

# OBTAINING, RECORDING AND USING HOST DATA FOR REARED PARASITOID WASPS (HYMENOPTERA)

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## ABSTRACT

To redress the failings of the past, strong advice and protocols are given for appropriately recording the data of reared parasitoids, with particular emphasis on avoiding the mistake of blithely overlooking the actual host. A concept of audited rearings (with exact recovery of host remains and parasitoid cocoons for each parasitoid reared) as opposed to substrate rearings is introduced. Advice is given on interpreting published (supposed) host information, especially as accrued from uncritically abstracted literature, and warnings made against inappropriately using or citing it. A largely objective simple scheme is proposed for assessing the value of rearing records in a succinct and easily interpreted way that could be applied to databasing.

## INTRODUCTION

At all taxonomic levels, accurate biological information is crucial for interpreting the organisms involved. Nowhere is this more true than for the host repertoires of species of parasitoid wasps. There have been several papers (e.g. Shaw 1994, Noyes 1994) demonstrating, analysing and bemoaning the unreliability of published host records of these parasitoids (particularly Ichneumonoidea) made available as a result of uncritical compilation from the published literature, despite the great value that sources collating the total literature (e.g. Taxapad: Yu *et al.*, 2016 and forerunners) have contributed in other respects. Two points are fundamental: (i) the level of recorded misinformation really is so high that there is little hope of using the published “data” to arrive at meaningful understandings of the true host repertoires of parasitoid species – a fact that is surprisingly under-appreciated – and (ii) the mistakes that so badly undermine the resource have (presumably all) been unintentional. A good proportion of the errors that have entered the literature are, of course, the result of parasitoid misidentification; but trying to address that in any comprehensive way would be a major problem and in any case it is beyond the scope of this contribution. Rather, this paper seeks to limit the errors and misconceptions surrounding host identity that are commonly made, and then comment on possible ways to assess the value of existing literature records. The need is sharpened by current initiatives to resume the abstraction of literature on Ichneumonoidea following the demise of Taxapad from 2015. A similar scheme for Chalcidoidea was last updated in 2019 (Universal Chalcidoidea Database: Noyes, 2019) and in that case includes a simple four-category subjective guide to the likelihood of host records being accurate, but there is no such rider for the data in Taxapad.

The largely common-sense recommendations for good practice given here are made particularly so that the most can be made from newly reared parasitoids, whether in the context of biological control or other interests that might include taxonomy and systematics, biodiversity and conservation, or ecology. The advice is

for amateur naturalists (who contribute so much to our knowledge) just as much as for professionals who might be, for instance, involved in crop protection, and it covers deliberate as well as accidental (by-product) rearings made by those whose interests are focused elsewhere (e.g. devotees of the host group).

“Making the most” obviously means providing unambiguous information that is as useful as possible, but it also includes avoiding giving misinformation, whether by carelessness or ambiguity. Every time a rearer of a parasitoid publishes the finding, or even writes a data label to record the event which others may then use, an apparently scientific statement is made – a contribution that is either informative or accidentally misinformative. The responsibility on us all is to make sure it is the former, and remains so, through a series of careful practices and protocols. Similar needs surround the handling and interpretation of records already in the literature, and suggestions for at least considering the reliability of a published record through an expression of various codable facets are made.

### Protocols

Protocols for rearing parasitoids, in particular to avoid mistaking the origin of the reared adult (especially, from an overlooked host), have also been given several airings (e.g. Shaw, 1997, 2017a), and excellent comprehensive guidance concerning the collection and preservation of biological voucher specimens of all kinds (of which reared parasitoids comprise just a small subset) has been given by Huber (1998). Here the issues covered are principally (i) biological data involved in labelling reared parasitoid specimens and (ii) making and controlling literature citations of new rearings and old records. The emphasis is on the correlation between host and parasitoid, with only passing consideration of accuracy of parasitoid determination and the ability to correctly identify (as opposed simply to recognise) the host.

It is important to understand that there are two common practices leading to reared parasitoids. The first (preferred whenever possible!) applies when a known and counted number of certainly identified individuals of a single host species are being reared in a closed environment; being fed on a pabulum that has been carefully searched to eliminate all possible extraneous taxa; and are being counted again at each food change, with each parasitoid cocoon found being related to a specific host mortality and the host remains recovered (e.g. Shaw, 1997). This might be termed AUDITED REARING. Rearing a parasitoid from a single host in isolation is the very epitome of an audited rearing, but batch rearings can, with the scrupulous control indicated above, be just as reliable. Host remains should always be recovered and kept (fully dried out) along with the emerged parasitoid cocoon if there is one, preferably in a gelatine capsule pinned on the same carrier pin as the adult (not glued to card). The host remains are the voucher of the host; it is vital that they are the actual item, though, and not just one of its fellows that somehow died. I have sometimes seen cast skins preserved in lieu of the real host remains, which is clearly not an effective audit, just a subjective view of the host species. The site in which the parasitoid finally pupated (usually its cocoon or a host-derived structure) not only helps to validate the rearing but will also contain its final larval exuviae, examination of which (e.g. Short, 1978) can provide valuable taxonomic data.

The second situation arises (unfortunately all-too-often) when the number of host individuals being reared together is undetermined; there is no really closely controlled guarantee that only the single supposed host species is present; and host remains cannot be reliably associated with the parasitoid cocoon or adult exactly (not just generally: exactly). There are various subsets of this, that might range from

a tea-chest full of foliage and *Lymantria dispar* (Linnaeus) caterpillars, to timber in emergence cages within which completely concealed hosts might be parasitised. It is appropriate to regard all parasitoids resulting from these as SUBSTRATE REARINGS, and to recognise that there will always be uncertainty, to varying degrees – unless definite exact correlation between host remains and parasitoid can be made (in which case, of course, the rearing becomes AUDITED for that particular individual). For others, there is less certainty about the host (and also in the exact correlation of the adult to its cocoon) than in fully audited rearings, and the labelling of reared parasitoids should reflect that.

It is always worth searching through as much of a collected substrate as time permits before adults eclose, to try to convert as many as possible of the rearings into AUDITED rearings. If that is not possible beforehand, much can still be recovered by going through the substrate carefully after the event and, for that reason, it is as well not to have too large a quantity of substrate in any one rearing container; it is better to spread it over several. Units in which the host is concealed, such as leaf-mines or galls, should be reared in apparent individual isolation, for example in separate tubes. Then, parasitoid emergences can be related back to the exact item, which can be searched for contaminants (which will be frequent, as a high incidence of invasion of such structures is commonplace), leading to AUDITED rearings.

It is important, too, to be aware that what looks like a clean rearing environment (rearing cage, trap-nest, etc.) might actually be harbouring other occupants, whether feeding therein or just as stowaways. Rearing predatory aculeates poses particular problems in that emerging parasitoids might either be already present in prey items or result from the aculeate itself.

## GOOD PRACTICE

### Labelling

The really important thing that everybody should be able to achieve is ALWAYS to write (or provide facilitating information for) a clear, stand-alone data label that will be understandable to anyone. Never use codes that refer to a list somewhere else (apart from specimen ID codes for DNA sequences; see below), and avoid abbreviations that will not be easily and widely understood. In addition to giving the host, careful and accurate labelling can provide important understanding of the parasitoid's developmental biology and phenology. If, as is increasingly the trend, specimens are being databased with the use of digital (e.g. Q code) labelling that might also include DNA sequences, make that label an addition to, not a replacement for, a written label – for reasons of both security and maintaining the widest utility.

For labelling mounted specimens acid-free thin card (thick enough to grip the pin shaft well; paper does not), permanent water-proof (and alcohol-proof) ink, and clear handwriting (or print) are standards in common use. Labels should be readable without having to move the insect, so pin them face up – and avoid obliteration of data when pinning! To avoid the need to prize labels apart to read them (which inevitably causes them to loosen, then swivel, on the carrier pin), when it is necessary to write two labels to catch all the data, pin them back-to-back so that the whole data can be read without separating and hence loosening labels. (Unfortunately, preferences rather than standards control the reading direction). Dated determination labels for the parasitoid should be separate (i.e. additional).

Taxonomists often prefer to mount specimens themselves, in which case they might prepare the data labels, and in any case reared parasitoids are often transferred without permanent labels. But it is essential that at all times they are accompanied with the full data (even if not yet in the form of a neat label to be pinned with the specimen) enabling a clear and informative label to be made. As well as the usual data standards for location, the information provided should include as much as possible of the following (of course, not all will be possible but best practice would not deviate materially when it is), and should express any doubt clearly:

*For AUDITED rearings*

- Binomen in full of host (without abbreviation of generic name)
- Binomen in full of plant if appropriate, or give pabulum or other substrate
- Stage collected (prefix it O for ovum [or put egg], or L [with instar if possible, such as L3 or 3<sup>rd</sup> instar L] for larva, or Pup. for pupa) [or suitable variant for groups or items that do not fit, e.g. egg sac, mine, gall etc.]
- Collection date (in form dd. roman mm. full yyyy, prefixed “coll.”; if collected as parasitoid cocoon, prefix it “coc. coll.”)
- Any intermediate date if applicable, such as date an endoparasitoid larva erupted (prefix it “coc.” as in practice the cocoon will always follow quickly, but if it is an external parasitoid visible at the time of collection prefix collection date “coll. w. ecto.” and wait for its cocoon date)
- Adult emergence date (prefixed “em.”)
- Name of collector. The name of the collector (often followed by “leg.”) is usually taken as the person who determined the host. If someone else determined the host, “det. [their name]” should be entered after the host species name as well.

If the parasitoid is gregarious it is important to add that (without it, it will be presumed solitary); just “greg.” might be put if the brood size is unknown, or e.g. “(4♀,3♀em.)”, with the brackets indicating that it was not the whole brood, but if the information is there it is valuable to put (e.g.) “brood of 26 (20♀,3♂)” to indicate 26 cocoons from which 20 females and 3 males emerged (i.e. from 3 cocoons nothing hatched), but if the whole lot emerged it would just be (e.g.) “brood of 22♀,4♂” and if emergence was too low for the numbers to be of interest it might be left as just “brood of 26”. It is worth putting “of” after “brood” because some people assign numbers for different broods (so “brood 26” could mean something else).

If the specimen has associated molecular data an indication of this allowing connection to the sequence(s) should also be part of its labelling (though it might be separate, and added later). It is of course vital that this connection works, so whatever archive (BOLD, GenBank etc.) holds the sequence must also cite the code (typically as sample ID) used in the labelling of the specimen, which might involve iteration with the database supervisor. For practical reasons DNA-related code labels are most often separately affixed.

*Rationales/Pitfalls/Variation*

- Using the full binomen. This is not just to avoid uncertainty between e.g. two species going under the abbreviated name *L. dispar*, but especially to ease the interpretation of obsolete or misspelled names (which inevitably will sometimes arise). Including the author name for the specific epithet also helps.

- Uncertain host identity. This is not uncommon, especially if numbers are small and no adult host is reared. Record uncertainty as in these examples: *Orthosia* sp. = genus determination is certain but species cannot be given even probably. ?*Orthosia* sp. = genus determination only probable. *Orthosia* ?*gothica* = certainly *Orthosia*, probably *gothica*. ?*Orthosia gothica* = probably that species but might not even be *Orthosia*. Give a determination at the level you can: noctuid or geometrid (with a colour if clear) is better than just Lepidoptera, and even that is better than nothing, but always keep to what you (or the stated host identifier) are sure of.
- Dates given as dd. roman mm. yyyy (e.g. 08.viii.2008), with the year in full, are completely unambiguous and free of confusion caused by cross-Atlantic variation, so adhere to that. (Remember that 9/11 in Europe should refer to a date in November).
- A single date without prefix is so ambiguous as to be without value. In long experience I have found that approximately half of the people who supply only one date (free of prefix) mean date of emergence, and the other half mean date of collection. It should ALWAYS be possible to provide a prefix, even if only one date is known and even if it is only a month. But two dates will give invaluable information about the phenology and possibly the voltinism of the parasitoid.
- Gregarious broods. Usually only a proportion of a gregarious brood would need to be mounted, the rest being put into a gelatine capsule below one of them. Put all the cocoons plus host remains into another capsule, under another mounted specimen; DO NOT separate the cocoon mass to keep a single cocoon with each adult, which will be interpreted as the parasitoid being solitary and would also destroy the sometimes characteristic appearance of the cocoon mass or similar.
- I have suggested that, if necessary (which would only be because the person identifying the host is not the same as the collector), “det.” [determined by, or in Latin determinavit] goes before the name of the identifier rather than after so that it doesn’t get confused (as it might if it followed the name) with a usually much less important identification of the pabulum. This does not apply to the name of the collector, which might best be followed by “leg.” [a contraction of the Latin collegit, meaning (s)he who collected it] which is usually added in many countries though less often in some others (including Britain). It is usually clear enough without “leg.” if the collector’s name comes at the end of the label.

#### *For SUBSTRATE rearings*

It is just as above, but with uncertainty introduced appropriately for the host name (possibly also pabulum). It needs a bit of thought as to what level of uncertainty is appropriate, but any uncertainty must be made clear. Use “Bulk reared ex *Lymantria dispar*” for the (unaudited) individuals arising from the tea-chest example above if the rearings of the parasitoid taxon were numerous. But express more caution for things in very small numbers in large bulk rearings, such as “Bulk reared (few) ex *Lymantria dispar* (many)” [giving the numbers would be a refinement, but it is unlikely to be practical] or if it is a really small number probably “?” comes in; and pay attention, too, to any other potential host that might also have arisen. For the more extreme cases when even the presence of hosts is less certain, put the emphasis on the substrate, and use “with” to indicate the possible host, as in “Ex 3 year old *Larix* logs with *Tetropium castaneum*” if that was the only suitably-sized possible host present, but if there were several possible (appropriately sized) hosts list them all

in descending order [with numbers is a refinement]. Often “Ex moss, algae, etc. scraped from fallen wood” will be all that is known if potential host density is low. And if the wood was still there, as part of the substrate, it would be “Ex fallen wood with moss, algae, etc.” [but it would be advisable to separate them]. In general, substrates should be kept for at least a year to be reasonably sure that all the species of potential host will have revealed themselves.

### Literature citation

There is again a great deal of harm to avoid, and many unwanted opportunities to foul up, resulting in more “don’t” than “do” recommendations (Shaw, 2017a). This will apply especially to recording material labelled by others.

Pay attention to the exact data on any label, or published statement, and be careful not to shed any uncertainty, e.g. in the form of question marks, “aff.”, “cf.”, “near”, “agg.”, etc., and their interpretation. This applies both to host determinations and to parasitoid determinations (Noyes, 1994). Exact citation (in quotes) is recommended when reiterating recorded data.

If host remains are absent, it is sensible to note that fact when publishing a rearing record because (carelessness aside) that in itself represents some degree of uncertainty. Similarly, if a fully audited host association is being given, add that host remains are present (especially if the record is crucial, unusual or surprising).

Distinguish between specimens actually seen and being newly recorded, and records taken from the literature. For the latter write “recorded from” [which is true and verifiable], not “reared from” or “a parasitoid of” [both of which are quite likely not true and certainly not verifiable], and give original references. It is, however, generally acceptable, even sensible, to make statements such as “the type was reared from [host name]”. But there is absolutely no point in transcribing a list of recorded supposed hosts from *Taxapad*, and this should be very strongly discouraged. This is because citing already published host records can very easily appear to be giving fresh data, and in that way a confirmation of the previously recorded supposed host, and if it is done at all it should be with the original reference so that the source is clear (see Shaw, 1993 for a brief case study of how false information builds in bulk). Similarly, when giving an individual record that could be interpreted as novel, and yet has already been published elsewhere, it is important to make that clear in order to avoid double-accounting.

Take opportunities to comment negatively on host records that are almost certainly wrong, and to correct clear errors. Also, if publishing on specimens with old determination labels for the parasitoid, be aware that taxonomy is a rolling process and that determinations made before the latest revision might easily be incorrect – one good reason why determination labels are dated. Splitting also occurs in host groups, but it has been a greater issue for parasitoid taxonomy.

Cite rearings (as host mortalities) quantitatively. This helps errors and genuine but freak occurrences to become marginalised without necessarily choosing between them, consistent with the conceptual definition of host range (or repertoire) given by Shaw (1994) as “the host range of a particular parasitoid species . . . includes only the species of potential hosts that the parasitoid is usually able to attack successfully, following a pattern of searching behaviour enabling it to encounter them regularly”.

Avoid using terms such as “polyphagous” when it is possible to express the host repertoire in a more informative way (e.g. Shaw, 2017b).

And finally, be sure ALWAYS to cite a repository, and any codes relating to archived DNA sequences, for the reared specimens in any publication.

### Interpreting literature records

There are several considerations to offer in trying to make useful sense of literature records, such as the accumulations in Taxapad. On the face of it, the host from which the holotype of a parasitoid species was described, if any, should normally have pride of place for reliability (though of course the host still might have been misidentified – even in the original rearing – and there is also the possible complication of presumption, outlined later). In fortunate cases for which the possibility exists, considering the host objectively linked to a parasitoid name (i.e. the host of the type) can be extremely helpful in resolving taxonomic muddles and uncertainties, especially those arising from sequence data comprising BINs in need of a name.

Original descriptions aside, the publications citing the host association would need to be consulted. Then:

Discount all secondary citations, that will falsely be making it look as though the parasitoid has been reared from the cited host on more occasions than it has (cf. Shaw, 1993). Secondary citations are usually obvious, and very often accompany faunistic lists in which no reared material features. Regard anything that does not explicitly cite new information as a secondary citation.

When new data are presented, assess reliability. Who determined the host? How was the rearing conducted and was it clear that potential contaminants were eliminated? Who determined the parasitoid, and/or is a keyword or other means mentioned? Lack of clarity in these matters doesn't, of course, necessarily invalidate the record, but if none are addressed the record is certainly the weaker.

Consider the date of the determination behind the record. How up-to-date was the taxonomy? Splits in concepts of species have been great, involving both host and especially parasitoid taxa. Many of the innumerable erroneous records in the literature are a special category of parasitoid misidentification based simply on immature taxonomy (i.e. they arose before a reliable revision and key was available).

Consider the likelihood of the record being correct, based on what is known of the biology of the parasitoid taxon (at the level of species, genus or tribe). A mismatch is not a clear reason to reject the record, but it should at least raise a question. Sometimes, knowing something of the parasitoid and the supposed host reveals mismatches of other kinds (even size), and ecological knowledge, including having some idea of what else might be found in or on the host pabulum, can help enormously in evaluating the reliability of host records. In this way records of for example Diplazontinae (really parasitizing aphidophagous Syrphidae) and Aphidiinae (really parasitizing Aphididae) as parasitoids of foliage feeding Lepidoptera can be rejected through marginalisation, as can many instances of secondary parasitoids being mistaken for primary parasitoids (the literature is rich in all of these falsehoods).

As a backstop, is there a cited repository [= depository; I am not making a distinction]? If not, the host remains cannot be assessed and – even more crucially – the determination of the parasitoid cannot be verified.

### Value-scoring

In an attempt to encapsulate some of the above to judge the value (which is a bit softer than reliability) of host records for parasitoids in a simple way, the following recipe to give a 5-digit string is proposed. Trying to boil this down to a numerical “reliability score” is impractical and risks doing more harm than good, but the

codified summary of (mostly objective) salient points would have the considerable benefit of being readable at a glance. In addition to aiding judgement on any particular host record, it might be especially helpful for concisely expressing information during the databasing of records. The string (in this order, A being first, B being second, etc.) would be:

- A. Host is same species as host of holotype = 1. Close relative = i. Otherwise (including holotype not reared) = 0.
- B. Host consistent (phylogeny or ecology) with expectation for parasitoid or its relatives = 1. Insufficient knowledge of parasitoid or its relatives to judge = i. Anomalous = 0.
- C. Fully audited rearing (host remains and site of parasitoid's development to adult, e.g. cocoon, host pupa, etc., present) = 1. Deficient in some respects but judged convincing from context (subjective) = i. Substrate rearing = 0.
- D. Parasitoid determined by a named (or deducible) person during or at a date following the last relevant revision = 1. Determined by a named person prior to the last revision = i. Otherwise = 0.
- E. Named accessible repository for parasitoid given = 1. Probable accessible repository easily deduced = i. Repository not stated, not easily deduced, or inaccessible (would include destroyed collections) = 0.

As examples, a string 01i1i would tell a reader that the host was not closely related to the host of the type of the parasitoid but is broadly consistent with expectation, the rearing had been done under apparently careful protocols but without full audit, a known person had determined the parasitoid at an appropriate date, and that while there is no clearly stated repository one might easily be guessed. This could be quite a valuable record, but it would be much weakened if the string were 01iii (indicating that the determination was made prior to the last relevant revision), though that might be upgraded somewhat with a cited repository (01iii1). A string 11000 would indicate that the parasitoid was reared from the same host as the holotype, but not enough detail was given to be confident of adequate control over the rearing, it was unclear who determined it or when, and that there was no good prospect of verifying even the parasitoid's identity. Despite all this the record might be correct, but it could also rather easily suggest that someone had simply found a name for a parasitoid of the host in question and just guessed that it was that (this does sometimes happen), so it is arguably a rather poor record, and even if it were 11100 (reflecting a fully audited rearing) its value would not necessarily be improved. [If the first position is 1 (or i) the second will automatically also be 1, but despite this linkage certain other categories involving the first two digits can be independent, so scoring both is not always redundant]. A first position of 0 will be very frequent as the great majority of parasitoid species have been described from non-reared specimens, and the second position is always of the highest value; a 0 there should raise great suspicion (especially if followed by a further 0 in the third position) even if it is not to be discounted out of hand.

In these examples, and even with a 11111 designation, there is still no guarantee about the accuracy of the record, and the need for thought and judgement mitigates against trying to devise a quantified reliability score. However, in the above scheme there is at least a source of informed guidance from which to judge, or investigate further, as well as provision of a concise codified summary for possible use in a database.



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