THALASSAS

Thalassas, 2003, 19 (2): 9-12
An International Journal of Marine Sciences

THE INFLUENCE OF FORESTED WATERSHED ON FISHERIES PRODUCTIVITY. A NEW PERSPECTIVE

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Keywords: Fisheries productivity, forested watershed, humic substances, iron, macroalgae

In Japan, the tree-planting efforts by fishing communities to protect fishery resources have gained much attention in the past decade (Matsunaga, 1993). Now approximately 124 local fishing associations and some state governments throughout Japan are promoting these efforts to protect fishery resources for the future (Matsunaga, 1993).

The coastal zone of Erimo peninsula in Hokkaido (northern part of Japan) has recovered its fisheries productivity in part because of a coastal reforestation effort sponsored by the public and government during the last half-century (Matsunaga, 1993). The peninsula, originally developed for cattle grazing and trees had been clear-cut. Following this development, sediment runoff increased, and the macroalgal community deteriorated in the coastal zone. Subsequently, populations of sea urchins, which depend on macroalgae as food, decreased, and fish started avoiding these highly turbulent areas. Fortunately, both the public and government noticed the relationship between the forest and fisheries productivity and started tree-planting projects to prevent sediment run-off. Fifty years later, the fish catch has increased by approximately 250 times. Although this represents an extreme demonstration of the potential influence of the coastal forest system on fisheries productivity, many fishing communities throughout Japan have started coastal reforestation efforts to protect marine resources.

Is the role of the forested watershed only preventing sediment run-off into the sea? Although reforestation in coastal zones is becoming a popular practice in some U.S. coastal areas (Walbridge, 1993), the scientific reasoning why the forested watershed is important in the case of Japan presents a new perspective to a conventional knowledge that the forested watershed acts as a filter of many pollutants. A striking phenomenon called "Isoyake" (barren of subtidal ground) has been devastating the northern Japan Sea for several decades (Fig. 1). Those areas previously dominated by brown algae (*Laminaria* and *Undaria*), are now completely covered by white coralline algae (*Lithophyllum*), changing the region's appearance to that of a desert (Kawai, 1997; Noro *et al.* 1983; Nabata *et al.* 1992). Therefore, some people call it these waters a sea desert. Due to this phenomenon,

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fishery yield has been decreasing because some fish such as herring depend on macroalgae as spawning ground, food, and shelter. Popular ecological hypotheses to explain this phenomenon such as by sea urchin's excessive grazing Iizumi, 1997; Taniguchi, 1997) and anomalous high temperature events (Fugita, 1997) do not satisfactorily explain this shift in algal composition.

A marine chemist from Japan, Katsuhiko Matsunaga of Hokkaido University, hypothesized that the deforestation of the coastal zone associated with dramatic coastal development in Japan during the past thirty years induced this phenomenon and suggested that it was linked to a reduction of bioavailable iron and humic substances leached from the coastal forest floor (Matsunaga *et al.* 1999). Matsunaga, who recently received the first Minamata environmental award in recognition of his work showing the relationship of coastal forests and marine productivity, is now giving seminars throughout Japan in an attempt to convince local coastal communities that protecting the forests near coastal zones is the best way to preserve fisheries productivity in the economically important coastal waters. He believes that iron chemistry and forest-derived humic substances are important keys to marine productivity and that coastal forests act as a processor to supply important nutrients such as iron for a constant high primary productivity (Matsunaga *et al.* 1999).

Matsunaga's group spent a decade proving this hypothesis. Iron has long been recognized as an important micronutrient for phytoplankton and macroalgae growth. Iron plays important roles in the rates of photosynthesis and nitrate uptake for the phytoplankton and macroalgae growth and is thought to be a limiting nutrient in some large areas of open ocean (Martin & Fitswater, 1988). Iron must be assimilated before appropriate photosynthesis and nitrogen uptake can occur. Although iron is an abundant element on this planet, it exists primarily in oxygenated forms unavailable for biological processes and bioavailable iron is rare even in coastal natural waters (Wells & Mayer, 1991). Also, the most stable form of iron has very low solubility and, therefore, cannot support algal growth once the bioavailable iron has been taken up during initial growth (Kuma & Matsunaga, 1995).

Matsunaga found that fulvic acids leaching from terrestrial forest systems enhance iron bioavailability by preventing ionic iron to become unbioavailable form of iron, iron hydroxides. Fulvic acids are a form of humic substances (resulting from the decay of leaf litter). These molecules are able to chelate ionic iron in anaerobic soils, preventing ionic iron to oxidize and maintain iron bioavailability once these iron-complex leach into highly oxygenated natural water.

His group found that iron concentration in the Isoyake area is extremely low (<2nM), which is similar to open-ocean levels (Matsunaga *et al.* 1999). They also found that iron requirement of brown algae is much higher than that of coralline algae (Suzuki *et al.* 1995). In addition, they found that humic substances kills the seed of coralline algae, but not that of brown algae (Suzuki *et al.* 1998). Therefore, they concluded that coastal deforestation may reduced the amount of bioavailable iron and humic substances leached from coastal forests and rivers, which in turn has led the algal species succession (from macroalgae to coralline algae) in the Japan Sea (Matsunaga *et al.* 1999). Kawaguchi *et al.* (1997) investigated bioavailable iron concentration and its effects on phytoplankton growth in both forested and urbanized salt marsh estuaries in the southeastern U.S. The results indicate that iron could be depleted much more readily in the urbanized estuary, and suggests that iron availability to estuarine phytoplankton may be reduced by urbanization-related practices such as coastal forest clear-cutting (Kawaguchi *et al.* 1997).

Deforestation along rivers and coastal zone promotes erosion of the humus layer (top soils) of forest soils which is a source of humic substances. Once eroded, the recovery of the humus layer is a very slow process. Therefore, the coastal reforestation and protection of buffer zones along rivers can potentially benefit marine resources both by acting as a filter of pollutants, and by indirectly maintaining the supply of humic substances into coastal waters.

The close relationship between forest and fish has been well known both in U.S. (e.g. protection of buffer zone for salmon)(USEPA, 1993) and Japanese fishing community (e.g. coastal forest provides insects as fish food, its shadow as shelter and control water runoff)(Makiguchi, 2002). It requires more research to

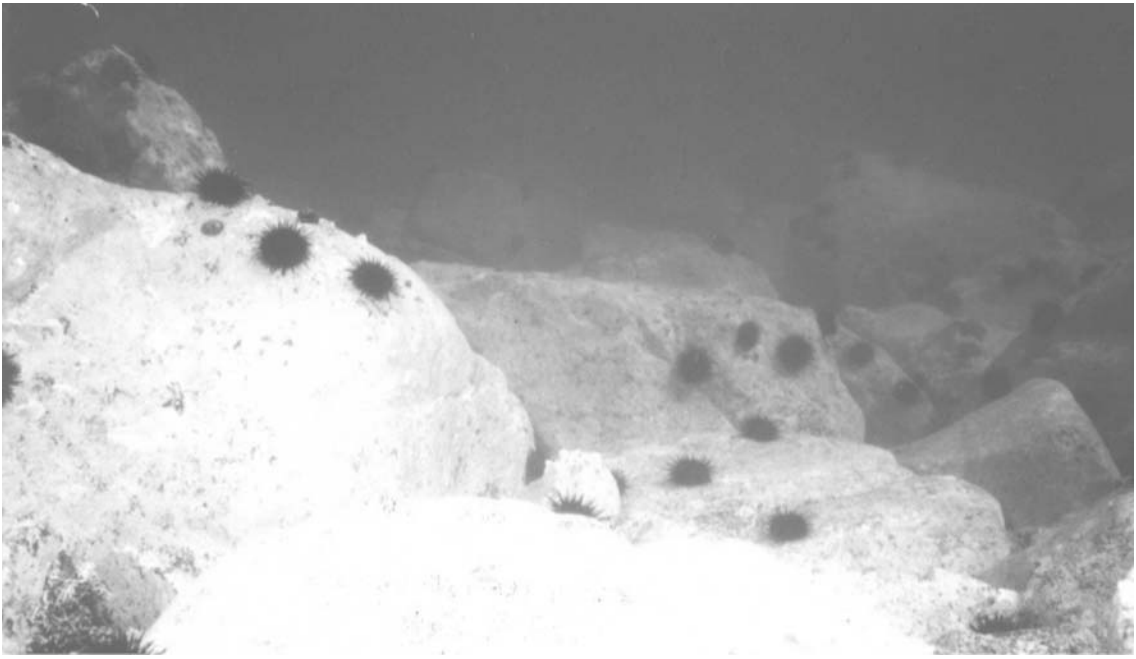

Figure 1.
"Isoyake" (barren of subtidal ground). Those areas previously dominated by brown algae (Laminaria and Undaria), are now completely covered by white coralline algae (Lithophyllum), changing the region's appearance to that of a desert.

completely understand the inter-relationship between forests and marine productivity. Marine resource management often is controlled by the episodic approach (e.g. new policy involvement after a catastrophe such as a fish kills has occurred)(Healy & Hennessey, 1994). However, grass-roots reforestation initiated by Japanese local fishing communities presents a new management paradigm that even without a complete scientific understanding we can initiate management practices such as reforestation and protecting buffer zones for protecting marine resources before it's too late.

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(Received: June, 29, 2003. Accepted: June, 31, 2003)