#ISCUA2019 PROCEEDINGS

The 1st International Symposium of Conservation for Underwater Archaeology

IBEAM
Institut Balear d'Estudis en Arqueologia Marítima
Edited by: Andrea Sanz, Enrique Aragón, Javier Rodríguez

UNIVERSO de LETRAS

#ISCUA2019. Proceedings

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First edition: 2021

ISBN: 9788418675362
ISBN eBook: 9788418856068

Organiser:

Sponsors:

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Underwater in situ mechanical reinforcement and stabilization of cracked pottery with the use of zip tie

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Abstract

In the Mediterranean Sea, the most common archaeological finds are amphorae. During an underwater archaeological survey, conservators-divers are often required to detach and lift cracked amphorae and other pottery which are either found loose on a sandy seabed or concreted in a rocky substrate. The main objective of this article is the *in situ* mechanical reinforcement and stabilization of cracked pottery before they are detached from the seabed and lifted, with the use of zip tie. Moreover, the dangers of removal and lifting of sensitive artefacts without support are investigated. The method, possibilities and restrictions of it are presented; applied in different environments and on various types and shapes of amphorae. The method will be compared with existing methods of temporary support and fastening, both for its application in the field as well as in the lengthy process of salt removal. The main criteria, upon which the method is evaluated, are reversibility, interaction with the archaeological material, the number of divers necessary for the application, application time, durability of materials, etc. Finally, the possibility of combining methods is examined for special cases. This method has been applied with success in real conditions, in the field of underwater archaeological surveys. The first experimental application took place in the survey of the southern Euboean Gulf. In the Fournoi survey, with a large scatter of shipwrecks, the wide range of finds of different typology, at different depths and burial conditions, gave the opportunity to the Fournoi conservation team to test and improve this method on a larger scale.

Keywords

zip tie

lifting

mechanical reinforcement

cracked

underwater

Fournoi survey

1. Introduction

During underwater archaeological surveys, shipwrecks or individual finds are detected. The procedure followed for the documentation of such locations also includes the sample lifting of representative archaeological finds. The choice of what is to be lifted mainly belongs to the archaeologist. Usually intact or almost intact objects are chosen. If such do not exist, then objects that save most of their profile are preferred. Especially in the shallow wrecks, but not only, the surface layer is fragmented from the underwater conditions and human intervention. There, it is not usually possible to find intact objects. The rocky bottom in the Greek waters is very common; an ideal environment for biological colonies and geological depositions which results in the concretion of the finds. In this framework the conservator diver is often called upon to detach and safely lift potentially cracked objects.

The greatest restriction is time. In an underwater survey, researchers come across a multifaceted situation. For example, in South Euboea 28 shipwrecks were discovered (Koutsoulakis, 2014) and in Fournoi archipelagos 58 (Campbell and Koutsouflakis, 2017; Koutsouflakis and Campbell, 2019); and in both cases all locations were documented simultaneously, where the conservation team was called upon to retrieve objects. Regarding the time available to work underwater, it is very limited. The depths most shipwrecks are detected are between 30 to 40 meters. That offers at 30 meters 20 to 25 minutes and at 40 meters 8 to 10 minutes. Bottom time includes the time to detect the object, to estimate its preservation state, to reinforce it if needed, to detach and finally lift.

Regarding the literature, ceramic finds such as amphorae are considered robust artefacts, therefore not much attention has been given in their *in situ* stabilization before detaching and lifting. Many handbooks and manuals, like those of Robinson (1981), Sease (1987) and Singley (1988) often deal mainly with the handling of marine archaeological objects and offer some lifting techniques. Practical information offered on lifting procedures are presented in some case studies from various underwater excavations (Bowens, 2009), and in a publication of Daley and Murdock (1992).

Another restriction is the limited budget in such surveys in contrast to underwater excavations where it is more likely an amount of money for conservation is predetermined. Consumable materials purchased for the surveys are preferred to be cheap and versatile.

Many conservation materials and methods that are used in an on land excavation cannot be used underwater due to a number of reasons, one for example being buoyancy. Materials that have positive buoyancy, shrink or distort under pressure are considered inappropriate for use, as these dimensional changes would most likely damage the find, whereas their positive buoyancy would make them practically difficult to handle underwater (Bardas and Pournou, 2019).

In the case of cracked finds, adequate reinforcement in the form of a bandage or cast has to be provided before detaching and lifting, since the danger of the cracks opening and the object collapsing by its own weight is existent (Daley and Murdock, 1992) (Fig.1).

It is essential that an estimation of the preservation state of the find is made before detaching as many cracks are hard to recognise underwater. Besides the fragmentation or the decrease of static stability of the object, valuable information may be lost; for example organic residues in the interior. Pre consolidation with acrylic resins is not possible and has not been experimentally applied, due to the fact that the microscopic structure of the pottery in waterlogged condition would not allow the penetration of any product applied. Therefore, the reinforcement method chosen before its transport to the atmosphere is of great importance, since it may also protect it throughout the journey to the conservation lab.

Figure 1. *A Late Roman 2 amphora from the Fournoi Underwater Survey which collapsed due to lack of mechanical reinforcement. Photo by Angelos Tsompanidis*

2. Materials and Methods

2.1. Zip tie

The zip tie [1], also known as cable tie, hose tie and by the brand name Ty-Rap®, due to its large durability is primarily used to fasten electrical cables or wires together, though it is also used in a wide range of other applications. The common zip tie is made of nylon 6/6, a type of polyamide which is made of two monomers each containing 6 carbon atoms. It is used when high mechanical strength, rigidity, good stability under heat and/or chemical resistance is required (e.g. radiator end tanks, rocket covers, air intake manifolds, oil pans, electro-insulating elements, pipes, various machine parts, also popular guitar nut material). Many types of zip ties exist depending on the required need. In this study the black "standard zip tie" is applied, the most common zip tie that can be found in any hardware store. It is UV resistant for outdoor use, has a working temperature of -40^{0}C to 85^{0}C and has positive buoyancy.

2.2. The method

The application of the method is very simple and fast. The zip tie is applied on the perimeter of the vessel externally, creating a "belt" which surrounds it and fastens. It is preferable to use three or four smaller sized zip ties which form a chain and not one large one that surrounds the entire perimeter. The zip tie chain has the advantage of control and sharing of the tension whilst applying. Also the spacing formed at the fastening points are shared and reduces the danger of it loosening (Fig.2). Multiple "belts" can be added depending on the needs and structure of the find.

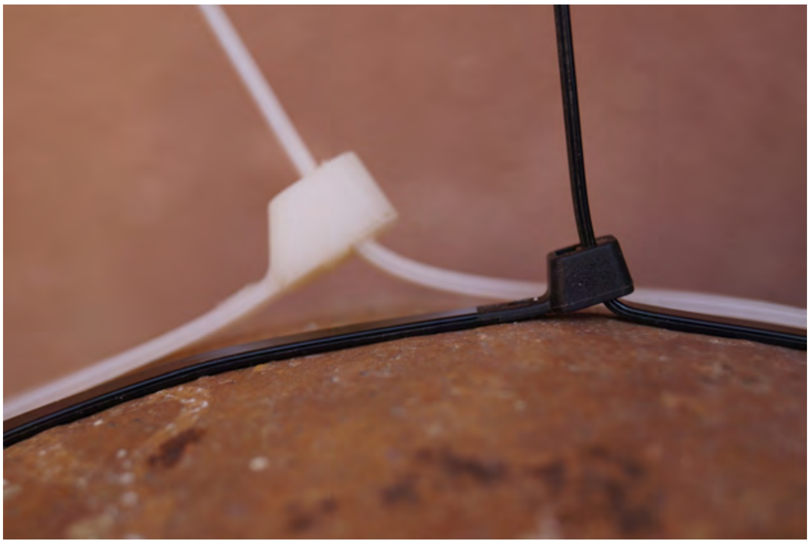

Figure 2. *The space created when using one big zip tie (white) compared to when using many small ones (black). Photo by Helen M. Bardas*

2.3. Reinforcement methods

Due to certain restrictions an underwater environment has, many reinforcement materials which are used in an on land excavation cannot be applied underwater. Those that could be applied are:

- Elastic bandage
- 3M™ Scotchcast™ Plus Casting Tape with polyurethane resin
- Resistance Bands
- Ropes – Straps
- Plaster of Paris
- Carbon Fiber Reinforced Cast

2.3.1. Experimental procedure and criteria

The zip tie method was initially compared with the elastic bandage and the 3M™ Scotchcast™ Plus Casting Tape with polyurethane resin, following an underwater *in situ* experimental procedure which evaluated each method based on the following criteria: i) application time, ii) cost, iii) accessibility to materials, iv) number of divers, v) reversibility and vi) short term preservation ability.

For the experiment a modern ceramic vessel was used as a simulation of a ceramic amphora. All dives were carried out at the same location, at a depth of 6 meters by three divers. Three applications of each method were carried out by each diver in order to obtain an average of the application time. Parameters such as the water conditions and the number of repetitions were kept constant for every method. The zip ties were secured into a bundle and transferred underwater, whereas the elastic bandage and the 3M™ Scotchcast™ Plus Casting Tape were transferred inside their packaging for optimal use, all inside a mesh bag. Each method was applied without a medium on the perimeter of the vessel on the "neck" (Fig 3).

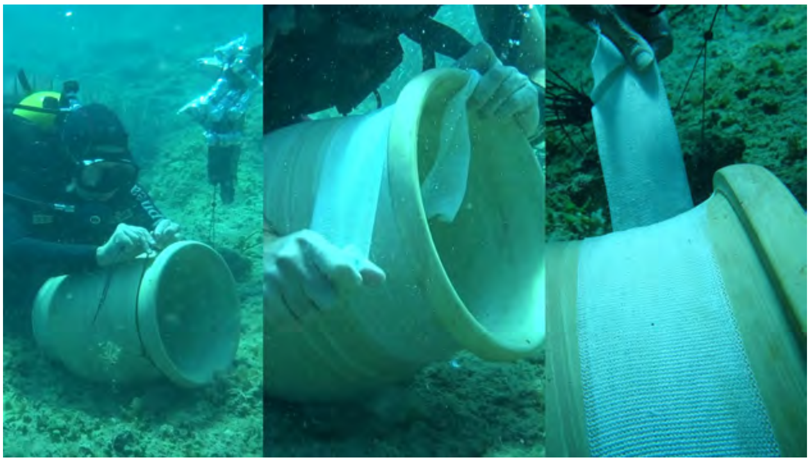

Figure 3. *From left to right: in situ application of zip tie, elastic bandage and 3M™ Scotchcast™ Plus Casting Tape Photo by: Helen M. Bardas*

The rest of the reinforcement methods were tested and evaluated in a controlled lab environment at the Ephorate of Underwater Antiquities in Athens. Resistance bands were applied on a number of amphorae with and without concretions but also observed amphorae which were lifted with resistance bands as a reinforcement method and were in the desalination process. Ropes and straps are mostly used to lift the object and very rarely to only mechanically reinforce it. They are usually used when no other materials are available. They can be difficult to manage and good knowledge of complex knots is required. Due to the above it was not compared to the zip tie method. Regarding the plaster of Paris method (Bekić, L. and Ferenčić, N., 2014), a modern ceramic vessel was placed in a large tank and secured. It was then covered with aluminium foil and gauze; and a sack of plaster was emptied on top of it (Fig.4). Every ten minutes the plaster's consistency was checked until hardened. The carbon fiber reinforced cast is a method which is prepared on land prior to the dive. It consisted of two polyethylene sheets, two sheets of peel ply and a sheet of carbon impregnated with resin, in the form of a 'sandwich' (Davidde-Petriaggi et al., 2014). This method was experimentally tested *in situ* on sensitive organic waterlogged wood (Bardas and Pournou, 2019) but due to its timely application, cost and not easy access to materials it was not compared with the zip tie method.

Figure 4. *Applying the plaster of Paris method on a modern vessel in the laboratory of the Ephorate of Underwater Antiquities. Photo by Helen M. Bardas*

2.4. Applications of the zip tie in the underwater field

The zip tie has been applied on various types of amphorae and other vessels from different underwater surveys. In the underwater field one comes across a challenging situation where the object which needs to be lifted may be heavily concreted with the bedrock or with other artefacts. During the detachment of an object from a cluster of finds or concretion, it is put under mechanical strain. In these cases the need to reinforce is greater, and other reinforcement methods alone cannot be used. A combination of zip tie, elastic bandage and in some cases also rope was applied for optimal reinforcement. Those amphorae cases from the Fournoi survey (Fig.5) and the southern Euboean Gulf were investigated and observed at the Ephorate of Underwater Antiquities.

Figure 5. *Conservator diver applying zip tie in situ before detaching an amphora. Photo by Aggeliki Bei*

3. Results and discussion

3.1. Reinforcement methods

The results of the *in situ* underwater experimental procedure are presented below (Table1):

	Zip tie	Elastic bandage	3M™ Scotchcast™ Plus Casting Tape
Application time	1min≤	1min≥	1min>
Cost	3.30€/100p	1.70€/1p	4.70€/1p
Accessibility to materials	√	√	x
Number of divers	1	1-2	1-2
Reversibility	√	√	√
Short term preservation	√	x	x

Table 1. *Results of the in situ underwater experimental procedure of the zip tie, elastic bandage and 3M™ Scotchcast™ Plus Casting Tape based on the criteria of the application time, cost, accessibility to materials, number of divers, reversibility and short term preservation ability.*

The zip tie method was indeed the fastest method compared to the others counting under a minute. It is very cheap and can be found in any hardware store. One diver is able to apply it easily underwater. Regarding reversibly, it can be easily removed by simply cutting it with a pair of scissors or knife. Zip tie has proved to be a steady material which does not alter drastically throughout the desalination process, though some loosening has been observed.

The elastic bandage took about a minute or more to apply due to the fact that when unrolling it the diver has to estimate how much pressure to apply on the cracked pottery in order to not damage it further. A second diver's assistance is advantageous. It is also cheap, easy to find and can also be removed easily. Regarding short term preservation the elastic bandage after 8 months in the desalination process gets moldy and loses elasticity (Fig.6).

Figure 6. A fresh elastic bandage (left) compared to an elastic bandage after 8 months during the desalination process (right). Photo by Helen M. Bardas

The 3M™ Scotchcast™ Plus Casting Tape takes over a minute to apply underwater and gets really tough to unroll towards the end of the tape; which is due to the polyurethane resin being activated immediately once exposed to water. A second diver is also needed as it is not easy to control the pressure applied by one diver. It is more expensive compared to the other methods and not very easy to purchase; as not all pharmacies sell them. The tape can be removed without harming the object though depending on how sensitive the surface is; as it parts of it may stick with the resin. Regarding short term preservation, as the elastic bandage it also got mouldy and the resin lost its strength after a period of 8 months in the desalination process.

The resistance bands were easily applied on every amphorae though were ripped on many which had concretions (Fig.7). During the desalination process, the resistance bands had lost elasticity and were stiff.

The plaster of Paris method was unsuccessful regarding the mechanical reinforcement. The plaster dispersed causing turbidness and covered everything. The plaster's consistency hardened in over an hour and only on the top part of the vessel (Fig.8).

Figure 7. *A ripped resistance band due to sharp encrustations on the surface of an amphora. Photo by Helen M. Bardas*

Figure 8. *The plaster of Paris method after the experimental procedure. Photo by Helen M. Bardas*

3.2. Applications of the zip tie in the underwater field

The zip tie due to its rigidity, flexibility and small diameter, is the only reinforcement method which can be applied on a concreted object before detaching, by taking advantage and penetrating into the small spaces that concretions usually form. Alternatively, with a minor intervention a small passageway can be opened where the zip tie can be passed through (Fig. 9). In all cases it is necessary to secure the zip tie on the application area so it does not move. Amphorae with ridges are exceptional cases because they are able to hold the zip tie in place. Similarly, areas of handles, the nub and other protruding characteristics of pottery or dents can also be used. Hard concretions on the object which are often encountered also help (Fig. 10). Regardless of the above, the zip tie works very well on cylindrical shaped amphorae, such as those of post roman African amphorae. It does not apply well in conical or circular shapes such as the lower sections and bottoms of classic amphorae from Chios or Globular, where the zip tie cannot be secured thus slipping off. An example of a combination of methods is an amphorae from Chios (Fig. 11) The zip tie has already been successfully applied on amphorae types: Africana 1, Africana 2, Africana 3, Bettle 6A, Late Roman 1, Late Roman 4 and Will type e; but also on other types of pottery (Fig.12).

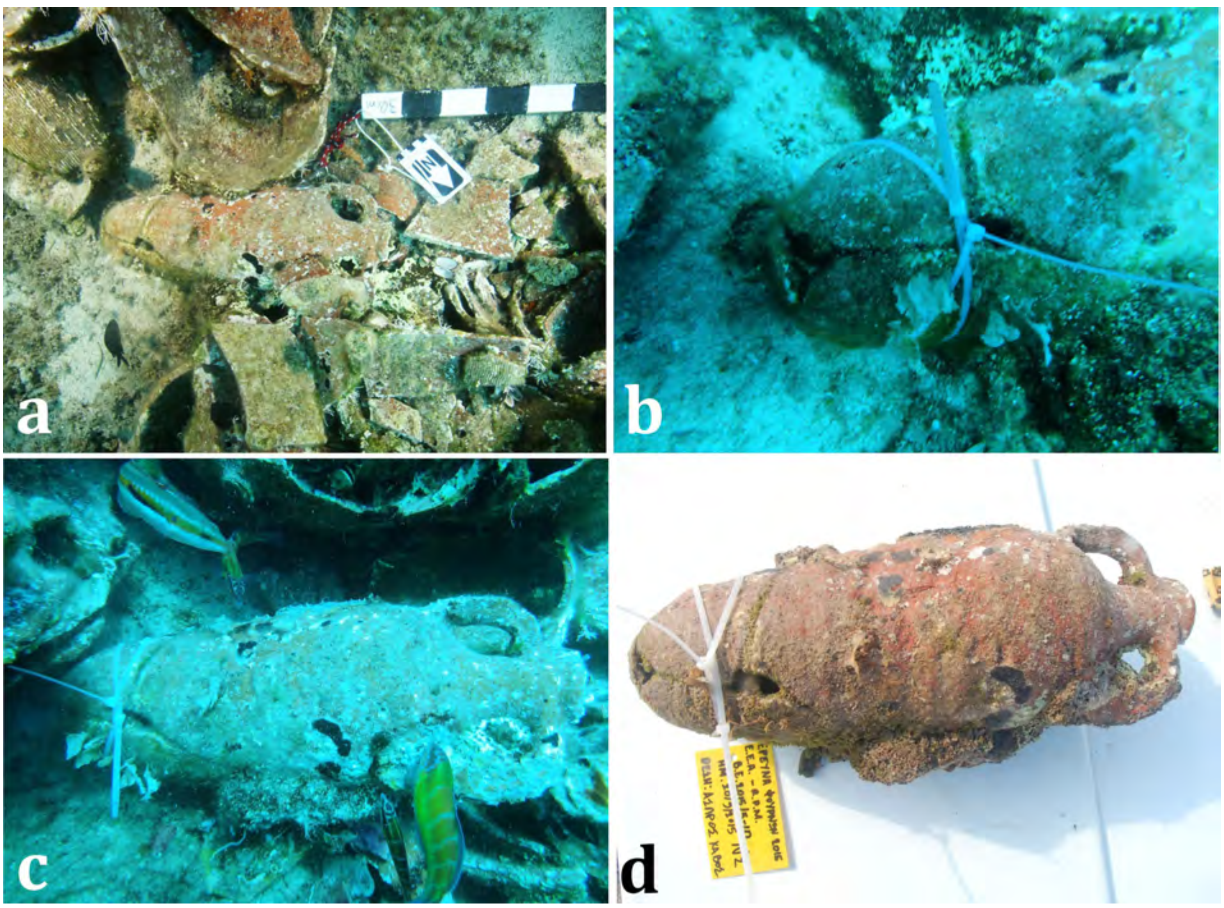

Figure 9. *An unidentified amphora from the Fournoi survey a) in situ before detachment, b) having applied the zip tie on the lower part, c) after detachment and d) after lifting at the temporary lab. Photo by Angelos Tsompanidis*

Figure 10. *Parts of the amphora where the zip tie is more secure. Photo by Angelos Tsompanidis*

Figure 11. *An amphora from Chios were a combination of zip tie, elastic bandage and rope was applied for optimal reinforcement. Photo by Vassilis Mentogiannis*

Figure 12. *Africana type amphorae mechanically reinforced with the use of zip tie. Photo by Petros Vezirtzis*

4. Conclusions

The zip tie offers many benefits in the mechanical reinforcement of cracked pottery underwater *in situ*, during their transport to the laboratory but also throughout the desalination process. It applies well on cylindrical amphorae, on amphorae with ridges, on necks and handles. It is reversible, low cost and easy to buy in any hardware store. It has a short application time underwater and remains stable with time. On the other hand it does not apply well on conical shaped amphorae and may cause scratches if the object's surface is sensitive; in which case a soft medium should be considered. Further investigation has to be made to test whether the zip tie chemically interacts with the pottery under certain conditions. This work hopes to add and recommend this method of mechanical reinforcement of crack pottery in the scientific community and help the conservator diver in the decision making process when having to detach and lift objects from underwater archaeological sites.

Endnotes

1 Patent from Fong Chen, K. 2015. *Elastic zip tie*. US9021665B2

Acknowledgements

The authors wish to thank the Beis family for providing the rib boat to carry out the experiments; Dr. G. Koutsouflakis for access to the archaeological material at Ephorate of Underwater Antiquities and most of all the “Korseai” Institute of Historical and Archaeological Research for their support and funding of this work.

References

Bardas, H and Pournou A., 2019, *From the sea bottom to the surface: Assessing underwater techniques for lifting waterlogged archaeological wooden objects.* In: *Proceedings of the 14th ICOM Group on Wet Organic Archaeological Materials Conference*, Portsmouth: ICOM *(pending)*

Bekić, L. and Ferenčić, N., 2014, *Conservation of underwater archaeological finds*. 2nd ed. Zadar: International Centre for Underwater Archaeology.

Bowens, A, 2009, Archaeological conservation and first aid for finds. In *Underwater Archaeology*. 2nd ed. Malden, 16. MA: Blackwell Pub.

Cronyn, J. and W. Robinson, 1990, *The Elements of Archaeological Conservation*. London: Routledge.

Campbell, P. and Koutsouflakis, G., 2017, Shipwreck capital of the Aegean - The Fournoi Underwater Survey. INA Q. 44, pp. 9-15.

Davidde Petriaggi, B., D. Gregory, and J. Dencker, 2014, Recovery of Fragile Objects from Underwater Archaeological Excavations: New Materials and Techniques by SASMAP Project. In *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection*, EuroMed 2014. eds. M. Ioannides et al 625–634, Cham: Springer International Publishing.

Daley, T. and Murdock, L., 1992, Chapter Twelve. In: R. Payton, ed., *Retrieval of objects from archaeological sites*. Wales: Archetype Publications Ltd, pp.133-145.

Florian, M., 1987, The underwater environment. In *Conservation of Marine Archaeological Objects*. ed. Pearson, C., 13-16. Kent: Butterworths & Co.

Hamilton, D., 1996, *Basic Methods of Conserving Underwater Archaeological Material culture*. Washington, D.C.: U.S. Dept. of Defense, Legacy Resource Management Program.

Koutsouflakis, G., 2014, Ναυσιπλοΐα και εμπορευματική διακίνηση στο Νότιο Ευβοϊκό από τον 6ο αιώνα π.Χ. έως τον *14ο* αιώνα μ.Χ. National and Kapodistrian University of Athens

Koutsouflakis, G. and Campbell, P., 2019, Η αρχαιολογική χαρτογράφηση του αρχιπελάγους των Φούρνων: μία ματιά από το επίπεδο της θάλασσας και του *β*υθού, in: Κορσιητῶν Νῆσοι-Αρχαιολογικά Ευρήματα Και Μια Προσέγγιση Της Ιστορίας Των Φούρνων Κορσεών, Municipality of Fournoi Korseon, Athens, pp. 144-225.

Pearson, C., 1987, *Conservation of Marine Archaeological Objects*. Kent: Butterworths & Co.

Robinson, W., 1998, *First Aid for Underwater Finds*. London: Archetype.

Rodgers, B., 2004, *The archaeologist's manual for conservation*. New York: Kluwer Academic/Plenum Publishers.

Sease, C., 1987, *A Conservation Manual for the Field Archaeologist*. Los Angeles: Institute of Archaeology, University of California.

Singley, K., 1988, *The Conservation of Archaeological Artifacts from Freshwater Environments*. South Haven, Mich.: Lake Michigan Maritime Museum.