ENVIRONMENTAL IMPACTS OF BIOLOGICAL CONTROL

Russell H. Messing, University of Hawaii at Manoa

Notes

I. Is Biological Control Safe?

A. Answer to the question depends on whom you ask. It is a controversial area…without much data.

B. What is the record? See Table 19.1.

1. The *frequency* of non-target impacts: it is not uncommon for an introduced natural enemy to attack a non-target host (or prey) species.
2. The *strength* of non-target impacts: data are minimal. Painstaking and expensive research is required. Duan *et al.* (1998) quantified impact on lantana gall flies. A few other studies showed impact of weed biocontrol agents on non-target plants. But these are mostly "snapshots."
3. See Stiling & Simberloff (2000) [page 39, paragraph 1] for an example of faulty logic based on preconceptions. *[always read scientific papers with a critical or questioning eye*]

C. What is the perception? Perceptions are important because policy makers, politicians, and regulators are usually not scientists.

1. Early biocontrol specialists: "*biocontrol is benign*"… generally thought to be safe, and to be one the most cost effective and environmentally sound methods of pest control, especially compared to the broad-spectrum pesticides often used.
2. The post-Howarth era: "*biocontrol is dangerous*" a backlash against the *laissez faire* attitude of earlier practitioners. "*Absence of evidence is not evidence of absence*" but many charges were leveled without substantiation.
3. Factors impinging on the perception of BC safety:

    a. Development and release of genetically modified organisms (GMOs): public often lumps new biocontrol agents with new genetically modifed organisms, in terms of risk and regulation.
    b. Focus on biological invasions. It is a hot topic now in the field ecology (invasive species).
    c. Concern about rates of extinction. the focal point of environmentalism around the world. A real concern, but is any of it attributable to biocontrol?

4. Current status: struggling for a balanced approach. Scientists, regulators, and informed voters must weigh risk from natural enemies vs. value of agriculture and native ecosystems.

Table 19.1. "Data" from Stiling & Simberloff (2000), citing previous studies on non-target impacts.

Type of Natural Enemy	Area	No. species released	No. attacking non-targets	Percentage attacking non-targets
Parasitoids	USA	313	50	16.0
Arthropod herbivores	World	33	7	21.2
All biocontrol agents	Hawaii	243	33	13.6
Parasitoids & predators	Canada	40	15	37.5

Notes

D. The joys of bureaucracy

1. Federal (USDA APHIS, EPA, U.S. Fish and Wildlife Service), NEPA.
2. State Hawaii Dept. of Agriculture, committees

II. What Types of Environmental Impact are Possible?

A. Direct parasitism/predation/herbivory of non-target species

Rhinocyllus weevils on thistles — an introduced herbivore biocontrol agent moves from feeding on the target weed to feed on native plants.

B. Competition with extant species

1. *Interference* (i.e., host access, microhabitats, mates). Some herbivores can actually block access to a weedy plant by other herbivores. Parasites can kill each other, or use up available oxygen, in side a host.
2. *Exploitation* (i.e., phenology important). Phenological synchrony between parasite and host is often important in successful BC…one natural enemy may disturb synchrony between another (better) enemy and its prey (or host). Predators (i.e., coccinellids) may just consume most prey.
3. "Vaccination" (theoretical consideration). One herbivore may trigger plant defences, and make a plant more resistant to a second (potentially more effective) herbivore species.

C. Hyperparasites and diseases

Commercially produced aphid parasites — even supposedly clean cultures of biocontrol agents can be contaminated with hyperparasitoids. Hyperparasitoids can really interfere with successful biocontrol. We know very little about diseases.

D. Simberloff's "*invasional meltdown*" hypothesis: new species can have synergistic effects

1. Ants and homoptera
2. Bees and weeds
3. Pigs and guava
4. Lantana gall flies and associates

III. The Value of Retrospective Studies...

A. Why bother? We can learn from the past, develop some level of prediction, and avoid mistakes in the future

B. Case histories:

1. Fruit fly parasites — plenty of species imported to Hawaii, some attack non-target flies, but impact is minimal.
2. Stinkbug parasites — accused of contributing to decline of Koa bug in Hawaii — but the data are inconclusive
3. *Opuntia* and *Cactoblastis* - a moth that was spectacularly successful in controlling pest cacti in Australia now threatens a native cactus in Florida (where it jumped from the Caribbean)

Notes

IV. Perspectives:

A. Biocontrol of arthropods vs. weeds — different historical development, different levels of testing.
B. Arthropod BC agents vs. vertebrate (& snail) agents: vertebrates and snails have a bad record: think of mongoose, cane toad, predatory snails.
C. Earlier introductions vs. more recent introductions: new laws and regulations have led to improved record of safety.
D. Island ecosystems vs. mainland ecosystems: ofen island flora and fauna (especially in very isolated places like Hawaii) have not evolved defenses to common herbivores/parasites/predators. Isalnds may be more susceptible.
E. Impacts of pathogens and nematodes: *Nosema locustae* against rangeland grasshoppers, *Baccillus thuringiensis* against forest Lepidoptera.

V. Methods: How to Measure Environmental Impacts:

A. Long term monitoring (at a minimum) — historically hard to obtain funding for long term studies. It's the least we should do.
B. Experimental methods — the same as used for assessing success of BC agents against the target pest. Physical exclusion, chemical exclusion, serological, behavioral, etc.
C. Life table or recruitment studies — perhaps the best data, but also the most difficult to obtain. and usually too late to remedy.

VI. How to Minimize Risk:

A. Conduct preliminary cost/benefit analyses — doesn't make sense to conduct a project if the prejected benefits are minimal. (but often hard to know)
B. Know your species! (the importance of taxonomy) — much can be learned about host range and potential risk by studying the biology of congeners.
C. Conduct studies in home area, <u>when possible</u>. This makes sense and is often demanded by BC critics, but the logistics are usully daunting.
D. Quarantine is critical — must be treated seriously. hypers, diseases, other contaminants must be removed.
E. Host range testing — must be done in quarantine, which precludes ecological realism.

   1. Define the list — centrifugal phylogeny. Parasitoids often choose hosts based on microhabitat.
   2. No-choice tests — most conservative. can the agent even develop on the non-target (in the face of starvation)?
   3. Choice tests — a bit more realistic. Does the agent hit the non-target if more suitable host is available?
   4. Limitatations — lab conditions can never truly predict the field outcome.

F. Post-release monitoring — mitigation plans? In some cases it may be possible to "recall" a natural enemy once released, especially if in field cages or other isolated situation, perhaps using pesticides. There may be an intermediate step between quarantine study and full field release. But…bugs are smart and adaptable.
G. Documentation and voucher specimens — important both for morphological and genetic examination,especially when groups of sibling species or host biotypes occur.

Notes

VII. Risk / Benefit Analysis

A. What currency shall we use? How does one weigh the value of a sub-species of a rare non-economic native insect? How does one compare that with the dollar value of a given crop?
B. Ecological and evolutionary time frames — natural enemies can evolve. Can they expand their host range over time? Can we ever predict safety with absolute certainty?
C. All pest control tactics entail risk- biocontrol should not be judged in a vacuum. It is only one alternative to pest control, and the risk must be weighed against the alternatives

1. Compare with pesticides — longevity, mobility, diverstiy of species affected.
2. Compare with doing nothing — this has risk, too.

D. The role of the scientist — we are not the decision makers. We can only try to provide information and the knowledge necessary to make predictions. After that, an informed citizenry has to decide on social and political priorities.

QUESTIONS

1. What is the overall safety record of biological control, especially as compared to pesticide use and other methods of pest management? In what areas do we have a strong information base, and in what areas are we weak?

2. What are the various ways in which a beneficial insect can harm the environment? Name some examples of well documented non-target impacts.

3. If you were going to conduct non-target host range testing of a parasitoid in quarantine, how would you decide which species to test? What if one of the species you considered at risk was not amenable to laboratory rearing? How would you solve that challenge?

4. Is risk analysis a precise science? How do you compare the risk of one tactic (biological control) with the risk of a different tactic (pesticides), when neither can be accurately quantified?

REFERENCES

Duan, J. J. & R. H. Messing. 1996. Risk analysis and decision-making in biological control - A case study with fruit fly parasitoids. J. of Agriculture & Human Values 13: 1-10.

Duan, J. J. , R. H. Messing & M. F. Purcell. 1998. Association of the opiine parasitoid *Diachasmimorpha tryoni* (Hymenoptera: Braconidae) with the lantana gall fly (Diptera: Tephritidae) on Kauai. Environ. Entomology 27: 419-426.

Follett, P. & J. J. Duan (Eds.). 2000. “Nontarget effects of biological control.” Kluwer Academic Publishers, Norwell, MA.

Follett, P. A., J. J. Duan, R. H. Messing & V. P. Jones. 2000. Parasitoid drift after biological control introductions: re-examining Pandora’s Box. American Entomologist 46: 82-94.

Howarth, F. G. 1983. Classical biocontrol: panacea or pandora’s box. Proc. Haw. Ent. Soc. 24: 239-244.

Howarth, F. G. 1991. Environmental impacts of classical biological control. Ann. Rev. Entomol. 36: 485-509.

Lockwood, J. A. 1996. The ethics of biological control: understanding the moral implications of our most powerful ecological technology. J. Agric. & Human Values 13: 2-19.

Louda, S. M., D. Kendall, J. Connor, & D. Simberloff. 1997. Ecological effects of an insect introduced for the biological control of weeds. Science 277: 1088-1090.

Miller, M. & G. Aplet. 1993. Biological control: a little knowledge is a dangerous thing. Rutgers Law Review 45: 285-314.

Pemberton C. E. & H. F. Willard. 1918. Interactions of fruit fly parasites in Hawaii. J. Agric. Research 12:285-296.

Stiling, P.& D. Simberloff. 2000. The frequency and strength of non-target effects of of invertebrate biological control agents of plant pests and weeds. Chapter 3 *In* “Nontarget Effects of Biological Control” (Follett, P. & J. Duan, eds.), Kluwer Academic Publishers, Norwell, MA.

van den Bosch, R. & F. H. Haramoto. 1953. Competition among parasites of the Oriental fruit fly. Proc. Haw. Entomol. Soc. 15: 201-206.

READING ASSIGNMENT:

Chapter 21: pp. 442–443. **Van Driesche, R. G. and T. S. Bellows, Jr. 1996.** Biological control. Chapman and Hall, New York. 539 pp.