Biological control of marine biofouling

Uriel N. SAFRIEL[1], Yosef COHEN[2], Neta EREZ[1], Daniel GATENO[1], Tamar KEASAR[1] and Yael DOLEV[1]

[1]Department of Evolution, Systematics & Ecology, The Hebrew University of JERUSALEM **(Israel)**
[2]Department of Fisheries and Wildlife, University of Minnesota, ST. PAUL **(U.S.A.)**

Marine biofouling is a mat made of bacteria, sea-weeds, and sessile invertebrates, which develops on man-made objects submerged in the sea. The mat makes the surface of ships' hulls uneven and rough. Due to the rough surfaces friction during movement increases, and speed is reduced. On stationary installations, biofouling intensifies corrosion, increases the mass of the installation and distorts its configuration. To combat biofouling, prior to submergence the object's surface is painted with "antifouling paints", which contain toxichemicals. The toxins initially prevent, later slow down the development of the mat, but eventually fade away. The vessel has to be drydocked, scraped and repainted. Stationary objects are scraped periodically by scuba-divers. These solutions are costly and never foolproof. Striving to improve effectivity the chemical industry produces chemicals of ever-increasing toxicity. The invention of Tributyltin has crossed the threshold between environmentally-safe and environmentally detrimental toxichemical. This chemical poisons the marine biota and damages mariculture.

B

We explore an alternative solution, biological control by limpets, applied to surfaces that should be protected. Limpets *Patella coerulea* can easily be detached from the shore and transplanted onto metal panels simulating a ship docked in the port of Ashdod, Israel (SAFIREL & EREZ, 1987). The transplanted limpets eat the unicellular algae and sporelings of the larger algae. While foraging for them the limpets crush and dislodge recruits of the fouling invertebrates. We found that the limpets accelerated the detachment and mortality of young recruiting barnacles *Balanus amphitrite*, presumably by repeated running over by the foot, thus undermining the barnacles' hold. Only when barnacles are > ca 1.5 mm in rostro-carinal diameter, they become safe from both physical detaching forces, and limpets.

We found that during winter, when fouling recruitment was slow, 15 limpets reduced the ca 90% biofouling cover of 20 x 20 cm experimental panels down to 1-3%, and barnacles density from 2.6-3.8 to 0.7-0.8 individuals/cm^2. With the commencement of the spring surge of fouling recruitment, the limpets controlling effect steadily deteriorated, but they continued to check the development of the high-mass bryozoan cover by the end of the 8 months-long experiment. The decline in limpets' controlling effect was due to a feed-back loop : heavy settlement of barnacles brought about an initial reduction in control that increased barnacles sizes and density. This induced accelerated mortality among limpets, bringing about a further increase in barnacles' density.

To achieve effective control, it is necessary to measure "Return time", t_r, the time it takes a foraging limpet to return to a previously foraged location on the surface, and "Critical time" t_c, the time it takes a fouling individual to get established on the surface such that limpets cannot remove it. The preferred density and size distribution of limpets is the one that achieves $t_r \geq t_c$ for the whole surface. The critical time for *Balanus amphitrite* ranges between 3-6 days. The recruitment rate with which the limpets have to deal with can be as high as 0.44 *Hydroides elegans*/cm^2/day and 0.06 *Balanus amphitrite*/cm^2/day.

Return time of *Patella coerulea* depends on its movement pattern. As of transplantation, limpets gradually increase their home range and mould territories. Their rate of movement increases with the density of recruiting algae, on which they forage. But the presence of other limpets also elicits movement, presumably for marking the surface with mucus, as a non-aggressive territorial defense measure. Even when algal density is low, a limpet moves more when there are many than when there are few other limpets on the surface to be protected. To find the optimal control, we develop a mathematical simulation model which is driven by these and other data on the life history of the fouling organisms, and the behavioral ecology of the limpets, obtained in field and laboratory experiments.

REFERENCES

SAFRIEL U.N. and EREZ N., 1987.- Effects of limpets on the fouling of ships in the Mediterranean. *Marine Biology*, 95 : 531-537.