
CHAPTER 3. USING THE SCIENTIFIC LITERATURE TO ESTIMATE THE HOST RANGE OF A BIOLOGICAL CONTROL AGENT

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INTRODUCTION

Early in any classical biological control project, researchers are likely to compile lists from the literature of the parasitoids and predators recorded as attacking the target pest in its native range or in other locations where it has invaded. One of the first tasks in such a project is to review this information and identify any species that seem promising enough for study as potential biological controls. One aspect of that synthesis of the literature is to form a preliminary assessment of the likely host range of any listed parasitoid or predator. In this chapter, we suggest how this process can be done effectively and point out some of the pitfalls likely to be encountered.

SOURCES OF INFORMATION

Journal articles, books, internet sources, and specimens in museum collections are the major sources of information on the likely host range of a new biological control agent. However, such information will be somewhat biased as parasitism (or predation) is more likely to have been recorded on pest species than on non-pest species. Information from computerized databases alone is not sufficient to identify all recorded hosts. Literature prior to 1971 is not covered in such databases and may contain useful information about hosts or prey of parasitoids and predators. Alternate hosts of natural enemies, for example, were often studied because such species could be used to rear parasitoids in the laboratory (DeBach and Schlinger, 1964).

In other cases, non-pest species attacked by natural enemies were studied as potential supplementary hosts for field populations of the natural enemy of interest (Huffaker and Messenger, 1976).

Major sources of information (scientific journals, conference proceedings, and reports) from 1971 forward are available on computer and are abstracted in such tools as CAB and AGRICOLA, available in most major university libraries. Older literature (back to 1913) can be assessed by using printed copies of the abstract journal *The Review of Applied Entomology*. Information since 1981 is found in *Biological Control News and Information* (published by CAB). Books of value include historical compilations of biological control programs in various regions (e.g., Clausen, 1978; Cameron *et al.*, 1989; Waterhouse, 1998; Waterhouse and Sands, 2001; Mason and Huber, 2002, among others), host/parasitoid catalogues such as Thompson and Simmonds (1964-1965), and regional catalogues of the major insect orders that contain natural enemies, such as Krombein *et al.* (1979)'s review of Hymenoptera in North America, Gibson *et al.* (1997)'s treatment of genera of Nearctic Chalcidoidea, and Arnaud (1978)'s catalog of the North American Tachinidae.

At the start of any effort to compile the literature on a candidate natural enemy, its current taxonomic status and any past synonyms must be determined. Sometimes, an agent that has been already introduced against the same or different pest was known by a different scientific name. Unrecognized synonyms can cause important information to be overlooked.

Taxonomists specializing on local groups of agents may often be based in museums in the countries where the target and potential agents are native species. Museum curators are often aware of little-known publications, such as natural history society newsletters or museum reports that may contain useful information on agent-host associations. Such printed sources are often missed, especially if they were published in unfamiliar languages. The curators may also be able to provide access to host or prey data on labels attached to specimens held in other official or private collections.

Many museums have computerized the information on the labels of the specimens in their collections, including information about hosts or prey that is rarely published. Such records may be helpful in identifying hosts for a particular parasitoid because voucher specimens of field-collected parasitoids, sometimes with the hosts from which they were reared, are often submitted to taxonomists to confirm identities and be retained in the museum's collection. Finally, email group lists may be useful tools for collecting scattered information about host records for species of interest.

BIOTYPES AND HOST RANGES

Another general problem with literature and museum records is that unrecognized biotypes may exist. Either the host or parasitoid might actually consist of several distinct populations that vary biologically but are lumped under a single taxonomic name. If for example, a host consists of a series of such populations, a parasitoid may only attack some of them. Con-

versely, a parasitoid may exist as several distinct biotypes, each of which attacks somewhat different hosts.

Unless biotypes are distinguished, a complex of narrowly specific parasitoids will incorrectly be viewed as one widespread, more polyphagous species. For example, molecular analyses have now shown that the braconid *Microctonus aethiopoies* Loan, used for control of various forage weevils, consists of at least two biotypes, one associated with weevils in the genus *Sitona* and the other with weevils in the genus *Hypera* (Vink *et al.*, 2003). Similarly, there are two biotypes of *Comperiella bifasciata* Howard, each adapted to parasitize only one of two closely related scales. The yellow scale biotype of *C. bifasciata* successfully parasitizes yellow scale, *Aonidiella citrina* (Coquillet), but it does not develop on red scale, *Aonidiella aurantii* (Maskell). The yellow scale biotype will oviposit in red scales, but many of the parasitoid eggs and some larvae become encapsulated, and no parasitoids develop (Brewer, 1971). By contrast, the red scale biotype of *C. bifasciata* successfully parasitizes up to 80% of adult females of *A. aurantii* (Smith *et al.*, 1997).

Because of the potential for biotypes, host range testing should be done with the exact geographic population of parasitoid that will be released; otherwise, testing and releases may employ different biotypes, which might differ in their host ranges.

ERRORS AND OUTLIERS

Misidentifications of parasitoids or of their associated hosts sometimes appear in the literature or on the labels attached to specimens in museums. For material in collections, the identities of the parasitoid and host can be checked with appropriate taxonomists if physical specimens are available. Whenever possible, this should be done before the host records are accepted as valid. The validity of host records in the literature is harder to assess as specimens either may not be available at all, or considerable effort and international contacts may be required to locate specimens and have them shipped to a competent taxonomist for identification.

In the process of assembling host records for a parasitoid or predator of interest, the use of some species as hosts will be supported by many records. This redundancy of information increases confidence in the validity of the information. Brief or unique records that are the only mention of a given species as a host for the parasitoid need confirmation. A single rearing record is, naturally, less certain than records for hosts from which the parasitoid has been reared repeatedly, over many dates and locations. Similarly, if two or more authors independently report attack by the parasitoid on a host, one has greater confidence in the record than if only a single report is found in the literature.

Some host records may be found that seem anomalously distant from the rest of the known hosts of a parasitoid. In some cases, outlier host records may simply be misidentifications, as discussed above. For example, the report of *Cotesia glomerata* (L.) from the arctiid *Pericallia ricini* F. (Ghosh, 1998) is almost certainly an error because the published picture of the cocoon (with a halo) and the solitary nature of the parasitoid brood do not match *C. glomerata*, which is gregarious and has cocoons that do not have a halo.

Less clear would be the case of *C. glomerata* specimens reportedly reared from *Colias lesbia* (Fab.) in Argentina by Sharkey *et al.* (2000). This record is an outlier in two dimensions: first, this is the only record of this species attacking hosts in the subfamily Coliadinae (within the Pieridae); second, the parasitoid cited is not native to South America, and while it has been released in Chile, it has not been released in Argentina and is presumed to still be only found west of the Andes. Is this record accurate? The *C. glomerata* species group includes a number of hard-to-distinguish species. At a minimum, this record needs a second opinion from another braconid specialist and perhaps even the use of some recently developed molecular markers. The latter would require the recollection of fresh material, preservation in 100% alcohol, and shipment to the laboratory with the necessary DNA markers. Similarly, there is a record of *C. glomerata* from *Ascia monuste* (L.) (a pierine) in Brazil (Scaglia *et al.*, 2003). This is an extreme outlier from the geographic point of view, for the reasons just mentioned. Again, such a record needs confirmation before it can be accepted as valid.

Other seemingly anomalous host records may represent “parasitoid errors” that can provide interesting insights into the factors affecting host selection by the parasitoid. *Cotesia glomerata*, for example, normally parasitizes pierine butterfly larvae associated with mustard plants. Attack of this species on *Aporia crataegi* L. (Jiang ShuangLin, 2001) is unusual in that the host of this pierid butterfly is a rosaceous plant (*Crataegus azarolus* L.) rather than a mustard oil crucifer; yet, this record is well substantiated. The chemical composition of volatiles from this host/plant complex relative to that of the typical host (*Pieris*/cabbage) would be of interest to see if some unsuspected similarity might exist. Even more unusual is the attack of *C. glomerata* on the tenthredinid sawfly *Athalia proxima* Klug (Johri *et al.*, 1992), a species quite distant from the parasitoid’s normal pierine lepidopteran hosts. This record, if accurate, may be a “parasitoid mistake” caused by the fact that this sawfly feeds on mustard oil plants, and thus its plant-herbivore chemical signature may resemble that of this parasitoid’s usual hosts.

USING NEGATIVE DATA TO YOUR ADVANTAGE

Sometimes the absence of parasitism under field conditions can be as useful as positive records from the literature. Information may exist that suggests that either a parasitoid species does not forage in a given habitat, or that certain hosts are in extensive contact with the parasitoid but not attacked. Recognizing and using such negative data can help in better estimating which, if any, of the native insects in an area where a parasitoid is proposed for release might be at risk.

HABITATS NOT USED BY THE PARASITOID

Parasitoids will only put native species at risk if they search the habitats of those species. Consequently, understanding the habitat limits of a parasitoid is helpful in predicting its host range. Literature reports or work done during the foreign collecting phase of a project may provide information on the physical characteristics of a parasitoid’s habitat (see the chapter by Casagrande and Kenis in this volume). Knowing which habitats a parasitoid enters can be used to identify non-target organisms that might come in contact with the agent. For example, because the braconid *C. glomerata* forages in sunny meadow habitats but not shady forest ones, *Pieris napi*

oleracea Harris is attacked in the northeastern United States by this introduced parasitoid, but *Pieris virginiensis* Edwards, an obligate forest butterfly, is not (Benson *et al.*, 2003ab).

In addition to a parasitoid or predator's general environmental adaptation (in terms of elevation, rainfall, temperature extremes, sun versus shade, etc), entomophagous species can be adapted to occupy certain plant species or plant communities, which may be preferred or even essential for the natural enemy's survival. For example, some species of phytoseiid mites are found only on a single species of tree in Australian rainforests (Beard and Walter, 2001). As such, prey species on other kinds of trees or in non-forested habitats would not come in contact with such predators were they used in a biological control program. Similarly, some species of whitefly parasitoids in the genera *Eretmocerus* and *Encarsia* show a marked preference to search some species of crop plants and not others for hosts (Goolsby *et al.*, 1998).

Field observations in a parasitoid's native range can be used to determine a species' habitat preferences. Kuhlmann *et al.* (2000) surveyed the habitat preferences of mirid plant bugs and their parasitoids in a variety of habitats in Europe as part of the process of selecting *Lygus* bug parasitoids suitable for introduction into North America against agricultural pest *Lygus* species. Sands and Coombs (1999) noted adaptation of the tachinid *Trichopoda giacomellii* (Blanchard) to grasslands and crop habitats in Argentina when evaluating the suitability of the parasitoid as an agent for controlling *Nezara viridula* (L.) in Australia. One non-target species tested, *Alciphron glaucas* (Fabricius), a species related to *N. viridula*, was not considered to be at risk from attack by *T. giacomellii*, even though it supported complete development by the parasitoid in the laboratory, because (unlike *N. viridula*) the nontarget species was adapted to rainforest habitats.

HOSTS IN CONTACT WITH THE PARASITOID BUT NOT ATTACKED

Herbivores in contact with a parasitoid but not attacked can tentatively be listed as not in the parasitoid's host range. This assumes that these herbivores' ranges overlap geographically with that of the parasitoid and that adequate surveys to detect parasitism of the relevant species have been done. Using such negative data, one can narrow the scope of species requiring formal testing in laboratory host range tests. Such observations can be helpful in recognizing parasitism that sometimes results from 'laboratory artefacts' (*sensu* Sands, 1993), in which confinement in cages in laboratory host range tests can cause nontarget species to be parasitized. For example, the lack of attack by the thrips parasitoid *Thripobius semiluteus* Boucek on the non-target thrips *Hercinothrips bicinctus* (Bagnall) in the field in Australia allowed Froud and Stevens (this volume) to conclude that the low level of parasitism seen on *H. bicinctus* in their laboratory host range trials was really an artefact of confinement.

ARE HOST RANGES OF NEAR RELATIVES PREDICTIVE?

Frequently, in the course of foreign exploration for a classical biological control project, previously unknown parasitoids are found. Some insight into the possible hosts of such an undescribed species of parasitoid can be gained from information about the hosts of other parasitoids in the

same genus. Species of *Cotesia* (Hymenoptera: Braconidae) appear to be predominantly parasitoids of lepidopteran larvae. Similarly, all *Aphidius* species will be aphid parasitoids. However, the breadth of a new species host range is not readily predicted from its congeners, since many genera contain both host-specific and generalist species. Consequently, a candidate with an unknown host range should not be excluded from further consideration and testing simply because some of its congeners have broad host ranges (Sands, 2000). For example, the South American tachinid *T. giacomellii* is a narrowly host-specific parasitoid of the green vegetable bug, *N. viridula*, that develops only on a few related pentatomids (Liljestrom, 1980), but other species of *Trichopoda*, for example *Trichopoda pennipes* (Fabricius), have wider host ranges (Huffaker and Messenger, 1976), attacking species in several families of Homoptera (Pentatomidae, Largidae, and Coreidae) (Dietrick and Van den Bosch, 1957).

Similarly, species of *Metaphycus* are all internal parasitoids of soft scales (Coccidae), but some are monophagous and others polyphagous. For example, in Australia, *Metaphycus maculipennis* (Timberlake) attacks only the grapevine scale, *Parthenolecanium persicae* (Fabricius), while *Metaphycus helvolus* (Compere) attacks a range of species of soft scales in at least three genera (e.g., *Ceroplastes destructor* Newstead, *Coccus hesperidum* L., and *Saisettia oleae* [Bernard]). In the same manner, aphelinids in the genus *Aphytis* are all ectoparasitoids of armored scales; but while several species are restricted to single host species, others have broad host ranges. *Aphytis lepidosaphes* Compere is specific to *Lepidosaphes beckii* (Newman) and *Lepidosaphes gloverii* (Packard), whereas *Aphytis diaspidis* Howard is polyphagous and parasitizes at least 50 species of armoured scales in 27 genera (Rosen, 1994).

This variation in host range, at species level, applies equally to predators. For example, the North American lacewing *Chrysopa quadripunctata* Burmeister is a generalist predator, whereas the very closely related and sympatric *Chrysopa slossonae* Banks is monophagous, preying only on the alder wooly aphid, *Prociphilus tendatus* (Fitch) (New, 1991). Coccinellids in the genus *Rodolia* are all predatory on fluted scales (Margarodidae), but the individual species may differ considerably in the breadth of their host range. For example, in Australia, the larvae of the native coccinellid *Rodolia cardinalis* Mulsant are known to prey on *Icerya purchasii* Maskell, *Icerya aegyptiaca* (Douglas), *Icerya seychellarum* (Westwood), and *Monophlebulus comperei* Morrison and Morrison, but *Rodolia koebelei* (Horn) has only been found preying on *Icerya koebelei* Maskell. Larvae of *R. koebelei* could only be reared to adults on *I. koebelei* and when they were offered *I. purchasii*, *I. aegyptiaca*, or *I. seychellarum*, they failed to feed and all died (V. Brancatini, pers. comm.).

USING INFORMATION ON AN AGENT'S BIOLOGY TO UNDERSTAND ITS HOST'S NICHE

Even literature that, strictly speaking, is not about host records can be useful in understanding an agent's likely host range. By understanding the exact host stages that a parasitoid requires for oviposition, researchers can better design host range tests. Information on seasonal cycles, on parasitoid behavior during host attack, or on host responses (such as encapsulation) can all be valuable in understanding the parasitoid's likely host range. Parasitoid host ranges are likely to be narrower if hosts occupy specialized habitats that require specific adaptations for success-

ful exploitation. For example, the parasitoid *Cephalonomia stephanoderis* Betrem, a potential agent for the coffee berry borer, *Hypothenemus hampei* (Ferrari), is adapted to living in tunnels produced by its host in the berries of the coffee plant (Waterhouse and Norris, 1989; Waterhouse, 1998). The morphology of parasitoids and predators may also give some indication of their adaptive specialization and host preferences. For example, the white secretions produced by larvae of the Australian coccinellid *Cryptolaemus montrouzieri* Mulsant are very similar to the white secretions produced by many species of mealybugs, the predator's preferred prey.

Finally, all other things being equal, koinobiont parasitoids (species developing inside living hosts with immune systems, such as internal parasitoids of larvae, nymphs, or adults) are thought likely to be more host specific than idiobionts, which are either external to their hosts or are internal in eggs (which lack immune systems) (Godfray, 1994). Parasitoids that must contend with physiological host defences require a series of adaptations to defeat host immune responses and these requirements often limit the host range.

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