

A SIMPLE PAIN SCALE FOR FIELD COMPARISON OF HYMENOPTERAN STINGS

Christopher K. Starr
Department of Entomology
University of Georgia
Athens, GA 30602

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ABSTRACT

A scale is described for reporting the painfulness of stings received from aculeate hymenoptera under uncontrolled conditions. The applicability and limitations of the scale are discussed, and examples are given of ranked stings. The usefulness of the pain scale in studying mimetic associations between stinging insects is discussed, with an example.

Key Words: Venom, sting, pain, Hymenoptera.

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INTRODUCTION

Venom injection (stinging) is an important defense tactic among various animal taxa, the most obvious of which is the aculeate Hymenoptera. It would be useful, then, to be able to compare the defensive power of stinging by different species or colonies. The components of such a comparison would be the number of potential defenders in the colony or aggregation, their readiness to attack, and the effectiveness of a single sting. The first of these is easily and often known. No standard measure has yet been derived for the second, but there is good reason to believe it correlates positively with the first, especially within species. That means that individuals of larger colonies appear to need less provocation to attack. This paper deals with the third component.

By "stinger" is meant here the venom-injection apparatus, while "sting" refers to the event. Research into the stinger and its venom has shown impressive progress along three lines: a) morphology of the stinger (Robertson 1968; Maschwitz and Kloft 1971; Kugler 1978; Bettini 1978; Hermann and Blum 1981; Hermann and Chao 1983), b) venom chemistry (Habermann 1971; Bettini 1978; Blum 1981; Schmidt 1982, in press), and c) the toxic effects of venom (Habermann 1971; Bettini 1978; Schmidt, in press).

At the same time, our knowledge of the pain caused by venom is still at the anecdotal stage. This is consistent with the fact that recent progress in the psychophysics of pain (Melzack 1973, 1976; Carregal 1975; Marcus et al. 1977) has been based on temperature, pressure, and electric shock, but not chemically-induced pain.

Yet in the evolution of defense against large, primarily vertebrate predators, pain must be the key factor in sting effectiveness, much more important than toxicity or paralyzing power. Given the extensive toxicological literature, it would be convenient if toxicity were a good index of painfulness. This appears not to be so. Schmidt and Blum (1979) and Schmidt et al. (1980, 1984) give examples of wasps with very painful stings yet only slightly toxic venoms. Even if we find that

more toxic venoms are *usually* more painful, as appears reasonable, it will be the exceptions which are of special interest.

The Hymenoptera literature contains many brief descriptions of stings received in the course of field research. A common standard is lacking, though, so that it is often difficult to infer which of two species-stings mentioned in different reports is the more painful. The intention of this paper is to provide just such a standard, with the hope that over time a systematized body of comparative observations will accumulate.

THE PAIN SCALE

Pain is the body's alarm system in the face of injury, so that it is not surprising that its perception is graded into relatively few intensity levels. Humans can distinguish about 570 levels of light intensity, from barely perceptible to dazzling (Duke-Elder 1941) and about 90 levels of warmth below the pain threshold (Herget and Hardy 1942). But for pain induced by pressure or pricking, Hardy et al. (1947, 1952) put the number of distinguishable levels at just 22.

The complete fineness of discrimination is not commonly used in experimental pain studies. Chapman (1976) gives as the most common method of assessment a scale from 0 to 10, in which 1 represents the lower threshold of perception and 10 the upper threshold. The McGill Pain Questionnaire (Melzack 1975) has 6 levels over the same range, and that of Lutterbeck and Triay (1972) just 4. The scale described below has 5 levels, from 0 to 4. It is very close to the McGill scale, the only substantial difference being that McGill levels 4 and 5 are approximately equal to my level 4. Schmidt et al. (1984) use a pain scale of 1 - 4 for stinging hymenoptera, though without defining the levels. Inasmuch as all of the species they rank can penetrate human skin, and as their rankings agree very well with my own (Table 1) and with those given by Schmidt (in press) using the present scale, it seems that the rankings 1 - 4 of Schmidt et al. (1984) and this paper are virtually identical.

0. No pain
1. Pain so slight as to constitute no real deterrent.
2. Painful
3. Sharply and seriously painful.
4. Traumatically painful.

Rank 0 is common, as many species with a functional stinger are too small or weak to penetrate human skin. Rank 1 lies in that area in which the sting is clearly perceived (pain above threshold), yet most people would not say it "hurts." Stings of rank 4 are often medically serious events, producing strong physical reactions and durable pain even in persons without a history of acute reaction to stings (numerous pers. comm.), but attention is given here only to short-term pain, within a few seconds of the sting.

The distinction between ranks 2 and 3 may often be unclear. The intention is to distinguish between the great mass of painful stings (2) and those which stand out as clearly more painful than, for example, most honey bee stings, though not of traumatic intensity (3). One possibly useful characterization is that rank-3 stings, just from the pain itself and apart from any surprise or fear, produce loud cries, groans and/or long preoccupation. The examples in Table 1 will add to this distinction.

Table 1. Examples of ranked hymenoptera stings. Each of these is based on at least two stings, and as far as I know all follow the restrictions recommended in the text. Those marked with an asterisk are based on induced stings, explained in the text. Where a species has two rankings, this represents variation in stings, rather than uncertainty. Rankings of social species are all based on workers or the subcaste most commonly encountered outside the nest.

Family	Species	Rank	Source
Mutillidae	<i>Dasymutilla klugii</i>	3	d
	<i>Dasymutilla lepeletierii</i>	2	c,d
	<i>Dasymutilla</i> small sp.	1 - 2	d
	<i>Pseudomethoca</i> small sp.	2	e
Pompilidae	<i>Pepsis formosa pationii</i>	4	d
Scoliidae	<i>Trielis flammicoma</i>	1	e
Eumenkiaie	<i>Monobia quadridens</i>	2*	a
Vespidae:			
Stenogastrince	<i>Eustenogaster luzonensis</i>	3	a
Vespidae:			
Polistinae	<i>Apoica pallens</i>	2	c,d
	<i>Brachygastra bilineolata</i>	2	c,d
	<i>Brachygastra lecheguana</i>	2	a
	<i>Metapolybia docilis</i>	0 - 1	a
	<i>Mischocyttarus angulatus</i>	1*	a
	<i>Mischocyttarus atrocyaneus</i>	1*	a
	<i>Mischocyttarus costaricensis</i>	1*	a
	<i>Mischocyttarus melanarius</i>	low 2*	a
	<i>Polistes annularis</i>	3	a,c
	<i>Polistes arizonensis</i>	2 - 3	d
	<i>Polistes comanchus navajoe</i>	2 - 3	e
	<i>Polistes dorsalis</i>	2	a
	<i>Polistes exclamens</i>	2	a
	<i>Polistes fuscatus</i>	2	a,d
	<i>Polistes infuscatus</i>	3	c,d
	<i>Polistes metricus</i>	high 2 - 3	a
	<i>Polybia diguetana</i>	0 - 1	a
	<i>Polybia occidentalis</i>	1	a
	<i>Polybia rejecta</i>	2	a,d
	<i>Polybia sericea</i>	2	c,d
	<i>Polybia simillima</i>	2	a
	<i>Ropalidia flavopicta</i>	1	a
	<i>Ropalidia</i> sp.	1 - 2	d
	<i>Stelopybia panamensis</i>	3	a
	<i>Synoeca septentrionalis</i>	4	b
Vespidae:			
Vespinae	<i>Dolichovespula maculata</i>	2	c,d
	<i>Vespa mandarinia</i>	2	d
	<i>Vespula flavopilosa</i>	2	e
	<i>Vespula maculiformis</i>	2	a,c

Table 1. Continued.

Family	Species	Rank	Source
	<i>Vespula pensylvanica</i>	2	c,d
	<i>Vespula squamosa</i>	2	a,c,d
Formicidae:			
Myrmeciinae	<i>Myrmecia nigriceps</i>	2*	d
	<i>Myrmecia pyriformis</i>	2 - 3	d
Formicidae:			
Ponerinae	<i>Dinoponera gigantea</i>	1 - 2	c,d
	<i>Ectatomma quadridens</i>	1 - 2	c,d
	<i>Ectatomma tuberculatum</i>	2	c
	<i>Odontomachus haematodus</i>	2	c,d
	<i>Odontomachus infandus</i>	3	a
	<i>Odontomachus</i> sp.	2*	a
	<i>Pachycondyla apicalis</i>	2	c,d
	<i>Paraponera clavata</i>	4	b,c,d
Formicidae:			
Pseudomyrmecinae	<i>Pseudomyrmex mexicanus</i>	1 - 2*	c,d
	<i>Pseudomyrmex triplarinus</i>	2	a
Formicidae:			
Dorylinae	<i>Eciton burchelli</i>	1 - 2	a,c,d
	<i>Eciton hamatum</i>	1	a
Formicidae:			
Myrmicinae	<i>Monorium pharaonis</i>	0	a
	<i>Myrmica hamulata</i>	1 - 2*	d
	<i>Pheidologeton</i> sp.	1 - low 2	a
	<i>Pogonomyrmex badius</i>	2 - 3	c
	<i>Pogonomyrmex</i> spp.	3	d
	<i>Solenopsis geminata</i>	low 2	a
	<i>Solenopsis invicta</i>	1 - 2	d
Formicidae:			
Formicinae	<i>Oecophylla smaragdina</i> (bite, with spraying formic acid into the wound)	2	a
Anthophoridae	<i>Centris pallida</i>	1 - 2	d
	<i>Diadasia r. rinconis</i>	1 - 2	d
	<i>Xylocopa virginica</i>	1 - 2	c,d
Apidae	<i>Apis cerana</i>	2	a
	<i>Apis mellifera</i>	2	a,d
	<i>Bombus sonorus</i>	2	d

a = Personal observation

b = Numerous personal communications, Costa Rica

c = Schmidt et al 1984

d = Schmidt, in press

e = J. O. Schmidt, personal communication

I suggest that for experienced observers it will often be useful to distinguish between low-2 and high-2 stings. This should be done with caution, only when a sting seems clearly at the lower or upper end of rank 2.

In order for the pain scale to have its intended reliability, certain constraints on use are necessary. I suggest the following:

1. Reports should be made only by adult observers in good health.
2. Disregard all stings accompanied by allergic reactions.
3. Reports should not come from observers who are rarely stung. This is to avoid mixing pain with novelty.
4. Reports should be based only on events in which a very small number of stings are received at once.
5. A ranking should never be based on just one sting. Although individual social wasps probably sting rarely (I suspect that most never do), so that significant day-to-day variation in venom volume is unlikely, uncompleted or grazing stings are not uncommon. It is not known to what extent the regular use of the stinger by solitary wasps causes variation in venom delivery.
6. Reports on stings received through free attack by the insect (volunteer stings) are preferable to those deliberately induced by holding her between the fingers or against the skin (induced stings). We are not always so fortunate, though, as to be attacked by those species of special interest. Induced stings can contribute useful data if used with caution. Species which fail to penetrate the skin in an induced situation can sometimes sting under their own power, as with *Polybia diguetana*, *P. occidentalis* and *Metapolybia docilis* (personal observation); no rank 0 should be based on induced stings. Care must also be taken that induced stings are solid and direct. In addition, reports based on induced stings should be identified as such.

DISCUSSION

Given a hymenopteran defender against a vertebrate intruder, the two biologically relevant questions about the sting are: a) Does it have immediate value, by way of turning back that particular intrusion? and b) Does it have long-term value, by way of the intruder's memory? Any method of ranking sting pain from different species will contribute to answering these questions.

The goal in this regard must be a standardized, exact clinical method, such as those used in comparing venom toxicities. I have elsewhere (Starr 1981) suggested an approach to this, but we are still a long way from having a tested method of this type. Until we do, a non-clinical scale such as described above seems the best hope for progress.

The question of objectivity is entirely irrelevant in evaluating any pain scale, as we are concerned with how it *feels*. On the other hand, the question of reliability is central. If perception variation between different humans is so great that same-species reports from different people would show no strong positive correlation, then the scale is worse than valueless. There is good reason to expect such correlation. Although it has yet to be shown for specifically chemically-induced pain, the reliability of reported pain between individual humans and within individuals at different times is in general much greater than biologists would tend to expect. This result is summarized in Wolff and Wolf's statement (1958) that all healthy human beings have approximately the same capacity to feel pain. The

expected reliability of pain-scale data is well within the norms of present-day pain research.

A second assumption is that other vertebrate species would each rank stings in the same *sequence*, i.e., that given two stings, they would respond similarly to the question "Which is more painful?" This reasonable working assumption is completely untested at present.

Clearly, though, different species must have differing thresholds for slight, serious and traumatic pain. To a small mammal our ranks 2, 3 and 4 might well all be so painful as to have identical biological meaning, while our rank 1 could represent a much wider pain spectrum than it does for us. This serious limitation of the pain scale cannot be overcome. It underlines the fact that stings of the same rank do not make up a natural universal grouping, but simply indicate the limits of our own resolution.

To what extent can the pain scale meaningfully rank non-hymenopteran stings, or the pain from defensive tactics other than stinging? To each of these the answer is: to only a very limited extent. The venoms of some taxa, such as snakes, and tiffids, produce pain largely as an irrelevant-by-product. In addition, it must be asked whether the animal is normally able to manipulate venom into a large aggressor. The venom apparatus of spiders, for example, must nearly always be useless against a vertebrate attacker. Some few other groups, such as scorpions and centipedes, appear to use pain as a deterrent, and it may sometimes be of interest to rank them.

For non-stinging defense, such as the purely mechanical use of sharp structures, the pain scale seems applicable only in a very few cases.

It should sometimes be meaningful, for example, to compare the bite-pain of some ant and termite workers with the sting-pain of some other ant workers or the jab-pain from the pseudostinger-genitalia of many aculeate males. The action of *Oecophylla smaragdina* major workers in spraying formic acid directly into a bite wound is very like a sting in form and effect (Table 1).

Sting-pain comparisons can be of immediate use in the study of mimetic relationships within the Aculeata. For example, Costa Rica has six species of social wasp genus *Stelopolybia*, each of which very closely resembles one or two sympatric species of *Mischocyttarus* (personal communication). There can be little doubt that each pair is a mimetic association, but is it batesian or müllerian? In revising these genera, Richards (1978) repeatedly remarks that one or another *Mischocyttarus* is a mimic of a certain *Stelopolybia*, implying a batesian relationship. Inasmuch as each species can sting, the possibility must be entertained that the mimicry is müllerian for at least some classes of potential predators. If, however, one member of the pair stings significantly more painfully than the other, the mimicry would appear to be batesian for some predators. Richard's implied prediction is corroborated in its only test to date, that involving the pair of *S. panamensis* and *M. melanarius* (Table 1).

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