FOULING ON A DEEP-ANCHORED SUBMARINE HULL

I. E. Davies and E. G. Barham · Research and Development · 12 April 1965

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA 92152 · A BUREAU OF SHIPS LABORATORY

THE PROBLEM

Investigate and report on the factors in the marine biological environment that pertain to underwater sound; identify and study organisms affecting sound attenuation and reflection. Investigate the distribution of such organisms in space and time to gain a predictive understanding of their fluctuations in critical areas of the ocean. Specifically, examine U.S. Navy submarine SQUAW (No. 29) and report on the biological fouling present after approximately 5 years of submergence at a depth of 200 feet in the deep oceanic environment. Identify the fouling organisms, estimate their numbers, and describe their distribution on the hull.

RESULTS

1. The fouling intensity on SQUAW was relatively light compared to equipment submerged in shallow water for an equally long period.

2. Vertical stratification was pronounced; hard, calcareous forms were concentrated on the upper surfaces, the sides were dominated by algae and the bottom by tube worms.

3. Associated noise-producing organisms would raise the ambient sound level in the vicinity of the target.

RECOMMENDATIONS

1. Make further studies of fouling processes in the deep oceanic environment.

2. Arrange for better communication between operational organizations of the U.S. Navy and scientific personnel working in this field so that prompt inspections can be made of all such platforms which are recovered from deep sea moorings.

ADMINISTRATIVE INFORMATION

The work covered in this report was performed under NEL Problem No. L40951, SR 004 03 01, Task 0588. The authors wish to acknowledge the assistance of LTJG R. F. Crowe, USNR, of USS COCOPA, for his excellent report on the salvage operation, and the help of the National Steel and Shipbuilding Co., in the examination of SQUAW while in their drydock. The report covers work from 23 November 1964 to 20 January 1965 and was approved for publication 12 April 1965.

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ILLUSTRATIONS

REVERSE SIDE BLANK

INTRODUCTION

The development of modern military undersea technology has led to increasing applications of buoys, equipments, and sensors positioned in the deep sea environment. Knowledge of biological fouling and deterioration of structures and materials in this environment is meager, and studies are underway at the U. S. Naval Oceanographic Office,[1] the U. S. Naval Civil Engineering Laboratory,[2] and other places.*

This report describes the type and degree of biological fouling to be expected on antifouling-treated structures buoyed at several hundred feet of depth in the temperate, pelagic environment for long time periods.

In November 1959 the U. S. Navy submarine SQUAW was anchored off the coast of Mexico in about 1000 fathoms of water at a hull depth of approximately 200 feet. On 3 October 1964 part of her hull was reported showing at the surface. The next day the U. S. Navy fleet tug COCOPA (ATF 101) was dispatched to recover SQUAW and tow her to San Diego, where it arrived on 4 October 1964 and was berthed at the Naval Station until 10 November 1964, when it was drydocked. The authors learned of her presence on 23 November 1964, a few hours before SQUAW was scheduled for sandblasting, and a hurried inspection was made of the hull and mooring tackle. Photographs were taken and samples of fouling organisms collected for identification.

Unfortunately, desiccation of soft-bodied forms had taken place in the long interval the hull had been exposed. Also, many of the hard, calcareous forms had been dislodged during towing and mooring activities. Despite these

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*See U. S. Naval Oceanographic Office Informal Manuscript Report 0-1-64, Marine Fouling Research, a State-of-the-Art Report, by J. R. De Palma, p. 33, 1964 (unpublished manuscript) for an annotated bibliography.

limitations, the unique history of SQUAW and the scarcity of similar data justify recording of the findings.

HULL FOULING

Fouling on the SQUAW exhibited a striking vertical zonation (fig. 1), and each zone contained a distinct assemblage of organisms. For the purpose of this report the zones will be designated as follows:

1. The upper zone: The top deck and sides down to a heavy mat of *Ulva sp.* (a green alga commonly known as sea lettuce). This region was exposed to sun and air for over 30 days after recovery.

2. The *Ulva* zone: The heavy mat of *Ulva* on the upper sides of the pressure hull.

3. The free zone: The 2-to-3-foot strip around the hull, just below the *Ulva* zone, which was free of major fouling.

4. The lower zone: The bottom and sides below the free zone.

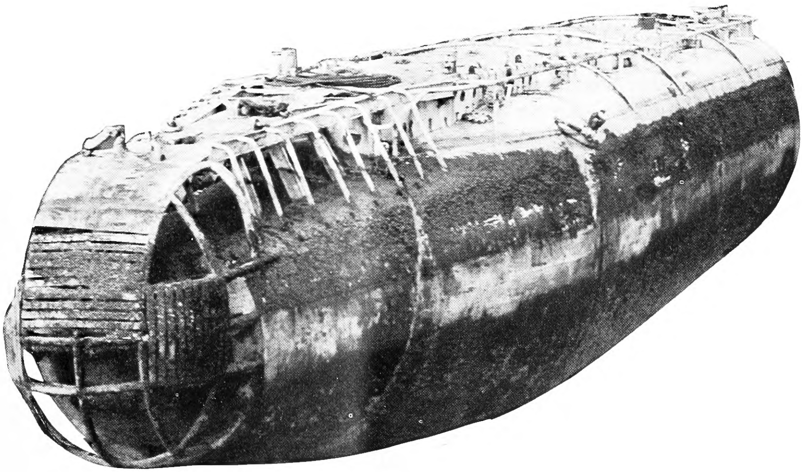

Figure 1. Stern view of SQUAW in drydock, displaying striking vertical zonation. The waterline on the hull while in the bay awaiting drydocking is marked by the black scum line above the algae zone. (National Steel & Shipbuilding Co. photograph)

Upper Zone

Since this zone was emerged for a period of approximately one month, it is doubtful that a true picture of the original fouling can be constructed. Personal communication with the salvage officer on COCOPA, and polaroid pictures taken when the submarine surfaced, have indicated a much heavier fouling than that observed when the boat was in drydock. The salvage officer reported a heavy concentration of large anemonies on the upper surface, which made walking on the deck impossible. Those anemonies that remained at the time of examination were so dehydrated as to be unrecognizable. It is also possible that the mat of *Ulva* continued up over the top surfaces.

The False Jingle, *Pododesmus macroschisma* (fig. 2E), was the most prevalent organism associated with this zone. Hundreds of these shells littered the top deck. Many had been dislodged and left only scars or chordate-shaped byssus attachment remnants (figs. 2I, 3, 4). By observing the littered shells and scars made by the jingles on the deck and superstructure, it is estimated that at least 50 percent of the upper zone was covered by these animals (figs. 3, 4). The shells ranged in size from one to 4 inches in diameter with an average of approximately $2\frac{1}{2}$ inches. One upper valve of the rock scallop, *Hinnites multirugosus* (fig. 2C), was found on deck, and the shell was free of fouling, which is unusual for this species. Under the deck grating, on the deck supports, and on the railings, were several tests of large Serpulid tube worms, probably *Laeospira*. Clusters of small, parchment-shelled tube worms, tentatively identified as *Phyllochaetopterus prolifica*, were common in similar situations.

On the vertical sides of the deck plates, leading down to the cylindrical pressure hull, were the tests of barnacles, *Balanus tintinnabulum californicus* (fig. 2B), ranging in size from $\frac{1}{2}$ to $1\frac{1}{2}$ inches. The total barnacle population of this zone consisted of less than 50 individuals. Small solitary corals, identified* as *Paracyathus stearnsii*

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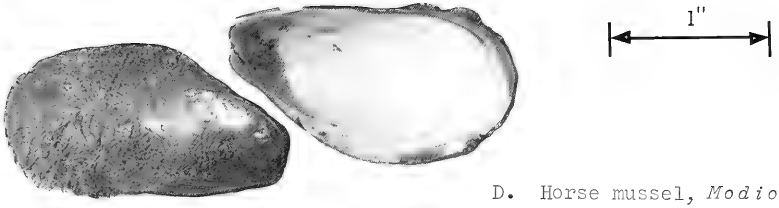
*by Dr. E. Allison, San Diego State College.

A. Barnacle, *Balanus flos*.

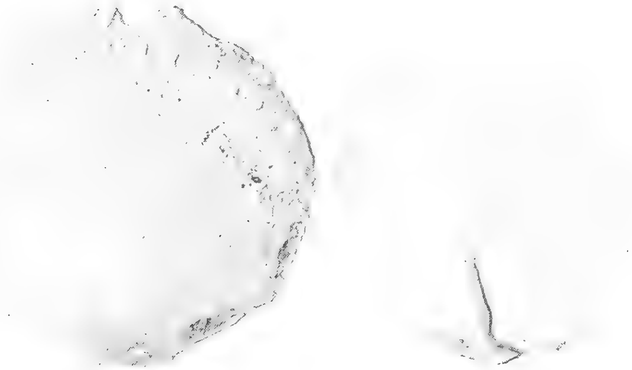
B. Barnacle, *Balanus tintinnabulum californicus*.

C. Rock scallop, *Hinnites multirugosus*.

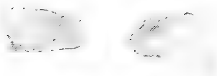
Figure 2. Hard, calcareous forms collected from SQUAW.



D. Horse mussel, *Modiolus fornicatus*.

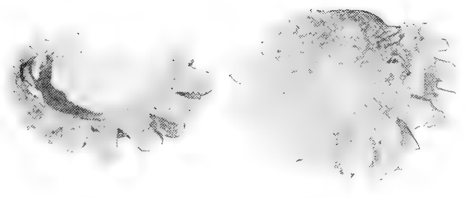


E. False jingle, *Pododesmus macroschisma*.

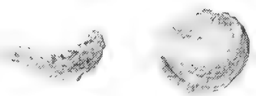


F. Date mussel, *Botula californiensis*.

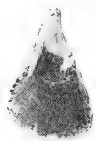
Figure 2 (Continued)



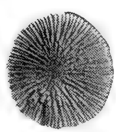
G. Clear jewel box, *Chama pellucida*.



H. Pacific left-handed jewel box, *Pseudochama granti*.



I. Hinge and byssus attachment plate of *P. macroschisma*, which fills the notch in the lower valve.



J. Solitary coral, *Paracyathus stearnsii*.

Figure 2 (Continued)

(fig. 2J), were interspersed among these barnacles and in other scattered locations (fig. 4). These ranged in size from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch in diameter. Several large anemonies were attached to the sides. Their dehydrated condition made identification difficult, but they were probably a species of *Metridium* (fig. 4). Also present on the sides were dried colonies of small anemonies that appear similar to *Corynactis sp.* (fig. 4).

From two of the large brass valves, mounted on top of the pressure hull, were collected two specimens of a locally rare barnacle, *Balanus flos* (fig. 2A). The larger specimen is approximately $1\frac{3}{4}$ inches and the smaller approximately one inch. Both specimens were growing on the vertical face of the outboard side of the two valves. These were the only specimens of *B. flos* found on the hull.

Shells of the California horse mussel, *Modiolus fornicatus* (fig. 2D), ranging in size from $\frac{1}{8}$ inch to $1\frac{3}{4}$ inches, were scattered about the upper zone. These were always singular in occurrence (fig. 4). One small California date mussel, *Botula californiensis* (fig. 2F) was found. Three specimens of *Chama*, probably *C. pellucida* (fig. 2G), with a size range of $\frac{1}{8}$ inch to $1\frac{3}{4}$ inches, and one *Pseudochama*, tentatively identified as *P. granti* (fig. 2H), $\frac{3}{4}$ of an inch long, were also collected. One specimen of *Chama* was taken from a brass valve while the others were removed from the vertical sides.

Figure 3. Shells of false jingles litter deck. Byssus attachment plates at left mark scars of dislodged valves.

Figure 4. Jingle shells, solitary coral (upper center), and date mussel (lower center) on upper deck. Dried sea anemonies (probably *Metridium* sp. and *Corynactis* sp.) and jingle scars cover the rails.

Ulva Zone

The sea lettuce, *Ulva sp.*, was the only fouling organism observed in this zone. The mat of dried algae was approximately ½ inch thick over the entire area (fig. 1). This growth was sharply terminated vertically at the point where light would be reduced by the curvature of the hull. It is difficult to state how much of the upper zone was covered with this growth before emergence, but the polaroid pictures of the hull immediately after recovery show what could be *Ulva* covering the upper surfaces.

Free Zone

The 2-to-3-foot-wide strip, immediately below the *Ulva* zone, was completely devoid of macroscopic fouling. This strip was continuous around the entire hull except for the area at the rounded stern (fig. 1). Here the *Ulva* continued downward and blended into the lower zone fouling. Since this zone continues along the tapered flanks of the hull, it was very probably not caused by rubbing alongside piers.

Lower Zone

The lower zone of SQUAW was 100 percent fouled. Comprising roughly 85 percent of this fouling was the colonial tube worm *Phyllochaetopterus prolifica*. These worms grew in a sinusoidal fashion close to the substrate, then projected from the substrate at their distal ends. Individuals became heavily entwined with one another to form a mat-like structure that covered the entire bottom (fig. 5). Branches of dried hydroids were interspersed with these worms and their condition made identification difficult. Dried colonies of crustose and arborescent bryozoans round out the major fouling in this zone. These latter organisms were concentrated along the keel.

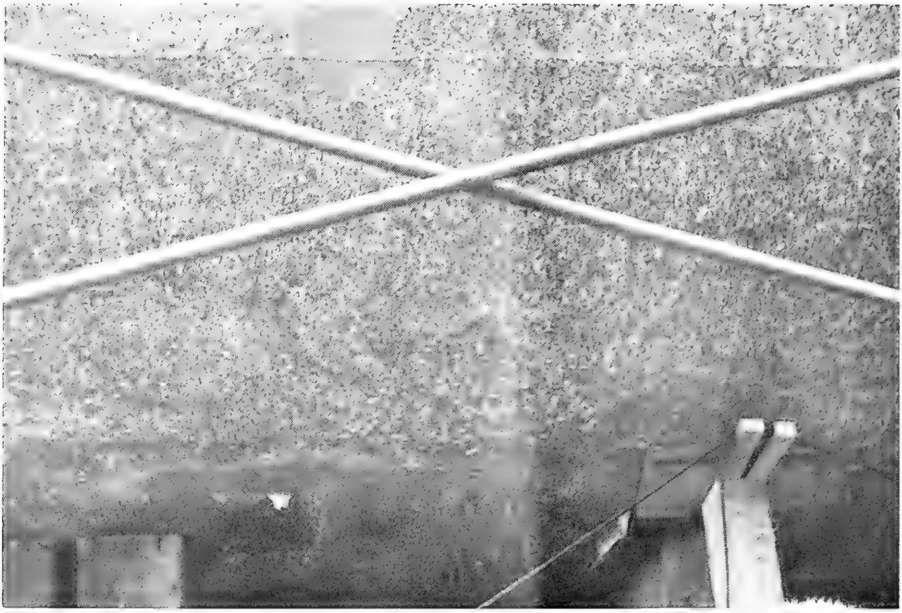


Figure 5. Mat of tube worms covers lower zone of SQUAW. Hydroids are common along the keel.

Three specimens of the horse mussel, *Modiolus fornicatus*, were found on the hull. Approximately 20 tests of barnacles, *Balanus tintinnabulum californicus*, were cemented to the bulkheads of the rear ballast tank inside the hull. These were the only barnacles observed in this zone.

MOORING TACKLE

Portions of the tackle used in the deep mooring of the hull, consisting of a pile of $1\frac{1}{4}$-inch chain (fig. 6) and some heavy polypropylene line (fig. 7) were also available for inspection. The chain was almost entirely covered with a foliaceous red algae. One large jingle, *Pododesmus macroschisma* was observed. Also present were colonies of the small tube worms, *Phyllochaetopterus prolifica*. A loose scab of rust, perhaps $\frac{1}{16}$-inch thick, covered the links.

The line, which seemed to be in excellent condition externally was also fouled by red algae, but not as heavily as the chain. The tube worms, *P. prolifica*, present on the line seem to have taken hold in the creases of the lays. This is, in fact, where most of the fouling had settled. Many small horse mussels, *M. fornicatus*, were also found in the lays of the line (fig. 7). Scattered colonies of unidentified bryozoans and the base plates of barnacles were observed. There was no evidence of marine borers on the line. With the exception of the algae, the line was more heavily fouled than the chain.

Figure 6. Red algae, tube worms, and bryozoans cover mooring chain links.

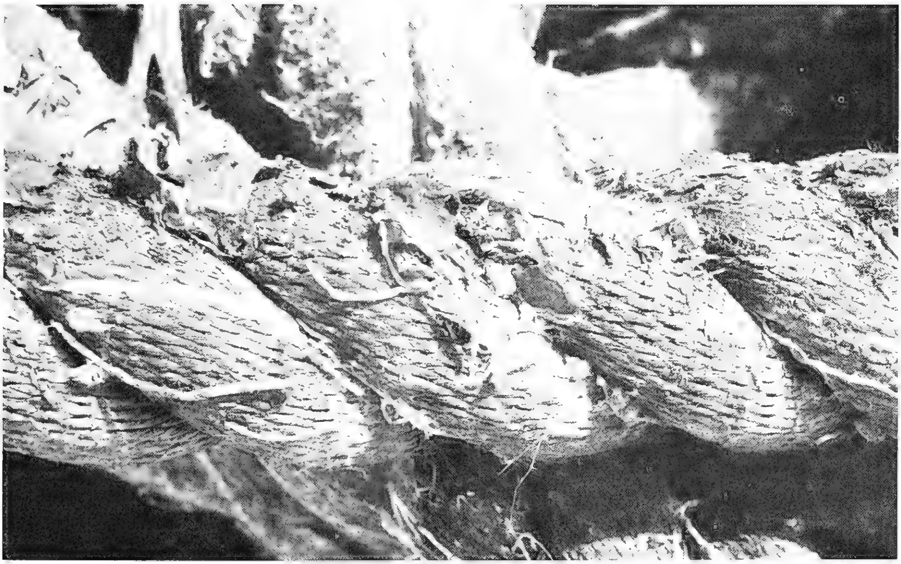


Figure 7. Polypropylene line with numerous tube worms and small horse mussels concentrated along lays. A light fouling of red algae is also present.

DISCUSSION

As would be expected, the fouling of SQUAW was relatively light in contrast to similarly treated structures submerged for equal time periods in coastal waters. However, considering the location, depth, and treatment of the hull, the degree of fouling is considerable. Several phenomena are of interest.

The sparse settling of barnacles on the hull may be an indication of the effectiveness of the antifouling treatment against balinoid cerripeds. On the other hand, barnacle fouling may be lighter at these depths. Barnacles were only found on the superstructure, inside ballast tanks, and on brass valves.

The growth of jingles on the upper surfaces is strikingly similar to the location of thick stacks of another bivalve growing on the upper surface of a siltstone reef at a depth of 35 feet off Corona Del Mar, California.[3] Apparently hard, calcareous foulers can be anticipated on the upper surfaces of deep-moored platforms.

The tube worms fouling the lower sides and bottom of the hull were growing in a similar ecological situation to that found in the littoral zone of northern California, where their membranous tubes mat large areas of vertical, or slightly overhanging, rock faces.[4] Such growth will probably foul the light restricted regions of similarly moored platforms.

While algal growth may have been accelerated during the time the hull was confined in the shallow waters of the bay, the pattern of distribution, and the observations by the salvage officer, clearly indicate that the majority of plant growth had taken place *in situ*. Minimum light intensity of about one percent of noon sunlight is required for sufficient photosynthesis to support the growth of green plants. In clear oceanic waters this could correspond to a depth of about 330 feet, equivalent to a depth of only 3 feet in turbid harbors.[5] The sharp cutoff of green algal growth, where shaded by the curvature of the hull, indicates SQUAW was near the critical depth for photosynthesis. Red algae normally can flourish at lower light intensities than green algae. This could explain the growth of red algae on the mooring chain, part of which probably extended outside the shadow zone of the hull. The hull and its associated fauna possibly attracted noise-producing fishes, thereby raising the ambient sound level in the area.

Previous studies[6] have shown that even within harbors distinct assemblages of fouling organisms can be correlated with water transparency. The history of SQUAW indicates the type of fouling communities to be expected on structures in clear, oceanic waters.

CONCLUSIONS

1. Antifouling-treated structures moored in the deep sea environment for long time periods will experience light to moderate fouling.

2. The types of fouling organisms will differ from those occurring in harbors and productive shallow waters adjacent to shore.

3. The organisms growing on such structures will occupy niches similar to those of the natural environment.

4. A variation in light appears to be the primary factor governing their distribution.

5. Sufficient light is present at a 200-foot depth to support photosynthesis in this area of the ocean.

6. All of the fouling animals on SQUAW were filter feeders, which indicates a high organic content of water at

this depth and geographic location. (Animal growth in tropical areas should be considerably less.)

7. Noise production by bivalves and associated fishes would raise the ambient noise level in the area of the moored hull.

RECOMMENDATIONS

1. Further studies of fouling processes in the deep ocean environment should be initiated.

2. Better communication should be arranged between operational organizations of the U. S. Navy and scientific personnel working in the oceanographic field so that prompt inspection can be made of all such structures recovered from deep sea moorings.

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2. Submarine hulls - Marine fouling

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