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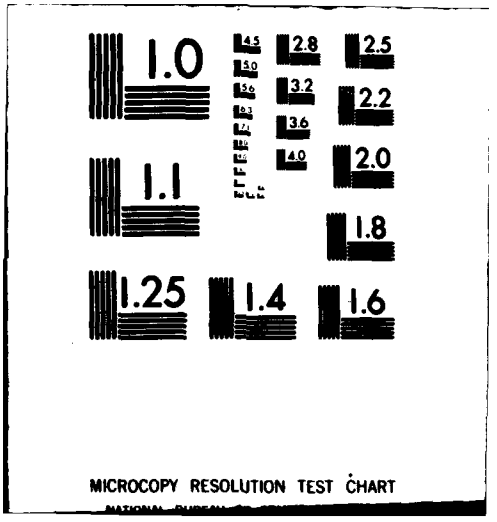
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UNITED STATES FRIGATE *CONSTELLATION*:

Monitoring of Water at Constellation Pier, Baltimore Harbor, for the Presence of Marine Wood-Destroyers— First Year of Observations, from April 1978 to May 1979

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Environmental Biology Branch
Environmental Sciences Division

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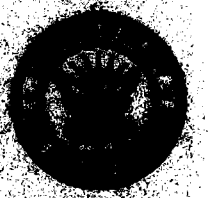

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The United States Frigate *Constellation* is permanently berthed at Constellation Pier in Baltimore Harbor. Recently, an extensive program of repair and restoration was begun and a schedule of preventive maintenance established. Because the hull and other wooden structures of *Constellation* are susceptible to degradation by wood-destroying organisms, the preventive maintenance program includes the monitoring of the water adjacent to the hull for the presence

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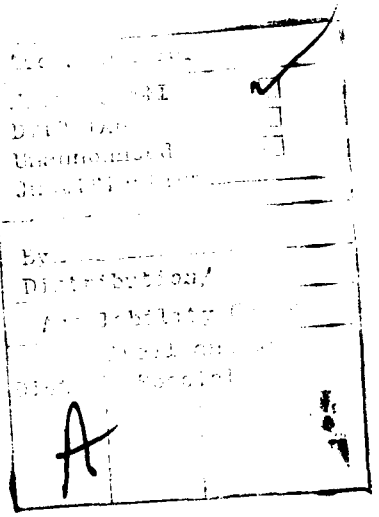
20. ABSTRACT (Continued)

of marine wood-destroyers and inspection of internal wooden structures for fungal degradation. Environmental and biological data were obtained from three field inspections performed since the monitoring program began. The biological data show that there is no marine-borer (*Bankia gouldi*) activity in the water at Constellation Pier, and unless there occurs an unusual and prolonged change in climatic conditions which would increase the salinity of the water, a future infestation of *B. gouldi* is not likely. Consequently, there is no current threat to the hull of *Constellation* by this borer, and no action is now required to protect the hull of *Constellation* from borer attack. Currently, the most serious threat to the hull is the presence of lignicolous fungi on the wood at and below the waterline. Fungal damage, if any, can be determined when *Constellation* is moved into drydock for hull inspection and maintenance.



UNITED STATES FRIGATE *CONSTELLATION*:

MONITORING OF WATER AT CONSTELLATION PIER, BALTIMORE HARBOR, FOR THE PRESENCE OF MARINE WOOD-DESTROYERS— FIRST YEAR OF OBSERVATIONS, FROM APRIL 1978 TO MAY 1979

INTRODUCTION

The United States Frigate *Constellation* (Fig. 1), launched 183 years ago on 7 September 1797, became the first fighting ship of the fledging United States Navy to sail the high seas and, under the command of Captain Thomas Truxton, the first Navy vessel to engage—and defeat—an enemy man-of-war. In and out of comission several times over the years, *Constellation* was recomissioned for the last time at 144 years of age by President Roosevelt to serve as the Flagship of the Atlantic Fleet during World War II.

Fig. 1 — U.S.F. *Constellation*, permanently berthed at Constellation Pier, Baltimore Harbor

When permanently decommissioned in 1955, Constellation possessed the longest service record of any fighting ship in the history of the Navy. Also, by remaining afloat since her launching, *Constellation* has spent more time continuously in the water than any other ship in the world. Now classified as a National Historic Shrine, the "Yankee Race Horse" is permanently berthed at Constellation Pier in Baltimore Harbor whose waters first wetted her hull.

Recently an extensive program of repair and restoration was begun. Included in this program are primary and secondary hull repairs; restoration of companionways, partitions, bulkheads, and other internal structures; repair of fittings, masts, spars, and rigging; and replacement of missing items. A

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schedule of preventive maintenance includes continuous monitoring of the hull for evidence of biological degradation caused by terrestrial or marine wood-destroying organisms.

MONITORING PROCEDURES

The monitoring program was begun in the spring of 1978 with the installation of two arrays of untreated wood, subsequently increased to four, in the water adjacent to the hull of *Constellation.* Each array is composed of five 10- by 20-cm southern pine sapwood panels spaced approximately 1.5 m (5 ft) apart (center to center) on a supporting line; the lowest panel is positioned about 60 cm (2 ft) from the bottom. The maximum water depth is 7.6 m (25 ft), and the tidal range is about 1.2 m (4 ft). Three of these arrays are between the hull and the pier at the bow, stern, and amidships; the remaining array is amidships, outboard. These panels, which serve as a substrate for settling marine fouling and boring organisms, are inspected semiannually; an array removal/replacement schedule was established to provide for the removal of two arrays at each inspection, exposed for 6 and 12 months, respectively. The removed panels, which are replaced with new wood, have their surfaces examined in the laboratory by light microscopy for the presence of borer entrance holes and are examined internally by radiography for the presence of borer tunnels. At each inspection measurements of hydrogen-ion (pH) and oxygen concentrations, salinity, and temperature are made on the surface water adjacent to the hull. In addition, culture plates inoculated with hull scrapings taken across the waterline of Constellation are incubated to determine the presence of lignicolous fungi and bacteria.

RESULTS OF THE FIELD INSPECTIONS

Physical and Chemical Variables

Salinity, oxygen concentration, and water temperature all play an important role in successful growth and reproduction of marine organisms and can serve as indicators of a suitable environment for the presence of these organisms in the water column. For this reason these variables and the pH of the water were recorded at Constellation Pier; these values are presented in Table 1 for the initial panel installation and for the three subsequent field inspections.

Table 1 — Physical and chemical data relating to the water column adjacent to the hull of *Constellation* and taken at the time of initial panel installation and at the subsequent field inspection

Date	pH	Oxygen (ppm)	Salinity (‰)	Water Temp. (°C)
April 1978	6.8	8.6	3.5	11.0
Nov. 1978	6.9	3.3	9.2	14.0
May 1979	7.2	8.3	3.3	14.5
July 1979[1]	6.8	6.0	3.0	27.0

[1]Nonscheduled inspection to get additional fungal information prior to dry-docking of *Constellation* for hull inspection and repairs.

Water pH and temperature have remained relatively constant since the monitoring program began except for the high water temperature recorded at the most recent inspection; a similar seasonal temperature distribution has been recorded at the head of the Patuxent River estuary [1,2]. The salinity of the estuarine waters in the upper Chesapeake Bay is very dependent on fresh-water runoff. Minimum salinity occurs in the spring as a result of an increase in river flow, and a subsequent decrease in river flow during the summer and fall months maximizes this variable [3]. The seasonal variation in salinity measured at Constellation Pier is typical of that for estuarine waters in the upper Bay [1,2,4,5], including four locations within Baltimore Harbor itself [6]. The observed decrease in the amount of oxygen in the water between spring and fall can be attributed to an increase in the population of oxygen-consuming organisms and to an increase in water temperature, which would decrease oxygen solubility.

Marine Borers

Although *Teredo navalis, T. bartschi,* and other teredine species are present in the more oceanic waters at the mouth and in the lower reaches of Chesapeake Bay [7], the only marine borer known to be present at the northern end of the Bay is *Bankia gouldi* Bartsch [1,4,8], which normally ranges as far north as the mouth of the Patapsco River. However, its presence in the estuarine waters of the upper Bay depends on the variable salinity caused by the annual fluctuation in fresh-water runoff. Spawning of *B. gouldi* in Chesapeake Bay probably begins in late spring [4], and the infestation of wood by these borers continues through October, with the activity usually peaking in July. Once the larvae have settled and metamorphosed, *B. gouldi* probably becomes more tolerant to the subsequent decrease in salinity which occurs during the winter and spring months. The presence of *B. gouldi* is reported [1,4] in waters with a salinity of 3 to 16 ‰, averaging 9 ‰. While the average salinity at Constellation Pier is somewhat lower (6 ‰), the minimum salinity value recorded is within the above-quoted range, and the increase in salinity of the water which occurs during the period of *Bankia* activity would enhance the possibility of the borer moving further up the Patapsco estuary. Other data [6] indicate that a salinity less than 7 ‰ is lethal to *B. gouldi.*

Laboratory examination of the panels removed after 6 and 12 months of exposure at Constellation Pier (Fig. 2) did not disclose the presence of *Bankia.* These results confirm the conclusions of the earlier study of the factors controlling the presence of the shipworm (and other borers) in Baltimore Harbor [6]. Also, *Bankia* was not recorded at Lower Marlboro on the Patuxent River estuary [1], where the salinity profile is similar to that at Constellation Pier. Under normal circumstances an influx of *Bankia* as far up the Patapsco estuary as Constellation Pier is not likely; however, a prolonged period of diminished rainfall would increase the salinity of the water sufficiently to produce a more hospitable environment for this borer. This series of events actually occurred in San Francisco Bay. The disasterous influx of *T. navalis* into the Bay in the early 1920s was preceeded by a prolonged period of reduced rainfall which allowed the salinity of the water to increase to a tolerable level [9]. Such a climatic phenomenon could occur for the Chesapeake Bay area.

Fouling Organisms

The yearly settlement of epifaunal organisms at Constellation Pier is generally similar to that in the Patuxent River estuary as far as the pattern of settlement is concerned [1]. Here a repeating pattern of biotic succession results in a mature fouling community in the fall; this community dies away during the winter, and the cycle begins anew in the spring. A detailed identification of the fouling organisms present on the panels removed at each inspection was not made because the monitoring program is concerned primarily with the presence of marine borers in the water column. However, an abbreviated listing of those organisms which had settled on the panels removed during the November inspection is presented in Table 2 to show the diversity of species; other species would be present at other times of the year, depending on the stage of biotic succession at the time of panel removal. The

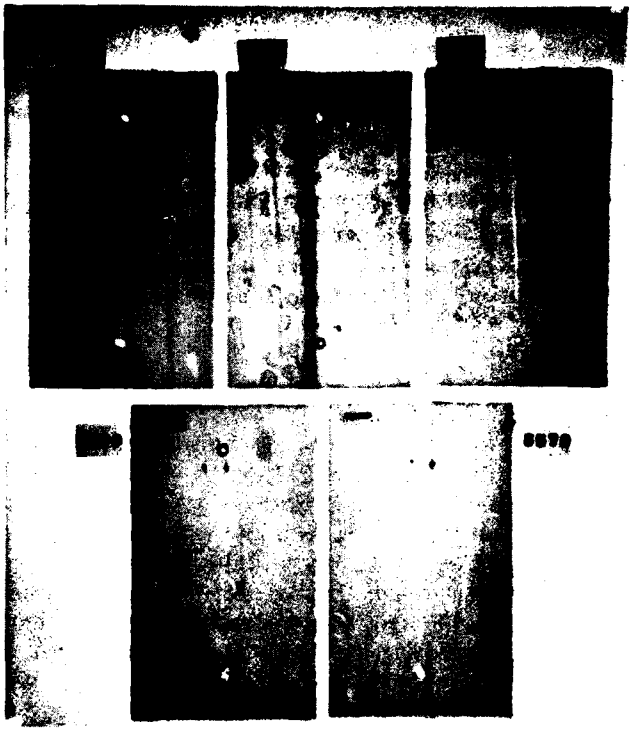

Fig. 2 — X rays of pine panels removed at the May 1979 inspection after 12 months of exposure in the harbor water adjacent to the hull of Constellation. The first numeral in each number indicates the relative position of the panel in the array from top (1) to bottom (5). No borer tunnels are present; the round markings are caused by residual barnacle bases.

Table 2 — Representative population of fouling organisms, showing species diversity. The organisms were obtained from panels removed during the November 1978 field inspection. The heaviest accumulation of organisms occurred on the three middle panels of the array, ranging in depth from 2.4 m (8 ft) to 5.4 m (18 ft). This listing is not complete, and other species will be found at other seasons of the year.

	Animals
Protozoa	(ciliated and stalked)
Platyhelminthes	(free living turbellarians)
Nematoda	(roundworms)
Annelida	(Polychaetes or segmented worms, most of which were tube-dwelling, whose adult and larval tubes comprised most of the dense, brown mat covering the panels)
Mollusca	(Nudibranch gastropods and pelecypods, primarily *Mytilus edulis*)
Bryozoa	
Arthropoda	(Crustaceans including harpacticoid copepods with egg sacs and two species of barnacles, one being *Balanus improvisus*, the other unidentified)
	Plants
Algae	(*Melosira*, *Thallasiothrix*, *Navicula*, *Bacillaria*, and *Grammatophoria*, which are all diatoms)

total biomass (dry) of fouling organisms (159 g) on the panels removed at the May 1979 inspection was less than that of the previous fall inspection and was composed predominantly of *Mytilus edulis*, although many barnacles were also present. The distribution of fouling organisms on each panel array followed the same pattern at the first two inspections; no panels were removed at the last, unscheduled inspection. The heaviest accumulation of biomass occurred, in both cases, on the supporting line and the two included panels between 1.5 m (5 ft) and 5.4 m (18 ft). This distribution is shown on the set of panels in Fig. 3. A more detailed record of the epifaunal community will be made in the future.

Fig. 3 — Panel array removed at the May 1979 inspection. The heaviest accumulation of fouling organisms occurred on the supporting line and included panels between 1.5 m (5 ft) and 5.4 m (18 ft). The top panel (1) of the array is on the right; the bottom panel (5) is on the left.

Microorganisms

Waterline scrapings and those from above the waterline were removed from the hull of Constellation during the field inspections, transported aseptically to the laboratory, and used to inoculate plates containing one of four media: potato dextrose agar, marine agar 2216, agar containing pine sawdust, or autoclaved harbor water plus pine sawdust. The plates were incubated for 3 weeks at 26°C. The results of this microbiological study are presented in Table 3; generally, the same organisms were isolated from the hull at the spring and fall inspections. Examination of microbial colonies that grew on the culture plates showed a diverse population of fungi and indicated that the hull of Constellation is infested at the waterline and just below, predominantly by fungi belonging to the order Sphaeropsidales and by *Trichocladium* of the order Moniliales. These organisms are common wood-inhabiting fungi. No lignicolous bacteria were isolated.

SUMMARY

Environmental and biological data were obtained from the three field inspections performed since monitoring of the water adjacent to *Constellation*'s hull began. The biological data show that there is no marine borer activity in the water at Constellation Pier; consequently, there is no current threat to the

Table 3 — Summary of the microbiological determinations made on the hull scrapings from *Constellation* and on the harbor water

Inoculum	Medium	Observations
Waterline scrapings	Potato dextrose agar	Several types of fungal growth, but the predominating form was a dark brown fungus identified as a *Trichocladium* species
	Marine agar 2216	A *Pseudomonas*, algae, and a white filamentous fungus unidentified due to lack of reproductive structure
	Pine sawdust agar	*Trichocladium* sp.
	Harbor water/pine sawdust	Extensive brown mat identified as *Trichocladium*
Scrapings from above waterline	Potato dextrose agar	Many diverse types of fungal growth, most of which contained reproductive structures typical of Spheropsidales
	Marine agar 2216	White fungal growth with no reproductive structures; bacteria
	Pine sawdust agar	White fungal growth
	Harbor water/pine sawdust	No growth
Harbor water	Marine agar 2216	Bacteria, predominantly *Pseudomonas*
	Harbor water/pine sawdust	No growth

hull of Constellation by these organisms. And, unless there is an unusual and prolonged change in climatic conditions which would increase the salinity of the water, a future infestation by *Bankia* is not likely. No action is required now to protect the hull of Constellation from *Bankia*. However, it is remotely possible that the hull of Constellation was infested with *Bankia* before the monitoring program began; these animals could have become established in the wood during a previous period when the water of Baltimore Harbor was hospitable to *Bankia* larvae. The only way to detect the presence of these animals with certainty is to remove the hull planking and open it sacrificially. Because of the remoteness of the occurrence of a prior infestation, such action is not warranted.

The most serious threat to the hull of *Constellation* now is the presence of lignicolous fungi on the wood, particularly at and just below the waterline. The extent of fungal damage, if any, can be determined when *Constellation* is next moved into drydock for hull inspections and maintenance. An inspection of the hull for the presence of previously settled *Bankia* could be made simultaneously.

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ADDENDUM

In mid-July 1979 an unscheduled inspection was made to determine the extent of fungal deterioration of the hull planking farther below the waterline than was done earlier. Hull scrapings were taken from various depths and at different locations on the submerged portion of the hull and were brought back to the laboratory for processing by the same techniques used previously. The culture plates were read after 4 weeks of incubation. As expected, microbial growth occurred on all the plates, with fungi predominating. Fungi were especially heavy on those plates inoculated with the waterline scrapings; on these plates the cultures grew most prolifically. The experimental details and results are summarized below.

Sample No.	Section of Hull sampled	Sampling Observations	Medium	Laboratory Observations (4 weeks)
1[a]	Waterline, amidships, starboard	Barnacles attached to wood	Marine agar 2216	Predominantly *Pseudomonas*
			PDA&Y[b] agar	Fungal structures typical of Sphaeropsidales[c]
			Harbor water/ pine sawdust	Bacteria, mixed Sphaeropsidales
2	1.5-m (5-ft) depth, amidships, starboard	Barnacles attached to wood	Marine agar 2216	Mixed bacteria, predominantly *Pseudomonas*
			PDA&Y agar	Worms, protozoa, fungal structures typical of Sphaeropsidales
			Harbor water/ pine sawdust	Protozoa, Sphaeropsidales
3	3-m (10-ft) depth, amidships, starboard	Barnacles attached to wood		
4	1.2-m (4-ft) depth toward the bow, starboard	Barnacles attached to wood	Marine agar 2216	Mixed bacteria
			PDA&Y agar	Mixed bacteria
			Harbor water/ pine sawdust	Fungal fragments
5	1.8-m (6-ft) depth toward the bow; starboard	Barnacles attached to wood	Marine agar 2216	Mixed bacteria
6[a]	Waterline, amidships, port	Algal mat present	Marine agar 2216	White fungus, with identifying structures absent
			PDA&Y agar	Protozoa, worms, sphaeropsidales
7	1.2-m (4-ft) depth, amidships, port	Barnacles attached to wood		
8	1.2-m (4-ft) depth, amidships, port	Barnacles attached to wood	Marine agar 2216	Mixed bacteria; white fungus, with identifying structures absent
9	2.4-m (8-ft) depth, amidships, port	Barnacles attached to wood	Marine agar 2216	Mixed bacteria, white fungus
			PDA&Y agar	Mixed bacteria, white fungus
			Harbor water/ pine sawdust	Worms, protozoa, Sphaeropsidales
10	3-m (10-ft) depth, amidships, port	Barnacles and algal mat	Marine agar 2216	Mixed bacteria
			PDA&Y agar	Worms, protozoa, Sphaeropsidales
			Harbor water/ pine sawdust	Sphaeropsidales
11	Harbor water		Marine agar 2216	Mixed bacteria
			PDA&Y agar	Sphaeropsidales
			Harbor water/ pine sawdust	No growth

[a] Plates inoculated with waterline scrapings developed the most prolific growth of fungi.

[b] PDA&Y = potato, dextrose, agar, and yeast medium

[c] Specific fungal identifications were generally not possible because of the absence of the necessary reproductive structures.