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ELIMINATION AND CONTROL OF AQUATIC PESTS IN THE ENVIRONMENT

Lavinel G. Ionescu,[a,b] João Marcos Hohemberger, [b] Juliane Vicenzi [b] and Carlos Pérez Bergmann [b]

SCIENCO Scientific Consulting Services [a]
Huntington Beach, California, USA
&
Departamento de Materiais [b]
Escola de Engenharia
Universidade Federal do Rio Grande do Sul
Porto Alegre, RS, BRASIL

ABSTRACT

The present paper is a brief review of possible methods that can be used to control or eliminate aquatic pests from the environment, with particular emphasis on the golden mussel, ***Limnoperna fortunei (Dunker 1856)****. This bivalve mollusk, native of Southeast Ásia, has infested most of the rivers in Northern Argentina, Uruguay, Paraguay and Southern Brazil and is causing serious environmental difficulties and biofouling. In addition, it causes serious problems to water treatment stations and hydroeletric power plants.*

RESUMO

O presente trabalho representa uma breve análise dos métodos que podem ser usados para combater ou eliminar várias pestes aquáticas com ênfase sobre o mexilhão dourado, ***Limnoperna fortunei (Dunker 1856)****. Este molusco bivalve, originário do Sudeste da Ásia, invadiu grande parte dos rios do norte da Argentina, Uruguai, Paraguai e sul do Brasil e está degradando o meio ambiente na região. Além disso, está causando sérios problemas no abastecimento de água e geração de energia hidroelétrica.*

KEYWORDS: Aquatic Pests, Golden Mussel, Biofouling, Hydroeletric Power Plants, Water Treatment

The present paper is a brief review of the possible methods and technologies that could be used to control or eliminate aquatic pests from the environment , with emphasis on bivalve mollusks and in particular the golden mussel, *Limnoperna fortunei* (Dunker 1856).

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Major preoccupation with marine pests and negative impacts caused by exotic aquatic species began soon after World War II , although control of undesirable organisms in the environment was known since ancient times.[1-24]

Navigation and particularly the use of ballast water seem to be the main causes of infestation of ports, marinas, gulfs, estuaries and rivers throughout the world.

The methods and management technologies usually applied to control the pest species are: a) Physical-Mechanical (physical removal, destruction, fire, etc) b) Chemical (organic and inorganic pesticides or biocides) and c) Biological (habitat, predators, pathogens, parasites and genetic manipulation).[1-4]

The more common aquatic species involved include toxic phytoplankton, macroalgae, ctenophores, echinoderms, mollusks, crustaceans, polychaete, bacteria and others.[1]

Harmful algal blooms (HABs) caused by toxin producing strains of phytoplankton may occur all over the world and affect all coastal areas having a strong economic impact were coastal aquaculture and tourism are important. They are known popularly as red or brown tides.

Among the macroalgae, four species have been identified as agents of world wide pest problems: *Undaria pinnatifidia, Codium fragile ssp. tomentosoides Caulerpa taxifolia,* and *Sargassum muticum. Caulerpa taxifolia* poses a serious problem in the Mediterranean and is particularly sensitive to copper sulfate and other copper compounds.

The Atlantic comb jelly *Mneniopsis leidyi* is a ctenophore that was introduced by ballast water in the Black Sea and affected seriously the ecology and fish productivity. This comb jelly has spread also into the Azov, Marmara and Mediterranean Seas Apparently, the best control of this ctenophore is the introduction of fishes that are specific predators.

The European green crab, *Carcinus maenas*, is a crustacean that causes serious damage to fisheries, aquaculture and native fauna in Eastern and Western United States, Canada, Australia, Japan and South Africa. Its control and elimination appears to be difficult.

The polychaete worm *Sabella spallanzanii*, originally from Sardinia, causes difficult problems to scallop fishers, abalone hatcheries and aquaculture in California, New Zealand and Australia.

Among the echinoderms or seastars, we mention *Asteria amurensis*, a species of the Northern Pacific that infested marine environment in Southeast Australia, mainly Tasmania. The elimination of undesired seastars in Japan, Australia, and the United States is by physical removal.[1]

Vibrio cholerae is a bacterium that is the causal agent of cholera, a disease characterized by diarrhea, vomiting and general prostration. It is transmitted through ingestion of food and beverages contaminated by feces and is predominant ia areas of poor hygiene and sanitation. This disease has killed millions of persons and continues to be a major health problem. According to well-informed sources, the seventh pandemic began in 1961 in Indonesia and spread to Africa, the Mediterranean and Eastern Europe. In 1991, ballast water from an Asian cargo ship, contaminated coastal waters mollusks and fishes in Peru and the disease spread to the rest of Latin America, affecting more than a million people and causing 10.000 deaths. Supposedly, the *Vibrio cholerae* strain responsible had been previously identified in Bangladesh. The recent cholera cases in Paranaguá, Paraná, Brazil have been traced to contaminated ballast water. Strains of *Vibrio cholerae* have been detected in Chesapeake Bay, the Gulf of Mexico, Japan and Australia.

Among the mollusks, some of environmental interest are *Corbula gibba, Crassostrea gigas, Mytilopsis sallei, Potamocorbula amurensis* and *Musculista senhousia.* Serious problems as fouling organismas are caused by three groups:
l) Mytilacea (*Mytilus edulis, Musculista senhousia, Perna ssp, Limnoperna fortun*ei,)
2) Dreissenacea (*Dreissena polymorpha, Mytilopsis sallei. Dreissena bugensis*) and
3) Corbiculoidea (*Corbicula fluminea, Corbula gibba, Potamocorbula amurensis*).

Some of these mollusks are a source of food for human consumption , poultry feed, fertilizers,while others are used as bioindicators, biofilters, pollution monitoring or cause serious biofouling, damage to water treatment installations, hydroelectric plants and aquaculture.

Perna viridis, Perna perna and Crassostrea virginica are some species that have been widely studied.

From an environmental point of view, two bivalve species are of maximum interest: the Zebra mussel (*Dreissena polymorpha*), originally from the Black Sea, that has infested almost half of the navigable waterways of the United States and the Golden Mussel (*Limnoperna fortunei*) that is becoming a grave and serious problem in Argentina, Brazil and Paraguay.[22-26]

Limnoperna fortunei (Dunker 1856) or Golden Mussel is a freshwater bivalve mussel native of Southeastern Asia. It is common in rivers and estuaries of China and its economic impact was first recorded in Hong Kong and South Korea and later in Taiwan and Japan.

In South America, its presence was first confirmed by G. Darrigan and his collaborators[16] in the River Plate in 1993. Along with *Corbicula fluminea* (Müller 1774) and *Corbicula largillierti* (Philippi 1881, the golden mussel (*Limnoperna fortunei*) is the third invading freshwater bivalve species to enter South Amereica through the River Plate (Rio de la Plata).

Its introduction is most probably due to the discharge of ballast water with high concentration of the bivalve and its larval stages by ships coming from Southeast Asia. The life of the species is similar to marine mytilids and it attaches to many hard objects, including rocks, ship hulls, wood, etc. with a byssus (an adhesion apparatus) consisting of numerous protein tethers or byssal threads.

In the subtropical region it grows rapidly, the adult reaches a length of 3-4 cm and its life span is about three years.The adults are dioic, with about two thirds of the population being female and they reproduce at least once or twice a year.[25-34]

Figure 1 shows some typical adult specimens of the golden mussel and Figure 2 gives a complete classification of the species and also shows a larval stage.

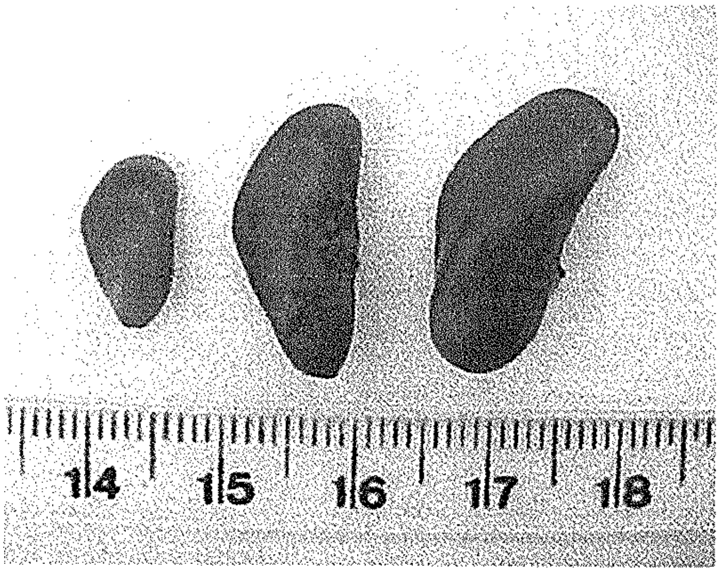
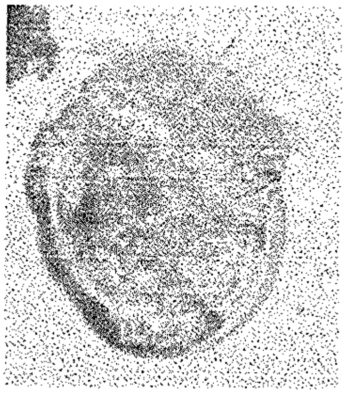


Figure1. Some Typical Adult Specimens of *Limnoperna fortunei* (Dunker 1856)[2]

Phylum: Mollusca
Class: Bivalvia
Subclass: Pteriomorpha
Order: Mytiloida
Superfamily: Mytiloidea
Family: Mytilidae
Genus: Limnoperna
Species: Limnoperna fortunei (Dunker 1856)
Common Name: Golden Mussel

a. Classification



b.Veliger larva

Figure 2. Complete Classification of the Golden Mussel, *Limnoperna fortunei* (Dunker 1856) and an example of a larval estage.

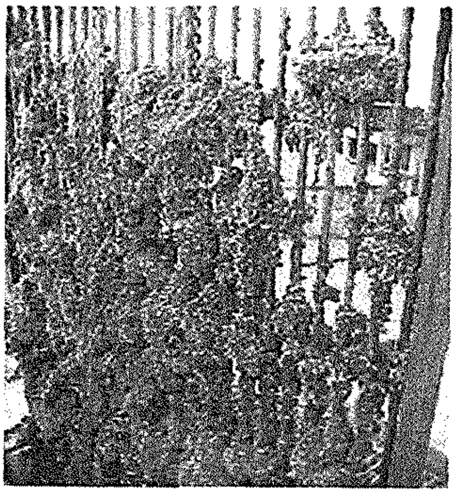
In the subtropical region, the golden mussel exhibits rapid growth, begins reproduction at an age about 30 days. It reproduces once or twice a year and has a short life span (about three years).

Its panktonic larval stage have been studied in detail[15-34]. A total of nine different larval stages have been described, five without valves and four with valves.According to C.D. Mansur and her collaborators,[7] the first one recognized as a ciliated stage develops into the trocophora (length from 80 to 125 µm) with four distinct stages. The valved stages include the D" shaped (length 120 to 150 µm), the straight hinged veliger (length 150 to 190 µm), unbonated veliger (length of 190 to 220 µm) and pediveliger (length of 220 to 250 µm)After the larval stages come the plantigrades (approximate length of 300 µm) that have a small peduncle and secrete the byssus threads that permit fixation on solid surfaces.

They attach to all kinds of hard materials, including submerged vegetation, hulls of ships, anchors, fishing equipment, parts of water distribution and irrigation systems and even other crustaceans.

Limnoperna fortunei was already considered a pest when it invaded coastal waters in South Korea and Hong Kong in the 1960's. It causes microfouling and it has a profound ecological economic and technological impact, affecting native fauna and microfauna, water supply, treatment and distribution and hydroelectric power plants.[31-34]

This species can reach densities of more tha 100,000 individuals per square meter. Figure 3 illustrtates some examples of highly dense colonies of *Limnoperna fortunei.*



(a)

(b)

Figure 3. Examples of High Density Colonies of ther Golden Mussel.[2]

(a) Grating from the Water Treatment Station of Porto Alegre
(b) Turbine from the Itaipu Hydroelectric Power Plant

The high density of individuals, at times coupled with empty shell accumulation or mass mortality can cause water pipeline contamination, pipeline diameter reduction, water velocity decrease due to friction and pipeline blockage.

Serious damage and economic loss may result as far as water treatment and distribution, electric power plants, navigation docks, dams and irrigation systems are concerned.

On the other hand, the ecological and environmental impact caused by this exotic mussel, especially with regard to competition for food and living space with native species is of paramount importance.Fishing, hatcheries, oyster cultivation and other types of aquaculture activities can be seriously impaired.

The map in Figure 4 shows the extent of the spread of Limnopern fortunei (Dunker 1856) in South America. As can be seen, the golden mussel has been detected the River Plate, Paraguay, Uruguay and Paraná Rivers. Its presence has been shown also in the Lagoa dos Patos, Guaíba, Jacuí and other minor rivers .In terms of Brazil, it already covers the states of Rio Grande do Sul, Paraná, São Paulo, Mato Grosso do Sul and Mato Grosso. Hydroelectric power plants and water treatment and captation stations throughout the entire area have been affected. Even the gigantic Itaipu Hydroelectric Plant faces the infestation with the golden mussel.There is a major preoccupation that *Limnoperna fortunei* may reach the basin of the Amazon.[2]

At the present time there are no biological methods that are effective in the control of the golden mussel.

Among the physical methods[38-42] that have been tried, especially with the zebra mussel , and may be used with Limnoperna fortunei are anoxia and hypoxia (normally reducing the oxygen content in the aquatic environment) by continuous bubbling of nitrogen, ultraviolet radiation, electric or magnetic fields and acoustics. The acoustic methods involve, cavitation, sound waves, hydrodynamics and vibration. Physical methods widely used today are actual physical removal and destruction of the mussel. Of course, they imply temporary and partial shutdown of of water treatment plants and pumping stations, hydroelectric power plants and shipping docks.

Chemical methods, again have been widely studied and applied against the zebra mussel. In general the chemical compounds used are oxidizing agents with free radicals, metal ions and various types of biocides. They have been amply described in reports by the United States Army Corps of Engineers and others.[38-42] Some representative examples of chemical agents used are shown in Table I. Usually the mortality rate is very high, but other living organisms also pay a high toll.

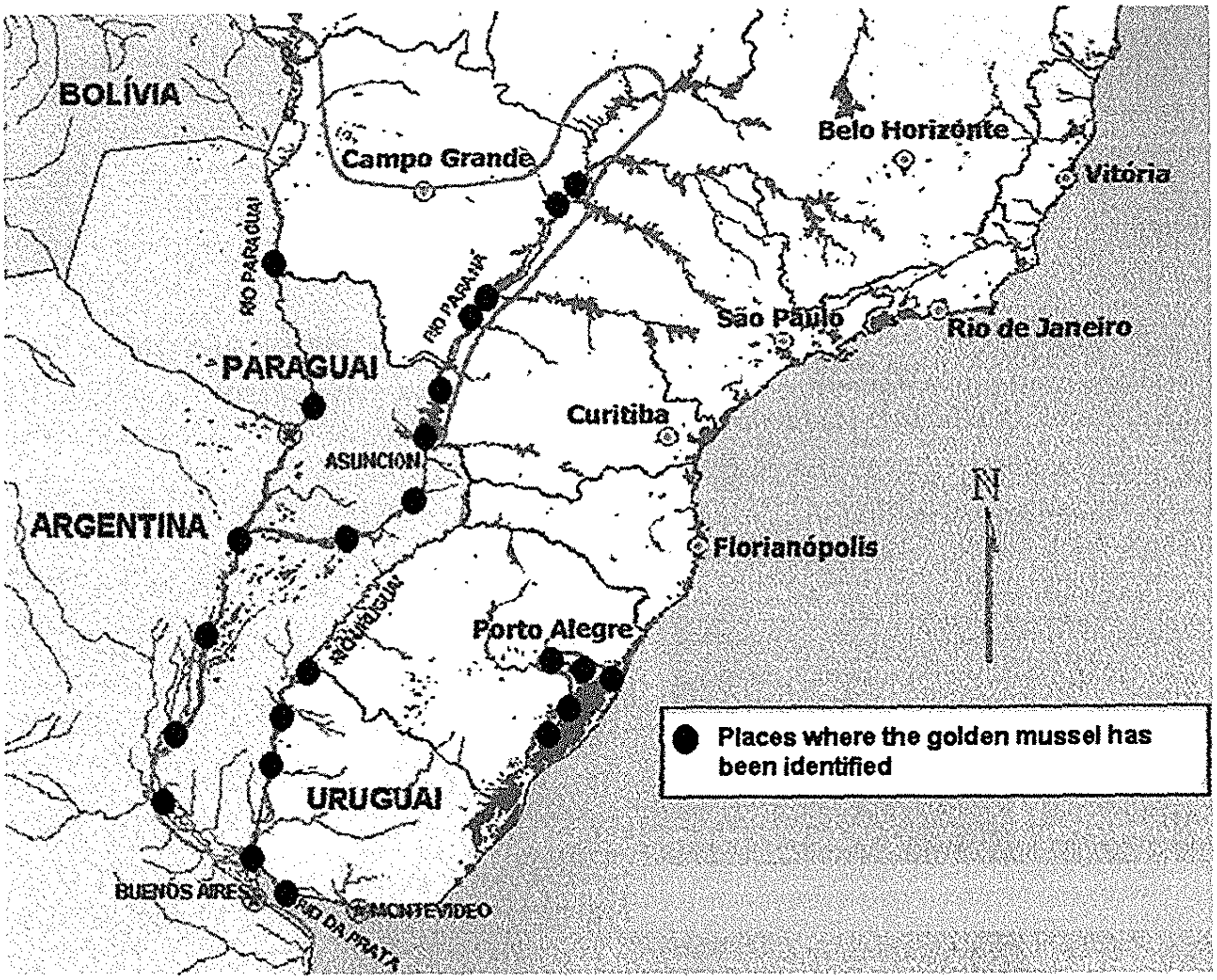


Figure 4. Occurence of the Golden Mussel, *Limnoperna fortunei* (Dunker 1856), in South America.[2]

Pratically all chemical substances may act as free radicals, alter the permeability of membranes or block enzyme action, as in the case of most metals. The physiology and toxicity of metals in different mollusks has been studied in detail.[8-15] Quaternary nitrogen compounds, that usually are also surfactants, alter the properties of biological membranes. Oxidizing agents, that include free radicals, are responsible for braking many chemical bonds and are powerful biocides.

From environmental and technological aspects, probably the most efficient methods of control are at the larval stages. They may involve actual killing of the larvae with oxidizing agents or biocides or prevention of their fixation to hard surfaces. To prevent fixation, one possibility is the use of anti-incrusting paints with tributyl tin or copper oxides or other metals. In this case, the presence of the metals as nanoparticles may be very useful.[18] Another possibility is the use of metal coated surfaces. Bioinspired antifouling materials and the mechanism of mussel adhesion[36,37] has been recently described in detail by L. Dalsin and B. Messersmith.[35]

Table I. Some Examples of Chemical Agents Used to Control Mussels.[38,41]

Chlorine	Tributyl Tin Oxide
Sodium Hypochlorite	Aluminum Sulfate
Ozone	Copper Sulfate
Chloramines	Acridine
Chlorine Dioxide	Dimethylbenzyl Ammonium Chloride
Bromine	Dodecyldimethyl Ammonium Chloride
Bromine chloride	N-Triphenyl Methylmorpholine
Sodium Bromide	Dodecylguanidine Hydrochloride
Sodium Chloride	Alkyldimethylbenzyl Ammonium Chloride
Potassium Hydroxide	Endod (Plant Extract from the Soap Berry)
Potassium Chloride	Metal Ions from Various Salts Including
Potassium Dihydrogen Phosphate	Silver, Mercury, Zinc,Lead,Copper
Dipotassium Hydrogen Phosphate	Cadmium, Tin, Gold,Chromium, Manganese
Potassium Permanganate	Commercial Molluscicides

Much more sophisticated and expensive methods involve the use of radioactive isotopes impregnated in surfaces and the use of "biobullets".[40] These are actually small food particles that contain microencapsulated highly toxic and lethal compounds. The mussels take in the "biobullets" that are later dissolved rapidly in the digestive tract and release the toxic compounds.

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