REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

on is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, pleting and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

AD-A229 982

2. Report Date.
1990

3. Report Type and Dates Covered.
Proceedings

4. Title and Subtitle.

USS Princeton (CG 59): Impact of Marine Macrofouling (Mussels and Hydroids) on Failures/Corrosion Problems in Seawater Piping Systems

5. Funding Numbers.

Program Element No.	61153
Project No	03102
Task No	310
Accession No	DN094463

6. Author(s).

Dr. Joanne M. Jones and Dr. Brenda J. Little

7. Performing Organization Name(s) and Address(es).

Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529-5004

8. Performing Organization Report Number.

PR 90:056:333

9. Sponsoring/Monitoring Agency Name(s) and Address(es).

Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529-5004

10. Sponsoring/Monitoring Agency Report Number.

PR 90:056:333

DTIC
ELECTE
DEC 10 1990
S E D

11. Supplementary Notes.

Navy Corrosion Control Workshop
*Continued on next page

12a. Distribution/Availability Statement.

Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract *(Maximum 200 words).*

The presentation summarizes some of the information that will be released as NAVSWC TR 90-176 on macrofouling problems within the seawater piping system of the USS PRINCETON (CG 59) and its contribution to the failures/corrosion problems observed. Some sections of NAVSWC TR 90-176 appeared in NAVSSES 10310-1 (March 1990). The macrofouling problems were due to the marine mussel (Mytilus edulis) and hydroids. Serpulids were also observed but to a lesser degree than mussels and hydroids.

Mytilus edulis has previously been shown to cause fouling problems in sea chests and seawater piping systems. Hydroids (animals) formed dense, plant-like colonies in CG 59 seawater piping systems. Copper (from the copper-nickel seawater piping) gives the hydroids a green color so that they have the appearance of seaweed. Shrimp, crab, sponges, other unidentified crustaceans and fouling debris were observed by a fiber optics examination in the main sea chest. When water was pumped from the sea chests, intact mussels and hydroids and fragments of serpulids were removed and located in downstream strainers and heat exchanger tubes.

Due to the observed failures/corrosion problems and the extent of the macrofouling in the seawater piping systems, an environmentally safe, thermal (steam) control method for the macrofouling was recommended. Biological systems respond very strongly to temperature. Marine organisms, possibly as a result of the relative stability of their natural environment, are extremely sensitive to temperature fluctuations. Relatively small increases in temperature cause significant mortality in Mytilus edulis and efforts to use thermal control to inhibit Mytilus have been successful as reported in the literature. The following temperature-time requirements have been established for total kill of*

14. Subject Terms.
(U) Biofouling; (U) Corrosion; (U) Biodeterioration; (U) Electrochemistry

15. Number of Pages.
17

16. Price Code.

17. Security Classification of Report.	18. Security Classification of This Page.	19. Security Classification of Abstract.	20. Limitation of Abstract.
Unclassified	Unclassified	Unclassified	SAR

*Mytilus: 106 F for 1 hour, 95 F for 7 hours, 82 F for 4 days and 77 F was completely ineffective for all durations evaluated. There is also a synergistic effect of chlorine with heat treatment.

The heat treatment should take into account temperature constraints for electronic equipment using seawater cooling systems (i.e., 105 F for indefinite periods of time; MIL-STD-1399 NAVY Section 101; 14 Jan 1972) and for the lubricating oil coolers/hydraulic oil coolers (i.e., 90 F for large surface ships using inlet seawater cooling; MIL-C-15730K ships; 12 Nov 1973). If flushing to the outside of the ship after thermal treatment is not possible, then a dilution of the organic nutrients in the sea chest is necessary to prevent downstream macrofouling and microbiologically influenced corrosion (MIC) problems. It is essential that all systems be up and running since stop-and-go operations could lead to higher fouling and MIC in the piping systems from the organic matter released from the sea chests and left stagnant in the piping systems. Also, more frequent checking and cleaning of the strainers and baskets would be needed after any control treatment for biofouling in the sea chests.

Without a fouling control procedure, failures/corrosion problems as observed in CG 59 seawater piping systems are likely to occur especially if ships are:

(1) moored in regions (high and middle latitudes) where Mytilus mussels are the dominant fouling species

(2) are anchored at times of the year for Mytilus spawning

(3) are at mooring depths below the recommended navigational draft (i.e., 31 feet for CG 59).

Accession For

NTIS GRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification

By
Distribution/

Availability Codes

Dist	Avail and/or Special
A-1	

The First Annual Navy Corrosion Control Workshop

UNITED STATES NAVY

MISSION ENHANCEMENT THROUGH MATERIAL ENGINEERING

SHIPBOARD CORROSION CONTROL

COHOSTS:

Naval Research Laboratory ◊ **Naval Sea Systems Command**

• Marine Corrosion Facility • • Corrosion Control Branch •

29 – 31 October, 1990

Key West, Florida

90 12 7 030

USS PRINCETON (CG 59): IMPACT OF MARINE MACROFOULING (MUSSELS AND HYDROIDS) ON FAILURES/CORROSION PROBLEMS IN SEAWATER PIPING SYSTEMS

Dr. Joanne M. Jones
NAVSWC/Code R301
10901 New Hampshire Avenue
Silver Spring, MD 20903-5000
(301) 394-4839

Dr. Brenda J. Little
NOARL/Code 333
Stennis Space Center, MS 39529-5004
(601) 688-5494

ABSTRACT

This presentation summarizes some of the information that will be released as NAVSWC TR 90-176 on macrofouling problems within the seawater piping system of the USS PRINCETON (CG 59) and its contribution to the failures/corrosion problems observed. Some sections of NAVSWC TR 90-176 appeared in NAVSSES 10310-1 (March 1990). The macrofouling problems were due to the marine mussel (*Mytilus edulis*) and hydroids. Serpulids were also observed but to a lesser degree than mussels and hydroids.

Mytilus edulis has previously been shown to cause fouling problems in sea chests and seawater piping systems. Hydroids (animals) formed dense, plant-like colonies in CG 59 seawater piping systems. Copper (from the copper-nickel seawater piping) gives the hydroids a green color so that they have the appearance of seaweed. Shrimp, crab, sponges, other unidentified crustaceans and fouling debris were observed by a fiber optics examination in the main sea chest. When water was pumped from the sea chests,

intact mussels and hydroids and fragments of serpulids were removed and located in downstream strainers and heat exchanger tubes.

Due to the observed failures/corrosion problems and the extent of the macro-fouling in the seawater piping systems, an environmentally safe, thermal (steam) control method for the macrofouling was recommended. Biological systems respond very strongly to temperature. Marine organisms, possibly as a result of the relative stability of their natural environment, are extremely sensitive to temperature fluctuations. Relatively small increases in temperature cause significant mortality in Mytilus edulis and efforts to use thermal control to inhibit Mytilus have been successful as reported in the literature. The following temperature-time requirements have been established for total kill of Mytilus: 106 F for 1 hour, 95 F for 7 hours, 82 F for 4 days and 77 F was completely ineffective for all durations evaluated. There is also a synergistic effect of chlorine with heat treatment.

The heat treatment should take into account temperature constraints for electronic equipment using seawater cooling systems (i.e., 105 F for indefinite periods of time; MIL-STD-1399 NAVY Section 101; 14 Jan 1972) and for the lubricating oil coolers/hydraulic oil coolers (i.e., 90 F for large surface ships using inlet seawater cooling; MIL-C-15730K ships; 12 Nov 1973). If flushing to the outside of the ship after thermal treatment is not possible, then a dilution of the organic nutrients in the sea chest is necessary to prevent downstream macrofouling and microbiologically influenced corrosion (MIC) problems. It is essential that all systems be up and running since stop-and-go operations could lead to higher fouling and MIC in the piping systems from the organic matter released from the sea chests and left stagnant in the piping systems. Also, more frequent checking and cleaning of the strainers and baskets would be needed after any control treatment for biofouling in the sea chests.

Without a fouling control procedure, failures/corrosion problems as observed in CG 59 seawater piping systems are likely to occur especially if ships are:

(1) moored in regions (high and middle latitudes) where Mytilus mussels are the dominant fouling species

(2) are anchored at times of the year for Mytilus spawning

(3) are at mooring depths below the recommended navigational draft (i.e., 31 feet for CG 59).

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

HISTORY OF CG 59 SEAWATER PIPING SYSTEM FAILURES/CORROSION PROBLEMS

SEAWATER PIPING AND FIREMAIN SYSTEMS FAILURE/CORROSION PROBLEMS (FALL 1988 THROUGH FALL 1989)

Strainers: Failed duplex strainer housings and vent lines were related to Fleet problems with poor quality C. M. Bailey strainers. A Monel 400 strainer basket experienced long-term corrosion under heavy fouling.

Piping: Corroded piping on HPAC, SPS-49 and CIWS systems. Numerous firemain leaks were traced to poorly tightened flange joints and weld cracking during a severe storm.

Valves: SPS-49 inlet regulating valve totally corroded. Severe CIWS system corrosion including 19 of 20 valves replaced, corroded strainer, corroded low flow alarm plungers, hole in check valve body and piping problems (Fleet-wide problems with CIWS components). Galvanic corrosion of improperly installed steel plug.

Coolers: Main engine lube oil cooler failures caused by under-deposit pitting in static seawater. CG 59 Prairie, Masker and Hydraulic oil coolers are at risk due to under-deposit corrosion and seawater stagnation. Failed CRP and Masker coolers. SPS-49 cooler failure and plugged tubes. #2 control condenser leaking. Condensate drain cooler failures show extensive tube fouling with shells, barnacles and wood chips; also extensive inlet tube and tubesheet damage. This problem may be a class problem (CG 59, CG 52 and CG 58).

Zn anodes: Rapid Zn anode deterioration in A/C condenser needing replacement every 3 weeks.

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

THE MACROFOULING PROBLEMS ON THE USS PRINCETON (CG 59) WERE DUE TO THE PRESENCE OF MUSSELS (*Mytilus edulis*) AND HYDROIDS.

Hydroids: Hydrozoans are animals with a stem (pedicel) and a flowerlike hydranth (usually central mouth and ring of tentacles).

Most hydroids have a tough, chitinous periderm covering the stem (may extend up around the hydranth).

Colonies of hydroids can be small or large, bushy plant-like colonies several feet tall. Hydroids can form dense growths (often tangled knots of battered stems) on pilings, buoys and jetties.

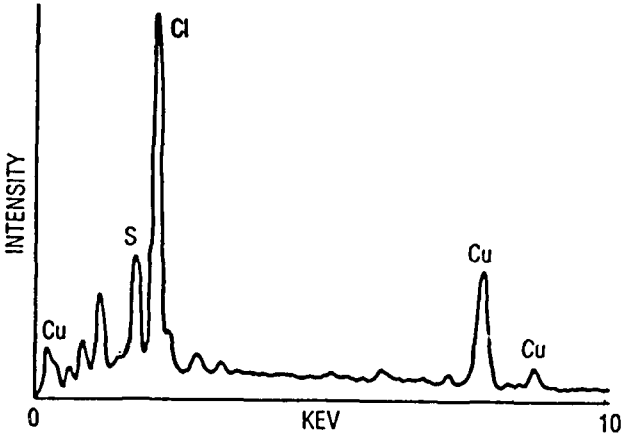
Hydroids Removed from CG 59:

The hydroids had collected large amounts of chlorine, sulfur and copper as demonstrated by EDAX (energy dispersive X-ray) analysis.

The copper gives the hydroids a green color and was picked up from the copper-nickel seawater piping. These hydroids (although green in color from growing on copper) are animals not seaweed or grasses.

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

DENSE COLONIES OF HYDROIDS (ANIMALS) REMOVED FROM CG 59 SEAWATER PIPING SYSTEMS HAD THE APPEARANCE OF SEAWEED; COPPER (FROM THE COPPER-NICKEL SEAWATER PIPING) GIVES THE HYDROIDS A GREEN COLOR



EDAX SPECTRUM OF THE HYDROIDS REMOVED FROM CG 59 SEAWATER PIPING SYSTEMS SHOWED LARGE AMOUNTS OF CHLORINE, COPPER AND SULFUR

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

Shipboard Systems Where Mytilus edilus (Blue Mussel) and/or Hydroids Were Removed

USS PRINCETON (CG 59)

FWD Cond. Drain Cooler (inlet tubes)	Small shells, coarse shell fragments
Y-strainer #3 A/C Chilled Water	Very small shells to medium sized shells
FWD MGR LO Strainer	Small to medium sized shells; hydroids
8" Strainer Engine Rm #1	Hydroids; medium sized shells
AFT Prairie Head	Lots of hydroids; fine shell fragments
AFT CRP Head	Lots of hydroids; fine shell fragments

USS ANTIETAM (CG 54)

#2 Spy Radar Skid	70% fouled with hydroids; some barnacles
#1 Main Sea Water Strainer	Small, medium and large shells (ship reports no massive shell incursion)

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

INTACT MARINE MUSSEL SHELLS, MYTILUS EDULIS, REMOVED FROM CG 59 SEAWATER PIPING SYSTEMS RANGED IN SIZE FROM APPROXIMATELY 8MM X 11MM (TWO WEEKS OLD) UP TO 17MM X 30MM (TWO MONTHS OLD)

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

THE MACROFOULING PROBLEMS ON THE USS PRINCETON (CG 59) WERE DUE TO THE PRESENCE OF MUSSELS (*Mytilus edulis*) AND HYDROIDS.

Marine Mussels (*Mytilus edulis*):

Generalized Information	Observed on Shell Samples Removed from CG 59
Mussels will settle on practically any substratum especially when the surface is roughened.	
Mytilus mussels do not settle on copper-containing surfaces.	None of the macrofouling organisms were attached to the copper-containing piping system, strainers or heat exchangers.
Mytilus is sessile, anchoring its body by numerous byssal threads.	Some intact mussels were attached by byssal threads to form a long string.

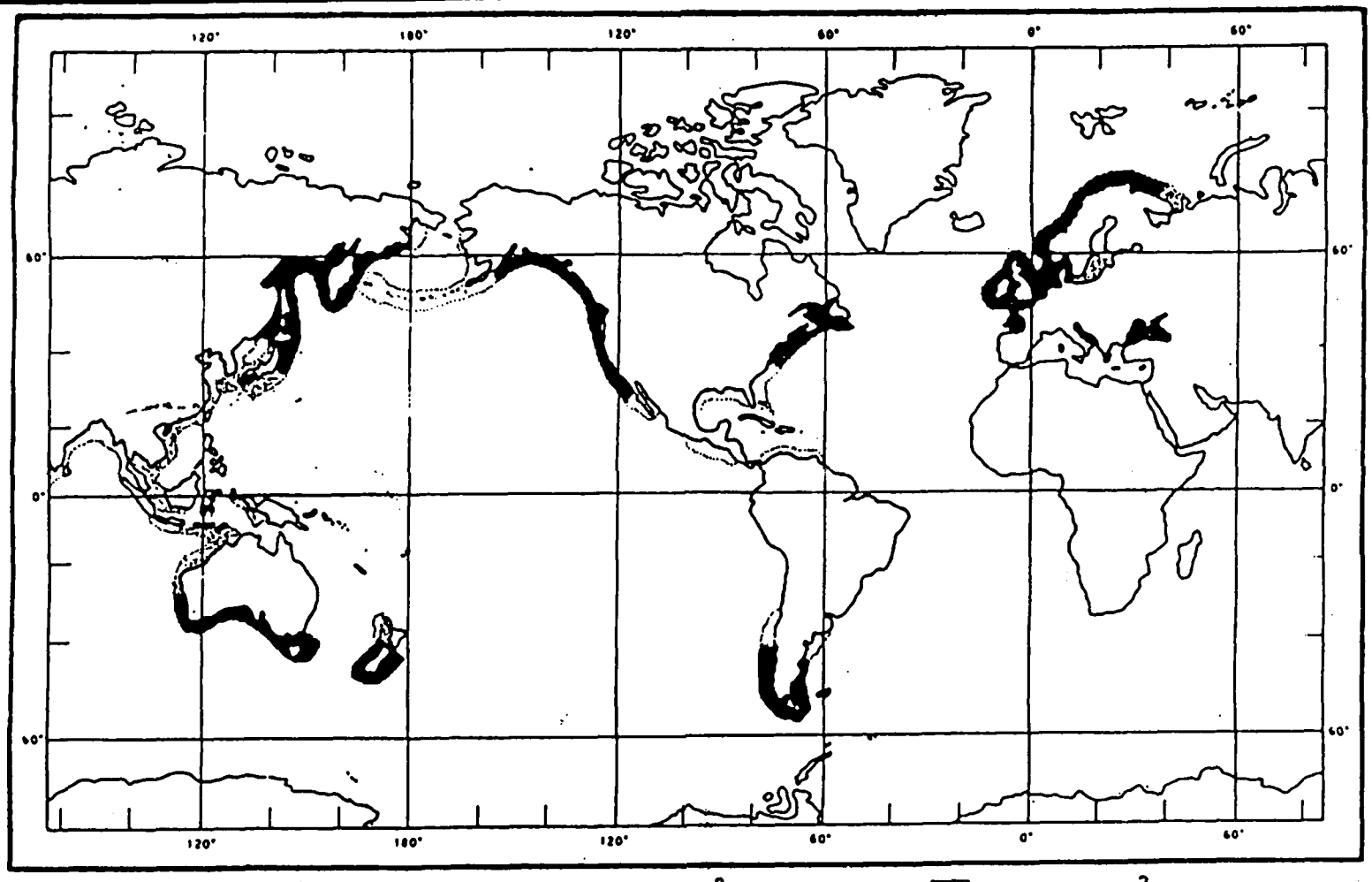
AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

THE MACROFOULING PROBLEMS ON THE USS PRINCETON (CG 59) WERE DUE TO THE PRESENCE OF MUSSELS (*Mytilus edulis*) AND HYDROIDS.

Marine Mussels (*Mytilus edulis*):

Generalized Information	Observed on Shell Samples Removed from CG 59
The size of the whole organism can be related to age. Growth is rapid in spring and summer and slight or absent in winter.	Intact *Mytilus edulis* shells represented four size classes, indicating four age groups from two weeks old to two months old. It is impossible to determine the precise age of the mussels without specific information about the growth medium and habitat conditions.
Mytilus shells grown in the dark are often thinner and less densely pigmented than those grown in light.	The shells/shell fragments that were collected from the seawater piping systems were easily broken.

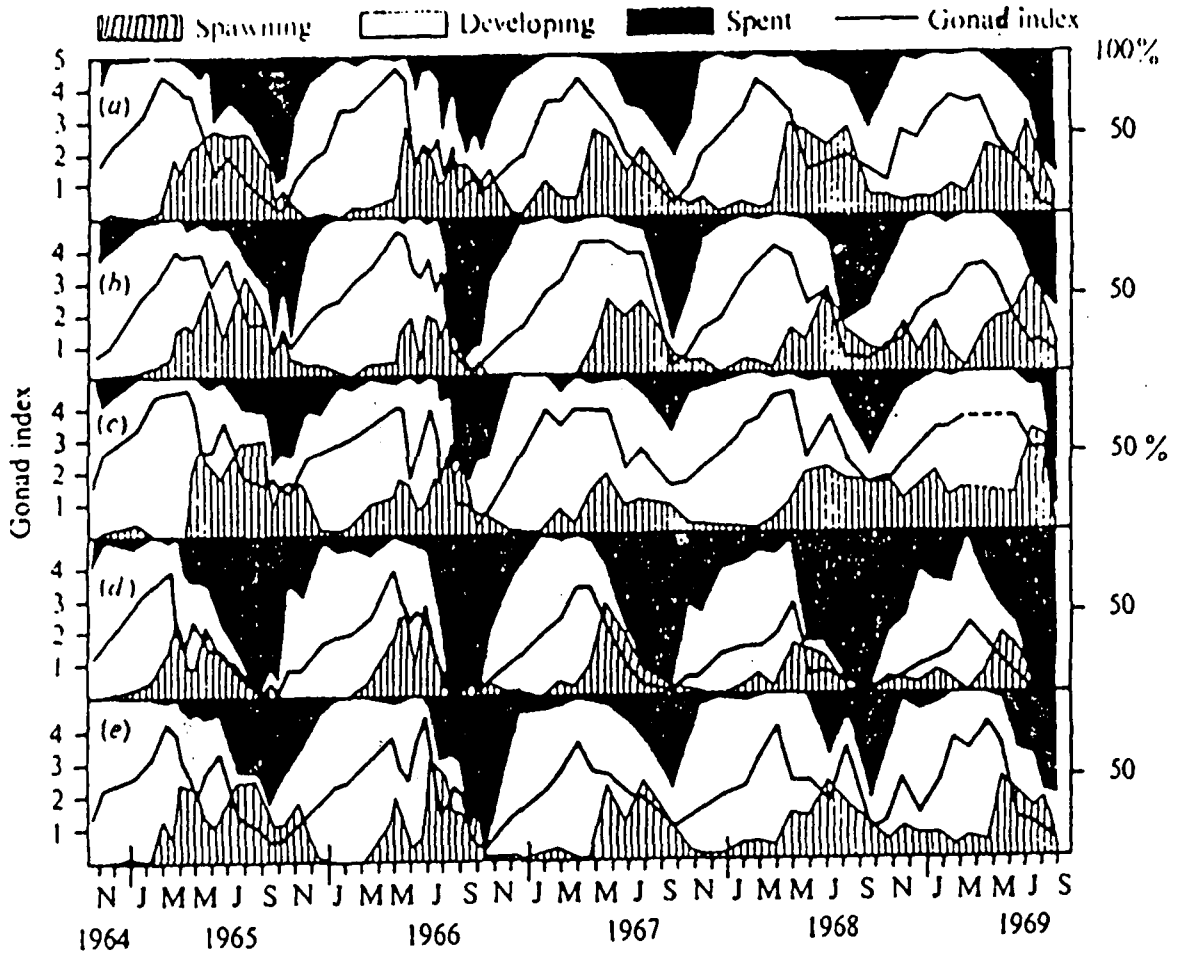
AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM



Up to 40 kg/m^2/yr Up to 20 kg/m^2/yr Up to 10 kg/m^2/yr

DISTRIBUTION OF MYTILUS MUSSEL BEDS SHOWN HERE INDICATES THAT MUSSEL FOULING CONDITIONS ARE MORE SEVERE IN HIGH AND MIDDLE LATITUDES WHERE THESE MUSSELS ARE THE DOMINANT FOULING SPECIES (FROM LITTLE AND DEPALMA, 1988)

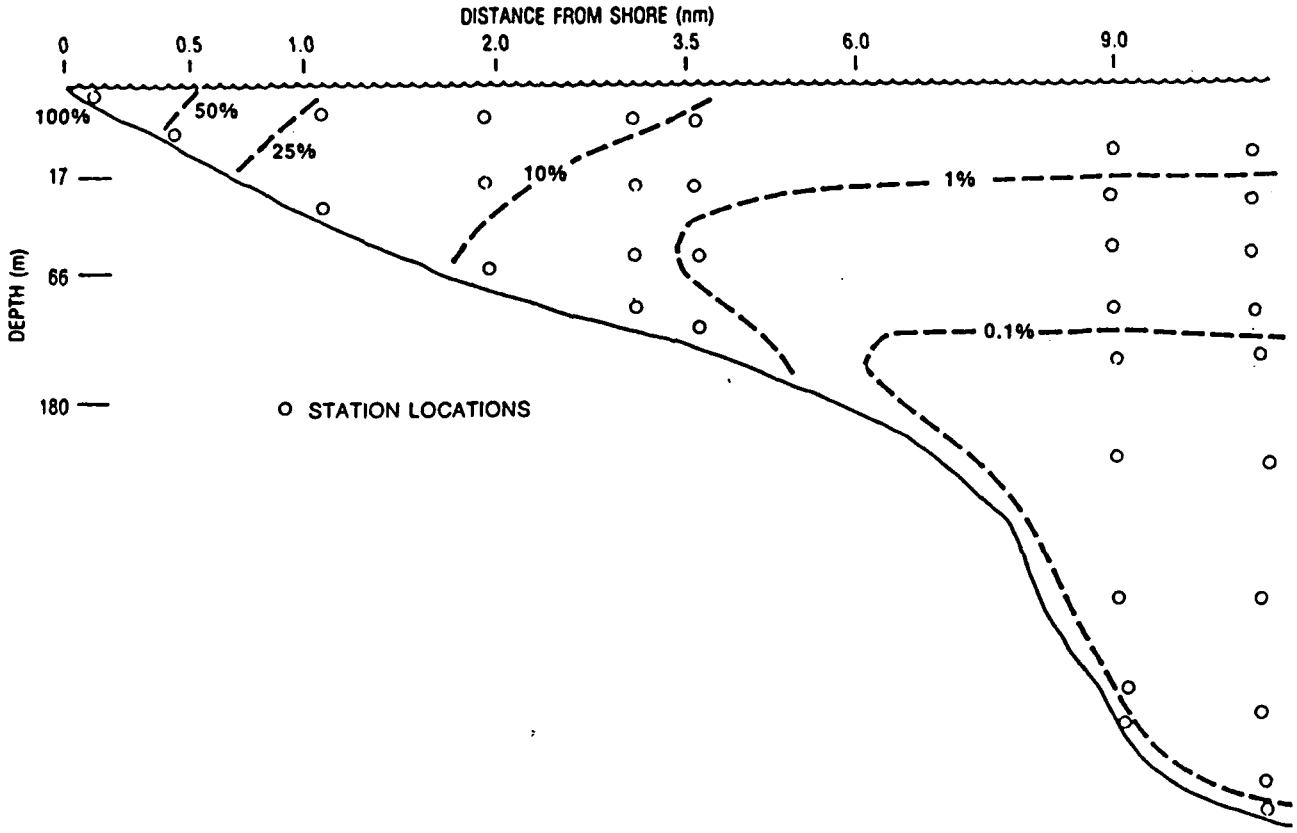
AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM



The gonad index and the percentage distribution of spawning, developing and spent individuals of *Mytilus edulis* in five populations over five years.

(BAYNE, 1976 FROM SEED, 1975)

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM



NUMBER OF MYTILUS MUSSELS THAT COULD CAUSE FOULING PROBLEMS DECREASES WITH THE DISTANCE FROM THE SHORE (FROM LITTLE AND DEPALMA, 1988)

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

SUMMARY/CONCLUSIONS

1. Some of the sea chests (depending on their size/volume) appear to have low flow areas which encourages fouling by microorganisms, macroorganisms and inorganic materials (a fiber optics examination of main sea chest showed fouling that included inorganic deposits and macroorganisms such as shrimp, crab, and other unidentified crustaceans).

2. *Mytilus edulis* (mussel) has previously been shown to cause fouling problems in sea chests and seawater piping systems. Significant biofouling was observed in CG 59 #6 main sea chest as well as a hard, material deposit (EDAX analysis showed S [from SRB], Fe and Cl).

   Macrofouling problems on CG 59: Due to the mussel, *Mytilus edulis*, and hydroids.

3. Hydroids (animals; not seaweed or grasses) had collected large amounts of Cu, Cl and S; Cu gives the hydroids a green color and was picked up from the Cu-Ni seawater piping. Serpulids (worms) were observed but to a lesser degree than mussels and hydroids.

AEGIS COMBAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

SUMMARY/CONCLUSIONS

4. Mussel shells and/or hydroids were removed from CG 59: FWD condensate drain cooler (inlet tube), Y-strainer #3 A/C chilled water, FWD MGR Lo strainer, 8" strainer Engine Rm #1, AFT Prairie Head, and AFT CRP Head; and from USS ANTIETAM (CG 54) #2 Spy radar skid and #1 main sea chest strainer.

   Four size classses of intact mussel shells were present (four age groups). Some intact mussels were attached by byssal threads to other mussel shells to form long strings.

5. The macrofouling problem (not just mussels but also hydroids) is of a recurring nature with large quantities of macroorganisms in the seawater piping systems that results in shell problems in strainers and baskets along with the blockage of heat exchanger tubes leading to some of the failures/corrosion problems in the seawater piping systems.

6. The source of the recurring mussel macrofouling problems in the seawater piping systems would not be from piers/pilings.

SUMMARY/CONCLUSIONS

7. If CG 59 was at or near the mooring depth specified for this cruiser, then the large quantities of mussel shells that repeatedly foul the seawater piping system would not be coming from mussels on the sea bottom (not known at this time if there even are mussel beds below the ship prior to the observed shell problems).

8. The marine macrofouling problem could be a combination of mussels attached in the roughened sea chest/seawater inlets, as well as, mussel shells pulled into the seawater system when a ship is moored at lower depths in areas with mussel beds below the ship.

9. Future investigations on macrofouling corrosion problems/failures on AEGIS ships should include:

   Fathometer readings, anchorage sites (i.e., areas where Mytilus is the dominant fouling organism), dates of moorage (i.e., corresponds to the time of year for mussel spawning), fiber optics examinations of sea chests and diver examination to determine if mussel beds are below the ship (i.e., mussels could be pulled into the seawater systems if the fathometer readings are significantly below the recommended navigational draft).

AEGIS COMPAT SYSTEMS CORROSION PREVENTION AND CONTROL PROGRAM

SUMMARY/CONCLUSIONS

10. Biological systems respond strongly to temperature (relatively small temperature increases cause significant mortality in Mytulis). Efforts to use thermal control for Mytilus have been successful.

    Total kill of Mytilus: 106 F for 1 hour, 95 F for 7 hours, 82 F for 4 days and 77 F was completely ineffective for all durations evaluated.

11. Recurring failures/corrosion problems in the seawater piping systems suggest the need to control macrofouling.

    Thermal Control: Environmentally safe control method.

    Easily managed without equipment modifications/added expense.

    Capability to flush sea chests after treatment to the outside of the ship rather than through the seawater piping or dilution of organic matter by flushing all systems.

12. ESSENTIAL: All systems be up and running when macrofouling control procedure is used.

    Stop-and-go operations could lead to higher fouling and MIC in the piping systems from under deposit corrosion and seawater stagnation.

    More frequent checking and cleaning of strainers and baskets needed after any control treatment for biofouling in the sea chests.