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Fouling Organisms and Effects on the Hull of the R/V K. Piri Reis

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Özet: ***R/V K. Piri Reis gemisindeki fouling organizmalar ve etkileri***. Tekne yüzeyine yapışan fouling organizmalar istenmeyen etkilere neden olurlar. R/V K. Piri Reis üzerindeki fouling organizmaların etkisi geminin havuzlandığı dönemde araştırılmıştır. Geminin boyalı ve boyasız kısımlarına yerleşen ve fouling olayını oluşturan topluluklar hakkında bilgi sahibi olabilmek için bu kısımlar incelenmiştir. Her iki kısımda da toplam 8 takson belirlenmiştir. *Hydroides elegans* ve *Balanus amphitrite* hemen hemen toplam bio-kütlenin%100 ünü oluşturur. Bu iki türün bio-kütlelerinin yüzde oranları ise boyalı ve boyasız kısımlarda farklıdır. Boyalı kısımdaki *B. amphitrite* bireyleri küçük yapışma düzlemine sahiptir ve boyanmamış kısıma göre daha fazla sayıda bireyle temsil edilir. Pürüzlülük ölçümleri ve hesaplarından, geminin bu ilave direnç nedeniyle performansındaki düşüş%30 civarındadır. Bu sonuç, aynı çevresel koşullarda geminin temizleme işleminden önceki ve sonraki durumlarında ölçülen hızları arasındaki farktan da anlaşılır.

Anahtar Kelimeler: Fouling organizmalar, tekne pürüzlülüğü, direnç artışı.

Abstract: Fouling organisms that attach to the hull surfaces cause undesirable affects. In order to determine the affect of fouling organisms on the hull the R/V K. Piri Reis was investigated while in dry-dock. The treated and untreated parts of the hull were examined to contribute to the knowledge on the settled fouling community. A total of 8 taxa were recorded from two parts. *Hydroides elegans* and *Balanus amphitrite* comprised almost 100%of the total biomass. The biomass percentages of these two species varied between the treated and untreated surfaces. *B. amphitrite* specimens have small basal plates in the treated part and they are represented by a higher number of individuals according to observation on the untreated part. From the roughness measurements and calculations, it was determined that the performance loss due to this additional resistance was about the%30. This result was confirmed by differences in ship speed measurements before and after the cleaning operation in the same environmental condition.

Key Words: Fouling organisms, hull roughness, resistance increment.

Introduction

Fouling phenomenon, which is used to describe organisms settled directly to an artificial object in the sea, cause to increase the ship resistance, ship main engine power and fuel consumption. These organisms also cause to increase depreciation of the material. Especially calcareous fouling organisms harm to the coating and painting layer applied to the surface. This harm affects the structures that have metallic surfaces and causes corrosion.

The main resistance components depend on the ship design characteristics. Environmental effects such as waves, currents, winds etc. and ship roughness cause additional resistance. In order to decrease this additional resistance and hence the total resistance, since it is not possible to prevent environmental effects, it is only possible to minimize the ship roughness.

The ship roughness can be divided in to four components as the plate, painting/coating, and corrosion and fouling. Fouling roughness can produce more additional resistance compared to the other roughness components. Fouling organisms can cause engine power losses between 10%-100% depending on service profile, dry-docking period, types of antifouling paint and seawater properties (abiotic factors). Malone and Little, 1980 emphasized that the settlement of fouling organisms is encouraged with diminished ship speed (less than 3 knots). According to the measurements carried out by the Norwegian Ship Research Institute, it has been proved that 1/10 mm increase in the surface roughness causes 5-7% power increase (Sillerud, 1980). Fouling of the wetted surface can be removed by dry-docking but this operation brings extra costs.

The problem of fouling is extremely complicated and needs interdisciplinary researches. Investigations to collect base-line data of organisms are essential to determine actual status for effective control (Santhakumaran, 1989). Little data on fouling organisms in Turkish waters is available (Pınar, 1974; Özdemir, 1994; Koçak *et al*., 1999 and Koçak & Küçüksezgin, 2000). Few organisms are able to tolerate the entire range of fluctuated conditions. Of these, salinity and temperature are more important factors in controlling the succession of fouling organisms (Rajagopal *et al*., 1990; Ahamet *et al*., 1992; Koçak *et al*., 1999).

In this study, we aim to elucidate the common structures of the hull of the R/V K. Piri Reis that had a route between the Eastern Mediterranean Sea and the Black Sea in the year 1998-2000.

Material and Methods

In order to determine the effect of fouling, K.Piri Reis was chosen as a case study. The main characteristics of the ship are given in the list below.

Length:	36 m.
Breath:	8.05 m
Draft:	2.30 mt, 2.80 mt.
Gross Tonnage:	280
Speed:	10 knots
Main Engine:	610 HP

Toxic effects of organotins were observed in a variety of marine invertebrates (Karande *et al*., 1993). During the application of antifouling paint small patches of the hull remained untreated part due to the wooden holders which fix the ship in the dry-dock. Thus, we had an opportunity to examine the organisms settled in the treated and untreated parts of the hull. The main difference between the two parts was the intensity of light. As a treated region, an area close to the water line of the ship was chosen where the fouling organisms were homogeneously distributed. However, the untreated part, which was located on the bottom section of the hull, received a lower intensity of light.

A quadrate of 400 cm^2 was considered to collect the animals from the treated and untreated part. The materials collected were fixed with 5% formalin solution. The species composition of the main taxonomic groups was determined under a stereo-microscope and wet weight values of the total biomass were calculated.

In order to determine the effect of fouling on ship resistance, which is described by the formulation given below, hence speed loss, we measured the ship speed before dry-docking. It was about 7 knots at constant engine power.

$R_T = \rho/2.C_T.S.V^2$ where;

ρ : Water density

S : Wetted area of the ship

V : Ship speed

C_T: Total resistance coefficient that can be separated into the components as:

$C_T=(1+k).C_F+C_R$

C_F= Frictional resistance coefficient for smooth surface
C_R= Residuary resistance coefficient
k= Form factor

The above definitions are based on the assumption no ship roughness, whereas, the roughness causes an increase for the frictional resistance and the total resistance coefficient. The below equation was given for increment for the frictional resistance (ΔC_F) from the statistical analysis of data obtained from the model studies:

$\Delta C_F \times 10^3 = 105 (k/L)^{1/3} - 0.64$ where
k: roughness height

ΔC_F could be accepted as 0.0004 for all ships from the analysis carried at the Taylor's experimental tank (Hartley, 1980).

Distribution of roughness and heights caused from either fouling organisms or other effects such as surface conditions of construction materials, construction technologies, type of painting and coatings, application technique are rather irregular over the wet surface of the ship. Due to the irregularity of this roughness, it becomes difficult to define it with a mathematical function. Statistical values can be obtained from the measurements and roughness defined as the mean apparent amplitude (MAA) and average height roughness (AHR) (Byrne, 1979). Both definitions ignore the location of roughness over the ship hull. These approaches do give sufficient accuracy in the calculations of the additional resistance caused by fouling roughness.

The formulation gives the required effective horse power (EHP) value in order to determine the engine break horse power (BHP):

$EHP= R_T.V/75$

$BHP= \eta_0\eta_p\eta_h\eta_{tr}$ EHP

Also, it should be mentioned here that roughness increases on the surface of the propeller causes a decrease in propulsion efficiency (η_p) and an increase in the total resistance. Although this issue is very important it has not been considered in this work.

Result and Discussion

A total of 8 taxa were recorded from the treated and the untreated parts (Table 1). The dominant species *Hydroides elegans* (Serpulidae) and *Balanus amphitrite* (Cirripedia) comprised almost 100%of the total biomass. They were observed to be dominant settlers and the first organisms to colonize on the panels (Sasikumar *et al*., 1989 and Koçak *et al*, 1999). The biomass percentages of these two species varied on the treated and the untreated surfaces. In both parts, barnacles constituted substrates to host for the epibionts such as *Hydroides* spp. These types of substrate organisms are called basibiont (Wahl, 1989). In this case *B. amphitrite* provides a hydro dynamically favorable position for the settlement of *H. elegans* which act as nutrient traps.

In antifouling paint a number of trace elements in high concentration were used to prevent settlement of a fouler. Some bacteria possess a detoxification mechanism for converting main toxic components (Brock and Madigan, 1987). After a certain time period, on the treated and untreated surfaces, the frequently observable colonizing sequence begins with a formation of a primary film comprising bacteria (Relini G., 1974). Settlement of cypris larvae of *B. amphitrite* on the bacteria adsorbed surfaces can be affected by the species of adsorbed bacteria and their extra cellular products (Maki *et al*., 1988).

In the treated part, total wet weight of fouling was higher than that in the untreated part. *H. elegans*, were the dominant species and comprised 62, 4% of the total biomass. This species is known as a preferential component of the fouling communities in the polluted site (Koçak *et al*., 1999). *H. elegans*, with its vertical tubes, produce dense populations and showed many variations in its opercular structure (Koçak *et al*., 1999; Moran, 1984).

Table 1. Sessile fouling organisms in scrapped materials

Groups	Treated	Untreated
Protozoa		
Foliculinidae (sp.)	+	+
Bryozoa		
Bugula neritina (Linnaeus,1758)	+	
Annelida		
Hydroides elegans (Haswell, 1883)	+	+
Pileolaria militaris Claparède, 1870	+	+
Mollusca		
Mytilus galloprovincialis Lamarck, 1819	+	
Arthropoda		
Balanus amphitrite Darwin, 1854	+	+
Balanus eburneus Gould, 1841		+
Tunicata		
Ascidiacea (sp.)	+	+

Barnacles play an important role in fouling phenomenon and caused many problems (Malone and Little, 1980) especially to the ship operators (Ahamet, *et al*., 1992). They require clear substrate space to colonize but they are also capable of producing larvae during the year. This capability could be an effective complement to poor competition ability (Smedes, 1984). The number of individuals of *B. amphitrite* were quite profuse in the area (492 individual per 400 cm^2). The biomass value of *H. elegans*, settled on the surface and on the *B. amphitrite* shells was the highest in the total biomass (Figure 1, 2). A lower percentage of barnacles (37, 1%) in the total biomass was due to the small basal plate of *B. amphitrite* specimens. It may be explained that the presence of numerous small barnacles on the treated part was due to the late settlement of spat by continuous leaching of chemicals from the surface for long periods (12-24 months). Santhakumaran, 1978 showed that the intensity of organisms is more on the treated panel with different preservatives than on non-toxic controls.

The other group, bivalve was represented by the species, *Mytilus galloprovincialis* that comprised 0.4%of the total population. This species is not a pioneer and requires an already consolidated and hard biological substratum in order to settle and establish itself (Tursi *et al*., 1984).

In the untreated part, barnacles were represented by 192 individuals; *B. eburneus* and *B. amphitrite* were found. The former was not observed in the other site. The main difference between the sites was the changing portion of two main groups, serpulid and barnacle in the biomass. *B. amphitrite* and *B. eburneus* were the principle constituents of barnacles dominated on the untreated surfaces but the number of individuals was lower than that counted on the treated surface. The diameter of basal plate in settled organisms was larger and covered almost the whole surface. Spirorbids and serpulids adhered to the shells of barnacle using them as substrate organism (basibiont). Serpulids did not have an important role in the biomass (13.4%) as compared to the treated part. The changing ratio of the main groups on these two substrate may be related to the effects of shading which may either be direct or indirect (Glasby, 1999). Light intensity may be important in structuring epibiotic assemblages in the two different parts on the hull.

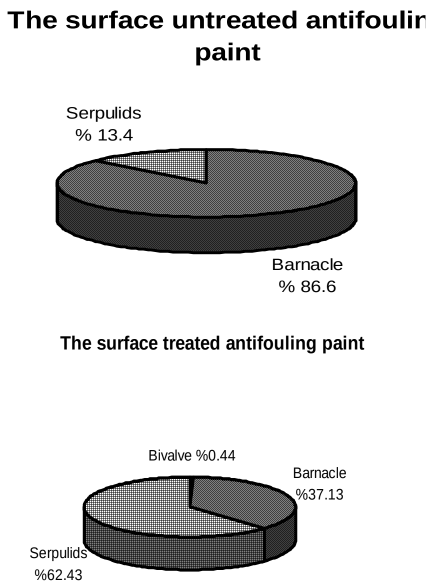

Figure 1. Biomass of the main groups among the scrapped materials

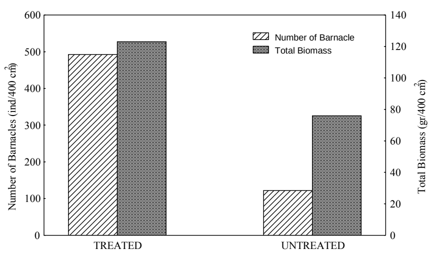

Figure 2. Total biomass and number of barnacles in the two different parts

When R/V K. Piri Reis was in dry-dock, roughness measurements were carried out over the ship's wetted surface. Measurement points were selected randomly and then the average amplitude, additional resistance caused by roughness and required effective horsepower was calculated. Average height roughness (AHR) definition ignores the location of roughness over the ship hull. From this calculation it was determined that the performance loss due to additional resistance was about the%30. This result was confirmed by differences in ship speed measurements before and after the cleaning operation in the same environmental condition.

As a conclusion in the fouling community on the hull of the R/V K. Piri Reis, two groups, barnacle and serpulid appeared to be capable of dominating regardless of previous colonization patterns. Both serpulids and barnacles cause major problems on the ship hull. Fouling roughness causes additional resistance hence increment in fuel expenses, which is the important part within the operational cost of a ship.

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