Status of Biotic Agents, other than Insects or Pathogens, as Biocontrols

by

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INTRODUCTION

Insects and pathogens always have played an important role in research on biological weed control because of their host specificity which is important in selective control. Also nematodes offer possibilities in this respect, but they are studied only occasionally.

However, selectivity is not always necessary and even sometimes unwanted. This is especially the case in situations where a whole or nearly a whole complex vegetation has to be controlled or kept in a low stage of biomass-development. Here other biotic agents can be used as well, even when they are polyphagous. This situation occurs especially in aquatic vegetations, but occasionally also on non-agricultural land and in certain perennial crops. The applied agents are diverse, and human phantasy has not yet been exploited sufficiently in this field of research.

BIOLOGICAL CONTROL OF TERRESTRIAL VEGETATIONS

Biological control in its strict sense is seldom found on the land, although sheep, goats and geese are used in some parts of the world (DeBach 1972). These animals are rather selective in their feeding behaviour so that a high plant diversity is not always conserved. The latter can be a requirement in the management of certain vegetations, for example on road verges, maintenance paths along waterways and railway embankments. Other control methods can also be adapted to meet this requirement, for example mowing of a vegetation after the seedfall of the annual and biennial weeds.

Such biological or ecological line of thought is also behind some other methods used in practice or still under investigation.

In pasture, for example, weeds are controlled by improving the growing conditions of the desirable grasses or by using such a mixture of grasses that soil coverage is always assured and weed germination is prevented. Another way is the grazing management; different animals or different grazing intensity give different weed control (Lynch, 1973).

The technique of biological weed control through better competition by the crop itself is still open to various possibilities. In forestry in the Netherlands the use of higher grade (older) plant material is recommended now to increase the ability for competition while possibilities in other crops could be realized, for instance via varietal improvement. An example is the host resistance against *Orobanche* and *Striga* species, which has been increased in breeding programs with sunflowers, tobacco, tomatoes, beans and sorghum (a.o. Racovitza 1973; Cubero 1973; Kassan, Dagg, Kowal & Khadr 1976). The exploitation of parasitic plants to control certain weeds has just been released in the Netherlands, especially with *Rhinanthus spp.* against grasses on road verges.

Next to increase in the competitive power of the crops it is possible to use harmless weeds for the prevention of other species. In the Netherlands *Phragmites communis* is being used in reclamation districts not only to promote soil improvement after water has been removed, but also to prevent the establishment of noxious weeds for future agriculture. This "replacement control" (Piemeisel 1954) is investigated now on some scale also in ornamentals and in orchards as an alternative for the black soil situation, achieved by other weed control methods. Experiments with various low-growing, soil-covering plants are in progress. It is still too early for conclusions, but *Sedum acre* could be useful in apple orchards. A cover of this small succulent seems capable of competing with unwanted perennial grasses, which may consume so much water that deficiency in the trees develops. Its own water use is small, while the biotope is not suitable for mice. There is some similarity in this approach with the "soft weeds" concept in plantation crops in the humid tropics. These relatively harmless soil covers are maintained for soil pro-

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tection against erosion and irradiation. Again here it is hoped, that more noxious plants can be kept under control by dense soil covers.

Another type of biological control which deserves more attention is the use of allelopathy the phenomenon that certain plants cause harmful effects to other plants through the production of chemical compounds ("natural herbicides") that escape into the environment. Rice (1974) quotes various examples of crops that have in principle the ability to suppress certain weeds.

BIOLOGICAL CONTROL OF AQUATIC VEGETATIONS

In the aquatic situation the use of biotic agents other than insects and microorganisms is preferable when most of the noxious weed species have to be brought down simultaneously to a low level. There is an exception for deeper waterbodies, where often the weed problem is caused by one single floating species (*Eichhornia, Salvinia, Pistia, Azolla*) or by blue-green algae (*Microcystis, Oscillatoria*). Here the introduction of insects and mites, respectively viruses proved to have good prospects. In the shallow waters decrease of one weed species is not effective, for other species will usually take over its place. It is not astonishing therefore, that many different organisms are investigated in relation to their capacity to control aquatic weeds (Table 1). In the aquatic situation allelopathy is studied as well (Szcepanski 1971). Especially the debris of *Glyceria aquatica* (or bacteria present in this debris) has an inhibity or influence on other emergent macrophytes.

Mammals

The coypu or nutria (*Myocastor coypus*) is often mentioned as a voracious consumer of aquatic weeds (Nat. Sc. Res. Counc. etc. 1973), but the use of this rodent has never been investigated in detail. Being imported from Latin-America to Europe for its fur it escaped and is now an unwanted animal in various southern countries where winter does not diminish the population sufficiently and where the "aquatic rats" as they are called destroy dams and dikes by their burrowing activities.

The use of another group of animals is thought to have better prospects: the *Trichechus* species or manatees. Various experiments, especially in canals and lakes in Guyana (Nat. Sc. Res. Counc. etc. 1973) showed that these animals are not selective in their food choice and very efficient: one adult consumes more than 200 pounds of wet vegetation per day. However, some important conditions for their use as high temperature and deep water are not always fulfilled. Moreover there is a lack of knowledge on sea-cow husbandry and breeding, because extinction of these animals is already a serious threat in their natural habitats at the moment (Blackburn, Sutton & Taylor, 1971). To collect more knowledge the foundation of an International Manatee Research Centre is proposed by the National Science Research Council of Guyana and the National Academy of Sciences, U.S.A., in which tropical countries in South America, Africa and Asia are greatly interested.

Table 1. ORGANISMS STUDIED FOR BIOLOGICAL CONTROL OF AQUATIC WEEDS

MAMMALS	*COYPU* (Myocastor coypus)
	MANATEE (Trichechus spp.)
BIRDS	*GEESE, DUCKS, SWANS, COOTS* (Anser anser, Anser sp., Anas platyrhyngos, Cygnus olor, Fulica atra, Aythia ferina, Galliluna chloropus)
REPTILES	*TURTLES* (Pseudemys floridana, Hardella thurgii, Kachuga tectum, Chelonia mydas*)
FISH	MANY SPECIES (grazers, mowers, roilers)
ECHINOIDS*	
MOLLUSCS	SNAILS (Marisa cornuatietis, Pomacea australis, Pila virens (?), Pila globosa (?), Strombus gigas*)
CRUSTACEANS	*CRAYFISH* (Orconectes causeyi)
	tadpole *SHRIMP*
INSECTS	*MANY SPECIES*
MITES	*MANY SPECIES*
MICROORGANISMS	*MANY SPECIES* (bacteria, fungi, viruses)
ALGAE	monocellular *GREEN-ALGAE*
MACROPHYTES	*BOTTOMGROWERS* (Eleocharis spp., Saggittaria subulata, Alisma gramineum, Tillaea aquatica)
	SHADOWING PLANTS (Nymphaea alba, Nuphar lutem, Nymphoides peltata, Potamogeton natans, Lemna spp., trees and shrubs)

*sea weeds

Birds

Many ducks, geese, swans and coots, domesticated or not, are consumers of aquatic plants. The smaller species of ducks are rather selective: they prefer duckweeds and other small plants with soft tissues. Geese and swans mostly consume a certain amount of terrestrial plants as well. Other water-birds consume seeds and/or fruits of aquatic plants so that their reproduction is diminished (Nat. Sc. Res. Counc. etc. 1973).

A great advantage of birds is their own easily adjusted reproduction (Franz & Kreig 1972) and the fact that different species with a different food choice can be kept together. Examples of the practical use of birds for control of aquatic weeds are still rare. In Hawaii geese are reported to be successfully used to control grasses (Ross 1971) and birds are used in fishponds in Eastern-Europe. Kvet & Hudec (1971) report very good results with the gray-lag goose (*Anser anser*) controlling predominantly emergent plants, especially during breeding and moulting when the aminals do not much fly away. Also Dobrowolski (1973) observed good results, but postulates that natural populations will never achieve sufficient control, since no more than 2% of lake macrophyte production was consumed. An artificially increased mixed population of water-fowl however, could consume up to 90% of the aquatic plant production.

Reptiles

In many reports the use of herbivorous turtles is mentioned as a possibility for aquatic weed control, but only two cases are known: one in Florida with *Pseudemys floridana* (Yount & Crossman 1970) and one in Pakistan with *Hardella thurgii* and *Kachuga tectum* (Chokder 1967). In both cases results were promising, but as with sea-cows husbandry of turtles is difficult and the bottleneck for economic use.

Fish

At the moment herbivorous fish are most promising for aquatic vegetation control. Many species are investigated (Table 2), but most of them have one or more properties making them of low practical value or of only local interest. This can be their selectivity as in the silver dollar fish (*Metynnis roosevelti* and *Mylossoma argenteum*), that consumes tender shoots only (Nat. Sc. Res.

Table 2. FISHSPECIES STUDIED FOR BIOLOGICAL CONTROL OF AQUATIC WEEDS AND A SELECTION OF RELEVANT REFERENCES.

ACANTHORHODEUS ASMUSSI	Gaevskaya 1969
ARISTICHTHYS NOBILIS	Voropaev 1968, Krupauer 1971
CATLA CATLA	Verigin 1966, Chokder 1967, Munro 1967, Nikolskii et al. 1968
CHANOS CHANOS	Fao 1961
CIRRHINA MRIGALA	Verigin 1966, Nikolskii et al. 1968
CTENOPHARYNGODON IDELLA	Many ref., cf. Van Zon et al. 1976
CTENOPHARYNGODON X CYPRINUS HYBRIDS	Duthu & Kilgen 1975
CYPRINUS CARPIO	Threinen & Helm 1954, King & Hunt 1970, Sills 1970
ETROPLUS SURATENSIS	Raj 1973
HEMIRAMPHUS BRASILIENSIS*	Blackburn et al. 1971
HYPOPHTHALMICHTHYS MOLITRIX	Krupauer 1971, Von Menzel 1974
KYPHOSUS SECTATRIX*	Blackburn et al. 1971
LABEO CABASU	Chokder 1967
LABEO ROHYTA	Verigin 1966, Chokder 1967, Nikolskii et al. 1968
MEGALOBRAMA TERMINALIS	Gaevskaya 1969
MELICHTHYS RADULA*	Blackburn et al. 1971
METYNNIS ROOSEVELTI	Yeo 1967, Blackburn et al. 1971
MUGIL SPP.	Prowse 1969
MYLOSSOMA ARGENTUM	Yeo 1967, Blackburn et al, 1971
PARABRAMIS PEKINENSIS	Gaevskaya 1969
PUNTIUS JAVONICUS	Chokder 1967
SCHIZOPYGOPSIS STOLICZKAI	Gaevskaya 1969
SCHIZOTHORAX ARGENTATUS	Gaevskaya 1969
SPARISOMA RADIANS*	Blackburn et al. 1971
TILAPIA HYBRIDS	Blackburn et al. 1971
TILAPIA MELANOPLEURA	Morawa 1963, Junor 1969, Prowse 1969, Yeo & Fisher 1970
TILAPIA MOSSAMBICA	Morawa 1963, Nikolskii et al. 1968, Prowse 1969, Yeo & Fisher 1970
TILAPIA NILOTICA	Avault et al. 1966, Yeo & Fisher 1970
TILAPIA ZILLII	Morawa 1963, Yeo & Fisher 1970
TRICHOGASTER PECTORALIS	Chokder 1967

*sea weeds

Counc. etc. 1973) or in *Trichogaster pectoralis* that nearly exclusively feeds on duckweeds (Chokder 1967). Also polyphagia can be a disadvantage, like in *Tilapia melanopleura* that gives often excellent weed control but also excellent predation on other fish (Junor 1969). Many of the studied fish species are only suitable under tropical or subtropical circumstances; *Tilapia* hybrids are more tolerant to lower temperatures (Blackburn, Sutton & Taylor 1971), but yet their use in temperate areas is restricted to cooling-water ponds (Morawa 1963, Nikolskii, Verigin, Makeeva & Popova 1968).

Until now the best practical possibilities are offered by the following species.

a. *Ctenopharyngodon idella* (White amur or grass-carp) is a non-selective herbivore from China, well adapted to both low and high temperature. Natural breeding of this species is impossible in most parts of the world (Van Zon 1976; Van Zon, Van der Zweerde & Hoogers 1976 and many references in WRO 1971). Where breeding is possible, there are prospects in the use of sterile hybrids of the white amur and the Israeli carp (*Cyprinus carpio*) (Duthu & Kilgen 1975) and in the use of monosex white amur (Stanley 1976).
b. *Hypophthalmichthys molitrix* (Silver carp) is a plankton feeder, also from the East-Asian river systems. It has a practical value in lakes against blooms of green monocellular algae in East and Middle Europe (Krupauer 1971, Von Menzel 1974).
c. *Aristichthys nobilis* (bighead) is also a plankton feeder from the same origin. This species is less selective in its feeding than the silver carp, consuming large quantities of zooplankton but also of blue-greens, a big problem in eutrophic lakes all over the world (Voropaev 1968; Krupauer 1971).
d. *Tilapia*-species are found in all tropical waters. Some of them are useful for weed control in warmer countries; especially *T. mossambica* against green planktonblooms (Chokder 1967; Prowse 1969), and *T. nilotica* against filamentous algae (Avault, Smitherman & Shell 1968). *Tilapia* species are very fecund and therefore only suitable where predators can keep their number down (Prowse 1969).
e. *Cyprinus carpio* (common or Israeli carp) is not a specific consumer of plants, but it can still give efficient weed control by stirring up bottom mud, which covers plants and prevents photosynthesis. However this will not affect all aquatic species (King & Hunt 1967; Sills 1970). Also the turbidity of the water is a disadvantage both from an aesthetical point of view and because of the negative effects on other fish and waterfowl (Threinen & Helm 1954).
f. *Catla catla* (Indian carp) seems useful against algal blooms, and to a less extent against filamentous algae and macrophytes (Verigin 1966). Successful experiments are reported from the USSR, Rhodesia (Munro 1976) and India and Pakistan (Chokder 1967).
g. *Chanos chanos* (Milkfish) has been applied against algae and some other weeds in ricefields in Thailand (FAO 1961).
h. *Mugil spp.* (Mullets) are used against algae blooms in brackish waters (Prowse 1969).

All other fish species are used on a very small scale. More research is required to determine their possibilities outside their natural habitats.

Evertebrates

Much work on biological control of aquatic weeds is done with insects and mites, but this is beyond the scope of this review.

The second important group with respect to research-input is that of the molluscs. Special attention was paid to the South-American snail species: *Marisa cornuarietis* and *Pomacea australis*.

Both animals consume large quantities of aquatic plants, but they require rather high temperatures and high stocking densities. They are not exclusively herbivorous (Yeo & Fisher 1970). *Marisa* eats for example also other snails, and is even used in Puerto Rico to control the mulluscean vector of Schistosomiasis (Blackburn, Sutton & Taylor 1971). *Pomacea* also eats terrestrial plants.

A gastropod (*Strombus gigas*) is also feeding on sea-weeds, as various echinoids (Rendal 1965).

The crayfish *Orconectes causeyi* is reported to control submerged weeds and algae in fishponds in the USA (Dean 1969) and the tadpole shrimp offers great possibilities in transplanted rice in Japan, where it nibbles away all germinating weeds but not the larger rice plants (Matsunaka 1974, pers. comm.).

Microorganisms

The work with fungi, bacteria and viruses is also beyond the scope of this paper, but the promising results of Israelian and American investigators with various microorganisms against the world-wide problem of blooms of blue-green algae should be mentioned (Safferman & Morris 1964; Shilo 1971; Fogg, Stewart, Fay & Walsby 1973).

Plants

Aquatic plants can be used to control other (more noxious) aquatic plants by competition for space and for light.

Competition for space mostly takes place at the bottom of a waterbody. Certain small fast-growing, sodforming makrophytes can be exploited to crowd out other plants by planting them or by stimulating their growth selectively. Most research has been done with *Eleocharis*, especially the needlerush, *Eleocharis acicularis* (Yeo & Fisher 1970; Van Zon 1973). Johannes (1974) established that the germination of seeds is prevented mechanically in a dense stand of *Eleocharis*.

Yeo & Fisher (1970) and Blackburn, Sutton & Taylor (1971) quote various American studies on other suitable aquatic weeds, namely narrow leaf waterplantain (*Alisma gramineum*) dwarf arrowhead (*Sagittaria subulata*) and pigmyweed (*Tillaea aquatica*).

Competition for light can be exploited by stimulation of plankton-growth. It is achieved by fertilization, a common practice in fishponds in Europe. Higher plants are also used to control algal blooms, e.g. duckweed in India (Alikunhi, Ramchadran & Chaeduri 1952).

The use of shadow from trees and shrubs along waterways to decrease the growth of aquatic plants is described by Lohmeyer & Krause (1975) and practiced in certain parts of the Netherlands (Hopmans 1970; Van Zon 1973). In the Netherlands the possibilities of broad-leaved, floating species like *Nymphaea alba, Nuphar luteum, Nymphoides peltata* and *Potamogeton natans* are under investigation now. The effect of these floating plants on water transport is studied in the same experimental set-up.

CONCLUSION

Biological control with other agents than insects or pathogens offers various possibilities. Some are already successfully used on a practical scale in aquatic situations. For special problems promising agents are in an advanced stage of development.

In terrestrial situations the possibilities have to be analyzed further and more brainstorming seems urgently needed.

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