SALVINIA MOLESTA IN KAKADU NATIONAL PARK: BIOLOGICAL CONTROL

M. H. Julien[1] and M. J. Storrs[2]
[1] CSIRO Division of Entomology, Long Pocket Laboratories, Indooroopilly Q 4068, Australia
[2] CSIRO Division of Entomology, c/- The Office of the Supervising Scientist, Jabiru NT 0886, Australia

Summary. Releases of the salvinia weevil, *Cyrtobagous salviniae*, in 1984/85 to control salvinia, *Salvinia molesta*, in Kakadu National Park resulted in establishment and spread but not satisfactory control. A preliminary study suggested that lack of control may have been due to high temperatures (9). In 1991 CSIRO began a consultancy for ANPWS to monitor the environment, the weevil and the weed to determine why biological control was not successful. The results so far suggest that weevil abundance declined after the weed was severely damaged and that temperature was not a major limiting factor. Successful biological control occurred in some billabongs while in others, similarly heavily damaged mats failed to sink because they were tightly packed and held together by other vegetation.

INTRODUCTION

Kakadu National Park, located in the Northern Territory of Australia, approximately 300 km east of Darwin, is dominated by two major river systems, the South Alligator River and the East Alligator River. The floating weed, salvinia, was first found in the Park in 1983. Manual removal and chemical control of salvinia was not successful and it quickly spread to cover all major billabongs on Magela Creek, a tributary of the East Alligator River (9).

Releases of the salvinia weevil were made on Magela Creek in 1984 and 1985 (9). The weevil established, spread and severely damaged the weed in the years following its release (C. Wilson and A. Skeat pers. comm., 1990). However, during the period 1987 to 1989 there was little flushing of Magela Creek during the annual wet season, activity by the weevil apparently did not prevent growth of the weed and salvinia spread to cover much of the surface of the billabongs. Concern for the wetlands increased and steps were taken to reduce the chances of the weed spreading by restricting access to infested areas and inspecting vehicles after they crossed infested streams. Unfortunately, salvinia was found in Nourlangie Creek, a tributary of the South Alligator River, in 1990 where it has since spread to infest a number of billabongs and associated swamplands.

Between 1986 and 1989 Skeat (9) determined a significant negative correlation between adult weevil numbers and temperature. He concluded that the apparent relationship between high water temperature and low weevil populations required further study. In July 1991 ANPWS contracted CSIRO Division of Entomology, to determine the factors that were preventing satisfactory control of this weed.

METHODS

Five study sites were selected in billabongs on Magela Creek where environmental parameters, plant growth and weevil activity were recorded. A floating wire mesh pontoon was located amongst salvinia at each site. A 2x2 m floating quadrat was placed within each pontoon and observations were made within the quadrat. The pontoons provided protection from crocodiles and support for the observer and equipment including temperature sensors and data loggers.

Two hundred adult weevils were released onto salvinia in the floating quadrats in each pontoon. One hundred terminal ramets of salvinia were inspected each week and the numbers of terminal buds damaged by the weevil and the numbers of adults observed were recorded. Populations of the weevils and the damage they caused were similarly monitored at locations away from the pontoons. These populations originated from the initial releases made in 1984/85.

Relative growth rates (RGR) for salvinia were measured at Ja Ja and Jabiluka Billabong sites in uncrowded conditions. Thirty salvinia plants were collected from the billabong. Fifteen were dried and weighed and the number of ramets per plant recorded. The other fifteen were placed into a 1x1m floating quadrat. After two weeks, the fifteen plants from the quadrat were dried, weighed and the number of new ramets recorded. This was repeated every two weeks at both sites and the RGRs for dry weight and for numbers of ramets were calculated (3).

Daily maxima and minima and hourly temperatures were recorded at each site by sensors located as follows. In a mini-screen 1.5 m above water level, in shade 10 cm and 2 cm above salvinia, in water 2 cm and 10 cm below the surface and in a salvinia plant. Daily rainfall was recorded at each site.

Samples comprising 15 plants of salvinia were collected each week, dried, ground and analysed for concentrations of nitrogen (N), phosphorus (P) and potassium (K).

RESULTS AND DISCUSSION

Temperature. Temperature relations of the weevil have been studied in some detail (2, 8) and the optimum range for development is approximately 25 to 36°C. However, little is known about the effect of higher temperatures on this weevil. The effects of temperature on the weed are well known for normal field temperatures, the optimum for growth being 30°C (6). Buds exposed to constant temperatures above 43°C for more than 2 or 3 hours died (10).

Maximum temperatures at Jabiru are 3°C higher than Darwin during September, October and November: the average maxima for Jabiru were 35.7°C, 37.5°C and 36.5°C, respectively. Climate matching using CLIMEX found no other area in the world known to have salvinia with similar climatic pattern and high summer temperatures except Oenpelli which is within 100 km of Jabiru and had a high temperature match of 96%. The high temperature match with Darwin was 71%.

Temperature variation between sites. Temperatures for similarly located sensors varied between the five sites on the Magela by +-1.5°C for maxima and +-1.25°C for minima but the differences were not systematic. Consequently, further discussion here will include two sites only.

Salvinia temperatures. Daily minimum temperatures were within the range known to be suitable for growth of salvinia and development of the weevil. Averages did not exceed 35°C and were mostly between 28°C and 32°C, within the optimal range for the weevil. The maximum temperatures exceeded 45°C on a number of occasions between December 1991 and March 1992 but rarely during the same period in the following year. Maximum temperature exceeded 40°C almost daily during the same periods. On very hot days hourly averages can exceed 40°C for up to five hours.

Water temperatures. The adult weevils are mobile and can seek cooler or warmer situations while immature stages are less mobile being inside the stem as larvae or under water, in cocoons as pupae. Consequently we consider that temperatures measured just below salvinia provide a more realistic indication of temperatures experienced by all stages of the weevil. The daily minima are higher and the maxima lower in water than in salvinia. The absolute maximum temperatures in water rarely exceeded 40°C, occasionally exceeded 38°C and were mostly within the range suitable for weevil activity. An inspection of hourly water temperatures for hottest days indicated that the maxima were considerably lower, under 38°C, and the period of time when temperatures may adversely affect the weevil was much shorter, than in salvinia. On most summer and all winter days, temperatures remained within the range for normal activity by the insect.

Rainfall. Most rain fell as storms that effected some parts of the floodplain but not others. Rainfall in the Magela Creek catchment area, not necessarily in the study area, was important as run-off and flooding, and had significant impacts on the Magela system.

In the 1991/92 wet season, rainfall was such that the billabongs filled slowly and the flood water moved slowly down the system. Flooding peaked on the 30 January 1992 at Ja Ja Billabong and three weeks later, 20 February 1992, at Jabiluka Billabong, a distance of 6 km. As a result little flushing of the billabongs occurred. In the 1992/93 wet season rain fell in a much shorter period, 25 to 26 January 1993, causing floods that swept down the system within days. Salvinia mats were flushed onto the floodplain.

Nutrients in salvinia tissue. The main factor influencing growth of the weed besides temperature was the availability of nutrients (6). Level of nitrogen in host plant tissue also influenced the life cycle and population dynamics of the weevil (1,7,8) and the rate and amount of damage the weevil caused to the weed (4, 5).

Nitrogen concentration in salvinia tissue was relatively high in billabongs in Kakadu, the average for all sites was 1.24%. The relatively high biotic productivity in these tropical billabongs probably contributed to high nutrient levels in water and to deposition of nutrient rich sediments. However, concentrations were lowest in the upstream billabongs suggesting that run-off in the upper Magela Creek carried lower nutrients than run-off from the floodplains that surrounded the downstream billabongs. In Ja Ja and Jabiluka Billabongs, located on the floodplain, nitrogen in salvinia peaked sharply when the annual summer floods occurred. Run-off and flow that stirred sediments made nutrients available to the weed. As biomass of salvinia increased on these billabongs, nutrients became relatively scarce and N in tissue declined towards the end of the dry season. The levels of N, P and K in plant tissue were within ranges observed elsewhere in the world where biological control was successful and did not restrict weevil populations in the billabongs.

Relative growth rates (RGR) of salvinia. The availability of nutrients was the major factor that influenced growth of salvinia in the billabongs. RGR was highest, in Ja Ja and Jabiluka Billabongs following flooding when N in tissue was highest, and lowest during the dry season, when there was no flow and nutrients were scarce. The flood peak in 1991/92 took three weeks to move between these two billabongs, and N and RGR peaked at Jabiluka about three weeks later than at Ja Ja. High temperatures experienced by salvinia during summer did not appear to restrict growth.

RGR was similar to the ranges observed elsewhere in the world for salvinia and allowed the weed to double its weight, measured as dry weight, in less than 6 days when growth was fastest, and under 19 days when growth was slowest.

Weevil abundance, plant damage and biological control. Adult weevil numbers and buds damaged increased during August, September and early October and declined thereafter. At Ja Ja Billabong site, for example, the first field generation of adults peaked in September 1991 with 16 adults per 100 buds when 60% of buds were damaged. This was followed by the emergence of second (in late October) and third (in December) field generations, which were smaller than the first and caused less damage. This trend occurred at each study site, including sites where the field populations were being monitored, and always before the hottest period of the year. Though temperature appears not to have been the primary cause, the reasons for the decline are not clear.

The weevil damaged the weed to such an extent, that in some billabongs during 1992, successful control of the weed was achieved in under eight months. The lack of control in other billabongs was not due to low damage by the weevil, but to physical and biological factors preventing the damaged mats from sinking. The heavily damaged mats were so tightly packed or bound together by other vegetation that they were prevented from sinking. However, in February 1993, annual floods removed the remaining mats of salvinia.

Populations of weevils and buds damaged remained low and constant on salvinia growing in a floating grassmat. The salvinia always appeared healthy and green in this situation. This phenomenon has been observed in Botswana (I. W. Forno, pers. comm., 1993) and in PNG (M. H. Julien, unpub. obs., 1993). In both countries biological control has been successful for some years. On Magela Creek billabongs, grassmats remained intact after heavily damaged mats had sunk or been removed by floods. It is likely that grassmats provide a reservoir of salvinia for the next season's growth and support low populations of the weevil that invade the next season's new growth.

When annual floods failed to flush salvinia mats from billabongs enormous build up of biomass followed. This was the case during the period 1987 to 1989. It appears that when damaged mats were not flushed out, regrowth occurred from dormant buds within those mats. The following season's growth of salvinia and other vegetation added to the already high biomass and contributed to a thickening mat of mixed vegetation. Such mats provide habitats that are much less suitable to the weevil. They are less likely to sink, require larger floods to flush them out of the billabongs and are more difficult to control.

We are planning to test the use of herbicides, integrated with biological control, to reduce surface covered by salvinia. Judicious use of herbicides during the early dry season may prevent billabongs from becoming covered with salvinia without destroying weevil populations. Once weevil populations develop, biological control should take over. In billabongs where salvinia is heavily damaged by the weevil, but mats are bound together by other vegetation, herbicides might be used to kill the binding plant species and thus promote sinking. This may help prevent the massive accumulation of biomass that can occur if successive season's growth is permitted to accumulate.

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