# THE PEST STATUS OF PSOCIDS IN THE UK

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**Abstract**—Psocids, and particularly the species *Liposcelis bostrychophila*, have become an increasingly recognised pest of stored food products and grain. In the UK, *L. bostrychophila* is the most important cause of consumer complaints in some areas of the food industry. A similar picture emerges from other European countries. Extrapolation from warehouse psocid population dynamics to psocid prevalence in products in the home is erroneous since different, although similar looking, species are found in the two habitats. Patterns of psocid prevalence in households and storage facilities are presented and discussed.

*Liposcelis bostrychophila*, is parthenogenic yet shows considerable variability in morphology, physiology and behaviour between populations. In addition there are differences at the molecular level among four polymorphic enzymes. Several of these patterns of variability are vectored along a north south axis in the UK. The possible causes and implications of this suite of variations are discussed.

## INTRODUCTION

Psocids, members of the exopterygote order Psocoptera, are usually considered to be of minor significance as insect pests (Gorham, 1991; New, 1974) and generally of little economic importance (Mockford, 1993). Most psocids are free-living on the surfaces of trees, other vegetation or in litter where they have no impact on humans. About 3500 species of Psocoptera have been described world-wide (Smithers and Lienhard, 1992) but only a small fraction (about 50) of are known to frequent human dwellings, warehouses and food stores (Mockford, 1991). In recent years there has been a gradual world-wide recognition that psocids do produce a series of distinct pest problems in the area of food and grain storage (Rees, 1994a, 1994b; Turner, 1994).

In the UK there are 51 psocid species recorded as native together with an additional 36 species which are casual imports or of dubious taxonomy (Broadhead, 1964). Those most likely to be found in domestic or storage situations are shown in Table 1. Nine of these 16 species are generally uncommon in the UK. For example, *Liposcelis entomophila* is of considerable importance in grain storage facilities in tropical countries (Leong and Ho, 1995; Pike, 1994; Rees, 1994b) but the British climate usually appears to be too cool for it to be troublesome in the British Isles. Other species listed in Table 1 are native to the UK and very infrequently come indoors, usually in the autumn (eg. *Ectopsocus briggsi* and *Lachesilla pedicularia*). The remaining seven species, two in the family Trogiidae and five liposcelids, are those most commonly met with indoors. However the key species involved in the vast majority of psocid related problems in the UK is *Liposcelis bostrychophila* (Badonnel).

*Liposcelis bostrychophila*, a 1mm long, wingless species of tropical origin, was first described in the UK by Broadhead and Hobby, (1944a; 1944b) as *L. granicola* and but was later synonymised (Broadhead, 1950) with *L. bostrychophilus* Badonnel, a species which has been described earlier from Mozambique (Badonnel, 1931). Lienhard (1990) revised the Palaeartic species of the family Liposcelidae, changing the family name to Liposcelididae and feminising a number of specific names (including *bostrychophilus* to *bostrychophila*) to bring them in line with the gender of the generic name. A review of this species, including much previously unpublished information, has recently been published (Turner, 1994).

Obr (1978), in his large-scale study of psocids in factories, storage and dwellings on Czechoslovakia, found that there were distinct differences in the habitats of different psocid species. *Liposcelis bostrychophila* was primarily a domiciliary species whilst other liposcelids were more commonly found in factory and storage sites. That is broadly the experience in the UK (Turner, 1994; Turner and Maude-Roxby, 1989). Infestations in UK households are due to *L. bostrychophila* in over 90% of cases whilst factories and warehouses are usually colonised by the other species in Table 1.


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Table 1. Stored product psocids of storage facilities and domestic situations in the UK (data extracted from New, (1974) with additional details from Turner pers. obs.). Location normally found in: H=household: S=storage facilities.

| Family | Species | Location |
|---|---|---|
| Trogiidae | *L. patruelis* | H,S |
| | *Trogium pulsatorium* | H,S |
| Psoquillidae | *Psoquilla marginepunctata** | H,S |
| Psyllipsocidae | *Psyllipsocus ramburii** | H,S |
| | *Dorypteryx domestica** | H,S |
| Liposcelidae[2] | *Liposcelis bostrychophila* | H |
| | *L. brunnea* | S |
| | *L. corrodens* | H,S |
| | *L. decolor** | H,S |
| | *L. entomophila** | S |
| | *L. mendax** | H,S |
| | *L. pearmani* | S |
| | *L. pubescens* | S |
| Sphaeropsocidae | *Badonnelia titei*[1]* | H,S |
| Ectopsocidae | *Ectopsocus briggsi** | H,S |
| Lachesillidae | *Lachesilla pedicularia** | H,S |

* these are relatively uncommon in domestic or storage situations
[1](Welch, 1983; Welch, 1992; Welch and Plant, 1980)
[2]Following (Lienhard, 1990)

A wide range of mainly farinaceous products (Turner, 1987; 1994) may be eaten by psocids but it is usually important that the product has some moisture content. Thus dry pasta products are relatively unattractive whilst 'quick-cook' pasta, which has been partially cooked and has an appreciable water content, is far more attractive to psocids. An intrinsically moist product in porous packaging, eg. wheat flour in paper bags (with a typical water content of 12–14%), attracts any psocids in the vicinity and this property is exploited in monitoring programmes where bags of flour are used as traps Products which are sold in sealed packaging and then left, partially used and open, in a cupboard will absorb water vapour and possibly become attractive to any psocids in the kitchen. Paradoxically, flour in paper bags gradually dries out over several months, becoming less attractive with time.

## PATTERNS OF PREVALENCE

Data on the prevalence of psocids mainly comes from two sources. Information on prevalence in factory and warehouse sites has been obtained from monitoring programmes using bags of flour as trapping devices. The focus has been on flour production and storage facilities in the UK with some small input from retail outlets as well. Prevalence data from households is drawn from numbers of psocid related complaints received by the flour industry and from household surveys.

The typical seasonal pattern of prevalence in warehouses is shown in figure 1, with numbers peaking in the mid summer months (July-September) and dropping to zero in midwinter. Such patterns need some explanation. They cannot record true abundance since the trapping procedure relies on the psocids being attracted to the bag-traps and on their mobility to find them. Species will vary in their 'trapability' depending on how attractive the bag trap is to them and on their exploratory behaviour. Activity will vary with season, being high in warm summer months and very low in the cold winter months. These prevalence patterns therefore indicate the relative numbers of each psocid species that are active in a month. Such figures are of value in judging the potential threat to products stored in the warehouse thoughout the year but do not necessarily indicate changes in psocid population size with time.

The data in figure 1, from an unheated warehouse shows a marked seasonal pattern, with numbers trapped being greatest in mid-summer and least in mid-winter. Some species are more

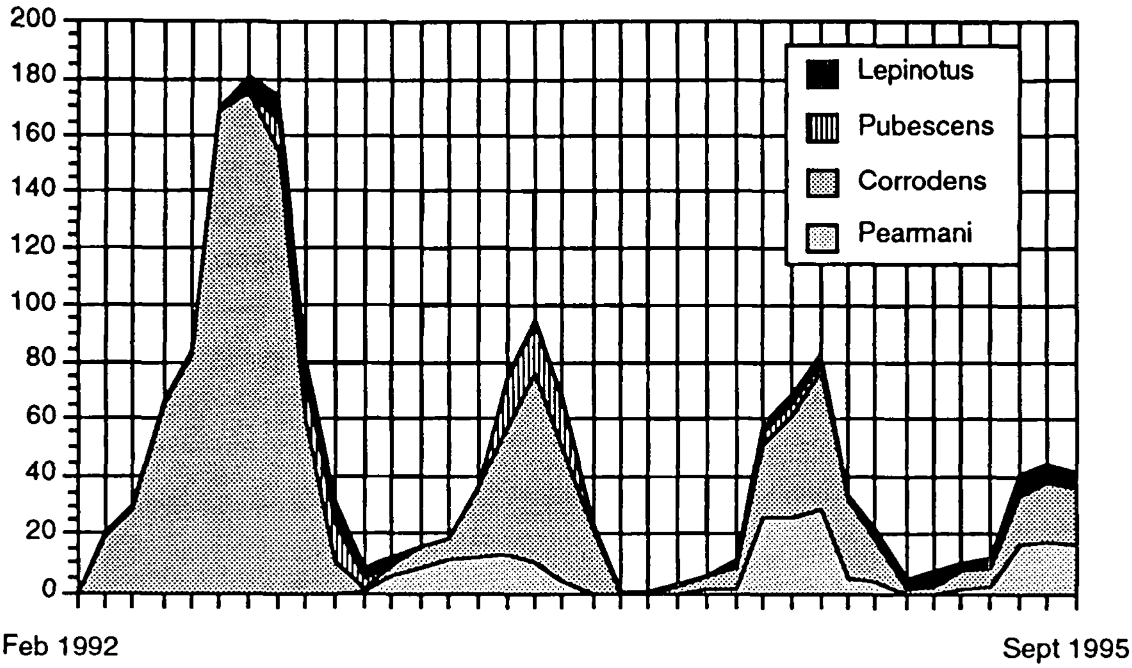


Figure 1. Fluctuations in the numbers of individuals of the four commonest psocid species in Warehouse H. The species are (from top to bottom)*Lepinotus patruelis*, *Liposcelis pubescens*, *L. corrodens* and *L. pearmani*.

seasonal than others. *Lepinotus patruelis* can be found in low numbers at most times of the year, whilst the liposcelids tend to be common only in the summer period. Among the liposcelid species there is a suggestion in figure 1 that they form a overlapping sequence with *Liposcelis pearmani* being first in the year followed by *L. corrodens* and then L. *pubescens*. A shorter sampling interval than the monthly programme which generated these data, is needed to show any further details of the phenology and activity patterns of these species. Furthermore these data only refer to adults as it is usually impossible to identify the trapped nymphal stages with any certainty. The cause of the gradual decline in the heights of the summer peaks over the 4 years is unknown but may be a result of the continual removal of individuals as a result of the sampling process. The general seasonal pattern of prevalence shown in Warehouse H have been recorded in other warehouse facilities.

An equivalent sampling programme for domestic sites has not been carried out. In principle psocid prevalence patterns might be expected to be similar to that seen in the warehouse but with the added complication that domestic situations are usually heated in the winter months. Monthly records of psocid-related customer complaints to the flour industry and retailers also show a distinct seasonal pattern (Fig. 2) but here the peak is in the autumn months of September and October and the low is in the spring. It is tempting to suggest that the build-up of psocids in the warehouse is giving rise to domestic problems several months later until it is realised that the data presented in figure 2 relates, almost without exception, to *Liposcelis bostrychophila*, a species not recorded in figure 1.

Since the 1960's the number of psocid-related complaints per year has been increasing. This is not a phenomenon restricted to the UK but is also seen in other countries where data are available (Turner, 1986; 1987). Figure 3 presents information on the annual numbers of psocid-related complaints in the UK and Denmark, where detailed records of all complaints are collated by the Statens Skadedyrlaboratorium (Danish State Infestation Laboratory).

The temporal patterns of annual complaint levels in Denmark and the UK are highly correlated (Figure 4) suggesting that they are being driven by a similar variable. The gradual increase in the complaint numbers through the 1970's changed in the early 1980's and began to oscillate about a mean of approximately 40 complaints per million of population. The post-1980 oscillations are significantly correlated with summer temperature (fig. 5).

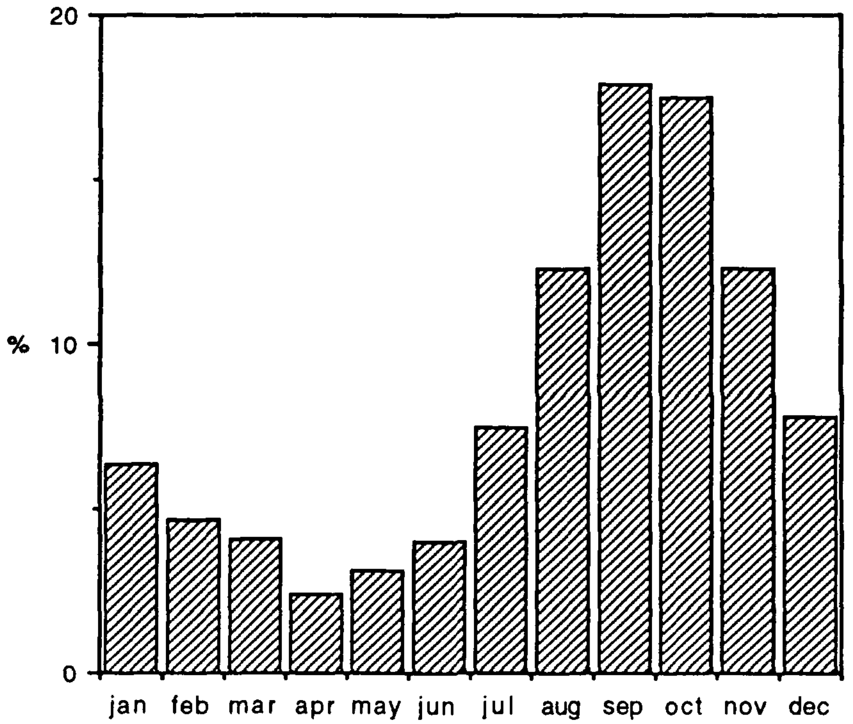


Figure 2. The seasonal variation in the average numbers of psocid related complaints (expressed as the percentage of the annual total attributed to a month) to the group of participating UK food companies for the period 1982–1992

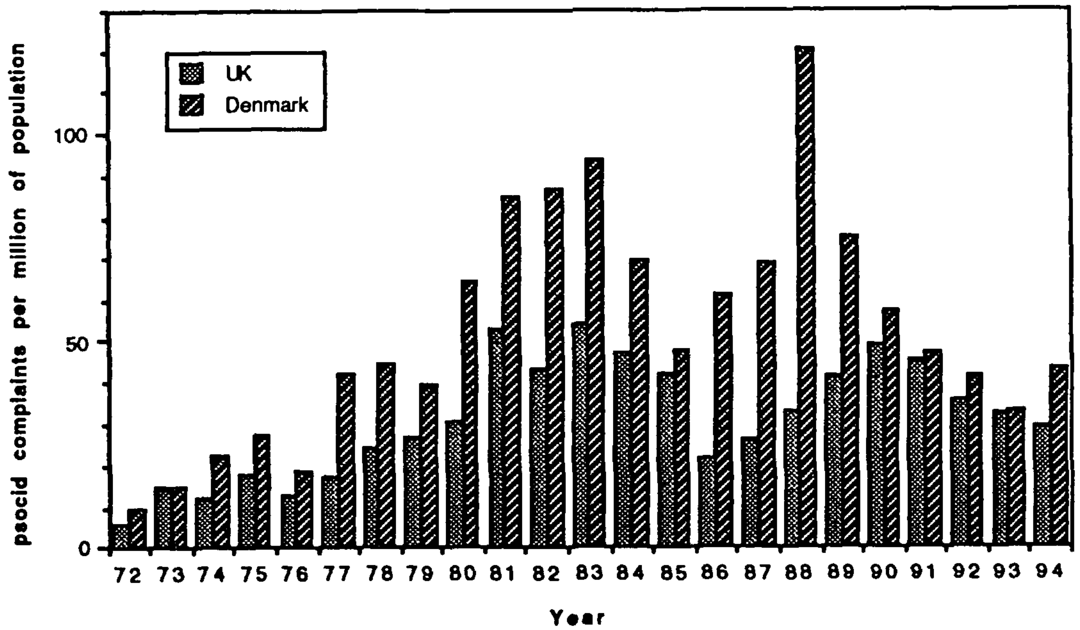


Figure 3. The annual fluctuation in numbers of psocid-related complaints in the UK and Denmark. The data are expressed as complaints per million of population.

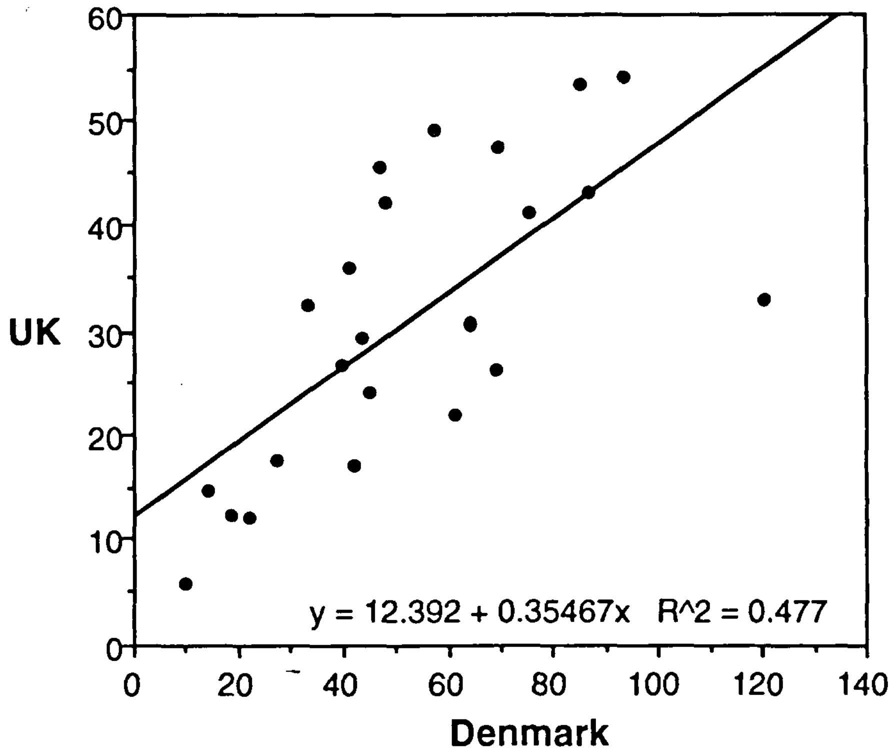


Figure 4 The correlation between numbers of psocid-related complaints per million population in the UK and Denmark.

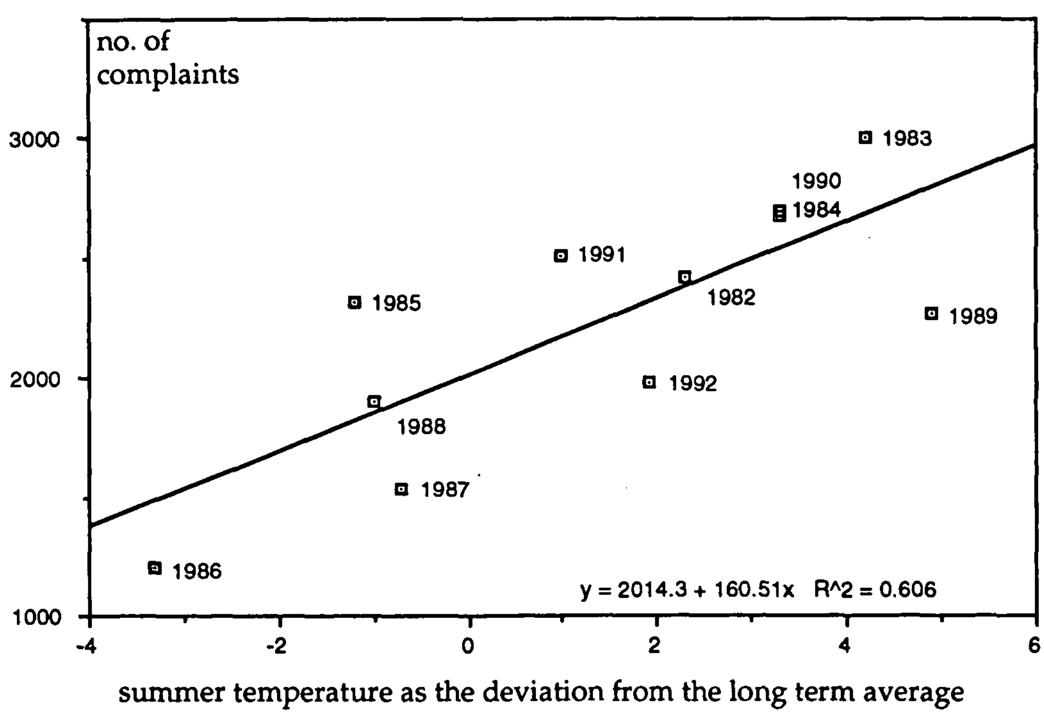


Figure 5 The influence of summer temperatures on the annual numbers of psocid-related complaints in the UK for the period 1982 to 1992. The temperatures are expressed as the sum of the monthly deviations from their long term (50 yr) averages for June to September inclusive. Thus an average summer will be 0, a cooler than the long term average will be -ve and warmer than average will be +ve.

Thus warm summers will generate higher number of complaints of psocid infestation than cool summers. Since *Liposcelis bostrychophila* is a tropical species the relationship seen in figure 5 may be explained by the amount of time in the summer during which temperatures are above 20°C, this being the minimum temperature at which this species produces eggs (Turner, 1994). The longer this window and the higher the temperatures, the faster will be the population growth of *L. bostrychophila*. Whilst very low population levels in a kitchen may pass undetected there will be some threshold population size at which the psocid numbers are sufficient to be noticed and some action taken by the householder.

The remaining, and still considerable, variation in figure 5 is probably due to the vagaries of the way the data are obtained. People react differently to finding psocids in their cupboards. As part of a survey of psocids in kitchen cupboards (Turner and Maude-Roxby, 1987; 1989) 66% of the respondents to a questionnaire said they would not complain and just throw out infested food. That same study found that about 15% of households contained *Liposcelis bostrychophila*, which figure is almost certainly an under-estimate due to the relatively ineffectual trapping methods used in the survey. Using the figure of 15% gives an estimate of about 3 million households with *L. bostrychophila* in the UK as against the figure of between 1000 and 4000 households derived from figure 3. A final area of uncertainty is an increasing trend to process complaints by retailers and then pass back information and costs to manufacturers which are then not comparable with other complaints data.

In an analysis of the relative adaptability of stored product pests (Sinha, 1991) developed a predictive tool, the climate plasticity index ($I_P$), based on a species physiological responses to temperature and humidity. Not surprisingly those pests which are most cosmopolitan, eg. *Tribolium castaneum* and *Anagasta kuehniella* have high $I_P$ scores (700 and 600 respectively). Turner (1994), calculated the $I_P$ for *L. bostrychophila* to be about 635 placing it among the leading storage pests in terms of its adapability. Whilst psocids do not produce the levels of damage in storage facilities that *Tribolium* or *Anagasta* can produce, their plastic physiology explains their ubiquity despite their tropical origins.

Psocids can produce damage to stored products. Despite their small size, liposcelids physically damage grain in store (McFarlane, 1982; Shires, 1982; Watt, 1965) and will feed readily on grain products (bran, wheatgerm, flour, semolina, pearl barley etc.) without any fungal contamination being necessary. Grain damage is of considerable importance in the tropics (Rees, 1994b) but in the UK, *L. bostrychophila* is primarily a psychological pest (Turner, 1994). However there is a small amount of evidence from both Germany and Switzerland (Rijckaert *et al.*, 1981; Wyniger, 1985) showing that liposcelids are allergenic in susceptible people. The situation in the UK is currently being assessed (Turner *et al.*, 1996).

## POPULATION VARIABILITY AND GEOGRAPHIC TRAITS

Despite its obligate parthenogenetic reproduction, Turner and Ali (1993) reported the finding of considerable variability in the esterases of a collection of populations of *Liposcelis bostrychophila* from different locations in the UK. In addition to esterases, a further three enzymes have been found to be polymorphic; glucose phosphate isomerase, phosphoglucomutase and mannose phosphate isomerase. Individuals of a population are either all of the same polymorph for the four enzymes or show evidence of dimorphism in one or more of the enzymes. In no cases are more than two variants of an enzyme detected within a population (Ali, 1994). This suggests that the genes controlling these enzymes are either homozygous, in which case the individuals within a population all have the same enzyme morphs, or one or more of the genes are heterozygous and that some sort of exchange of genetic material takes place between chromosome pairs during cell division in the oocyte, in which case one or other of two enzyme variants is expressed. The process of cell division in the oocyte of *L. bostrychophila* in the absence of male gametes to produce a diploid egg is unknown.

Viewed as a whole, a study group of 116 *L. bostrychophila* populations divided into 47 groups on differences in the polymorphs of these four enzymes (Ali, 1994). Populations, clustered on the basis of their enzyme patterns, show no grouping geographically in the UK but instead appear to be spatially random in their distribution.

Morphologically the populations differ in size and colour. Those from the south of England are significantly smaller and lighter than those in the north (Ali, 1994).

In 1985, Pinniger made a casual comment on the tolerance of the laboratory culture of *L. bostrychophila* at MAFF, Slough, Berkshire, UK. to a synthetic pyrethroid insecticide. Our laboratory cultures originated from the same MAFF stock and, in trials on a range of insecticides, Pinniger's initial observation was confirmed for several formulations of three pyrethroids, permethrin, deltamethrin and cypermethrin on porous and non-porous substrates. In addition the role of mixed function oxidases was demonstrated as be important in detoxifying the insecticides (Turner, 1988; Turner *et al.*, 1991).

Populations of *L. bostrychophila* from different locations in the UK show a range of sensitivity to synthetic pyrethroids. Some populations are very sensitive to permethrin whilst others show a tolerance which is even higher than that seen in the laboratory culture. The modal sensitivity of the 117 populations in the study, measured as the percent mortality in a standardised experimental exposure to the insecticide, falls in the range of 15 to 35%. There is a significant geographic trend in these data with tolerance levels being highest in populations from the south of England and decreasing in more northerly locations (Ali, 1994).

## DISCUSSION

Since the early 1940's, when *Liposcelis bostrychophila* was first characterised in the UK, this species has grown in importance as a pest of domiciliary food stores. Whether the 1940's represents the time of introduction of this species to the British Isles is unknown due to the imprecision of liposcelid taxonomy prior to 1940 (Turner, 1994) but since records of this species in the 10 years after its description were from ships' holds and dockland warehouses (Broadhead, 1954), it appears to be a distinct possibility. However, as discussed below, a consideration of the evidence on variation suggests that *L. bostrychophila* has been in the UK for a far longer time.

This small insect is widely dispersed in households throughout the UK and it is probable that most of this dispersal process has been through movements of food. However there is little to suggest that food products are being infested during manufacture and packing since the psocid species in warehouses are not those that cause consumer complaints. In addition, if household infestations were originating from a small number of manufacturing foci, there might be expected to be a far greater uniformity in the population genetics of *L. bostrychophila*. Instead we find considerable variation which is, in the case of enzyme polymorphisms, spatially random. The following hypothesis attempts to pull together the disparate findings mentioned above.

To explain the very considerable variability, either the mutation rate must be very high in *Liposcelis bostrychophila* or this species must has been in the UK for a considerable time, far longer than the 50 years since the early 1940's. Since no changes were recorded in populations kept in the laboratory and monitored over a period of at least 18 months there is no evidence yet to suggest that the mutation rate is particularly high.

It is postulated that its current widespread distribution is the result of a gradual dispersal over many, possibly hundreds, of years. These dispersal mechanisms are unknown but they may be via food movements, on clothes or in baggage. Whatever the dispersal mechanisms, these insects move from place to place very effectively, as was seen in the rapid and dramatic infestations of new houses with strawboard internal walling in the 1980's (Berry, 1988; Turner, 1986; 1994). There may also have been repeated introductions from abroad in food shipments, but a small set of populations from outside the UK, examined by Ali (1994), did not show the same degree of variation as the UK populations.

Since there is no possibility for genetic exchange, mutations are retained within a population as long as they are not deletrious. In recent time there has been a tendency to keep houses far warmer than in the past and food is often kept in cupboards in heated kitchens. Thus the kitchen habitat has become partially isolated from the prevailing temperature patterns outdoors. Size is known to be influenced by temperature and a size/temperature relationship has been demonstrated in free-living psocids (Turner, 1974). In *L. bostrychophila* the size of individuals in a population is genetically controlled since size differences between populations persist when they are cultured in identical conditions. The variation in the size of *L. bostrychophila* in the UK may therefore be a genetic response to a north/south temperature gradient over time. Populations today may either still be being influenced by temperature differences or this size gradient may reflect historical events which occurred when the kitchen climate was closer to the ambient temperatures outside.

Current domestic situations provide a benign environment with few selection forces. Even populations with an apparently low fitness (eg. low egg production and short lifespan) can survive. The only obvious selection force in this situation is the use of insecticides. Synthetic pyrethroids are the insecticides of choice in storage and domestic situations by pest control companies. Since temperature influences population growth of *L. bostrychophila,* it is conceivable that psocid infestation problems (and therefore insecticide usage against them) have been greatest in the south where average temperatures are highest. There is no evidence for this except that there is a north/south gradient of insecticide tolerance to pyrethroids with those in the south having the highest tolerance. If this is the most potent selection force operating on *L. bostrychophila* populations in the UK then we will expect insecticide tolerance in populations to increase northwards, under the continued pressure of pyethroid use.

Which leaves the question, why has there been a trend of increasing numbers of complaints through time? At least some of this pattern is likely to be related to changes in the public attitude to the household environment and their food. The concept of the fitted kitchen with its modern lines and emphasis on cleanliness was introduced around the early 1960's. There is no link between the presence of psocids in food cupboards and the use of fitted units in domestic conditions (Turner and Maude-Roxby, 1989) but a gradual awakening of cleanliness issues would generate a lowered tolerance to insects of all types indoors. More recently the striving for, and the promotion of, perfection in products by supermarkets has further increased the public expectation and with it a further reduction in accepting any form of natural blemish or infestation. Such a change in public perceptions would, in an unquantifiable way, vary the sampling efficiency of using complaint levels as an index of domestic infestations.

The correspondence between the UK and the Danish experiences suggest very similar influences are at work in both countries but whether this is the result of a general european change in attitude towards pests or a genuine proliferation of *L. bostrychophila* in domestic situations is currently not determinable.

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