



Intersecciones en Antropología

ISSN: 1666-2105

intersec@soc.unicen.edu.ar

Universidad Nacional del Centro de la
Provincia de Buenos Aires
Argentina

Grosso, Mónica

Post-depositional processes studies of wooden artifacts from the 18th century Swift
shipwreck site (Patagonia, Argentina)

Intersecciones en Antropología, vol. 15, núm. 1, 2014, pp. 55-69

Universidad Nacional del Centro de la Provincia de Buenos Aires
Buenos Aires, Argentina

Available in: <http://www.redalyc.org/articulo.oa?id=179538578005>

- How to cite
- Complete issue
- More information about this article
- Journal's homepage in redalyc.org

redalyc.org

Scientific Information System

Network of Scientific Journals from Latin America, the Caribbean, Spain and Portugal

Non-profit academic project, developed under the open access initiative

Post-depositional processes studies of wooden artifacts from the 18th century *Swift* shipwreck site (Patagonia, Argentina)

Mónica Grosso

Received 21 August 2013. Accepted 20 February 2014

ABSTRACT

The HMS *Swift* was a British Navy sloop-of-war that sank off the Patagonia coast in 1770. The *Swift* shipwreck site, on the northern coast of Santa Cruz Province (Argentina), is a well-preserved underwater archaeological site. The high frequency of wooden artifacts at the site permitted the development of specific research designed to identify the primary natural and cultural post-depositional processes related to the preservation and spatial distribution of those artifacts. This paper presents the methodological framework for this research, which included both direct observations and experimental studies that led to the characterization of the organisms related to the shipwreck site and their interaction with archaeological materials. Results confirm that sedimentary conditions have played a central role in the preservation of wooden materials and their spatial distributions. Furthermore, the archaeological consequences of organisms' damaging activities (mainly those of marine wood-borer mollusks) are assessed.

Keywords: Wooden artifacts; Post-depositional processes; Shipwrecks; Underwater archaeological sites; Patagonia.

RESUMEN

ESTUDIOS DE PROCESOS POSDEPOSITACIONALES EN ARTEFACTOS DE MADERA DEL SITIO DE NAUFRAGIO *SWIFT*, SIGLO XVIII (PATAGONIA, ARGENTINA). En los ambientes subacuáticos marinos, bajo ciertas condiciones, puede preservarse una diversidad de materiales arqueológicos de origen orgánico e inorgánico. Uno de estos casos es el sitio *Swift*, embarcación de la Armada Británica que en 1770 naufragó en la costa norte de la actual provincia de Santa Cruz. La existencia de una gran cantidad de artefactos de madera brindó una interesante oportunidad para realizar investigaciones dirigidas a identificar los principales procesos posdeposicionales de índole natural y cultural involucrados en la preservación y en la distribución de estos materiales. En este trabajo se presenta el enfoque metodológico aplicado, el cual incluyó la realización de observaciones y estudios experimentales que permitieron caracterizar las comunidades de organismos asociados al sitio y su interacción con los materiales arqueológicos. Los resultados obtenidos confirman que las condiciones sedimentarias han desempeñado un rol fundamental para la preservación de los materiales y sus relaciones contextuales. Asimismo, se analizan las consecuencias arqueológicas de la actividad de organismos que ejercen una acción destructiva, entre los que se destacan los moluscos marinos perforantes de madera.

Palabras clave: Artefactos de madera; Procesos posdeposicionales; Naufragios; Sitios arqueológicos subacuáticos, Patagonia.

INTRODUCTION

Since the development of underwater archaeology as a scientific discipline in the 1960's, interest has increased in the factors that regulate differential preservation of shipwreck sites. In 1978 Keith Muckelroy proposed a pioneering model based on systematic research, which was later expanded upon by Ward *et al.* (1999) and Gibbs (2006). To date, most such studies have aimed to understand general processes involved in site formation and factors that contribute to *in situ* preservation of sites. Nevertheless, researches designed to improve our interpretations of the submerged archaeological record are still scarce (Grosso 2008, 2011). This situation can likely be explained by the common perception of shipwrecks as "time capsules". Contrary to this perception, though, it has been argued that research must take into account the social and technological biography of ships as well as their contents, that is to say, their temporal depth (Adams 2001). Moreover, it should be noted that the loss of a ship is a process that can last many hours or even days. Therefore, even at shipwreck sites that appear to contain well-preserved materials and to display original relationships between objects, the coherence and integrity of the context should not be assumed but archaeologically demonstrated (Adams 2001).

South America has also produced few studies on wrecksites formation processes; shipwreck archaeology in the region –with the exception of Argentina, Chile and Uruguay– is a field of study only now getting underway (Elkin 2011). In Argentina, archaeological research at the wreck site of the HMS *Swift* has included a multidisciplinary study of natural site formation processes from the beginning (Bastida *et al.* 2004; Elkin *et al.* 2011).

As part of my doctoral research –which focused on wooden material culture onboard the *Swift*– I analyzed the primary natural and cultural post-depositional processes that affected the preservation and distribution of wooden artifacts (Grosso 2011). Here, I summarize the methodological approach and main results of that study. Additionally, I hope it will contribute to provide information relevant to the interpretation of other shipwreck sites located in the region's underwater or intertidal marine environments.

LOSS OF THE HMS SWIFT

The *Swift* was a Royal Navy sloop-of-war stationed at Port Egmont, the 18th century British naval base in the Malvinas / Falkland Islands. Like all sailing ships at the time, the *Swift* was a wooden vessel. She had two decks, a length of 27.8 m and a breadth of 7.9 m (National Maritime Museum, Greenwich, NMM Draughts Box 52 N° 3603A 'sheer and profile', *Swift* and *Vulture*).

In March of 1770, the *Swift* was stranded on a rock off the coast of Puerto Deseado estuary. Several measures were taken to avoid sinking¹ but, eventually, the ship slipped away from the rock and sank. Very few items could be saved before the ship disappeared below the water (The National Archives, Kew, ADM 1/5304 Court Martial: Loss of HMS *Swift*, 29 September 1770; Gower 1803).

THE SWIFT ARCHAEOLOGICAL PROJECT

The wreck site is located in the harbor of present day Puerto Deseado city, in northeast Santa Cruz Province, Argentina (Figure 1).

Archaeological research at the site was begun in 1997 by the Programa de Arqueología Subacuática (Underwater Archaeology Program, or PROAS) of the Argentinean Instituto Nacional de Antropología y Pensamiento Latinoamericano (INAPL), under the direction of Dr. Dolores Elkin. To achieve the project's research goals, survey of visible structural remains and excavation of representative sectors of the ship were planned (Elkin *et al.* 2007, 2011).



Figure 1. Location of the *Swift* wreck site in the harbor area of Puerto Deseado (Map: C. Murray).

The ship remains cover an area of approximately 180 m². About 70% of the hull has survived, most still assembled, though sediments cover nearly 60% (Murray *et al.* 2003). The site is between 10 and 18 m below surface, depending on the bottom slope and level of the tide. The shallowest depth corresponds to the bow-starboard area, and the deepest to the stern-port. The hull lies on its port side with a list of about 60 degrees, such that the starboard side is the most exposed structural portion. While the port side of the upper deck is well preserved, the opposite side has collapsed or disappeared, with some frames and beams protruding up to 3 m above the sediment level. Neither masts nor yards were preserved (Figure 2). Many detached structural components, as well as cannons, anchors and a great diversity of organic and inorganic artifacts lie partially or totally covered by the sediments. Nearly all exposed elements are colonized by a variety of organisms, with the exception of those

scrambling devices. Extracting filters are processes that result in the loss of materials: elements floating away during the sinking, salvage operations, and disintegration of perishables. Scrambling devices are processes that move artifacts around, resulting in the loss of contextual information: the wreckage process, movement of the seabed (which may or may not bury elements), wave action, currents, and biological activity. Based on Muckelroy's proposal, Ward *et al.* (1999) produced an expanded model that distinguishes the primary processes affecting disintegration of a shipwreck on the basis of the ship's own characteristic, the sedimentary environment, and the hydrodynamic environment (Figure 3). The nature of the sedimentation process –whether it is accumulative or erosive– is considered the main factor in the shipwreck preservation, which, in turn, depends on sedimentary and hydrodynamic characteristics.

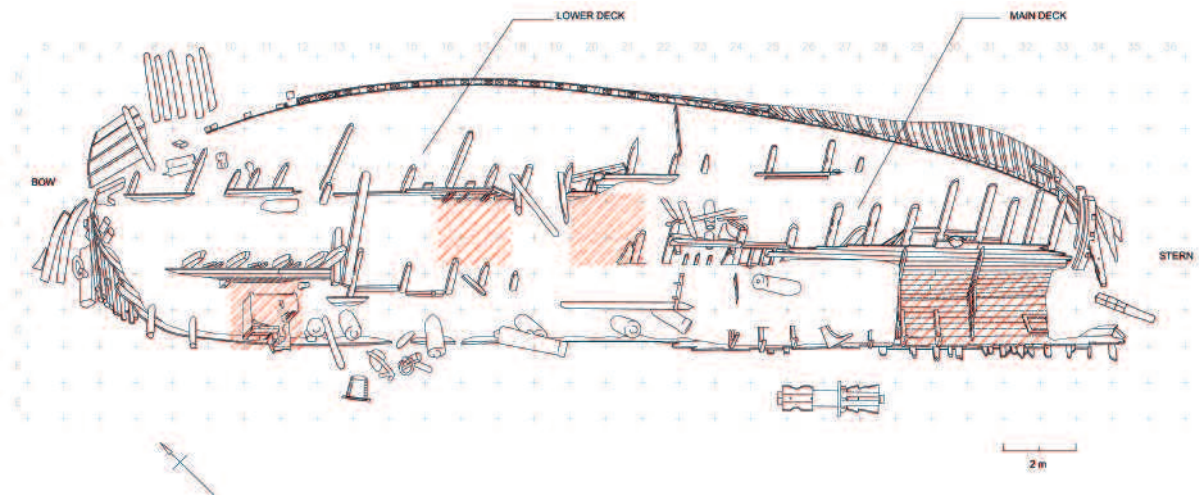


Figure 2. Site plan with the excavated areas highlighted (Drawing: C. Murray).

materials that may be toxic for them (like copper and copper alloys).

Twenty six percent of the more than 500 artifacts retrieved from the site since its discovery were made of wood. These materials are currently housed at the Museo Municipal Mario Brozoski, Puerto Deseado².

SHIPWRECK SITES FORMATION PROCESSES

Muckelroy's model of shipwreck site formation processes take into account the different components that contribute to the evolution of a shipwreck, from the time the ship was sailing to the presently-observed seabed distribution (Muckelroy 1978). He identified two main processes that operate during that timeframe: *extracting filters* and

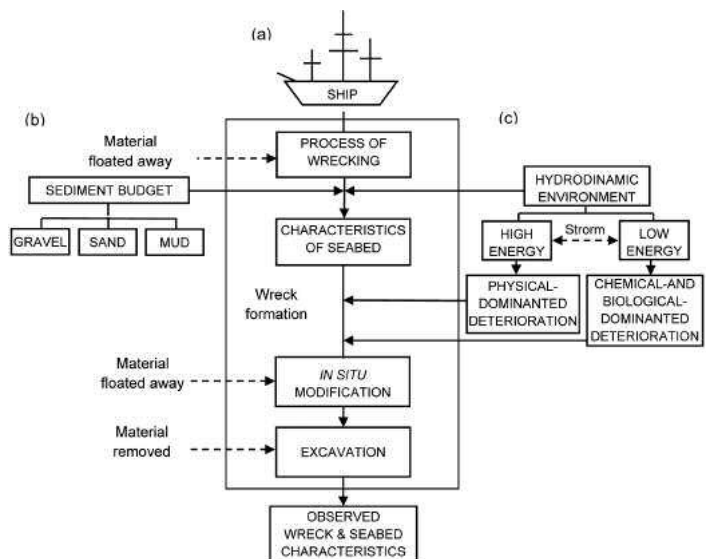


Figure 3. Muckelroy's expanded model. a) The wreck, b) the sedimentary environment, and c) the hydrodynamic environment. After Ward *et al.* (1999: 564).

Physical, chemical and biological processes are involved in the disintegration of a shipwreck, so it is important to identify and understand the dynamics of their interaction. Positive and negative feedback operate continually between the water, the sediment, and the wreck. In general, physical deterioration processes dominate in the early stages. Afterwards, as the shipwreck disintegrates and materials interact with the sedimentary environment, biological and chemical processes become relatively more important. In this model, the rate of shipwreck disintegration is equal to the sum of the rates of disintegration caused by physical, chemical and biological processes, in relation to the depositional history (that is, variation in sedimentary processes through time). The combination of these factors defines different possible levels of preservation (Ward *et al.* 1999).

BIODETERIORATION STUDIES IN MARINE ENVIRONMENTS

Marine environments have great biodiversity and a remarkable variety of colonization modes may develop in them. Solid marine substrates can be divided into two groups: soft or sedimentary bottoms and hard or rocky bottoms, each with species living in close association with them (Bastida *et al.* 2004, 2008). Sedimentary bottoms prevail in nature and, therefore, a great demand exists for colonization of hard bottoms by organisms that need hard substrata to live. Consequently, when anthropic material is submerged in seawater it is immediately colonized by organisms, providing that it is not toxic for them.

Among organisms that live in the sea, two main groups have been considered responsible for the most serious damage to man-made substrata: marine wood-borers, and biofouling (benthic communities associated to artificial substrata). These micro- and macro-organisms are capable of physico-chemical modification of materials as a result of their attachment to them (mechanical effects) and their metabolic processes. The search for methods to prevent the settling and harmful effects of biofouling has led to the development of biodeterioration studies as a specific field of research. Since the 1960s, Argentina has been a Latin American leader in this discipline. Studies on the experimental ecology of benthic communities have played a substantial role in biodeterioration research developing experimental systems to achieve controlled studies of the biological communities associated with diverse materials (see references in Bastida *et al.* 2004; Grosso 2008). Therefore, these studies provide basic information on the biological and ecological processes involved in the formation of underwater archaeological sites.

Marine wood-borers

There are two groups of wood-borers in marine environments: mollusks and crustaceans. Bivalve mollusks are represented by two families: Teredinidae ("shipworms") and Pholadidae ("piddocks"). Teredinidae is the larger group and is composed of a number of genera and species distributed around the world (but note that *Teredo* is often –and erroneously– referred to as the only genus). As soon as Teredinidae larvae find a suitable substratum, they begin to bore tunnels into the wood. Larvae gradually develop a soft, worm-like body with two valves at the front extremity that enable them to bore wood. As Teredinidae grow, they deposit a calcareous lining in the tunnel where they remain throughout their lives. A pair of siphons is the only part of the body that maintains contact with the seawater through the initial hole. A couple of calcareous pallets allow organisms to seal the hole when necessary. These elements enable taxonomic identification of species. As a consequence of the teredinids' activity, a piece of wood can be completely bored inside while externally only the small initial holes of 1 to 2 mm in diameter are visible (Eaton and Hale 1993). Tunnels only become exposed when a piece of wood is broken or its surface heavily deteriorated.

Pholadidae is a smaller group of mollusks than the Teredinidae and their geographical distribution is more limited. They also have a less significant role as destructive agents (Pournou 1999). Not all members of the Pholadidae family are exclusively wood-borers. Generally, they can be distinguished easily from the teredinids because they lack the characteristic worm-like body (with the exception of *Xylophaginae*) and do not create a calcareous lining in the tunnels walls. They have oval valves similar to those of the common clam but with a denticulate area for boring wood. Their tunnels can be 3 to 8 times the size of the valves (Eaton and Hale 1993).

Marine wood-borer crustaceans are represented by the orders Isopoda and Amphipoda. The first includes the most important groups: Limnoriidae ("gribble") and Sphareomatidae ("pill bug"). These organisms have small, segmented bodies –generally 2 to 4 mm long– and legs, so they are capable of moving over the wood surface. They produce superficial or sub-superficial galleries of 1 to 3 mm in diameter. The extensive network of galleries can lead to collapse of the superficial levels of the wood and, eventually, total destruction of the substratum.

Teredinidae mollusks have been recorded off the coasts of Buenos Aires, Chubut (Puerto Madryn) and Tierra del Fuego (Ushuaia) Provinces, and the Malvinas / Falkland Islands. Limnoriidae are reported only in the first three localities (Bastida and Torti 1972a, 1972b; Prosser Goodall 1978).

Biofouling communities

Contrary to what happens with wood-borers, few studies have been designed to understand the formation and development of biofouling communities in wreck sites (Thomson 1997; Randell 1998). This is remarkable in light of the fact that marine wreck sites develop into reefs of artificial origin.

When an artificial substratum is submerged in seawater a biotic colonization process begins, which leads to the development of a biofouling community. This “benthic succession process” begins with the adsorption of organic macromolecules, followed by the formation of an initial biofilm constituted mainly by bacteria and micro algae, and continues with the settling and growth of different species of invertebrates and macro algae that form communities of variable complexity and ecological characteristics. The process tends to conduct the community to a final, equilibrium stage known as the “climax stage”, after which the detachment and partial restart of a new cycle takes place (Bastida *et al.* 2008).

Biofouling in different parts of the world involves nearly 2000 micro- and macro-organisms (Florian 1987) and comprises aerobic bacteria, fungi, protozoa, diatoms, algae, bryozoans, coelenterates, polychaetes, mollusks and tunicates, among others. The diversity and variety of organisms differs according to the community stage of development and to local environmental conditions. Biofouling species can be sessile –attached to the substratum throughout its life by means of different mechanisms– or non-sessile.

POST-DEPOSITIONAL PROCESSES AT THE SWIFT SITE: GOALS AND METHODOLOGY

The goal of this research was to identify the primary processes responsible for the differential preservation of wooden artifacts, as well as those that modified the artifacts’ original depositional context. The wooden artifacts database contains 197 objects from superficial sediment levels and excavation areas, and includes multi-component and single-component artifacts, both complete and fragmented. The following functional categories were identified: tableware, cooperage, rigging, storage, tools, furniture, objects related to military or navigation activities, as well as unidentified elements. In each case the following data were recorded: provenience, general characterization, components (including other materials), and taxonomic identification when possible (Grosso 2011)³.

To understand natural formation processes, prevailing environmental conditions at the site were

considered with a focus on hydrological and sedimentological parameters. Systematic sampling was performed to record sediment characteristics by means of three transects along the ship’s length, each with five sampling stations. The following data were collected: qualitative and quantitative fractions, granulometric classification, concentration of organic matter, concentration of calcium carbonate, and relative amounts of bioclasts and faunistic groups represented (Bastida *et al.* 2004, 2011).

Afterward, a macroscopic examination of a sample of artifacts was conducted for the purpose of identifying the primary associations between different organisms and specific archaeological substrata, along with the consequences of these associations on the archaeological materials. The analysis included both *in situ* and recovered artifacts; the depositional context and general state of preservation were also considered.

Excavated areas allowed the examination of wooden elements that had been covered by sediments. As shown in Figure 2, 20 m² were excavated, distributed as follows: on the main deck near the galley (bow-port side) and the Captain’s quarters (stern-port side); on the lower deck, in a possible block storeroom, and forward of the main mast. In the two first areas listed, internal planking was reached while the others were just partially excavated.

Additionally, an experimental study was performed to obtain controlled information about biofouling communities and wood-boring organisms, including their basic ecological and biological characteristics (Bastida *et al.* 2004). This study was adapted from others previously carried out in biodeterioration research in Argentina (Bastida *et al.* 2008, see references therein). The experimental design used acrylic and pine wood panels of 10 x 5 cm fitted to acrylic frames of 30 x 40 cm. Samples were taken at 6 (cold and warm seasons), 12 and 24 months to monitor seasonal cycles of colonization, growth and successional strategies of the community. Additionally, panels of 12 x 12 cm composed of thin wooden layers were used to obtain complete wood-borer specimens. The frames were located at the bow and stern areas of the vessel. Biological and sedimentary analyses were carried out by the Laboratorio de Ecología Bentónica y Biodeterioro (Benthic Ecology and Biodeterioration Laboratory) of the Mar del Plata National University, under the direction of Dr. Ricardo Bastida.

Finally, to assess cultural formation processes, diverse sources of information were analyzed with the purpose of understanding the human activities that would have affected the site over the course of more than two hundred years.

ENVIRONMENTAL CONDITIONS

The Deseado estuary is 40 km long, depending on the marine influence, and up to 400 m wide. Its maximum depth is 32 m, near the entrance, while its minimum is 0.5 m, at the end of the estuary. The *Swift* site is situated off the north coast of the estuary and near its mouth, such that the hydrological parameters are similar to those of the adjacent open sea. Marine water in this area is renewed in a high frequency due to the influence of the tides (Kühnemann 1971). Average annual salinity is 33‰ (typical ocean waters are 35‰), and Ph values are slightly alkaline –characteristic of seawater– ranging between 7.8 and 8.2. Dissolved oxygen values vary between 7.85 and 9.56 mg/l and slightly lower in areas with anthropic impact. The water temperature ranges between 13° C (summer) and 4° C (winter) (Elkin *et al.* 2007).

Estuary tides are semi-diurnal; that is, two high tides and two low tides each day. They reach amplitudes of 4.2 m (average spring tides) so the estuary is considered a macro-tidal environment. This causes displacement of huge masses of water, which generates currents of up to 6 knots in narrow zones, though their speed decreases in some places according to topographic characteristics. Maximum currents at the site are about 2 knots. Waves have limited impact on the site; their maximum amplitude is 0.7 m. Prevailing winds are from the west and southwest and are generally strong (Kühnemann 1971). Underwater visibility is typically low, ranging from 0.1 to 2 m, with an average of 1 m. The low water transparency, and consequent limited light penetration, is caused by suspended sediment. Precipitation is scarce and without strong seasonal variance, with monthly values ranging from 5 to 45 mm. Sediment sampling at the site revealed a dominance of fine fraction sediments, with a significant presence of clay, mud, and fine sand (Figure 4). These small particles have a continental origin; they are swept by the rain towards the estuary. Coarse sands are very little represented, as are larger fractions, with the exception of some areas where a relevant abundance of granules and pebbles was observed (Bastida *et al.* 2011).

The sediment composition has contributed to the formation of low oxygen level deposits. The considerable quantity of organic material that cannot be mineralized due to the lack of oxygen generates hydrogen sulphide, easily detected by a pervasive, characteristic smell and the black coloration of the sediment. Negative Redox potential values (ranging from -140 to -314) confirm the anoxic nature of the burial environment. Concentrations of organic material reach high values of up to 9.02%. This is due to the high productivity of the water and benthonic communities, as well as the significant contributions

of the local harbor and its industrial fishery (Bastida *et al.* 2004, 2011).

SYSTEMATIC OBSERVATIONS AND EXPERIMENTAL STUDIES

Systematic macroscopic observations have permitted an assessment of the more conspicuous association of biofouling and wood-borer communities with archaeological substrata. Type of material, shape and superficial texture, context of provenience, and primary features regarding their state of preservation (e.g., structural weakness, marine erosion) were recorded in each case.

To gain a better understanding of biological communities associated with wood artifacts, it was also relevant to compare what happens to wooden ships' structural elements, as well as to artifacts made on other materials. Primary associations are summarized in Table 1 (Elkin *et al.* 2007; Grosso 2008). In each case, levels of biodiversity and biomass are identified. Both refer to the natural communities of the area, which are considered the maximum level of biomass and biodiversity possible.

Among the fouling organisms colonizing the shipwreck, tunicates ("sea squirts") are the most notorious, due to their size and distribution over the whole site on various types of substrata. Tunicates are able to develop communities of considerable size even from very small areas, chiefly in zones of good water flow, as in the case of frames and beams that are nearly vertical due to the ship list (Figure 5).

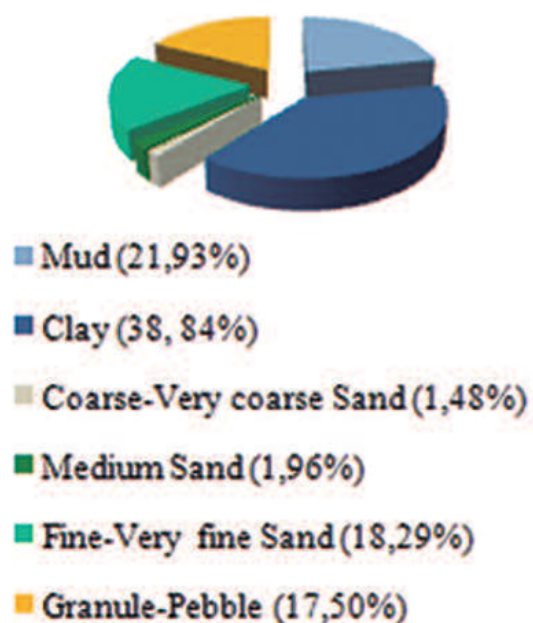


Figure 4. Granulometric composition of the *Swift* site. Sizes classification follows Udden-Wentworth scale (Bastida *et al.* 2011).

MATERIALS	Substrate surface	Fouling association (assemblages)	Biodiversity (B1) and Biomass (B2) levels
GLASS	Smooth surfaces (bottles)	Associations represented by several invertebrates groups	B1: Medium B2: Low
	Rough surfaces (windows emery glass panels)	Associations represented by several invertebrates groups and chordates	B1: High B2: Medium
WOOD	Ship structural components (beams and frames)	Associations represented by algae, invertebrates and chordates	B1: Medium B2: High
	Small artifacts over the sediment (pulley)	Associations represented by several invertebrates groups	B1: Low B2: Low
METAL	Iron	Associations represented by algae and invertebrates	B1: High B2: Medium
	Lead	Represented by only one invertebrate group	B1: Low B2: Low

Table 1. General characterization of the biofouling associated to diverse substrata.



Figure 5. Deck beams colonized by tunicates of solitary and colonial species (Photo: S. Massaro).

More conspicuous tunicates are from solitary species (e.g., *Cnemidocarpa verrucosa*, *Molgula* sp., *Paramolgula gregaria*, *Ciona* sp. and *Corella eumyota*) and colonial species (e.g., *Sycozoa gaimardi*, *Amaroucium* sp., *Didemnum* sp., *Polyzoa opuntia*). In the structural timbers mentioned above, there are also abundant small (*Corynactis carnea*) and large species of anemone (“sea anemones”). Species of red algae (*Rhodymenia* sp. and *Ceramium* sp.) and brown algae (*Dyctiota* sp.) are present, although in small amounts due to light limitations. Specimens of giant

kelp (*Macrocystis pyrifera*) detached from nearby seabottoms are transported to the site by currents. They can reach 30 m of length and frequently become tangled in structural timbers.

Small size wooden artifacts, such as blocks and pulleys, present comparatively minor species diversity relative to structural components and other substrata, such as glass of rough surfaces and iron; small coelenterates (anemones

Corynactis carnea) and arborescent bryozoans (e.g., *Hippotoa bouganvillei*) predominate.

Regarding biofouling effects on archaeological elements, it was observed that with the detachment of tunicates from wooden substrates, part of the woody tissue was also removed. Likewise, the activity of small organisms may have deleterious consequences, such as the impressions left by soft tubeworms (polychaetes) such as *Platynereis australis* (Figure 6a) or gastropod mollusks, as is probably the case with *Crepidula dilatata*. On the other hand, a positive outcome of biofouling organism growth might be that they provide a physical barrier against the abrasion produced by sediment transport (Thomson 1997; Jones 2003). Biofouling might also play an important role in preventing the settlement of wood-borers’ larvae (Nair and Saraswathy 1971; Pournou 1999).

Low visibility and biofouling organism coverage complicated the examination of wood-borer activity on archaeological materials *in situ*, which necessitated removal of organisms at specific points. Colonization was easily identified in ship structure timbers with minor biofouling coverage and with tunnels exposed on the bow’s main deck in the galley area, middle lower deck, and stern’s main deck forward of the mizzen mast, and bulkheads. Their activity was also identified in wood remains on the sediment surface at the bow and port side-stern areas. The morphology of the tunnels was consistent with those of teredinid mollusks species.

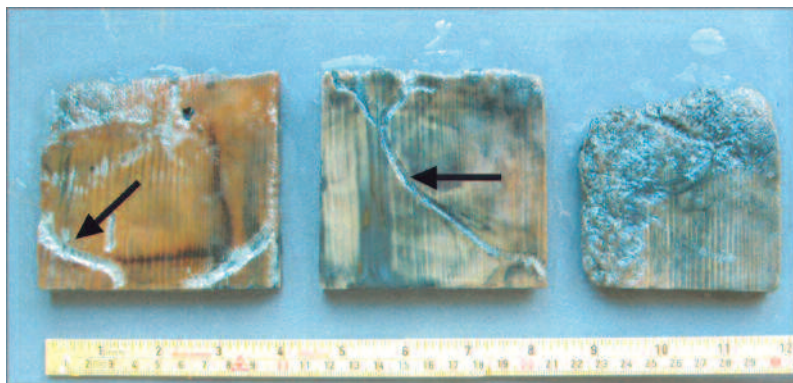
On the other hand, a survey of more than one hundred artifacts (n = 140) from excavated and seafloor surface contexts indicate that at least 15% had been colonized by wood-borers. This may be a conservative estimate, however, since the assessment was performed with the naked eye (Grosso 2008). More than 50% of these artifacts (including chests, boxes, furniture, etc.) were not in contact with seawater before *Swift* sank. Borer tunnel morphology was also indentified as

teredinids, with one exception, which was assigned to the Pholadidae family (Bastida *et al.* 2004). This is consistent with the fact that their members colonize wood occasionally. Diameters of Teredinidae tunnels at the *Swift* site are between 4 mm and 15 mm. Larger diameters are due to erosion processes. Wood-borers burrows were observed in high densities, even in some small artifacts, with a length that in some cases exceeds 20 cm (Figure 6b). Different wood species were colonized including *Ulmus* sp. (elm), *Quercus* sp. (oak) and pinaceae. While no living wood-borers were found, the presence of calcareous pallets permitted identification of *Bankia martensi*, previously documented in some parts of the Argentinean coast, but not in the Puerto Deseado area (Bastida and Torti 1972a).

The experimental study provided valuable information regarding identification and characterization of the biofouling community structure. Analysis of the 6-, 12- and 24-month panels included a description of biofouling organisms examined under a stereoscopic microscope. Primary species were identified and quantified, and their maximum density and biomass calculated (see Grosso 2008 and Elkin *et al.* 2011 for detailed information regarding methods and results). The activity of wood-borers was also considered. The results indicate that biofouling communities have a similar composition to those observed in other Patagonian localities (Bastida *et al.* 2004). Despite low water temperatures, they are present throughout

the year, though the warm season is characterized by increased colonization activities and growth rates. Indeed, warm months show greater taxonomic diversity and higher biomass (triple as a minimum) than cold months. The climax stage –when communities reach a balance and achieve their maximum development– is dominated by colonial species of tunicates *Paramolgula gregaria* and *Cnedomicarpa verrucosa*. These communities can evolve considerably, developing more than 10 cm of thickness on 10 x 5 cm panels (Figure 7). Given that other environmental parameters remain the same all year round, this study reveals that water temperature is the main factor regulating growth and development of biofouling organisms. Wood panels host higher biomass than acrylic ones, probably because organic material offers a more suitable surface for colonization, especially in its early stages. On wood panels, biodeterioration was mainly produced by bacteria, fungi and Folliculinidae (ciliated protozoans). The latter were able to perforate the substrata at a superficial level or settle in its natural irregularities. No wood-borer activity (neither mollusk nor isopods) on wooden panels was observed under the stereomicroscope during the two-year experimental study.

Finally, a systematic survey of non-archaeological wooden substrata along more than 5 km of the Deseado estuary's north coast was designed to evaluate historical and present day wood-borer activity in the area. This included examination of an early 20th century pier, wooden boats, and natural and anthropic wooden elements left by tides on the beach. Nearly a hundred wooden elements were observed, but only about 1% showed clear evidence of teredind activity. It should be noted that observed tunnels were eroded to a great extent indicating that the colonization was not recent.



a



b

Figure 6. a) Impressions left by soft tube polychaetes in chest components. b) Timber broken as a consequence of teredid activity. One of the tunnels still retains its calcium carbonate lining.

CULTURAL FORMATION PROCESSES

Documentary, historical and oral information was used to identify anthropic activities that took place in the *Swift* site area between its sinking and the present to assess their role in site formation processes. Documentary sources explain how survivors of the wreck managed to rescue some objects (two officers' chests and some spars) that floated away from the ship in the days after the sinking.

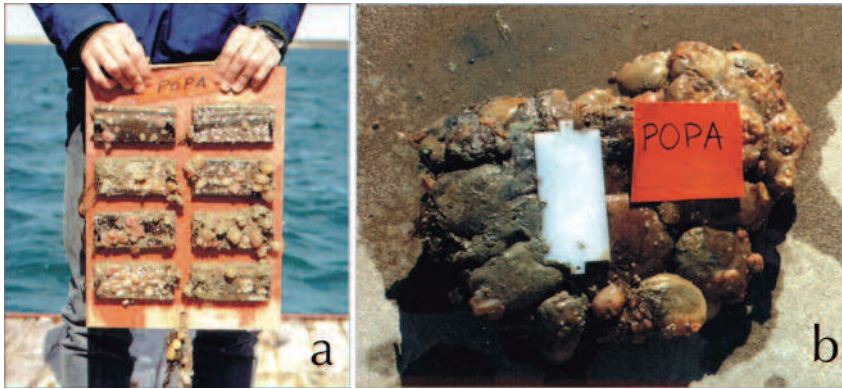


Figure 7. a) Wooden panels after one year of immersion. b) Significant growth of biofouling form one of the acrylic panels after two years of immersion.

Additionally, crew members dived into the wreck and managed to recover rigging elements and sails, which were used to build tents (Gower 1803). After the survivors left Puerto Deseado, no salvage operations or “opportunistic” recoveries (*sensu* Gibbs 2006) are documented for the wreck site. The only historical reference to such activity is the collection of rigging elements that were found on the coast by Antonio de Viedma’s expedition in 1780, which probably belonged to the *Swift* (Viedma [1837] 2006: 74-78). At the time of the wreck, no permanent human settlement could be found within hundreds of kilometers of the wreck. Until the end of the 18th century, the only people inhabiting the adjacent land were nomadic indigenous groups. It is important to mention, however, that Puerto Deseado is a natural harbor that has been frequently visited by vessels since the 16th century. Although salvaging shipwreck remains used to be a common practice, available evidence suggests that it is possible the *Swift* remained virtually unknown below the water’s surface until recently.

In the 18th and 19th centuries few settlements were established along the estuary coast, until 1884 when the town of Puerto Deseado was founded. At the beginning of the 20th century a pier for boats and small ships was operating near the wreck site. Large vessels could not come close to the shore due to their draught, but the anchors of boats and small ships could have damaged the *Swift*. A local resident indicated that in this area anchors and fishing tackle often became entangled (Elkin *et al.* 2011). This might have been an important factor in the physical deterioration of the most exposed structural remains, like the bow and starboard side.

In the last decades of the 20th century, Puerto Deseado evolved into one of the most active commercial ports on the Patagonian coast. In the harbor, large vessels are frequently towed between the wharf and a dry dock; the *Swift* site is very near the tow path. It is likely that the movement of the propellers –some of them very powerful– affects the superficial levels of sediment. Dredging is also occasionally performed

near the site, but a recent assessment during one of these operations indicated that it had no noticeable impact on the site (Elkin *et al.* 2011).

Finally, interventions on the site must be considered. After discovery of the shipwreck in 1982, local divers retrieved nearly 180 artifacts. These materials all lack information about their precise location (Elkin *et al.* 2011). According to the

divers’ reports, the artifacts were distributed on the sediment surface or buried up to 50 cm, so their extraction would have disturbed archaeological contexts. Afterward, four field seasons were carried out by the Argentinean Committee of the International Council of Monuments and Sites (ICOMOS), and one season by Fundación Albenga. The main goal of these initiatives was to perform non-intrusive recording of the ship, and only few artifacts were recovered (Elkin *et al.* 2011). At that time, and also over the course of subsequent archaeological work, divers’ displacement and equipment operation might have disturbed the superficial layer of sediment. Likewise, artifacts and structural components of the ship, previously protected by stable layers of sediments, became exposed at least temporarily during archaeological excavation activities.

PRESERVATION AND DISTRIBUTION PROCESSES

According to biodeterioration models, colonization by different microorganisms begins almost immediately after a ship sinks. Enzymes secreted by fungi and bacteria break down wooden cell walls (composed mainly of cellulose, hemicellulose and lignin), causing physical and chemical damage (Blanchette 2000). Non-biotic processes also take place, including hydrolysis, which usually occurs when the wood is immersed in water, and causes decomposition of molecules’ compounds (Pournou 1999). Furthermore, abrasive sediment particles transported by currents can erode artifacts (Jones 2003). In this way, the chemical composition and microscopic structure of wood are modified, making it more porous and permeable to the water.

Even if artifacts maintain their general shape, changes in their structural tissue and external appearance may occur. For example, some artifacts from the *Swift* site have polished edges caused by marine abrasion and others have a rough surface due to biotic activity. Quite often, the second case is

also associated with a significant loss of hardness and resistance; the wood becomes extremely soft (or spongy) at the slightest contact. Despite being fragile, artifacts' general shape may remain unchanged because water and the remaining lignin –more resistant to degradation than cellulose– support its shape (Jones 2003).

The degree to which organisms can leave impressions on wood surfaces depends on both the way they associate with the substratum and the condition of the wood tissue. Therefore, if the artifact is significantly decayed, even minor organic activity might leave marks (Figure 6a). Furthermore, regarding the consequences of tunicate detachment, we must bear in mind the cumulative effects of continuous cycles of fixing, development, and detachment of organisms and communities over more than two hundred years. The potential loss of archaeological information caused by these factors must be considered. Based on observation of several artifacts from the *Swift*, such losses include features associated with the artifacts' manufacture, use, or ownership (such as inscriptions and stamps; Grosso 2011).

The particular physical and chemical properties of different wood species are also relevant factors when considering the degradation and water-saturation processes in the marine environment. In this respect, it has been stated that porous woods like *Betula* sp. (birch), *Fagus* sp. (beech) and *Fraxinus* sp. (ash) become completely saturated within a few hours of being submerged and scarcely survive in the water. However, several artifacts manufactured with some of these species (*i.e.*, *Fagus* sp. and *Fraxinus* sp.) were found at the *Swift* site. Additionally, objects made from *Fagus* sp exhibit clear differences in their preservation, likely due to differences in their depositional histories. For example, the most degraded artifacts (tableware pieces) were found in the galley area, a location more exposed than the stern, where well preserved objects (such as a shoe last) were found completely covered by sediments (Figure 8).

It has also been noted that specific substances of certain wood species can be toxic for microorganisms,

thus inhibiting bacterial decay. This results in some coniferous species being more resistant to biodeterioration than some “hardwoods” (angiosperms). Nevertheless, as soon as those compounds leach out, these species become equally vulnerable to biodeterioration (Jones 2003).

In underwater environments wood permeability can be counteracted by the deposition of inorganic salts, calcareous materials, and the byproducts of metal corrosion, which, prevent its micro-structure from collapsing (Grattan 1987). This process depends on the chemical characteristics of the environment and the amount of time the artifacts have remained in that environment. This preservative effect has been observed in several artifacts from the *Swift*, typically boxes and a chest, which made possible to identify completely corroded elements (*e.g.*, hinges and locks) that otherwise would not have been noticed.

Colonization by teredinid mollusk larvae may also have occurred in the first years following the wreckage. There is some evidence to support this such as artifacts in the lower excavation levels in the stern area that show signs of colonization. Furthermore, it takes time for the wood to be eroded enough to expose teredinid tunnels and to lose the internal carbonate, as was observed in some cases. It is likely that wood-borer activity in the *Swift* began in the Malvinas / Falkland Islands, where *Bankia martensi* has been identified. Once the ship wrecked, colonization could have expanded to the entire shipwreck. The scarcity of wood-borer activity observed during the coastal survey supports the hypothesis that they are not a chronic problem in this area. Despite the fact that there is no clear evidence of teredinid activity at present, colonization events may be cyclical through time, and their future presence at the site should not be dismissed (Elkin *et al.* 2011).

In situ observations reveal that colonization has spread over structural elements and objects of varied forms and sizes, which supports arguments that different wood species and their hardness are not determining factors for wood-borer settlement (*e.g.*, Nair and Saraswathy 1971; Bastida and Torti 1972a). It is interesting to note also that artifact size has no apparent relation to the intensity of colonization (Figure 6b).

Comparing the effects of different biodeterioration agents, marine borers have been said to produce the most severe damage in a relatively short amount of time (Gregory 1998). Tunnels create empty spaces in the wood, which increase its permeability



Figure 8. A shoe last (INA 399) and a plate fragment (INA 471), both made from *Fagus* sp., exhibit differential preservation as a consequence of their particular post-depositional history.

and structural fragility. This leads to a reduction in its density and mechanical resistance (Pournou 1999), which reduces the weight of wood objects and makes them more vulnerable to being displaced by currents. In turn, fungi and bacteria play a relatively minor role in the deterioration of marine archaeological wood, though they do affect their long-term preservation (Gregory 1998).

At the *Swift* site, it was observed that artifacts more severely colonized by wood-borers were more prone to fragmentation. Small fragments are more susceptible to further biotic and abiotic deterioration. This is why, contrary to what happens with glass or ceramic fragments, wooden fragments tend to have a less significant diagnostic potential.

The deposition of thin particles of sediment was a slow but constant process since the *Swift* sank, until a certain stability was reached. The wreck constitutes an obstacle that slows down tidal currents, acting as a sediment trap.

The formation of an anoxic environment is beneficial to the preservation of archaeological materials, particularly organic ones, because the lack of oxygen prevents the development of most organisms, with the exception of specialized (anaerobic) bacteria. However it is worth noting that even a small portion of a wooden artifact that remains exposed it is enough for wood-borers to colonize the whole piece (Figure 9). In addition, sediment coverage also protects materials from the marine erosion produced by the sediment transportation of tidal currents.

As mentioned previously, the superficial stability of sediments can be modified by currents, archaeological work, and bioturbation produced by benthonic invertebrates, whose effects, while generally minor, can be cumulative and significant (Ferrari and Adams 1990). All of these factors can result in the exposure of archaeological materials to new oxygenated conditions, making them vulnerable to deterioration.

Recording the structural remains provided a more comprehensive view of the possible processes and successive stages of the ship's deterioration and, consequently, of the distribution and preservation of its contents. After the sinking, the elements that remained more exposed or closer to the water surface—the rigging, the bow and part of the starboard side—would likely have suffered the buffeting of waves and tidal currents, as well as the consequences of anthropic impact. In combination with this, the mechanical effects of the giant kelp *Macrocystis pyrifera* (Bastida *et al.* 2008) and large colonies of tunicates attached to the structural timbers could have further weakened them; according to the results of the experimental studies it is likely that, within one year of the wreck, macrofouling communities were

already well developed (Bastida *et al.* 2004). There is no clear evidence of wood-borers on beams and frames, though they did colonize the decks planks, so may have played a role in structural collapse.

The deterioration of structural boundaries like decks and bulkheads could have led to the dispersion of artifacts that had originally been retained in ship compartments. For example, those elements belonging to the missing sectors of the upper deck might have slipped towards the portside or collapsed together with that part of the ship, depending on their different attributes (e.g., material, dimensions, weight, and whether they were fixed or loose). At the stern excavation area (captains' quarters), materials on the sediment surface or near it did not maintain a clear contextual association. Objects that seem to come from the collapsed starboard area were found there. The integrity of the objects themselves was poorly preserved. For these reasons, contextual associations should be interpreted with caution, particularly in the case of cupboards, chests and boxes and their possible contents. On the contrary, in the lower levels of the excavation, bulkheads have been largely preserved



Figure 9. Part of this sea chest component was seriously deteriorated because of wood-borers activity and erosion processes. A well preserved area due to sediment coverage can clearly be observed (Photo: C. Murray).

and permitted the distinction between the Captain's cabin and his chamber. The spatial location and the integrity of the objects there seemed more clearly defined. Some examples of this are furniture (e.g., folding stools) found in what it seems to be its original storage location, and a cupboard and its content that have maintained their contextual relations. Sediment accumulated inside boxes and chests before nails and ironwork corroded, preventing the collapse of wood components and preserving the original content. This pattern has also been observed in other areas of the site where sedimentation was rapid, even in levels close to the surface (Figure 10).

The results obtained in these studies have been essential to discuss research questions related to material culture at the *Swift* site. This includes artifact provenience, function, and contextual associations; links between objects and crew members, and personal belongings versus navy property (see Grosso 2011, 2013).

CONCLUSIONS

Regarding post-depositional processes affecting the *Swift* site, the essential factors affecting the survival



Figure 10. Medicine chest found on the superficial level in the amidship area with a very well preserved content (Photo: C. Murray).

and distribution of archaeological materials are the environmental characteristics and their particular dynamics, even in those cases where human activity had a considerable influence. The integrity of materials is related to complex processes, which in turn depend on the depositional microenvironment and the physicochemical properties of the wood. As Ferrari and Adams (1990) indicate, it is important to approach this relationship not simply in terms of the environment influence on the archaeological materials, but as an interaction between them.

The shipwreck process, the bottom slope, and the prevailing current direction have been the most important factors that determined the distribution of artifacts towards the portside and stern areas. The accumulation of sediment at the *Swift* site has been a major control agent, facilitating the survival and integrity of the archaeological record. Teredinid mollusks have been the primary agent of biodeterioration, both in the aggressiveness of their action but also the rapidity of their colonization. Teredinids have played a fundamental role in the decay of wooden artifacts –resulting in partial or complete destruction– and also in their spatial distribution. Fouling organisms can also produce certain deleterious effects, particularly the loss of surface evidence in artifacts.

The results obtained to date allowed us to understand preservational and distributional processes at different scales, from the site as a whole, to excavated areas and individual components. The research should continue as the excavation progresses in new areas. At present, the interventions at the site are temporarily suspended until further progress with stabilization treatments can be made at the conservation laboratory. In addition, the biotic and abiotic microdeterioration processes in wooden artifacts is an issue that still requires investigation at the site, both in terms of continued study of formation processes and *in situ* preservation assessment. This research field has not yet been pursued in Argentine Patagonian waters and in the future could be developed in the region based in the work carried out in the last years by several research projects (e.g., Pournou 1999; Jones 2003; Manders 2004; Palma 2004).

Finally, the recovered data highlight aspects that must be taken into account when working at the site. The handling of wooden artifacts –underwater and on land– must be done with extreme care, even if the artifacts appear to be in a good

condition, since the structure of the wood could be very weak and therefore easily damaged. At the end of each fieldwork season, excavated areas must be covered (e.g., refilled with sediment) to avoid further colonization on newly oxygenated wood (see Gregory 1998, among others). Lastly, periodic monitoring of the site should be carried out.

In light of the information obtained to date, a considerable contribution to understanding formation processes at the *Swift* site was achieved. This knowledge may also be relevant for building predictive models for the assessment of other sites less well preserved than the *Swift*, both in underwater and intertidal environments of the Argentine Patagonian coast.

Acknowledgements

This research was only possible after many years of joint work. I am especially grateful to my PhD directors, Dr. Dolores Elkin and Dr. Ricardo Bastida, for their guidance and support. Dr. Bastida significantly contributed to the accomplishment of this research and has generously provided me with specialized bibliography. I would also like to thank all the people who have worked or assisted in the fieldwork and laboratory analyses, particularly the PROAS members and the team of the Laboratorio de Ecología Bentónica y Biodeterioro (Mar del Plata University), to Marilyn Castro and Glenn McConnachie for wood anatomical identifications, and to the friends from Puerto Deseado who have generously provided their help through these years. Several institutions have supported the HMS *Swift* Project since its beginning: Fundación Antorchas, Secretaría de Cultura de la Nación, Municipalidad de Puerto Deseado, Museo Municipal Mario Brozoski, Gobierno de Santa Cruz and the British Embassy in Argentina. I would also like to thank Women Divers Hall of Fame for the Cecelia Connelly Memorial Scholarship in Underwater Archaeology, which I had the honor to receive. I gratefully acknowledge Cristian Murray and Alejandra Elías for their comments, and to the anonymous reviewers and the editors Karen Borrazzo and Celeste Weitzel for their valuable observations and suggestions to improve this work, as well as for translating the abstract. Thanks also to Ana Castelli for her assistance with the translation and to Raven Garvey for her helpful review of the English language that have improved the final manuscript.

REFERENCES

- Adams, J.
 2001 Ships and boats as archaeological source material. *World Archaeology* 32 (3): 292-310.
- Bastida, R. and M. R. Torti
 1972a. Organismos perforantes de las costas argentinas. I. La presencia de *Lyrodus pedicelatus* (Quatrefages, 1849) (Mollusca, Pelecypoda) en el puerto de Mar del Plata. Clave para el reconocimiento de los Teredinidae sudamericanos. *Physis* 31 (82): 39-50.
 1972b. Organismos perforantes de las costas argentinas. II. La presencia de *Limnoria* (*Limnoria*) *tripunctata* (Menzies, 1951) (Isopoda, Limnoriidae) en el puerto de Mar del Plata. *Physis* 31 (82): 143-153.
- Bastida, R., D. Elkin, M. Grosso, M. Trassens and J. P. Martin
 2004 The British sloop of war HMS *Swift* (1770): a case study of the effects of biodeterioration on the underwater cultural heritage of Patagonia. *Corrosion Reviews*, Special Issue: Biodeterioration of Cultural Heritage 22 (5-6): 417-440.
- Bastida, R., M. Grosso and D. Elkin
 2008 The role of benthic communities and environmental agents in the formation of underwater archaeological sites. In *Underwater and Maritime Archaeology in Latin America and the Caribbean*, edited by M. E. Leshikar-Denton and P. Luna Erreguerena, pp. 173-185. Left Coast Press, Walnut Creek.
- Bastida, R., M. Trassens, J. P. Martin and M. Grosso
 2011 El papel de los sedimentos en la formación y conservación de los sitios arqueológicos subacuáticos: el caso de la HMS *Swift* (1770). In *El naufragio de la HMS Swift (1770)*. *Arqueología marítima en la Patagonia*, Specialized Studies section coordinated by R. Bastida, pp. 27-57. Vázquez Mazzini, Buenos Aires.
- Blanchette, R.
 2000 A review of microbial deterioration found in archaeological wood from different environments. *International Biodeterioration & Biodegradation* 46: 189-204.
- Eaton, R. A. and M. D. C. Hale
 1993 *Wood. Decay, pest and protection*. Chapman & Hall, London.
- Elkin, D.
 2011 Shipwreck Archaeology in South America. In *The Oxford Handbook of Maritime Archaeology*, edited by A. Catsambis, B. Ford and D. L. Hamilton, pp. 685-707. Oxford University Press, Oxford.
- Elkin, D., A. Argüeso, M. Grosso, C. Murray, D. Vainstubb, R. Bastida and V. Dellino-Musgrave
 2007 Archaeological research on HMS *Swift*: a British Sloop-of-War lost off Patagonia, Southern Argentina, in 1770. *The International Journal of Nautical Archaeology* 36 (1): 32-58.

- Elkin, D., C. Murray, R. Bastida, M. Grosso, A. Argüeso, D. Vainstüb, C. Underwood and N. Ciarlo
2011 *El naufragio de la HMS Swift (1770). Arqueología marítima en la Patagonia*. Vázquez Mazzini, Buenos Aires.
- Ferrari, B and J. Adams
1990 Biogenic modifications of marine sediments and their influence on archaeological material. *The International Journal of Nautical Archaeology and Underwater Exploration* 19 (2): 139-151.
- Florian, M-L. E.
1987 The underwater environment. In *Conservation of Marine Archaeological Objects*, edited by C. Pearson, pp. 1-20. Butterworths, London.
- Gibbs, M.
2006 Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 Years on. *The International Journal of Nautical Archaeology* 35 (1): 4-19.
- Gower, E.
1803 *An Account of the Loss of His Majesty's Sloop 'Swift', in Port Desire, on the Coast of Patagonia, on the 13th of March, 1770*. Winchester and Son, London.
- Grattan, D. W.
1987 Waterlogged wood. In *Conservation of Marine Archaeological Objects*, edited by C. Pearson, pp. 55-67. Butterworths, Londres.
- Gregory, D.
1998 Re-burial of timbers in the marine environment as a means of their long term storage: experimental studies in Lynæs Sands, Denmark. *The International Journal of Nautical Archaeology* 27 (4): 343-358.
- Grosso, M.
2008 Arqueología de naufragios: estudio de procesos de formación naturales en el sitio HMS *Swift* (Puerto Deseado, Santa Cruz). In Undergraduate thesis, Departamento de Ciencias Antropológicas II. Facultad de Filosofía y Letras, Universidad de Buenos Aires, Buenos Aires (CD ROM).
2011 Estudios de cultura material en sitios históricos de naufragio en el litoral patagónico. El uso de la madera en artefactos del barco británico HMS *Swift* (siglo XVIII). PhD dissertation, Facultad de Filosofía y Letras, Universidad de Buenos Aires, Buenos Aires.
2013 Qué llevar y cómo transportarlo. Acerca de los enseres de almacenaje en un barco de guerra inglés del siglo XVIII (Puerto Deseado, Santa Cruz). *Intersecciones en Antropología* 14: 157-170.
- Jones, M. (editor)
2003 *For future generations. Conservation of a Tudor Maritime Collection*. The Mary Rose Trust, Portsmouth.
- Kühnemann, O.
1971 Vegetación Marina de la Ría de Puerto Deseado. *Centro de Investigación de Biología Marina, Contribución Científica N° 30*. Buenos Aires.
- Manders, M.
2004 Protecting Common Maritime Heritage. The Netherlands involved in two EU-projects: MoSS and BACPOLES. *Mediterraneum* 4, Protection and Appraisal of Underwater Cultural Heritage, edited by F. Maniscalco, pp. 279-292. Massa, Napoli.
- Muckelroy, K.
1978 *Maritime Archaeology*. Cambridge University Press, Cambridge.
- Murray, C., D. Elkin and D. Vainstüb
2003 The Sloop-of-War HMS *Swift*. An archaeological approach. In *The Age of Sail 1. The International Annual of the Historic Sailing Ship*, edited by N. Tracy, pp. 101-115. Conway Maritime Press, London.
- Nair, N. B. and M. Saraswathy
1971 The biology of wood boring teredinid molluscs. In *Advances in Marine Biology*, Vol. 9, edited by F. Russel and M. Yonge, pp. 335-509. Academic Press, London and New York.
- Newsom, L. A. and R. B. Miller
2009 Wood Species Analysis of Ship Timbers and Wooden Items Recovered from Shipwreck 31CR314, *Queen Anne's Revenge* Site. Research Report and Bulletin Series QUR-R-09-01. *Queen Anne's Revenge* Shipwreck Project. Underwater Archaeology Branch, Department of Cultural Resources, State of North Carolina.
- Palma, P.
2004 Final Report for the Monitoring theme of the MoSS Project. *Moss Newsletter Final Report: 8-37*. The National Board of Antiquities.
- Pournou, A.
1999 *In situ protection and conservation of the Zakynthos wreck*. PhD Thesis. University of Portsmouth, School of Biological Sciences, Portsmouth.
- Prosser Goodall, R. N.
1978 *Tierra del Fuego*. Rae Natalie Prosser Goodall, Harberton.
- Randell, S.
1998 Marine growth on shipwrecks. *The Bulletin of the Australian Institute for Maritime Archaeology* 22: 107-108.
- Thomson, L.
1997 The biodegradation of the wreck *Day Dawn*. *The Bulletin of the Australian Institute for Maritime Archaeology* 21 (1&2): 119-124.

Viedma, A. de

[1837] 2006 Diario de un viaje a la costa de la Patagonia... desde el puerto de Santa Elena hasta la boca del Estrecho de Magallanes. In *Diarios de Navegación. Expediciones por las costas y ríos patagónicos (1780-1783)*, directed by N. Tello, pp. 45-98. Buenos Aires, Continente.

Ward, I., P. Larcombe and P. Veth

1999 A New Process-based Model for Wreck Site Formation. *Journal of Archaeological Science* 26: 561-570.

NOTES

1.- A detailed analysis of this "response to shipwreck's threat" (*sensu* Gibbs 2006) is in Elkin *et al.* (2011).

2.- Some of the *Swift's* artifacts are at different stages of the conservation treatment. Once taken out of the water, wooden artifacts must be stabilized and dried in a controlled procedure (see Jones 2003, among others).

3.- The identification of wood taxonomy based on its anatomical characteristics has limitations because generally the possible taxonomic specificity reaches only the level of genus or subgenus. Also, the deterioration of the cell structure of the wood sample may inhibit or make difficult the identification (Newsom and Miller 2009).

