Head Lice: Prevalence in Schoolchildren and Insecticide Resistance

A.M.R. Downs, K.A. Stafford and G.C. Coles

The head louse (Fig. 1) is an ectoparasite, confined to the scalp hair of humans. This insect has a life span of around 30 days and a high reproduction rate (ten eggs per day). The scalp provides an environment where the surface temperature and relative humidity (rh) hardly vary (30°C, 70% rh); neither the louse nor its eggs are able to survive outside this controlled environment. For this reason, head lice are usually found close to the scalp, but observation shows that they regularly wander through and over the hair. Head lice feed by sucking blood about every four hours, and can cause pruritus (itching). Subsequent skin excoriation may lead to secondary bacterial infections, which can be severe. The nutritional state and cleanliness of the host is not important and this infestation is found in all social classes. Adult head lice usually number less than ten, although host scalps may contain dozens or even hundreds of lice. Transmission is thought to be mainly from scalp-to-scalp contact that may need to be only fleeting if the lice happen to be positioned on top of the hair, away from the scalp surface. Hats, scarves, combs and fomites have also been implicated in transmission. In the laboratory, head lice can be used experimentally to carry and transmit Rickettsia prowazekii (typhus). This germ led to thousands of deaths across Europe during and soon after the Second World War, when it was transmitted through body lice. The epidemic was controlled with DDT following a mass eradication campaign to reduce body lice numbers. Currently, head lice infestations are confined largely to schoolchildren. As the vast majority of cases are asymptomatic, a parent's and child's main concern following identification of an infestation is of social stigma.

Control Methods

Historically, shaving the scalp has provided an effective control method and was documented as being highly successful for Napoleon's army. When comparing short hair to long hair, no significant differences in infestation rates can be found. In our study of Bristol primary schoolchildren (Fig. 2), we found that 4-5 year olds (76% of infested cases had <10 live adult head lice per scalp) had lower infestation rates than 7-8 year old (58% infested). In general, younger children (4-7 year olds) were significantly more likely ($p = 0.02$, $\chi^2$ test) than older children (7-11 year olds) to have lighter infestations. The younger children, especially 4-5 year olds, had shorter and finer hair and were easier to examine. Low infestation rates can be easily missed in longer hair. This may explain why it has been difficult, in previous studies, to prove that shorter hair styles, over-all, have lower infestation rates. Traditional regular combing has gained recent popularity, following a rigorous publicity campaign by the Community Hygiene Concern. Although probably useful for unknotting hairstrands cemented together by louse eggs and reducing the number of head lice carried, there are no published reports that the practice of combing can cure an infestation. A new

Fig. 1. Electronmicrograph of an adult head louse Pediculus capitis.

Fig. 2. The average percentage of boys (closed bars) and girls (open bars) infested with head lice per school year from three schools (n = 1001). Each $p$ value compares the difference of infestivity between boys and girls in each school year (Fishers exact or $\chi^2$ tests).
battery-powered device called the Robi comb™ has electrodes substituted for the teeth of a comb. When a louse-sized object falls between the electrodes, it is severed. Retailing at £25, this device may be little more than an expensive novelty item and has undergone no published clinical testing. On contact with water, head lice will cling onto hair strands and close their spiracles. This prevents the lice from being dislodged or water intoxicated when the scalp is wet. Eggs are also water impermeable. Similarly, the efficacy of contact with a noxious liquid (such as kerosene or vinegar, which have been used as head lice treatments) will also be hampered by this protective mechanism. Since these noxious agents are also volatile, their duration of effect is short. Such chemicals are skin irritants, toxic to humans or flammable.

Table 1 shows the insecticides that have been used to treat head lice. DDT was withdrawn because of toxicity and treatment failure, and lindane was voluntarily withdrawn in 1996 for similar reasons. Carbaryl is now only available by National Health Service (NHS) prescription because of a suspected mutagenic potential with chronic use. Piriperonyl butoxide is sold as a prophylactic agent against head lice. It is an irritant to lice, which will move away from impregnated filter papers. Our studies using impregnated filter paper (unpublished) found that pyriproxyfen butoxide is a non-lethal agent against body and head lice, but in combination with natural pyrethrum, it lowers the concentration of natural pyrethrum that is effective against lice. A postal survey of pharmacists in Glasgow, UK, suggested that the public may be using treatment insecticides as prophylactic agents against acquiring head lice.

### Evidence for Increasing Infestation

There is very little consistent data on the prevalence of head lice in the UK. In 1969, a primary school survey in Teeside showed a 12.5% infestation rate. By 1970, following aggressive publicity to encourage treatment and enforced treatment of non-complying families, this fell to 8.6%. A primary school survey of selected schools in England in 1975 showed an infestation rate of 1.9% in northern counties, 1.1% in southern counties, and 5.2% in London. Statistics collected for the Department of Health through school nurse surveys of head lice infestations in England and Wales (1970–1977) showed a rise in estimated prevalence in all schools from 1% to 1.5%. Of the three schools we examined in Bristol (n=1001) in 1997, which felt that they had a severe head lice infestation problem, we found an infestation rate of 18.7%. A French survey showed that the incidence may depend on season, season of schools, publicity and the consistency in the method of diagnosis. Figure 2 shows the average percentage of infested boys and girls per school year from our survey in Bristol. There were no significant differences in louse loads (greater or less than 10 live adult head lice per scalp) between males and females, and no difference in itching of pupils with heavy or light louse loads. Girls were significantly more likely (p<0.01, χ² test) to be infested with head lice, which is consistent with previous reports, but this becomes less significant in lower age groups (χ² or Fisher's exact test). The changing behaviour patterns of boys and girls at different ages may affect transmission rates and susceptibility to head lice infestation. These might include

### Table 2. Total number of dead and alive body lice and community head lice for all insecticides

<table>
<thead>
<tr>
<th>Concentration (g per 100 ml)</th>
<th>Body lice</th>
<th>Head lice</th>
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<tbody>
<tr>
<td></td>
<td>Dead</td>
<td>Alive</td>
</tr>
<tr>
<td>Malathion</td>
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<tr>
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<td>0.19/0.019</td>
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<td>4</td>
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<tr>
<td>Carbaryl</td>
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<td>3.2</td>
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</table>

<table>
<thead>
<tr>
<th>Concentration (g per 100 ml)</th>
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<th>Head lice</th>
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<tbody>
<tr>
<td></td>
<td>Dead</td>
<td>Alive</td>
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</table>

* Data from Ref. 19.

* Concentrations given are 2LD₅₀ for susceptible body lice, except DDT, where only LD₅₀ was achieved.

* All controls (not shown) remained alive. The concentration of insecticide is that into which Whatman no. 1 filter paper tests are dipped (PB = piriperonyl butoxide), prior to drying and use in 2 h contact tests.

* p<0.01 (Fisher's exact or χ² tests); other differences not significant.

* Estimated prevalence.
the frequency of personal grooming, the degree and frequency of close physical contact with friends and family, a shared sleeping environment, shared clothing and changes in hair styles. Since the 1970s, schoolchildren have been organized into small learning clusters to learn to play, thus encouraging cooperation and sharing. With older children, each child takes a more independent role, and there is more separation between individuals. This might create differing transmission rates, and might explain the higher prevalence in younger children. Another factor of potential importance is asymptomatic carriage of head lice in siblings and parents. 53% of our infested schoolchildren were asymptomatic and unaware that they were infested with head lice. The Birmingham research unit of the Royal College of General Practitioners has a weekly return service from 91 sentinel general practices throughout England and Wales. Data on head lice incidence from this study population in 1994 and 1995 (Ref. 13) show that, although children aged 5–14 are the group with the highest prevalence of head lice, children younger than 5 and adults comprised 45% of presenting cases.

The Office of National Statistics has shown a 6.7-fold increase in the incidence of head lice from 1971 to 1991 based on general practice consultations from 53 sentinel general practices throughout the UK. National Health Service prescriptions for all products with a license for use against head lice in England have risen from 407,000 in 1980 to 1,467,500 in 1995; a 3.7-fold increase. Over-the-counter sales account for approximately two-thirds of the total insecticide sales for human use. Sales information released by some pharmaceutical manufacturers (25% of the insecticide sales market for head lice) have shown a 1.1-fold rise in total drug sales between 1992 and 1996 for products against head lice.

## Insecticide Resistance

Increased insecticide tolerance to synthetic pyrethroids has been reported from England, France, Israel, and the Czech Republic.61–67 Anecdotal reports from England66 and France68 have also reported organophosphate resistance. Our study of primary schoolchildren in Bristol and Bath62 confirmed resistance to both malathion and permethrin. We compared the survival rates of school head lice with fully sensitive laboratory reared body lice for carbaryl, malathion and permethrin exposure in controlled conditions for two hours and found a significantly lower mortality (p < 10⁻⁶, Fishers exact test) of head lice for malathion and permethrin.

## Box 1. Possible Insecticide Resistance Mechanisms

### Mode of action of some insecticides

1. Inhibition of acetylcholinesterase (eg. by organophosphates, carbamates) leading to spastic paralysis and death.
2. Depolarisation of the sodium channels on peripheral nerves (eg. by DDT and pyrethroids) leading to tonic–clonic seizures and death.

### Resistance mechanism

1. Accelerated detoxification of insecticides, eg. enzyme-mediated oxidation, reduction, esterification.
2. Alteration of the insecticide binding site, eg. an altered acetylcholinesterase, an altered peripheral nerve sodium channel, knockdown resistance (kdr).

This was confirmed with an 82% failure rate for permethrin and a 64% failure rate for malathion on supervised topical treatment of infested cases.20 Table 2 shows the mortality rates for these insecticides as well as for DDT, B-cypermethrin, and piperonyl butoxide/natural pyrethrum 1:10 mix tested under the same conditions. Very high concentrations of permethrin or B-cypermethrin were unable to overcome this head lice resistance. Very high concentrations of malathion did partially overcome the observed malathion resistance. There were no differences seen between lice survival for carbaryl.

Box 1 shows the possible insecticide resistance mechanisms that an insect could evolve. It is likely that Bristol head lice employ a malathion-specific esterase that can be partially overwhelmed by higher concentrations of malathion. Since these head lice are resistant to DDT and a range of pyrethroids that cannot be overwhelmed by piperonyl butoxide (an agonist of oxidative detoxification) or very high concentrations of pyrethroids, then the resistance mechanism is likely to be due to kdr (knockdown resistance).21 This involves mutations in the para II sodium gated chloride channel.

## Future Options

Several small case studies have shown a therapeutic response for oral cotrimoxazole,22 oral and topical ivermectin,23,24 topical crotamiton,25 and topical 1% copper oleate shampoo.66 We have also assessed the novel flea adulticides, fipronil and imidaclopid, and found them to be 97 and 100% effective in vitro against head and body lice (unpublished). Alternative carbamates such as propoxur or alternative organophosphates such as temephos27 may be unaffected by the resistance mechanism against malathion. All these agents may have a place in the control of head lice. If a new agent is introduced into the human market, it is likely that head lice will eventually develop resistance. To reduce chronic use, and so slow the development of resistance, an option would be to have all insecticides available by prescription only. Strategies should be used to keep head lice levels to a socially acceptable minimum level. Strategies such as educational campaigns by community nurses, doctors and school teachers should promote head lice eradication. Although it is doubtful whether regular combing can cure a head lice infestation, it is likely to reduce the numbers of lice carried and should be promoted as the first line of treatment before insecticides. Children who fail to clear their infestations should be targeted by school nurses for treatment. All family members and classmates should be assessed for asymptomatic carriage. Ideally, all schoolchildren should be at separate desks during lessons to reduce transmission of head lice. Given the national rise in the prevalence of head lice and in insecticide sales, it is likely that the resistance phenomenon we have observed in Bristol and Bath is nationwide, and will require national changes in attitudes towards the treatment and surveillance of this ectoparasite.

### References

News


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Birds and their Parasites: Victims of Infection or Fashion?

Pj. Hudson

Vilnius, Lithuania
June 1998

Parasitology is one of those rare disciplines in which investigations on a single parasite–host interaction may range from the molecular to the population and community scale. The depths and intricacies of parasitology have a deep fascination for its advocates and raise a broad spectrum of questions. Few researchers can study the minutiae of these questions at the full range of scales. However, a focused conference that concentrates within a taxonomic group has the ability to reveal the various scales and be both stimulating and enjoyable.

This meeting specifically focused on the ecology of bird–parasite interactions and while it included both molecular and community studies, most were interested in the relationship between the parasite and the individual host. It is true that birds get more than their fair share of the limelight in ecological studies, but there is no escaping the advantages of working with birds. They are easy to identify, relatively simple to observe, have ornate secondary sexual characteristics, and both the birds and their parasites can often be manipulated. The special characteristics of birds permit us to address a range of interesting evolutionary and ecological questions although at times one has to admit that the birds rather than the discipline can dictate the questions, and that fashion has played a role in shaping these questions.

Flight and Parasite Dispersal

An obvious characteristic of the majority of birds is their adaptation to flight and a body temperature greater than other homeotherms. Body temperature rises when birds fly, and this may have an influence on infections. Olga Doink (Zoological Institute, St. Petersburg, Russia) has been investigating the variation in Isospora infections in passerine birds. She described how the production of oocysts fell during the period of migration and reported that birds kept in small cages were more likely to suffer from infections than birds kept in large cages. One hypothesis that explains these observations is that the act of flying raises body temperature and this may help to control the infections.

The ability to fly also permits birds to disperse infection, particularly on their annual migration between breeding and wintering grounds. Recent work has concentrated on some of the tick-borne diseases, as many of the ixodid ticks are active in spring and autumn, when birds are migrating. Helen Dubina (Zoological Institute, St Petersburg, Russia) and Alicja Gryczynska (University of Warsaw, Poland) provided evidence that migrating birds were capable of transporting Borrelia spirochetes, while others (Galina Efremova, Institute of Zoology, Minsk, Belarus; Dmitri Lvov, Ivanovsky Institute of Virology, Moscow, Russia) showed they could transport arboviruses. However, showing that birds are capable of dispersing parasites, and demonstrating that they actually do, are two very different problems. Clive Kennedy (University of Exeter, UK) provided evidence from a natural experiment to show how important birds could be at dispersing parasites. He has undertaken a detailed study of the fish helminths at a small isolated lake for 28 years. After 15 years of study, the fish population was carrying ten species of helminth, five of which were autogenic and five allogenic. However, the fish then suffered a massive winter mortality that decimated the parasite fauna. Subsequent sampling showed that the autogenic species colonized much faster than the autogenic species, presumably because birds brought them in. This study not only shows the importance of birds as parasite-dispersing agents, but also highlights how historical events can play an important role in influencing the presence of infections.

Host Fitness and Population Consequences

Many presenters specifically addressed the question of whether parasites were having an impact on host fitness. Such studies require experiments to determine cause and effect, although many workers still fall into the trap of simply looking at correlations. Nevertheless, many researchers were unable to find a difference in host fitness when they compared infected and non-infected individuals, but they did find a difference between heavy infections and light infections. Indeed, in a wide range of studies, there seemed to be an interesting dichotomy between two groups of birds. For example, Arne Skorping (University of Bergen, Norway) showed that there was a negative relationship between body fat and intensity of infection with Amdastomum onserns in female eiders (Somateria mollissima), although no such relationship was found among early breeders. His studies of willow ptarmigan (Lagopus lagopus) showed that wormy individuals were consistently wormy. Individuals with heavy infections of one species were likely to have heavy infections of other species, and so remained in the ‘tail’ of the frequency distribution. In contrast, a study by Dan Tompkins (University of Stirling, UK) on Heterokos gallinarum in pheasants (Phasianus colchicus) implied there was a dynamic state of affairs in this system, with infected individuals spending a relatively short period of time in the ‘tail’ of the distribution. He also showed a dynamic change in the relationship