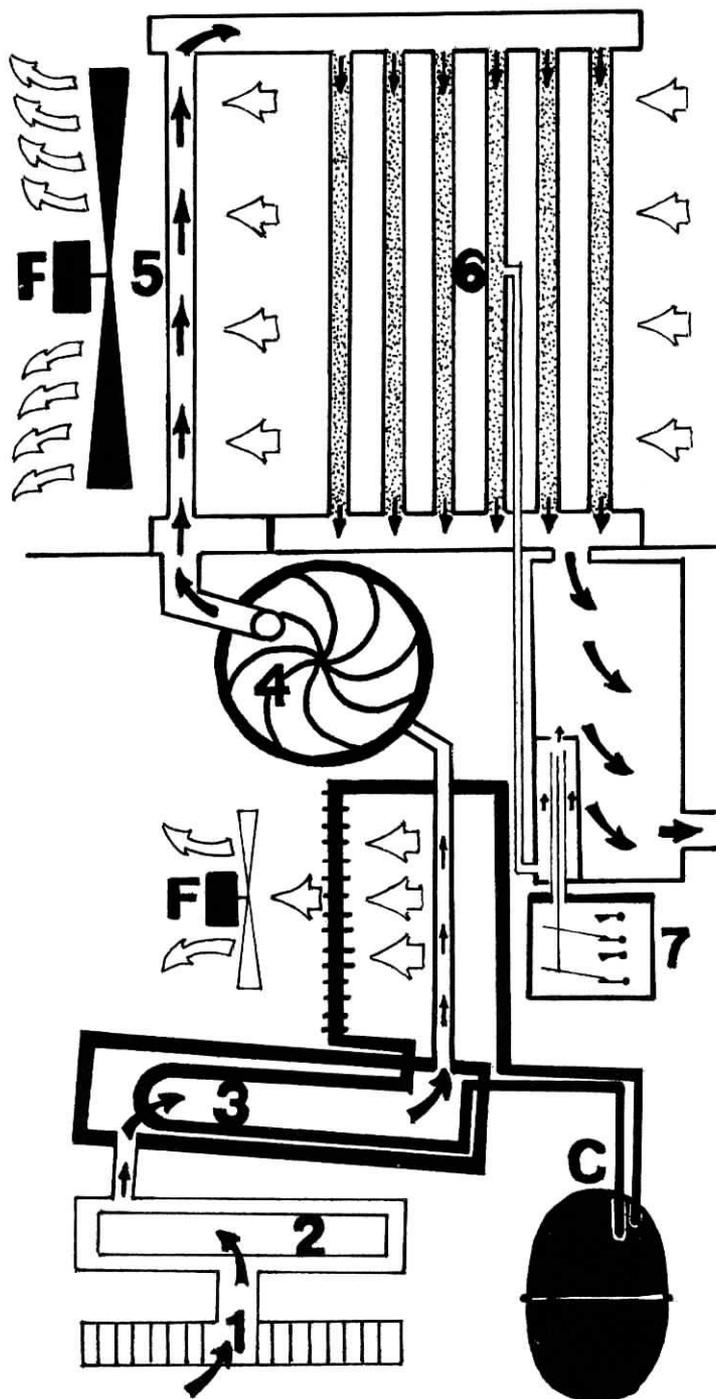


Figure 2. A schematic view of the module. (1) air intake, particulate filter; (2) steam generator; (3) dehumidifier cold box—C = compressor; (4) air blower; (5) heat exchanger; (6) silica gel buffer in heat exchanger; (7) humidistat. Solid arrows indicate the air-stream through module; outlined arrows indicate room air moved by two fans (F). After Michalski, 1982.

be used without costly modification so that it is relatively simple to retrofit the existing cases in an entire exhibit hall.

The module will produce and maintain a level of relative humidity within a range of 30% to 60% with fluctuation around the set point of less than 3% (Michalski, 1985). The humidity output of the module is dependent on the uniformity of the temperature throughout the room in which the cases are placed. The module does not control the temperature of the conditioned air, but rather passively follows the temperature of the room. Therefore, if the temperature inside a case is warmer or cooler than the air surrounding the module, the relative humidity inside that case will be lower or higher than the output of the module. As long as there are no major temperature differences between the inside and outside of the case, however, the system should work well.

One advantage of the module is that, unlike most mechanical systems, it is slow to produce extremely high or low relative humidity levels even if it malfunctions. The silica gel buffer column provides a slow response to a sustained change in the relative humidity. Instead of rising or falling immediately, the relative humidity in the case will gradually move towards the ambient relative humidity. In well-sealed cases, the column acts as a built-in safeguard against the malfunction of the module.

When compared to other methods of humidity control, the module is quite cost-effective. The module costs just \$8,750. Using standard calculations (Thomson, 1977) and the current cost of silica gel, it would take roughly \$18,000 worth of silica gel to control the same volume of air as a single module. There would also be the additional cost of modifying cases to provide drawers or compartments for the silica gel. In such a large building as the Field Museum, even numerous modules are much less expensive than installing an HVAC system capable of controlling individual halls or groups of halls. There would also be the added expense of sealing off the halls into discrete, controllable units.

The advantages of the module are that it is mechanically simple, extremely flexible, able to control large volumes of air, relatively inexpensive, and easy to maintain. It appears to be ideal for museums that cannot consider strict climate control of the whole building, yet have too many cases to make a silica gel buffer system too costly and labor-intensive to maintain.

#### THE FIELD MUSEUM MODULE

In 1987, a local Chicago company, Kennedy-Trimnell, built the first module for the Field Museum from blueprints provided by the Canadian Conservation Institute. Kennedy-Trimnell now produces the modules commercially.

In July 1987, the first module was installed in the Webber Resource Center, a study hall containing North American Indian ethnographic material. Nearly all of the artifacts on display are composed of moisture-sensitive materials, including wood, leather, skin, rawhide, sinew, hair, paper, bone, ivory, and glass trade beads. Prior to this installation, they were housed in a storeroom with a humidity level maintained at  $50 \pm 2\%$ . The module was to maintain the environment in the exhibit cases at the level to which the objects were accustomed.

The module was connected to two large walk-in cases with a combined volume of approximately 3,000 cubic feet. A system of plastic tubing was used to connect the module to the cases. Two-inch polyethylene tubing formed the main supply

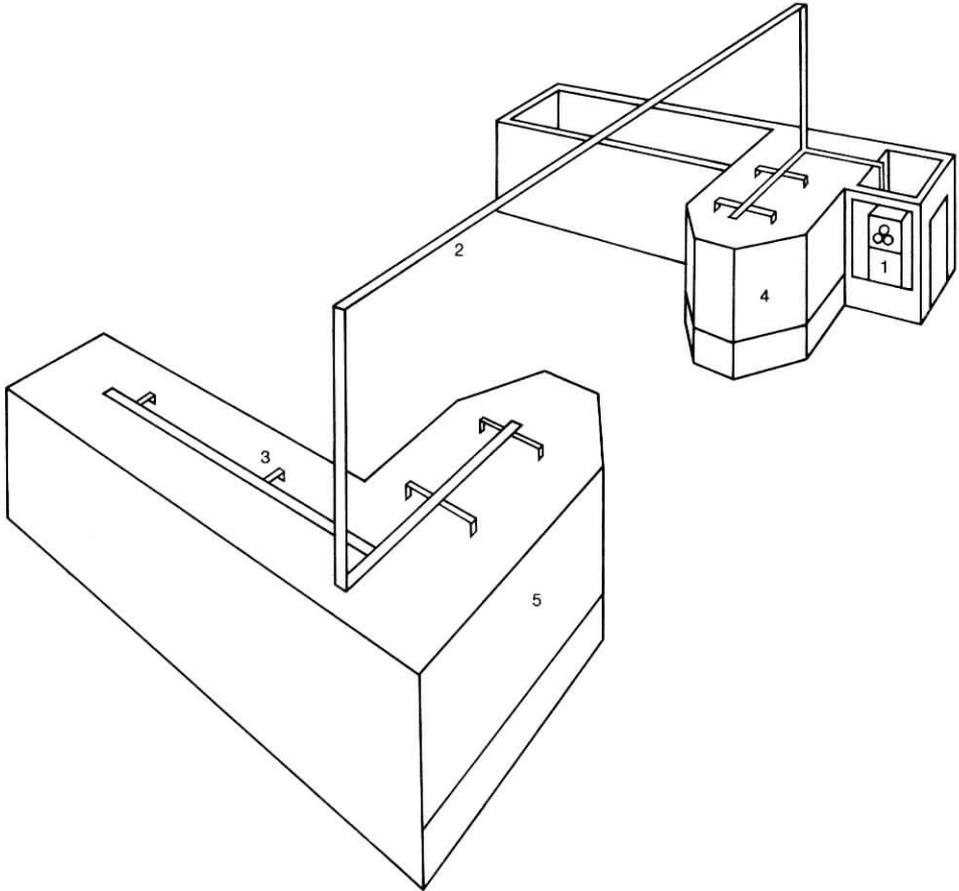


Figure 3. Schematic plan of humidity module installation in Webber Resource Center. (1) module; (2) main feed; (3) branch and drop feeds; (4) north case; (5) south case.

feed from the module to the tops of the cases. The cases face each other across the hall, so it was necessary to suspend a thirty-foot section of this tubing from the ceiling to connect the two cases (Fig. 3). A two-inch supply tube was installed along the length of the top of each case with one-half-inch tubes branching off perpendicularly. These smaller tubes were connected to half-inch holes perforating the ceiling of each case for the entry of the conditioned air. Once the module was installed, these holes were fitted with plastic plugs with openings of various sizes to regulate the air flow throughout the cases.

The module was adjusted to maintain the humidity level in the cases at 50%. Recording hygrothermographs were placed in each case as well as in the hall itself to record the ambient relative humidity. The results can be seen in Figure 4A.

It took the better part of a week for the silica gel column in the module to adjust to its new environment and then to bring the relative humidity in the two cases to the desired level of 50%. Last minute adjustments to the installation requiring staff access to the cases also affected the fluctuation of relative humidity during this first week. In subsequent weeks in July, August, and September, how-

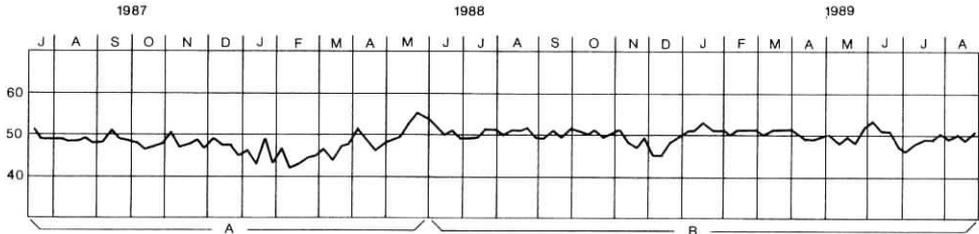


Figure 4. Average relative humidity (%) in the north case, Webber Resource Center. A. before installation of steam generation system; B. after installation of steam generation system.

ever, the machine did well. Through the end of August the relative humidity was maintained to within 2% of the set 50%, within 2.5% until the beginning of October. During this summer period, the machine was in a dehumidification cycle.

The module did not do as well in the subsequent winter months of 1987–88. During this period the ambient relative humidity in the hall averaged 32% with a low of 23%. Nineteen out of the 27 weeks, the humidity dipped below 30%. The module was in a humidification cycle and had to work considerably harder than it did during the summer to maintain 50% relative humidity in the two cases.

Adjustments and minor changes were made to the module in response to the conditions in the exhibit hall and the behavior of the module. As the winter progressed, it became clear that, due to the low ambient relative humidity and problems with the module's design, it was difficult to maintain the relative humidity in the cases at 50%. The average relative humidity in the cases dropped to 46%. Modifications to the original design were necessary to increase the efficiency of the machine.

The most significant modification to the module was the replacement of the evaporative plates with a steam generator as a means of humidifying the air. The steamer system provided more humidity and allowed the centrifugal blower to operate closer to its full potential. This increased potential treated case volume from 3,500 to 5,500 cubic feet.

The steam generator is an electric resistance element in a small metal tray that is located in the air intake (Fig. 5). Water boiled in the tray provides the humidity needed for the system. The water level in the tray is controlled by an auxiliary reservoir with a float switch to maintain the water level. The tray is gravity fed from the reservoir. The steamer currently being used will require replacement roughly every eighteen months.

After the steamer was installed in the last week of May 1988, fluctuations in the relative humidity in the cases decreased to 4% (Fig. 4B). With the exception of a few periods, fluctuations have remained at this level.

The drops in relative humidity, recorded in November and December 1988 and March 1989, occurred when safety switches in the module turned it off, when the fan motor and the solenoid burned out, and when the steamer unit needed cleaning. These problems led to further modifications of the module, the most significant of which was to make the fan self-cooling.

The maintenance of this module has been minimal. Once the steam generator

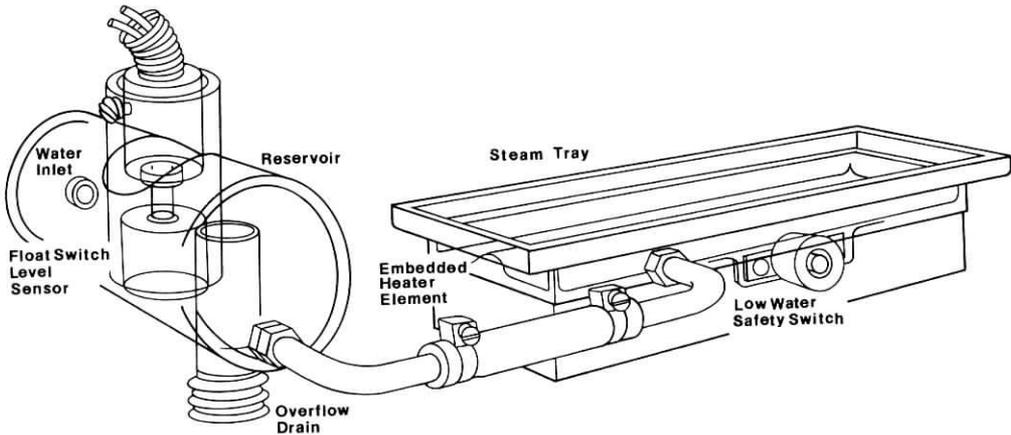


Figure 5. New steamer and float switch assembly.

was in use, the only chronic problem was with the water quality, which will be discussed below.

#### EGYPTIAN EXHIBIT

In November 1988, a renovation of the Field Museum's Ancient Egypt exhibit was opened using three humidity modules. A wide variety of cases were involved, ranging from large walk-in cases to small spaces less than a cubic foot in volume. As these cases were spread out over 15,000 square feet, an elaborate system of piping was needed to connect the cases to the modules. For example, polyethylene tubing was suspended from the ceiling in lengths of up to eighty feet to feed groups of cases.

Conditions in this exhibit area differ from those in the Webber Resource Center discussed above. The exhibit is on the ground floor in an area where there is poor ventilation. From November 1988 through August 1989, the ambient relative humidity ranged from 17% to 70%. The average weekly fluctuation was 15.5%, while in one week the fluctuation was 27%.

Initially, these modules did not perform as well as the first one in the Webber Resource Center. In fact, throughout the winter of 1988–89, it was difficult to get them to produce any humidified air at all. The reason for this had nothing to do with the performance of the modules themselves, but rather with the water supply. Chicago's water is extremely hard. In winter, when modules were humidifying the air, a thick encrustation quickly built up on the steamers. This forced the heating elements to work progressively harder until finally they would switch themselves off.

At first, attempts were made to remedy this situation by cleaning the steamer trays as needed with Lime-A-Way, a proprietary cleaner containing dilute sulfamic, acetic, and citric acids. Cleaning turned out to be a time-consuming and messy job, as each tray required cleaning at least once a week.

The only viable solution found to solve the problem was to connect a deionizer to the water supply of each module. During a humidification cycle, the module required two and a half gallons of water per day. No source of distilled water existed within reach of the modules to provide a plumbed-in source of pure water.

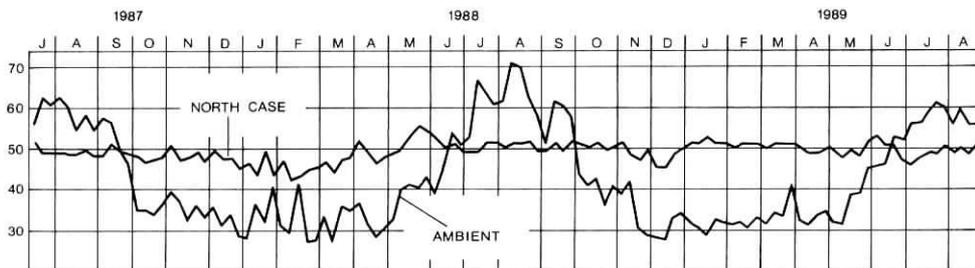


Figure 6. Comparison of ambient and north case relative humidity levels (%) in Webber Resource Center.

Using a nonplumbed-in source of water would have involved (1) modification of the module to provide a reservoir to hold the water and (2) considerable daily maintenance to ensure the reservoir was kept full. A deionizer connected to each module allowed the local water supply to be plumbed-in, keeping maintenance to a minimum. When one of the modules was tested with a deionizer, it worked extremely well, maintaining the relative humidity in its cases at the desired level of  $42 \pm 2\%$ . The steamer tray required no cleaning at all.

In June 1989, deionizers were connected to all three modules in the Egyptian exhibit. They are now working quite satisfactorily, producing the desired relative humidity level of  $42 \pm 2\%$  in the cases.

#### CONCLUSIONS

The module in the Webber Resource Center has been in operation now over two and a half years. Since the switch to the steam evaporator system in May 1988, the relative humidity in its two cases has been consistently maintained at  $50 \pm 2\%$ , excluding the periods with mechanical problems described above. Including these periods, the module has maintained an average of 48% relative humidity. Although there has been some fluctuation within the cases, it has not been as great as that in the hall itself during the same period (Fig. 6). All of the artifacts in the cases are in extremely good condition and no signs of dimensional change have been observed which might result from humidity fluctuations since being in this exhibit.

Since the installation of deionizers to the modules in the Ancient Egypt exhibit in June 1989, the desired levels of  $42 \pm 2\%$  have been maintained. If the water supply is hard, it will be necessary to use deionizers with the humidity modules.

In summary, I am very pleased with the performance to date of the humidity module. The staff of the Division of Conservation believes it has found a workable solution to the problem of displaying moisture-sensitive materials in uncontrolled exhibition areas, and is making a long term commitment to the use of more modules. Five more modules are being installed in the renovation of Field Museum's Pacific halls. It is hoped that they will also be used in non-anthropological exhibits as they are renovated and reinstalled.

#### ACKNOWLEDGMENTS

This project was funded in part by the National Endowment for the Arts (88-4432-0248). I thank Ralph and Sally Trimmell for their help throughout this project, for the drawings in Figures 2, 3, and

5, and for technical information in preparing this paper. Thanks also to Stefan Michalski, Richard Pearson, and Daniel Weinstock without whom this project would not have been possible.

#### LITERATURE CITED

- Michalski, S. 1982. A control module for relative humidity in display cases. Pp. 28-32 in *Science and Technology in the Service of Conservation* (N. S. Brommelle and G. Thomson, eds.). International Institute for Conservation, London, 185 pp.
- . 1985. A relative humidity control module. *Museum*, 146:85-88.
- Thomson, G. 1977. Stabilization of RH in exhibition cases: Hygrometric half-time. *Studies in Conservation*, 22:85-100.

# pH CHANGE IN A FORMALIN BORAX SOLUTION WITH INFERENCES ABOUT USES OF NEUTRALIZED FORMALIN IN VERTEBRATE COLLECTIONS

GRANT W. HUGHES AND JAMES A. COSGROVE

*Royal British Columbia Museum, 675 Belleville Street, Victoria, British Columbia  
V8V 1X4, Canada*

*Abstract.*—Experimental evidence showed that the pH of a formalin solution stabilized with borax decreased during the fixation of fishes. An acidic condition which could affect the calcium content of specimens was reached in some cases. Respondents to a survey on preservation practices indicated that most institutions attempted to neutralize the acidic nature of formalin and that borax was the most commonly used neutralizer. Test results indicate that the pH instability of these solutions necessitates a re-evaluation of the use of borax in attempting to maintain a stable pH through the fixation process.

In many North American vertebrate museums housing fish, amphibian or reptile collections, formalin, a solution of formaldehyde gas in water, is the most common fixative for initially preserving specimens. Due to the acidic nature of formalin, approximately pH 5, concern at many institutions about the possible decalcification of specimens has resulted in the use of buffers or stabilizers to raise the pH above acidic range. A number of different chemicals are used, such as calcium carbonate (as marble chips or dust), sodium phosphate, and sodium borate (borax). Each chemical has different neutralizing or buffering capacities.

The Royal British Columbia Museum procedure has been to stabilize 10% formalin in tap water with borax to obtain a pH of 8 prior to immersion of fresh fish or amphibian specimens for fixation. Spot checks of the pH during fixation showed a marked decrease in pH over time and we became curious about the rate of pH change. To document what was occurring, a controlled experiment was conducted to monitor the pH change of a standardized formalin/borax solution. The objective was to verify that pH was, in fact, reduced as fixation occurred and to determine the rate of reduction. Because the time taken to fix specimens in formalin may vary between researchers, or even collecting trips, clear documentation of pH reduction over time is needed in order to standardize procedures, if acidic pH is to be avoided.

In order to determine if similar traditional but untested procedures were being used by other institutions, a survey was sent to North American fish and herpetology collections managers requesting information on the use of formalin and buffering compounds.

## MATERIALS AND METHODS

Thirty 4-liter jars containing 2.25 liters of 10% formalin in tap water were stabilized to saturation with borax to pH 9.0. This is a saturated solution and therefore the most basic initial condition to counter acidification. The pH of each solution was measured in random order every week for 8 weeks using a Cole Palmer model 5985-75 digital pH wand. pH readings were adjusted for temperature. Three different regimes were set up:

1. 10 jars had a single specimen of bocaccio (*Sebastes paucispinis*) added to the solution on day 1. All fish had been captured in the same haul, frozen, thawed, wiped dry and weighed before being placed in formalin.

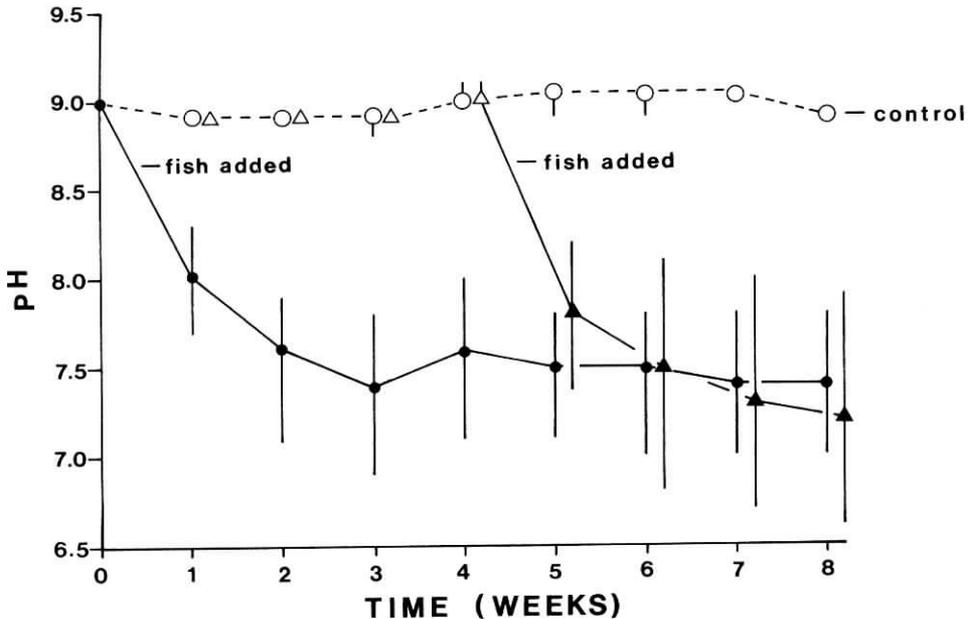


Figure 1. pH of solutions over time. Open points represent samples to which no fish had been added; solid points, samples containing specimens. Vertical bars denote the range of values. Each point represents an average from 10 samples.

- 10 jars had a single specimen of boccaccio added to the solution on day 28. Except for the length of time frozen, these fish were obtained and treated identically to those in series 1.
- 10 jars to which no fish were added served as a control.

Samples were kept under identical room conditions of temperature and light intensity and duration. There was no agitation of the jars throughout the experiment. Although it may have been desirable to run the experiment for a longer period of time, it was felt that 8 weeks fixation was far longer than most scientists fix fish and amphibians, so the experiment was discontinued.

Changes in pH were compared within and between the test series using multivariate analysis of variance to determine if changes were statistically significant.

#### RESULTS AND DISCUSSION

The pH of the "stabilized" fixative solutions decreased over time after fish specimens were added. pH of the control pH solutions remained essentially constant (Fig. 1). There were significant differences between experimental groups and the control ( $P < 0.001$ ) (Table 1). The pH decreased most rapidly when specimens were first added and moderated after approximately three weeks to be essentially stable. Larger fish resulted in a larger pH change than did smaller specimens (Fig. 2). Although the starting of the saturated solution was higher than the fixing pH used routinely in most museums, 3 samples still decreased by at least 2.1 pH units and became acidic before the completion of the experiment. An increase in pH was recorded in all jars during week 4. This was likely due to variability in the pH meter since both the control and experimental samples were affected. However the variation was minor when compared to the change within the experimental jars (0.2 pH units maximum when compared to a minimum decrease of 1.2 pH units in the experimental regime).

Results show that the addition of borax to formalin solutions does not ensure

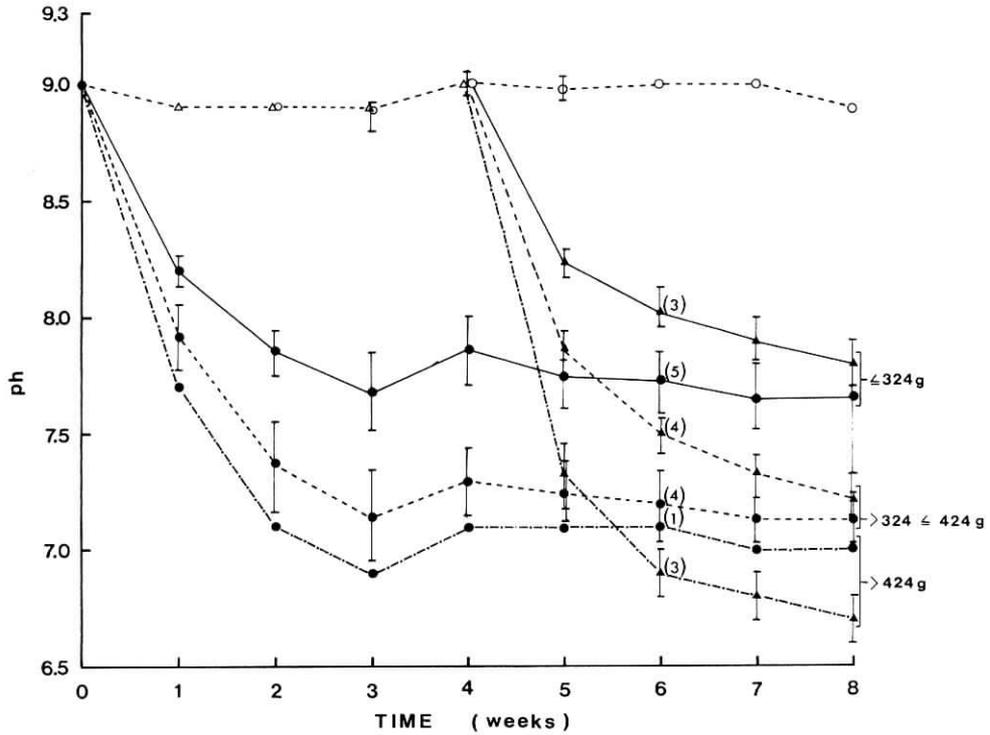


Figure 2. pH change of three weight categories containing fish specimens of the weight noted on graph. Each point is the mean  $\pm$  standard deviation. Numbers in parentheses refer to sample size.

a stable pH when fixing fish specimens such as *S. paucispinis*. This may instead result in an acidic condition during fixation which may cause deterioration of the specimen. Although acidic fixatives have some advantages such as precipitating cell proteins and thereby giving microscopically sharper images of cell proteinaceous structures, hardening latex-injected blood or lymph vessels, and enhancing the stainability of particular tissue or cell structure, they will also start a rapid decalcification of the bones and teeth of the specimen, often causing increased friability (Quay, 1974). Because formalin is well known to be acidic, with acidity

Table 1. Analysis of variance of pH change for the experimental results.

Hypotheses:			
	$H_{01}$ : pH is unaffected by experimental treatment		
	$H_{A1}$ : pH is affected by experimental treatment		
	$H_{02}$ : pH is unaffected by time		
	$H_{A2}$ : pH is affected by time		
Source	F	Degrees of freedom	Probability
Mean	318,486.86	1	<0.001
Treatment	603.03	2	<0.001
Week	75.75	8	<0.001
Interaction (treatment $\times$ week)	39.86	10	<0.001
Error (MS = 0.05856)			

Table 2. Summary of responses for survey concerning use of preservatives and neutralizers in 27 North American museums (number of responses shown in parentheses).

I Collection types	Fish	(25)	Amphibians	(7)	Reptiles	(6)	Total institutions	(27)
II Strength of formalin used	5-10%	(3)	10%	(20)	10-15%	(2)	Not used	(1)
III Neutralizer used	None	(13)	Borax	(9)	Marble chips/dust	(6)	Phosphates	(2)
Amount added	N/A		-teaspoon/L	(2)	-1.8 grams	(1)	-4 g sodium phosphate	
			-20 g/L	(1)	-handful	(1)	monobasic plus 6.5 g	
			-approx 25 g/L	(1)	-10-20 chips	(1)	sodium phosphate	
			-approx tbsp	(1)	-approx 1 spoonful	(1)	dibasic	(1)
			-tbsp by "eye"	(1)	-no answer	(2)	-no answer	(1)
			-variable to saturation	(1)				
			-20 ml saturated solution/L	(1)				
			-no answer	(1)				
pH tested	before use—No	(1)	before use—No	(5)	before use—No	(2)	before use—rarely	(1)
	after use—No	(1)	-weekly	(1)	-monthly	(1)	-no answer	(1)
	no answer	(12)	-monthly	(2)	-rarely	(1)	after use—rarely	(1)
			-no answer	(1)	-no answer	(2)	-no answer	(1)
			after use—No	(5)	after use—No	(3)		
			-monthly	(2)	-rarely	(1)		
			-yearly	(2)	-no answer	(2)		
IV Sources of methodology	Tradition, experience based on consensus		ASIH Curation Newsletter		LACM Collections Care Pilot Training Course		"Follows LACMNH staff"	Lagler's Fishery Biology
Procedures used	-not buffered	(4)	-not buffered	(2)	-not buffered	(1)	-borax 1 tsp/L (1)	-borax (25 g/L) (1)
	-borax (20 g/L)	(1)	-borax (25 g/L)	(1)				
	-borax (tbsp/L)	(1)	-marble chips (1.8 g/L)	(1)				
	-marble chips (handful/L)	(1)	-marble dust (ca. 1 spoonful)	(1)				
	-no response	(12)						

increasing over time, efforts have been made in many museums to counteract this effect.

A survey of formalin use conducted in conjunction with the experiment was sent to 84 ichthyologists or herpetologists to investigate procedures for fixing specimens in formalin and showed that borax is still in use at a number of institutions. Of the 27 institutions responding, there were at least 13 different procedures being conducted. These are summarized in Table 2 and show that, when formalin is buffered, it is buffered with borax in the majority of cases. Possible change in pH is not usually monitored by the institutions responding to the questionnaire. Our experiment showed that borax, a stabilizer still in common use, does not act as a sufficient buffer to stabilize pH.

These data support the work of Taylor (1977) who investigated the stability of borax/formalin solutions and others. In that study, specimens added to saturated borax decreased in pH but stabilized at pH 8.7 when the fish filled 4–5% of the total volume. In this experiment where fish volumes ranged from 10 to 25% of the total volume, the pH was much more reduced (up to 7× the reduction noted by Taylor). This pH change is due to the reaction of specimen with formaldehyde. Freeman *et al.* (1955) also report that 10% formalin neutralized with CaCO<sub>3</sub> to between 7.9 and 9.2 and filtered became acid within three hours of the start of fixation of liver (pH 5.3) and spinal cord tissue (pH 5.6) although unfiltered solutions remained slightly alkaline after a 48 hour fixation period. Continuation of the experiment may have resulted in more changes in pH, such as a slight increase in alkalinity primarily resulting from alkaline body fluids, followed by a slow increase in acidity presumably due to the production of formic acid (Taylor, 1977).

Observations by Taylor and Wayne Starnes (personal communication) indicate that borax, in addition to being a poor stabilizer, is involved in clearing or maceration of specimens if long-term storage of specimens in formalin/borax occurs, especially for small specimens. Therefore, other preservative solutions may need to be used. Other institutions responding to the survey indicate that they use marble chips or dust, or sodium phosphate to stabilize pH. Still others (Table 2) use unbuffered formalin. In most cases, the specimens are transferred from formalin fixatives to ethanol or isopropanol after a few weeks. These combinations of procedures result in the variety of approaches used at the museums surveyed.

Given the cost of fixing and preserving fishes, especially for purchasing stabilizers, it would seem that a re-evaluation of the variety of methods in use is in order. The least costly method would be use of unbuffered formalin so long as the fixation period is not sufficiently long to cause marked decalcification. This is the experience of California Academy of Sciences (D. Catania, personal communication) who stated that "any decalcification that might occur during normal fixation has not been significant in our experience" and the Illinois Natural History Survey (L. Page, personal communication) who stated that "we obtain excellent results and see no reason to buffer the formalin," and may very well reflect the best method.

#### CONCLUSION

Although widely used as a pH stabilizer, borax was found not to stabilize the pH of formalin fixative solutions used to preserve fish. Reports from some mu-

seums also suggest that the use of borax results in clearing and maceration of specimens. Therefore, its use should be re-evaluated. Institutions using buffers should evaluate their effectiveness and then decide whether or not fixation in unneutralized formalin produces acceptable results in the short term and manageable risks in the long term vis-à-vis final storage in alcohol preservatives.

#### LITERATURE CITED

- Freeman, B. L., E. K. Moyer, and A. M. Lassek. 1955. The pH of fixing solutions during fixation of tissues. *Anatomical Record*, 121(3):593-600.
- Taylor, W. R. 1977. Observations on specimen fixation. *Proc. Biol. Soc. Wash.*, 90(4):753-763.
- Quay, W. B. 1974. Bird and mammal specimens in fluid: Objectives and methods. *Curator*, 17:91-104.

# MODIFICATION OF STORAGE DESIGN TO MITIGATE INSECT PROBLEMS

STEPHEN L. WILLIAMS AND SUZANNE B. McLAREN

*The Carnegie Museum of Natural History, 4400 Forbes Avenue,  
Pittsburgh, Pennsylvania 15213*

*Present address for SLW: Natural Science Research Laboratory,  
The Museum—Texas Tech University, P.O. Box 4499,  
Lubbock, Texas 79409-3191*

*Abstract.*—A case study involving a pest infestation is described. Analysis of the problem made it obvious that the use of toxic chemicals in the cases would provide only short-term relief. The source of the infestation was the organic material that accumulated underneath storage cases. The existing storage design actually provided a protected area in which insect pests flourished. To correct the situation, special metal frames with adjustable legs were designed, assembled, and incorporated in the storage design. This modification provided better support for positioning storage units, easy access to areas below cases for cleaning purposes, and better protection against insects. Furthermore, the frames are easily installed, modified, dismantled, and reused.

Control of insect pests in natural history collections is becoming more difficult as chemical methods are restricted by health concerns and legislation. The elimination of insects is particularly challenging when housekeeping measures and locally applied pesticides are ineffective. This situation was encountered with the discovery that accumulations of organic debris beneath the cases provided refuge and nutrients for insect pests.

The Section of Mammals at The Carnegie Museum of Natural History has recognized the problems associated with pest control (Williams and Walsh, 1989a, b; Williams *et al.*, 1985, 1986, 1989). As a result of months of monitoring insect pests in collection areas, analyzing pest control alternatives, and evaluating existing storage designs, the Section of Mammals modified its storage design to promote better housekeeping and case leveling. The following discusses the pest problem and the solution which involved the construction of metal frames to raise storage cases above the floor level. It is believed that this information can be of use to others in developing portions of an integrated pest management program.

## METHODS AND MATERIALS

The project started with an infestation that became evident as insect pests (particularly larvae) were trapped in the lower lip on the inside of the door of some metal storage cases. This entrapment provided a rapid and effective method of monitoring pest levels in the collection. Documentation and analysis of the pest problem were based primarily on monthly inspections when cases were simply recorded as either having or not having pests. All pests were removed from the case using an aspirator. These procedures were followed for 17 months.

An assessment of the pest problem suggested that the source of the insects, especially larvae, was the organic debris beneath the cases. As sets of cases were removed from their initial position, debris beneath the cases was examined for insect signs and then placed in polyethylene bags. The debris was weighed to the nearest 0.1 g with a triple-beam balance. Patterns of debris accumulation were determined by plotting amounts (g/m<sup>2</sup>) on a map of the collection area.

A two-week application of paradichlorobenzene was used to eliminate pests inside the cases. Next, each case was emptied and vacuumed to help eliminate pests and to facilitate movement of the case without risking the safety of objects and personnel. To control pests outside the cases, a method for

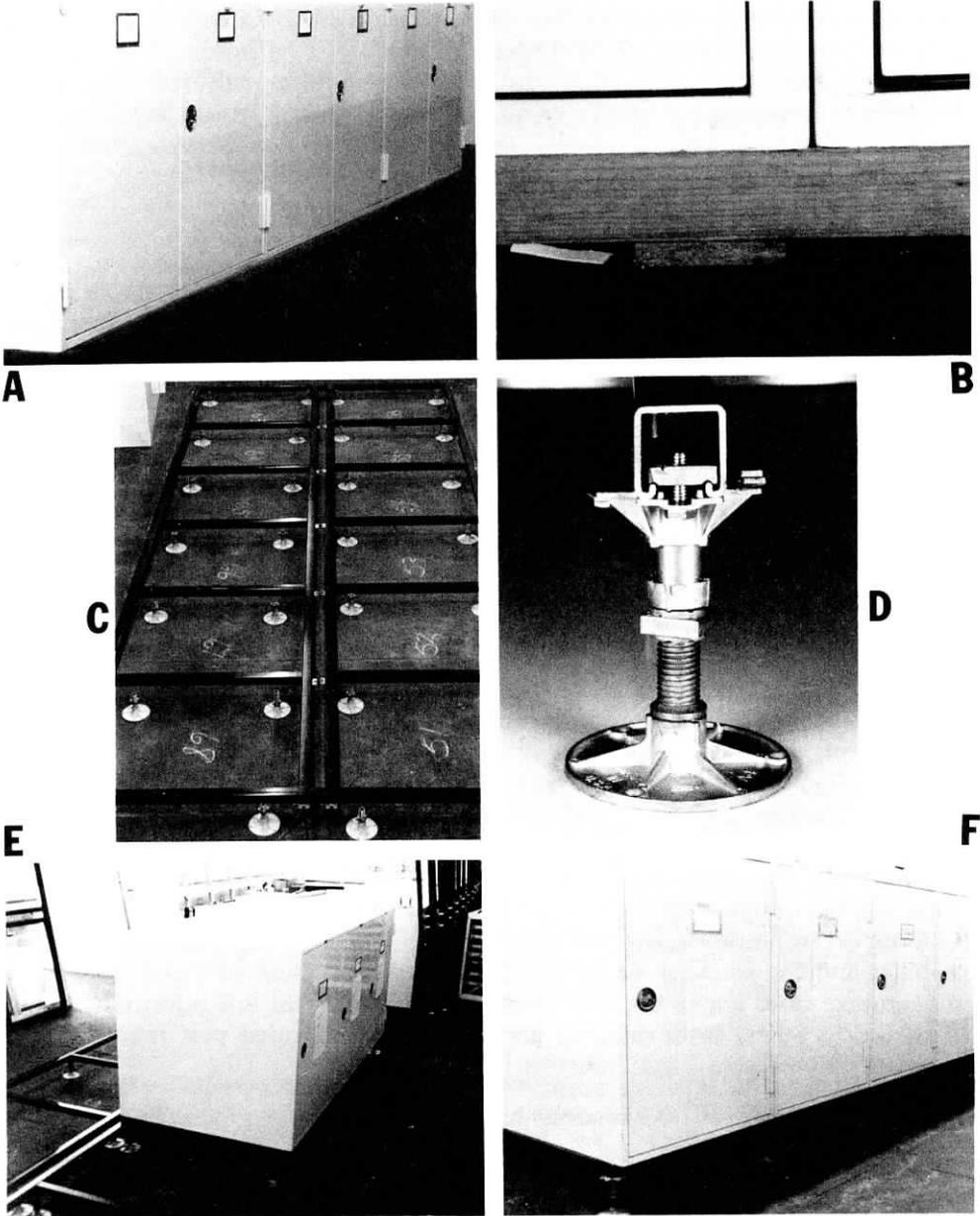


Figure 1. *A.* Storage cases on wooden frames typically used for leveling purposes. *B.* Close-up of wooden frame, showing accumulation of debris in inaccessible areas. *C.* Assembly of metal frame for a series of storage cases (legs are ready to be inserted at Unistrut junctions). *D.* Adjustable aluminum leg (attached to Unistrut) used for supporting metal frames and cases. *E.* Storage cases being positioned on assembled frames. *F.* Completed modification of storage design, showing cases in use on assembled frames.

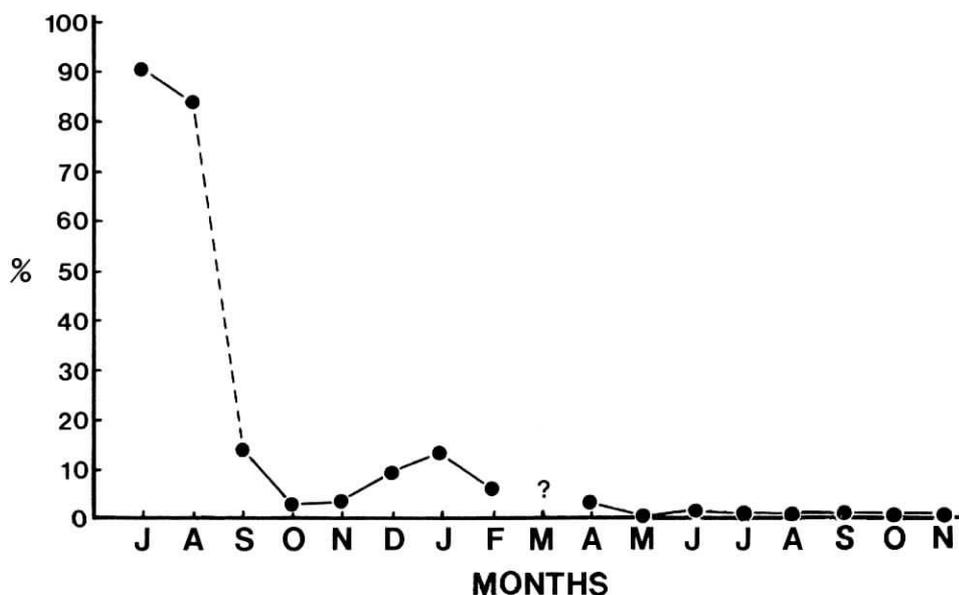


Figure 2. Graph showing the percent of cases next to the floor where live *Thyloglyphus* larvae were removed during a 17-month period. The broken line shows a reduction resulting from a two-week fumigation with paradichlorobenzene. The "?" represents a period when cases were not inspected because they were being placed on frames. During the last eight inspections following the storage modification, the monthly percent of infested cases ranged from 0 to 2.3 (mean = 1.3%).

regularly removing organic debris under cases was required. To meet this need, metal frames with adjustable legs were constructed.

The metal frames were constructed from Unistrut channels (Unistrut Corporation; 35660 Clinton Street; Wayne, Michigan 48184) and supplementary hardware (Fig. 1C). These materials were desirable because they can be used by anyone with a few simple tools (socket wrench, hacksaw, level, tape measure, heavy hammer, and lever), and by being "adjustable, demountable, and reusable," the system is extremely versatile. The Unistrut Corporation also manufactures a variety of supplementary hardware items that make it possible to customize any type of rack for storage purposes. The channel (P 1000) used for this project was made of low carbon, 12-gauge, strip steel coated with an acrylic enamel paint for inhibiting corrosion. There is a continuous slot with inturned lips on one side of the channel. Special slotted nuts fit inside the channel and engage with the lips, making it possible to attach other frame components with connecting bolts. Bolts, washers, and nuts (P 3008) are made of steel, coated electrolytically with zinc. Many Unistrut components conform to ASTM specifications, depending on the material and its intended use (Unistrut, 1988). All materials were ordered from the local Unistrut distributor.

The legs for the frame were three piece die-cast aluminum frame supports (Fig. 1D) consisting of a TA-4 Base, a BE-1 Head, and a TA-10 Stud (Access Flooring Supplies, Inc.; 52 E. Centre Street; Nutley, New Jersey 07110). The stud is threaded for a square nut, the latter of which serves as the height adjusting mechanism of the frame. When assembled, the leg with the Unistrut channel provides adjustable heights between 15.3 cm and 19.8 cm. If additional height is needed, the TA-3 and TA-9 can be used.

Unistrut channel was cut to in-house specifications for constructing frames suitable for the storage cases. The primary components of the frame were two channels extending the length of the row of cases. Although 20-ft lengths of Unistrut channel can be acquired, such lengths can be difficult to handle. Shorter sections of channel were placed between and perpendicular to the two primary channels so that the depth of the frame was about 10 cm less than the depth of the case. This allowed the front and back of the case to hang over the frame, thus promoting easy and attractive positioning, as well as potentially providing a better barrier against insects. If cases are set back-to-back, it may be desirable

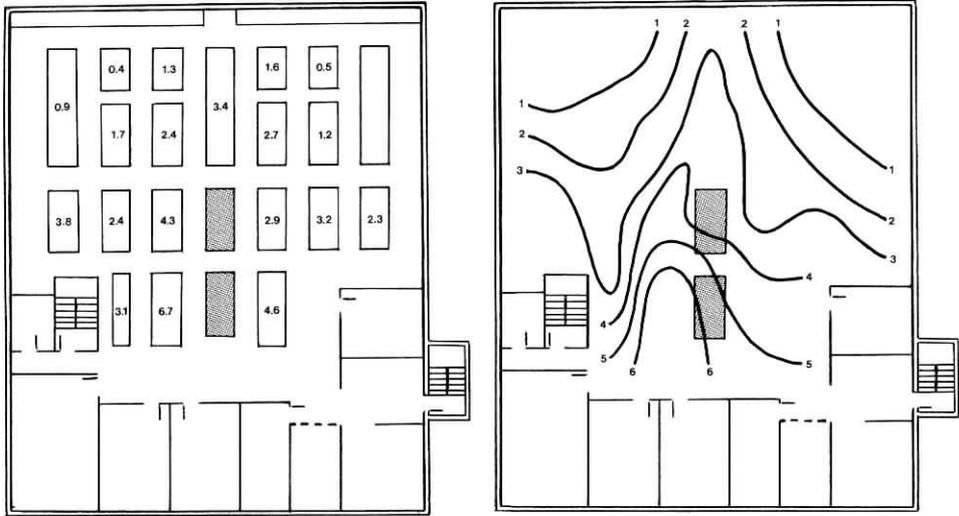


Figure 3. Diagram showing the relationship of debris accumulations under cases and primary work areas in the collection. *Left.* Amounts of debris ( $\text{g}/\text{m}^2$ ) collected under sets of cases. *Right.* Delineation map based on values in Figure 2A and superimposed over the collection area. The stippled areas represent tables where activities in the collection area are concentrated.

to use two longer pieces of channel at the ends to connect the two rows of frames together. At least 10 cm should be allowed between the two frames to keep the leg platforms from overlapping.

One individual can easily assemble a frame for 12 quarter-unit cases within 30 minutes. The weight of the Unistrut frames will vary according to case specifications. We found that framing for standard quarter-unit cases (Jackson, 1926) weighed about 30 kg for four units, or an average of 7.5 kg/quarter-unit equivalent. The cost of the framing per storage unit was approximately the cost of a drawer for the case.

## RESULTS

The primary insect pest observed in the storage cases was the larvae of the odd-dermestid beetle (*Thyodrias*), but occasionally adult red-legged ham beetles (*Necrobia*) and larvae and adults of two types of carpet beetle (*Anthrenus*) were also found (see Kingsolver, 1988). Inspections indicated that the storage cases most apt to be infested by larvae were those next to the floor. Examination of debris from underneath the cases revealed numerous larval exoskeletons and some live larvae. In July 1988, it was discovered that at least 90% of the cases on the floor contained live *Thyodrias* larvae (Fig. 2). Surveillance of the problem and removal of pests provided little relief.

In September, the collection was fumigated for two weeks with paradichlorobenzene; based on a follow-up inspection, it was estimated that at least 80% of the pests were killed by the treatment. Surveillance during the next few months showed that the number of infested cases gradually increased. By January, the percent of infested cases had increased to 12.9. There was a reduction of numbers in February, presumably caused by activity being retarded by cooler temperatures (19.6–20.8°C versus the normal 22.0°C). During March and part of April, the metal frames were assembled and the cases were vacuumed and replaced on the frames. The inspection at the end of April revealed that the number of infested

cases dropped to 2.3%; subsequent inspections had percentages of 1.4 or less (Fig. 2).

To develop an appreciation of the debris accumulation, the number of grams per square meter was determined for areas beneath sets of cases. Plotting quantities of debris showed the largest accumulations occurred near work areas (Fig. 3).

#### DISCUSSION

Perhaps the most significant finding in the current study was how futile the use of pesticides in the collection would have been. As with many pesticide applications in museums, the treatment is only for the symptoms and not the problem. By carefully examining the storage design, it was possible to make modifications that were equally, if not more, effective than the use of pesticides. The advantage to the non-chemical method of pest control is that it addressed the problem and is expected to have longer lasting benefits. However, it is not proposed that modification of storage design alone will solve pest problems. Instead, such modifications are best suited as a partial contribution to an integrated pest management program for the collection. Good storage design, good housekeeping, and good work-habits are all fundamental parts of any successful integrated pest management program.

For pest control purposes and general cleanliness, it is important that areas for eating, packing and shipping, and other routine collection activities be isolated from collection storage areas. It is equally important that doors to cases always be kept closed except when specimens are being removed or installed and that specimens not be left outside of cases unattended. Because this study showed that an infestation may grow even during the colder parts of the year, it is important that all pest control measures be instigated on a year-round basis.

Assuming that good work habits are already part of the collection management policy, there is still a need to be aware of the limitations of individual storage units. The consumer has the responsibility to inspect all storage units, use them properly, provide proper care, and notify the manufacturer of any problems encountered. With consumer guidance, manufacturers can improve products needed for collection care.

#### CONCLUSIONS

Considering the problems associated with the use of pesticides, such as health hazards, liability, and materials interactions, there is a need for identifying other methods of controlling insect pests in museums. The current study demonstrated the value of incorporating modifications in storage design to mitigate pest problems.

#### ACKNOWLEDGMENTS

The authors extend their appreciation to Drs. James King and Duane Schlitter for reviewing the manuscript; to George Long and Michael Stroz for assisting with moving storage units onto frames; to James Welsh (Unistrut Corporation) for assisting with designing frames.

#### LITERATURE CITED

- Jackson, H. H. T. 1926. The care of museum specimens of Recent mammals. *Journal of Mammalogy*, 7(2):113-118.

- Kingsolver, J. M. 1988. Illustrated guide to common insect pests in museums. Pp. 53–81 in *A Guide to Museum Pest Control* (L. A. Zycherman and J. R. Schrock, eds.). Foundation of the American Institute for Conservation of Historic and Artistic Works and Association of Systematics Collections, Washington, D.C., xi + 205 pp.
- Unistrut. 1988. Unistrut. General Engineering Catalog, 11:1–126.
- Williams, S. L., and E. A. Walsh. 1989a. The effects of DDVP on the life stages of a museum insect pest. Pp. 34–41 in *Developing strategies for chemical pest control in museums*. *Curator*, 32(1): 34–69.
- . 1989b. Behavior of DDVP in storage cases. Pp. 41–49 in *Developing strategies for chemical pest control in museums*. *Curator*, 32(1):34–69.
- Williams, S. L., H. H. Genoways, and D. A. Schlitter. 1985. Control of insect pests in Recent mammal collections. *Acta Zoologica Fennica*, 170:71–73.
- Williams, S. L., C. A. Hawks, and S. G. Weber. 1986. Considerations in the use of DDVP resin strips for insect pest control in biological research collections. Pp. 344–350 in *Biodeterioration 6* (S. Barry, D. R. Houghton, G. C. Llewellyn, and C. E. O'Rear, eds.). CAB International Mycological Institute and The Biodeterioration Society, London, xv + 691 pp.
- Williams, S. L., E. A. Walsh, and S. G. Weber. 1989. Effects of DDVP on museum materials. Pp. 49–69 in *Developing strategies for chemical pest control in museums*. *Curator*, 32(1):34–69.

# COLORING LABELS FOR TYPE SPECIMENS

J. GISBERT AND R. GARCIA-PEREA

*Museo Nacional de Ciencias Naturales, C/ J. Gutierrez Abascal, 2,  
28006 Madrid, Spain*

*Abstract.*—As an extension of research on labeling papers and inks (Williams and Hawks, 1986; Walker, 1986; Gisbert *et al.*, 1987), we have tested labels made with Tyvek® and cotton rag papers impregnated with red and blue Rotring® permanent ink. The ink remained stable on the paper after a 15-month-long test period, and appeared to be unaffected by natural or artificial light, whether the labels were dry or in a 70% ethanol solution.

Museum specimen labels are at least as important as the specimens themselves, because they contain essential information. For this reason, the materials used for labels should be carefully selected to resist the effects of handling and exposure to fluids and fumigants (Hawks and Williams, 1986). In addition, labels for type specimens are often colored red for holotypes or blue for paratypes, following traditional practice. However, most inks change color under normal museum storage conditions, and thus are not practical for long-term coloring of type specimen labels, as they may affect the specimens. We present here results of experiments with permanent colored inks for type specimen labels.

## MATERIALS AND METHODS

We dyed Tyvek® synthetic paper (E. I. DuPont de Nemours Co., USA), which we have used for labeling purposes (Gisbert *et al.*, 1987, 1990), and cotton rag paper with blue and red Rotring® ink, a permanent ink recommended by Williams and Hawks (1986). Both blank labels and labels previously inscribed with black Rotring® ink were tested.

The red and blue ink was applied on both sides of each label with a brush. After it had dried for 1 hr, the operation was repeated. Once the colored ink dried again, the blank labels were inscribed using either black Rotring® ink or printer ribbon ink. The Tyvek® samples were embossed using an Epson® dot-matrix printer (Gisbert *et al.*, 1987).

The completed labels were compared with a color guide and their colors were recorded. The labels were divided into two experimental groups—one group was maintained dry, the second group was immersed in a 70% ethanol solution. Each group was again divided and exposed to either natural light (through a window) or artificial light. The test labels were monitored for 15 months, by comparing them with the color guide.

## RESULTS AND DISCUSSION

The color of the test labels under all experimental conditions remained unaffected during the 15-month period. There was no difference in the permanence of the ink between the cotton rag and the Tyvek® test labels. The inscriptions on the labels impregnated with the red ink were legible, whether they were applied before or after the color treatment of the label. The blue ink, on the other hand, was so dark that the inscription in black ink applied after the label was color treated was not legible.

We recommend further experiments to confirm the long-term stability of ink-impregnated labels under a variety of conditions. We also recommend further experimentation with blue inks to achieve a tone that will enhance the legibility of the inscribed data.

## ACKNOWLEDGMENTS

We thank Casanovas y Roca S.A., representatives of Rotring in Spain, for providing inks for our experiments, and Iberia Spanish Airlines for their cooperation. We also thank B. Thomas for the English translation and C. J. McCoy for his suggestions.

## LITERATURE CITED

- Gisbert, J., R. Garcia-Perea, and F. Palacios. 1987. (Abstract). Use of TYVEK® synthetic paper for labelling in vertebrate collections. *Collection Forum*, 3(1-2):31.
- . 1990. Labeling vertebrate collections with TYVEK® synthetic paper. *Collection Forum*, 6(1):35-37.
- Hawks, C. A., and S. L. Williams. 1986. Care of specimen labels in vertebrate research collections. Pp. 105-108 in *Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections* (J. Waddington and D. M. Rudkin, eds.). Life Sciences Misc. Publ., Royal Ontario Museum.
- Walker, S. 1986. Investigation of the properties of TYVEK pertaining to its use as a storage material for artifacts. *International Institute for Conservation—Canadian Group Newsletter*, 12(1):21-25.
- Williams, S. L., and C. A. Hawks. 1986. Inks for documentation in vertebrate research collections. *Curator*, 29(2):96-108.

## LABELING VERTEBRATE COLLECTIONS WITH TYVEK® SYNTHETIC PAPER

J. GISBERT, F. PALACIOS, AND R. GARCIA-PERIA

*Museo Nacional de Ciencias Naturales, C/ J. Gutierrez Abascal, 2,  
28006 Madrid, Spain*

*Abstract.*—The special properties of Tyvek® synthetic paper make it very suitable for labeling vertebrates in many circumstances—collecting, processing, storage of dry skins and skeletons, and fluid-preserved specimens. Tyvek® paper will withstand most of the mechanical and chemical processes used on vertebrate specimens (fixation, boiling, maceration, staining, degreasing). It is also resistant to the most commonly used fumigant substances. This paper may be written on by hand, typewriter, or dot-matrix printer, with the advantage that the imprint remains embossed permanently.

Around 1972, the Spanish manufacturers of the technical drawing paper we had been using to label our vertebrate collection changed from cotton fiber to cellulose fiber. The new paper softened and fell apart in liquids used for specimen preservation. In 1974, as a consequence of a search for a suitable substitute, we acquired a roll of Tyvek® synthetic paper. We have obtained excellent results with this product over the last 14 years for all labeling processes in specimen collection, preparation and storage. Since we are aware that many institutions have not resolved their label problems, we have summarized the characteristics, advantages, and disadvantages of this paper for specimen processing (Table 1).

*Description of material.*—Tyvek® is a synthetic paper made of pure polyethylene fibers manufactured by DuPont (E. I. DuPont de Nemours Co., Textile Fibers Division, Richmond, Virginia 23261 USA). It is commercially available in different gram weights. We use type 1056.D (54 g/m<sup>2</sup>), series 10. It is light weight (lighter than other papers of the same thickness), highly resistant to tearing, easy to cut and perforate, and very economical.

*Uses.*—Tyvek® has proven ideal for long-term storage of specimens in standard preserving and fixing fluids (70% ethyl alcohol and 10% formaldehyde) and under freezing conditions, including with liquid nitrogen. In the process of preparing skeletons, Tyvek® paper has been successfully used during maceration, chemical cleaning (boiling with tap water and sodium perborate, ammonium hydroxide and potassium hydroxide treatment), degreasing (carbon tetrachloride, ethylene trichloride and gasoline) and bleaching (hydrogen peroxide and sodium hypochlorite).

It is also unaffected by skin tanning processes utilizing salt and potassium aluminum sulfate or with commercial preparations. Fumigation of the collection has indicated the resistance of Tyvek® paper to a mixture of carbon tetrachloride and ethylene dichloride, as well as to paradichlorobenzene. We have also used it during tissue preparation and found it to be stable in 5% nitric acid, xylol, toluol, paraffin, chloroform, acetic acid, and Bouin's fixative, although labels stain yellow with picric acid. It is resistant to all conventional detergents.

*Marking.*—Tyvek® synthetic paper can be written on with any of the standard procedures—India ink, ballpoint pen, pencil, typewriter, or dot-matrix printer. However, an important feature is that it can be easily embossed by writing with a hard pencil, fine point ballpoint pen without ink, or a typewriter or dot-matrix

Table 1. Results of using Tyvek paper for different processes commonly used in the management of vertebrate collections, based on 14 years of experience.

Type of material and labeling	Processes and applications	Resistance and results	Drawbacks	Time of use			
Fresh materials Temporary labeling	Complete specimens	Good	None	Different periods			
	Skins	Good	None	Different periods			
	Viscera	Good	None	Different periods			
	Frozen material	Good	None	Different periods			
	Frozen in liquid nitrogen	Good	None	Periods of 6 months			
Materials in process Temporary labeling	Processes with fixatives	Formaldehyde solutions (any percentage)	Very Good	None	14 Years		
		A.F.A. (Alcohol, Formaldehyde, Acetic acid)	Very Good	None	Different periods		
		Bouin's (Formaldehyde, Picric acid)	Good	Yellows	Different periods		
	Processes for cleaning skeletal material	Live organisms	Bacteria (Maceration)	Good	None	Periods of 12 months	
			Dermestids	Poor	Eaten		
		Chemicals	Boiling H <sub>2</sub> O	Good	None	Periods of 12 hr	
			Boiling H <sub>2</sub> O + NaBO <sub>3</sub>	Very Good	None	Periods of 12 hr	
			Treatment with KOH	Very Good	None	Periods of 60 min	
			Treatment with ammonia	Very Good	None	Periods of 24 hr	
		De-greasers	Carbon Tetrachl. CCl <sub>4</sub>	Very Good	None	Periods of 30 days	
			Trichloroethyl Cl <sub>2</sub> C=CHCl	Very Good	None	Periods of 30 days	
		Bleachers	H <sub>2</sub> O <sub>2</sub>	Good	None	Periods of 24 hr	
			Sodium hypochlorite	Good	None	Periods of 24 hr	
		Skin tanning processes	Chemicals	Industrial processes	Good	Wrinkles	Different periods
				Salt + Potassium Alum	Very Good	None	During 14 years
Histological processes	Chemicals	Nitric acid 5% HNO <sub>3</sub>	Good	None	Different periods during histological processing		
		Xylol	Good	None			
		Toluol	Good	None			
		Paraffin	Good	None			
		Chloroform	Good	None			
Skin washing processes	Chemicals	Acetic acid CH <sub>3</sub> COOH	Good	None	In washing processes		
		Commercial soaps	Good	None			
		Commercial detergents	Good	None			
Drying processes	Ovens	Enzyme detergents	Good	None	Different periods		
		Less than 100°C	Good	None			
		More than 100°C	Poor	Shrinks			

Table 1. Continued.

Type of material and labeling	Processes and applications	Resistance and results	Drawbacks	Time of use
Processed materials Permanent labeling	Materials in preserving fluids → Vertebrates Ethyl Alcohol (any graduation)	Very Good	None	During 14 years
	Dry materials → { Study skins Skeletal materials	Good	None	During 14 years
		Good	None	During 14 years
	Processes of fumigation → Gases	Carbon Tetrachloride	Very Good	None
CCl <sub>4</sub>				
Ethylene Dichloride		Very Good	None	Different periods
CH <sub>2</sub> Cl-CH <sub>2</sub> Cl				
	Paradichloro-benzene	Very Good	None	During 8 years

printer without ribbon. The inscription is permanent and can be read directly or with raking light since the embossed letters become transparent. For normal labeling purposes, we recommend the use of a hard pencil (no. 4) because it offers the double possibility of being legible as conventional writing and by transparency and because the mark it leaves does not obscure the embossed impression.

*Disadvantages.*—We have observed several drawbacks, although none are excessive. Long periods of exposure to the elements (more than five years under outdoor conditions) make the paper fragile so that it breaks easily. Intense handling or use in processes like skin tanning causes it to wrinkle, although the embossed text remains legible. Small labels tend to slip when filled out on a smooth, polished surface. Dermestids can destroy the label. The paper shrinks in drying ovens at more than 100°C.

*Note.*—Since this paper was first submitted for publication, three other papers have appeared dealing with Tyvek® paper as a labeling medium. These papers (Walker, 1986; Jewett, 1987; Guelpen *et al.*, 1987) do not invalidate our findings.

#### ACKNOWLEDGMENTS

We thank B. Thomas for the English translation and Iberia Spanish Airlines for their cooperation.

#### LITERATURE CITED

- Jewett, S. L. 1987. Byron Weston Resistall Ledger and other papers used for labels in aqueous preservatives. *Curation Newsletter*, No. 9:1-2.
- Van Guelpen, L., J. F. McElman, and K. J. Sulak. 1987. Additional label papers for specimens in aqueous preservatives. *Curation Newsletter*, No. 9:3-4.
- Walker, S. 1986. Investigation of the properties of Tyvek pertaining to its use as a storage material for artifacts. *The International Institute for Conservation—Canadian Group Newsletter*, 12(1): 21-25.

# AN INDELIBLE PRINTING SYSTEM FOR PERMANENT RECORDS IN NATURAL HISTORY COLLECTIONS

F. PALACIOS AND J. GISBERT

*Museo Nacional de Ciencias Naturales, C/ J. Gutierrez Abascal, 2,  
28006 Madrid, Spain*

*Abstract.*—In an attempt to solve some of the problems of data recording systems (file cards, labels and catalogs) in natural history collections, such as the short life of standard typewriter or printer ribbon inks, the slowness of hand entries using indelible inks, the potential difficulty in interpreting handwritten data, and the poor legibility in fluids of labels embossed on synthetic paper without ink, we have successfully experimented with an indelible printing system. We impregnated standard nylon ribbons with Rotring® ink after eliminating the original ink with ethyl alcohol and hand soap. These ribbons can then be used in typewriters or dot-matrix printers with natural or synthetic paper. Ribbons can be conserved by wrapping them in plastic film and storing them at 4°C. This system is inexpensive and produces high quality, rapid printing, which makes it very practical for use in museum collections.

The two procedures used by most institutions for cataloging natural history collections, handwritten data entries using indelible inks and typewritten or printed data entries using limited-life inks, present different problems. Handwritten entries are extremely slow and therefore costly. Moreover, these entries are fraught with serious problems of interpretation for specialists who study the collections, leading to constant rechecking of the entries or non-utilization of data when it is illegible or equivocal. As for typewritten or printer generated systems, the fundamental drawback is that commercially available inks (black smoke pigment in an oil base) have a limited lifespan, which is inadequate for collection purposes.

Our own cataloging requirements led us to investigate a functional and long-lasting system within the constraints of our limited personnel and other resources. We concluded that a system combining the advantages of automatic data processing and indelible records would be the best solution, both economically and technically. We have obtained satisfactory results by printing on natural fiber and synthetic papers using indelible ink ribbons with a dot-matrix printer.

## MATERIALS AND METHODS

Commercially-marketed nylon ribbons were used. The ribbon was removed from the cartridge and washed two times in 96% ethyl alcohol to eliminate most of the ink. Residues were removed by washing the ribbon several times with water and hand soap. After air-drying, the ribbon was re-introduced into the cartridge and uniformly coated with ink by hand on the outer side of the ribbon using a cotton swab soaked in indelible black ink. The ink used was black Rotring® ink, as recommended by Williams and Hawks (1986) for general collection documentation use. The inking process can be speeded mechanically with a variable-speed bidirectional hand drill connected to the winder socket of the cartridge. Once the ribbon is impregnated, excess ink is removed with a soft dry cloth until no liquid film is visible on the ribbon. Dried-out, used ribbons can be easily recycled by repeating the inking procedure. We conserved some ribbons for future work by wrapping them in plastic film and refrigerating them at 4°C. They can also be conserved at room temperature by wrapping them in a damp cloth with the exposed part of the ribbon protected by a plastic film.

For the test, two small dot-matrix printers were used, one with a large ribbon cartridge containing a 5 m × 1.3 cm ribbon and the other with a compact cartridge containing a 5 m × 0.8 cm ribbon. The exposed part of the ribbon was 26 cm and 5 cm long in the respective cartridges.

### RESULTS AND DISCUSSION

This system has yielded normal (pica 10 and 12) and condensed print of good quality and color intensity, and is acceptable for records normally used in the documentation of modern natural history collections (such as specimen labels, taxonomic and geographic files, and catalog pages) on both natural fiber and synthetic papers.

The maximum output of ribbons during continuous printing was achieved by printing approximately the first 70% of the total using single-strike printing and the final 30% using double-strike printing. The number of words with a clear impression was approximately 10,000 for compact cartridges and 5,000 for large cartridges. Using only double-strike printing is preferable for collection records because of the better quality of printing, although, if excess ink is not removed from the ribbon after inking, the first part of the double-strike printing can smear with the second pass of the printer head.

System output seems to depend much more on the drying rate of the ribbon during the printing than on the amount of ink used. Thus, compact cartridges with a short exposed part of the ribbon dried more slowly and consequently had a better output than large cartridges with a long exposed part. However, the ribbons dampened with a solvent had an output similar to that of newly inked ribbons. We thus recommend that printers equipped with compact cartridges be used for collection work.

In addition to black Rotring® ink, other colors can be used for special purposes, such as red or blue on white paper to indicate type material.

### SUMMARY

The method described is useful for processes of automated cataloging of collections because of the considerable time savings. It also makes possible in-house generation of forms for file cards, labels and catalog pages, which are only available commercially in indelible ink as a special order. Due to its simplicity, the system is within the reach of any institution with the hardware and software for cataloging collections.

### ACKNOWLEDGMENTS

We thank Mariam Ali for assisting with the microcomputer tests, B. Thomas for the English translation, and C. J. McCoy for reviewing the manuscript and helpful criticism. We are also grateful to Iberia Spanish National Airlines for providing flights to our research team.

### LITERATURE CITED

- Williams, S. L., and C. A. Hawks. 1986. Inks for documentation in vertebrate research collections. *Curator*, 29(2):96-108.

## BOOK REVIEWS

**AN ANNOTATED BIBLIOGRAPHY ON PREPARATION, TAXIDERMISTRY, AND COLLECTION MANAGEMENT OF VERTEBRATES WITH EMPHASIS ON BIRDS, 1989, S. P. Rogers, M. A. Schmidt, and T. Gutebier** (Carnegie Museum of Natural History, Special Publication No. 15, Pittsburgh, PA, 189 pp.). This annotated bibliography is aimed at preparators of vertebrate specimens, whether of research material or of taxidermied mounts for education and display. The emphasis, as stated in the title, is on birds. A total of 1,231 references are given; essentially all of these are annotated, and the annotations are at times extensive (up to about 100 words). Sections of the bibliography range from the very general ("Museums and Collecting," "Bird Taxidermy," "Historical Preparation") to the very specific ("Fluid Specimen Preparation," "Washing, Degreasing, Relaxing and Remaking of Skins," "Post-Mortem Changes in Skin Measurements"). Extensive, though less exhaustive, searches of the non-English literature yielded 145 references in other languages; these are listed and annotated in a separate section at the end of the work. An author index concludes the work.

The hard work and critical insight that went into the preparation of this bibliography is evident throughout. This work will be invaluable to anybody searching to refine techniques of preparing bird specimens for research or for exhibition. A reprint collection based on this bibliography would be an excellent and often-consulted adjunct to a preparation laboratory library (I've already begun one at my institution, inspired and aided by this work). The usefulness of this publication goes beyond the needs of the preparator or taxidermist. Collection Managers and those charged with the preservation of bird and other vertebrate collections will wish to consult this bibliography for a number of reasons. Foremost, for collection care professionals, are the sections of the bibliography that go beyond actual preparation procedures: "Labeling Specimens and Field Notes" (25 citations), "Collection Management and Conservation" (33 citations), "Feather Structure and Conservation" (13 citations), "Fumigation, Preservatives and Mothproofing" (25 citations), "Post Mortem Changes in Skin Measurements" and "Post Mortem/Preparation Changes in Color" (23 citations), "Mammal Preparation and Collection Management" (43 citations), "Preparation and Collection Management of Lower Vertebrates" (27 citations), "Materials for Vertebrate Collections" (11 citations), "Vertebrate Research Collections" (11 citations), and "Bibliographies on Preparation and Collection Management" (21 citations).

Prospects for the long-term preservation of vertebrate collections depend, ultimately, on two things: the treatment, storage, and care of specimens in the past, and how these are handled in the future. This annotated bibliography will help those charged with collections care to investigate past treatments, techniques, and materials used in specimen preparation. Such knowledge will allow an informed analysis of the present ramifications of these prior treatments. The compilers of this work do not "certify" the conservation-worthiness of the techniques and suggestions put forth in the included papers, although many of the annotations are of a helpfully critical nature. Within this compilation is a comprehensive coverage of ideas and methods for specimen preparation and collection management. It is up to those of us who work with collections to extract and employ

these techniques thoughtfully and critically, with the long-term preservation of the specimens as a foremost guiding goal.

This bibliography is an important and critical addition to the libraries of all vertebrate collections, as well as those of individual preparators and taxidermists. Such an ambitious effort is certain to be incomplete, and the authors welcome additional citations.

This publication may be ordered from the Publications Secretary, Carnegie Museum of Natural History, 4400 Forbes Ave., Pittsburgh, PA 15213-4080; cost is \$15.00 plus \$3.00 postage and handling (\$6.00 in countries other than U.S.). Pennsylvania residents add 6% sales tax. Orders should be prepaid, with check payable to Carnegie Museum of Natural History.—*Kimball L. Garrett, Section of Ornithology, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007.*

**CONSERVATION OF NATURAL HISTORY SPECIMENS—VERTEBRATES, 1988, C. V. Horie and R. G. Murphy, Eds.** (The Manchester Museum and Department of Environmental Biology, The University of Manchester, Manchester M13 9PL, UK. 77 pp.). This booklet is a compilation of the talks given at The University of Manchester's short course on conservation of natural history specimens. The course is a cooperative effort of The Manchester Museum and the Department of Biology. Such joint efforts, sometimes surprisingly difficult to effect, should be lauded. Unfortunately, there is a great variation in quality and coverage within each chapter. This probably reflects differences in the authors' degree of interest and knowledge, and the time it takes to convert a talk into a paper.

The first chapter, "The Structure of Skin and Bone," is taken directly from the talk and is a straightforward presentation of the topic. The three layers of skin and their cellular and chemical components are discussed. Bone is described in terms of tissue containing collagen fibers. The chapter titled "Preparation of Bird Study Skins" tells the reader exactly what tools and chemicals are needed for the preparation of specimens. The chemicals include DDT (no longer available), and camphor and turpentine (which may cause more harm than good). The techniques are clearly described but extremely standard. No mention is made of the more recent skin-skull-skeleton preparation that produces both skin and skeleton from one specimen.

The field of taxidermy has been revolutionized since the post-war development of synthetic substances. The chapter on this topic is a good attempt at addressing some of these innovations but is all too brief. The first line of the chapter "Methods of Bone Preparation" dives immediately into procedures with the statement ". . . remove the skin. . ." The author covers dry decomposition, maceration, and animal consumptions, and lists the pros and cons of each method. The author recommends bleaching for appearance but fails to fully address the long-term conservation problems of such treatment.

An excellent chapter is "Damage to Skin and Bones." It is well written, contains a depth of information, and is referenced throughout the text. I plan to make use of this informative chapter in my own department. In it, Horie discusses the kinds

of damage to skin, in particular the many chemical reactions that occur and the structural alterations between the dermis and epidermis. It is this area between the dermis and epidermis that is particularly vulnerable to irreparable damage.

The chapter "Pests, Pesticides and Specimens," written by Askew, presents a good coverage of insect pests in the U.S. and U.K. Fumigants are then covered, including Dichlorvos, which is no longer readily available in the U.S. The author refers to preventive maintenance, but fails to present it as an organized and complete approach. As alternative techniques to fumigation, he recommends alternate rapid cooling and heating (I can only imagine that this is a conservator's nightmare), gamma radiation, and carbon dioxide. The latter two receive no discussion. Furthermore, no mention is made of freezing as a pest-killing technique, a method that is receiving a lot of attention in the U.S.

The chapter "Treatment for Deteriorated Specimens" is more comprehensive than most and is referenced in the text. What is missing is a discussion of tooth repair. The author presents the often-heard caveats that treatment should be documented and "if in doubt, leave well enough alone."

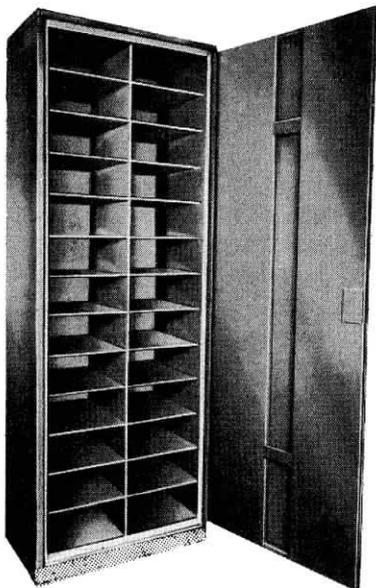
Garner's chapter, "Cleaning Fur," clearly outlines the specific techniques and solvents for cleaning fur. The chapter "Display and Curation of Specimens" discusses uv radiation, visible light (an excellent section), temperature, relative humidity, pests, air pollution, and mechanical damage. The author ends with a recommendation to display durable bone.

The last chapter, "Treatment of Specimens for Present and Future Use," raises many questions about what should be collected, what parts should be kept, and how they should be stored. Today's junk may be tomorrow's treasure. It serves well as the final chapter, having a philosophical bent. As the proceedings of a short course held at Manchester University in 1988, this book serves to familiarize the reader with the field of natural history conservation and some of the developments in that field. A few of the chapters are well done and expose the reader to new ideas. But caution must be observed, because in a number of instances the reader is not informed of the most recent developments in conservation approaches and techniques. The book points out that there are more questions than answers in the field of natural history collection preservation.—*Carron A. Meaney, Zoology Department, Denver Museum of Natural History, City Park, Denver, CO 80205.*

#### ADVERTISING

Advertising in *Collection Forum* is intended to serve the efforts of SPNHC members to manage and conserve natural history specimens. Ads should focus on products, services and/or applications that might be new to our members. Ads appearing in the journal do not constitute an endorsement by SPNHC. For information concerning rates and schedules, contact the Associate Editor for Advertising.

How many years would it take  
to replace your collection?



Herbarium Model 1-A

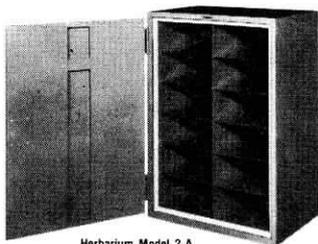
*Safe-guard your  
valuable  
specimens with*

*Lane*

**HERBARIUM  
CABINETS  
PERMANENT SPECIMEN  
PRESERVATION**

Lane Herbarium Cabinets provide maximum protection. Completely air sealed with the finest polyurethane resilient seal, double wall construction and equipped with the lane exclusive lift-off door.

- Double wall construction
- Pest proof & air tight seal
- Double panel door
- Lift-off safe type hinge
- Fumigant compartment
- 3-point locking mechanism
- Front & back air tight seals



Herbarium Model 2-A

FOR ILLUSTRATED BROCHURE, WRITE

*Lane*

**SCIENCE EQUIPMENT CORP.**  
225 W.34th Street New York, N.Y. 10122

Lane Science Equipment Corp.  
225 W.34th Street  
New York, N.Y. 10122

Dept. **E**  
Phone:  
212-563-0663

Name \_\_\_\_\_ Title \_\_\_\_\_

Institution \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_ Zip \_\_\_\_\_

Tel No. \_\_\_\_\_

## 1991 ANNUAL SPNHC MEETING

The 1991 meeting of the Society for the Preservation of Natural History Collections will be hosted by the Canadian Museum of Nature in Ottawa, May 6–11. The program will include tours (May 6); a three-day annual conference (May 7–9); Council, Committee and General Business Meetings; and a two-day training workshop (May 10–11). The workshop, entitled "Practical Approaches to Preventive Conservation for Natural History Collections", will be given by the Canadian Conservation Institute. For information, contact:

G. R. Fitzgerald  
Paleobiology Division  
PO Box 3443, Station D  
Ottawa, Ontario  
K1P 6P4  
FAX: (613) 954-4724



## Need A Hand?

THERE'S ALWAYS MORE WORK than staff and time to do it. Collections have a way of getting out of hand, and there's never enough time for research. We can take some of those problems off your hands. Give us a call — there's **no charge** for initial consultations or for consultations on grant proposals that include a funding request for our services.

SERVICES INCLUDE cataloguing, inventory, computerization, storage planning, and assistance with evaluation for deaccession. We'll be glad to quote on any curatorial task.

**Collections Management and Research**  
From N.Y.S. (800) 435-4438  
Elsewhere in U.S. (800) 482-4438  
or (607) 257-1969

**RM**  
*Rachel P. Maines and Associates*

121 Langmuir Lab, Cornell Research Park, Ithaca, N.Y. 14850

## PREPARATION OF MANUSCRIPTS

*General.*—It is strongly recommended that, before submitting a paper, the author ask qualified persons to appraise it. The author should submit three copies of the manuscript either typewritten or printed on letter quality printers. **All parts of the manuscript must be double spaced** with pica or elite type on 8½ × 11 inch (21.6 by 27.9 cm) or A4 paper and at least one inch (2.5 cm) margins on all sides. Manuscripts should not be right justified, and manuscripts produced on low-quality dot matrix printers are not acceptable.

Each page of the manuscript should be numbered. Do not hyphenate words at the right-hand margin. Each table and figure should be on a separate page. The ratio of tables plus figures to text pages should generally not exceed 1:2.

The first page includes the title of the article, names of authors, affiliations and addresses of authors, and the abstract if present. In the top left-hand corner of the first page, indicate the name and mailing address for the author to whom correspondence and proofs should be addressed. All subsequent pages should have the last names of the authors in the upper left-hand corner.

The preferred language for manuscripts is English, but a summary in another language can precede the literature cited, if appropriate. Manuscripts written in other languages will be considered if the language uses the Roman alphabet, an English summary is provided, and reviewers are available for the language in question.

*Abstract.*—An abstract summarizing in concrete terms the methods, findings and implications discussed in the paper must accompany a feature article. The abstract should be completely self-explanatory and should not exceed 200 words in length.

*Style and abbreviations.*—Symbols, units, and nomenclature should conform to international usage. Cite all references in the text by the author and date, in parentheses. Footnotes should be avoided. For general matters of style authors should consult the "Chicago Manual of Style," 13th ed., University of Chicago Press, 1982.

*Literature cited.*—This section includes only references cited in the manuscript and should be typed double spaced. References are listed alphabetically by authors' names and take these forms:

Jones, E. M., and R. D. Owen. 1987. Fluid preservation of specimens. Pp. 51–64 in *Mammal Collection Management* (H. H. Genoways, C. Jones, and O. L. Rossolimo, eds.). Texas Tech University Press, Lubbock, 219 pp.

Sarasan, L. 1987. What to look for in an automated collections management system. *Museum Studies Journal*, 3:82–93.

Thomson, G. 1986. *The Museum Environment*, 2nd ed. Butterworths, London, 293 pp.

*Tables and illustrations.*—Tables and illustrations should not repeat data contained in the text. Each table should be numbered with arabic numerals, include a short legend, and be referred to in the text. Column headings and descriptive matter in tables should be brief. Vertical rules should not be used. Tables should be placed one to a page, after the references.

All figures must be of professional quality as they will not be redrawn by the editorial staff. They may include line drawings, graphs or black and white photographs. All figures should be of sufficient size and clarity to permit reduction to an appropriate size; ordinarily they should be no more than twice the size of intended reductions and whenever possible should be no greater than a manuscript page size for ease of handling.

Photographs must be printed on glossy paper, with sharp focus and high contrast essential for good reproduction. Photos should be trimmed to show only essential features.

Each figure should be numbered with arabic numerals and be referred to in the text. Legends for figures should be typed on a separate sheet of paper at the end of the manuscript. Magnification scale, if used, should be indicated in the figure by a scale bar, not in the caption. Notations identifying the author and figure number must be made in pencil on the back of each illustration. All illustrations must be submitted as an original and two copies. Note placement of tables and illustrations in the margins of the manuscript.

*Evaluation of a manuscript.*—Authors should be aware that the following points are among those considered by the editorial staff when evaluating manuscripts: 1) Is the content appropriate to the purpose of the journal and society? 2) Are the contents clearly and logically presented and the paper well organized? 3) Is the methodology technically and logically sound? 4) Does the paper contribute to the body of knowledge and literature? 5) Is the study integrated with existing knowledge and literature? Is the literature cited appropriate for the study? 6) Are the conclusions supported by sufficient data? 7) Does the title reflect the thrust and limitations of the study? 8) Are the tables and figures clearly presented? Are they necessary to support the text?

## SUBMISSION PROCEDURE

Manuscripts intended either as feature articles or general notes should be submitted in triplicate (original and two copies) to the Managing Editor. Letters to the Editor and correspondence relating to manuscripts should be directed to the Managing Editor. Books for review should be sent to the Associate Editor for Book Reviews.

# CONTENTS

## Articles

- Freezing for museum insect pest eradication. .... *Mary-Lou Florian* 1
- A low-cost radioactivity test for geologic specimens. .... *Alice M. Blount* 8
- A new means of controlling relative humidity in exhibit cases. ....  
..... *Catherine Sease* 12
- pH change in a formalin borax solution with inferences about uses of  
neutralized formalin in vertebrate collections. ....  
..... *Grant W. Hughes and James A. Cosgrove* 21
- Modification of storage design to mitigate insect problems. ....  
..... *Stephen L. Williams and Suzanne B. McLaren* 27
- Coloring labels for type specimens. .... *J. Gisbert and R. Garcia-Perea* 33
- Labeling vertebrate collections with Tyvek® synthetic paper. ....  
..... *J. Gisbert, F. Palacios, and R. Garcia-Perea* 35
- An indelible printing system for permanent records in natural history  
collections. .... *F. Palacios and J. Gisbert* 38

## Reviews

- An annotated bibliography on preparation, taxidermy, and collection man-  
agement of vertebrates with emphasis on birds, by S. P. Rogers, M.  
A. Schmidt, and T. Gutebier. .... *Kimball L. Garrett* 40
- Conservation of natural history specimens—vertebrates, by C. F. Horie  
and R. G. Murphy, eds. .... *Carron A. Meaney* 41