DFID Post-harvest Fisheries Research Programme

Trainer's Guide to Controlling Blowfly Infestation of Traditionally Processed Fish

Part 1. Information and Guidelines

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ABOUT THIS GUIDEBOOK

This guidebook is derived from Johnson, C. and Esser, J. (2000) A Guide to Controlling Blowfly Infestation of Traditionally Processed Fish, an output of the DFID project 'Adaptation of a Systems Based Approach to Insect Control' (R6824). The content of the current guide has been informed by recent field research to evaluate the effectiveness of a systems-based approach in controlling blowfly infestation and places greater emphasis on the socio-economic context within which traditional fish processing takes place.

The systems-based approach to controlling blowfly infestation fully takes into account the biology of infestation, variations in processing parameters, environmental and socio-economic factors. It is a holistic approach that empowers fish processors to select those control measures that are appropriate to their particular circumstances.

Field trials designed to evaluate the effectiveness of the systems-based approach were conducted at several fish processing sites in the Indian coastal states of Andhra Pradesh and Orissa during 2000 – 2002. The research findings provided strong evidence that the systems-based approach offers a cost-efficient remedy to blowfly infestation that is particularly appropriate to the needs of small-scale fish processors.

The Guide, which is presented in two parts, is designed to equip development workers with the understanding and tools to enable them to provide practical assistance to fish processors who are experiencing losses as a result of blowfly infestation.

The field data collection and production of this guide were very much a team effort, involving researchers based in India and the UK. Members of the project team are:

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Further information on insect infestation of cured fish can be found in Johnson, C. and Esser, J. (2000) *A Review of Insect Infestation of Traditionally Cured Fish in the Tropics.* Department for International Development, London. 92pp. Copies of the Review and this Manual may be obtained from the Post-Harvest Fisheries Research Programme, NR International, Park House, Bradbourne Lane, Aylesford, Kent, ME20 6SN, United Kingdom. Email: ***phf@nrint.co.uk***

Copies of this training guide (Part 1 and 2) may be obtained from Natural Resources International Ltd., Park House, Bradbourne Lane, Aylesford, Kent, ME20 6SN, United Kingdom. Email: ***phf@nrint.co.uk***

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INTRODUCTION

Traditional fish processing is an important livelihood activity for large numbers of poor people in many tropical developing countries. For the poor in fishing communities, fish processing offers an opportunity for income generation that requires relatively low investment. Being a traditional household-level activity, it is relatively easy for poor people to acquire the skills and social approval necessary to take up fish processing. The socio-economic conditions in fishing villages allow processors to enter into a range of relationships with producers, other members of the community and buyers (traders and consumers), thereby facilitating flexibility of operation, financial security and occupational sustainability. The socio-cultural milieu in which traditional fish processing is conducted helps processors to access, virtually free of cost, many services that would otherwise make processing less cost efficient, or even unprofitable. Traditional fish processing is thus an outcome of a sensitive balance and integration between different technical, socio-economic, cultural and environmental factors.

A large majority of people involved in traditional fish processing are women e.g. on the east coast of India, more than 90% of fish processing is done by women. In rural areas, the fisherman's traditional role in the production cycle usually ends when he lands his fish catch on the shore and hands it to his wife or other female members in his family to process. The women, in turn, carry the fish to the processing areas near their houses, and processed them into salted and dried products before selling them in the market and using the income to manage the household. Before ice and transport systems became widely available, traditional fish processing was the main channel through which a household earned its income, and women were the main earners in the household. Even now, despite more fish entering the cold chain, this pattern continues to exist in certain parts of India and elsewhere, particularly in remote villages (Plate 1a).

A significant proportion of women involved in processing come from single, female-headed households, and the income from fish processing and trade is often their only source of income. Being poor, the women use the returns from one cycle of processing and marketing to finance the next. Profit margins are low, and the emphasis is on rapid turnover rather than holding out for higher prices. The prevalence of informal trading systems, involving a large number of intermediaries, together with uncertainty of market prices, fluctuations in product supply, and lack of storage facilities at markets present small-scale processors with risks and uncertainties, which to some extent, justify their preference for short cycle times over higher margins.

Traditionally processed fish includes fish that are salt-dried (Plate 1b), wet-salted, dried without salting, and smoked. Despite a general decline in traditional fish processing over recent years, there remains a strong market demand for traditional fish products, which continues to ensure livelihood and food security for a substantial number of poor dried fish producers and consumers.

Traditional operations may be adversely affected by factors such as monsoon rains, insect infestation, inadequate processing and storage facilities, and limited access to transport. As a result, significant losses occur. Measures taken by processors to reduce losses include using inappropriate insecticides (Plate 1c), processing alternative, lower value products, and passing losses on to the next buyer in the chain by shortening processing times. Such measures have negative implications for both processors and consumers.

Blowfly infestation is a major cause of post-harvest losses of traditionally cured fish in many tropical countries. For small-scale processors, it is a particularly serious problem that threatens livelihood security, and often has far reaching consequences upon socio-economic wellbeing.

With fish supplies becoming increasingly scarce due to depletion of fish catches and increased competition from fresh fish traders, the need for traditional processors to reduce losses and increase added-value is becoming critical.

Recent research conducted in the Indian Coastal States of the Andhra Pradesh and Orissa has demonstrated that by adopting a systematic and participative approach to introducing simple blowfly infestation control measures, development workers can assist fish processors in significantly reducing losses and improving product quality, thereby raising the incomes of processors and increasing food security for poor consumers, many of whom depend on dried fish as their main source of animal protein.

The purpose of this guide is to provide development workers with the information and tools necessary for them to effectively help fish processors reduce losses caused by blowfly infestation. Guidance is also given on improved processing techniques that should result in higher quality, safer and more wholesome, traditionally processed fish products.

Case study 1: The impact of blowfly infestation on small-scale fish processors

Malle Katulamma (aged 60), a small-scale fish processor in India, has been processing fish since her marriage about 40 years ago. Initially, she invested Rs* 100, and used her household utensils to process the fish. An empty space around her thatched hut served as the drying area. Over the last two decades, she has managed to equip herself with the tools of the trade and increase her investment in fish to Rs 2,000[1] . A mother of two sons and a daughter, she found the family becoming increasingly dependent on her fish processing income as her husband was frequently unemployed, and earned very little when he was employed. Her elder son died a year ago, leaving his wife and two daughters in her care. Her second son earns little and continues to be a financial burden, along with her old and ailing husband. Of necessity, her operations have remained subsistence based, and all her processing income goes into managing the household expenses, or paying off unending, long-term debts.

Katulamma buys her fish from the village-landing centre, and pays someone a small amount to carry them to her processing site. Her daughter-in-law and two grand-daughters help with preparing the fish for salting and drying. Depending on the size of the fish, they are gutted and washed before being brined in a vat. Malle covers the vat with a polythene sheet and palmyra leaves, but these give little protection against blowflies, whose larvae (maggots) can be seen crawling across the fish floating in the brine. When many maggots are present, she adds a dose of insecticide to the brine, which kills the maggots, but is potentially dangerous to Malle and her customers. Moreover, in spite of using insecticide, she cannot always reduce losses. In 2001, she suffered a big loss when she had to throw away the bulk of her fish due to infestation – she lost about Rs 1,800, more than 80% of her investment. This was a serious setback to her business and the family suffered badly as a result. There was no other source of income and little money to feed her family of six. Both adults and children made do with one daily meal, consisting of rice gruel and green chillies, for about a year. Katulamma eventually obtained a loan of Rs 2,000 from a trader and recommenced processing. Now, after more than a year, she still owes Rs 1,200 from that loan. Her children went without new clothes for over a year, and the marriage plans for her elder granddaughter have been put off until next year. She says a setback of this kind is a common experience for most small-scale processors. The unlucky ones are forced to close their operations and migrate to other areas in search of work.

Besides large-scale losses like this, the processors regularly lose about 20-30% of their fish through infestation. Masenamma, another processor in the village, invests about Rs 2,000 per processing cycle. Her losses due to infestation over four cycles during the monsoon season in 2001 amounted to an average of 20-30% per cycle. Others reported larger or more frequent losses. Thus, rather ironically, the peak fish-processing period, which occurs during the monsoon season, is also the time when losses are higher and processors incur the largest debts.

Because of fears of infestation, there are times when no processors will buy the large quantities of small pelagic fishes landed by beach-seines in the area. Consequently, the beach-seiners (who are also poor) are forced to dry tonnes of potentially nutritious food on the beach and sell it for a pittance as poultry feed.

* Indian Rupee (at time of publication $US 1 = Rs 48)

[1] This is the average value of the fish that a processor generally processes in a cycle, and is a rough indicator of the scale of her operation, i.e., the amount of money she invests in business. However, depending on availability of fish, many processors buy fish that are worth a lot more than what they actually invest on credit basis, on the understanding that they will pay the fishers after selling the product in the markets. This leads to all kinds of misconceptions and exaggerated claims, perpetuated by the processors themselves, about their financial status.

CHAPTER 1: UNDERSTANDING BLOWFLY INFESTATION OF TRADITIONALLY PROCESSED FISH

1.1 Biology of blowfly infestation

Infestation of traditionally processed cured fish by fly maggots or 'larvae' is a major cause of post- harvest losses. These losses are both physical, due to loss of fish flesh through the feeding activity, and economic, because there is less fish to sell, or because the price of the fish falls due to the damage.

The flies (Diptera), which attack fish, are known as 'blowflies' (Plate 2a). There are many species of blowfly, but those most commonly found infesting fish belong to the family Calliphoridae.

The lifecycle of blowflies (Plate 2b) involves four stages: egg, larva (or maggot), pupa, and adult (fly). The adult female blowfly mates and then finds a suitable material on which to lay her eggs. This is usually dead animal tissue e.g. a carcass, a piece of meat or fish. Some blowflies will lay their eggs on faeces. If they then settle to feed upon food intended for human beings, they may spread diseases such as dysentery or typhoid. These materials are chosen by the female blowfly because they are a good source of food for her offspring. Once a suitable food source has been selected, the female lays her eggs in a large mass; this is called 'oviposition'. Often other females will join her and lay their eggs in the same place so that many thousands of eggs are massed together.

After the eggs have been laid, the female blowflies will leave. The eggs will begin to develop into young larvae. This usually takes between 12 and 24 hours, depending upon the species of blowfly and the air temperature surrounding the eggs. When the larva has developed within the egg, it hatches by breaking the rubbery eggshell and wriggling out. The larva is creamy-white in colour. As the eggs were all laid together, many of the larvae will hatch at around the same time.

The larvae are very vulnerable to drying out or 'desiccation' and to predators at this stage, and so they rapidly burrow into their food. They begin to feed along with other larvae in large groups or "feeding packs" (Plate 2c). Larvae feed by secreting digestive enzymes onto the food. The enzymes begin to break down the structure of the food making it easier for the larvae to ingest. By feeding in packs, each larva benefits from the collective enzymes of all the other larvae. They feed like this for several days.

As they feed, they grow rapidly, increasing in size from approximately 2mm to 8 or 9 mm in length in just 3-5 days. To achieve this rapid growth, the larva sheds its old skin. This skin shedding is called a 'moult' and each period of growth between moults is called an 'instar'. Blowfly larvae have three instar stages, with the first instar larva being the newly hatched larva. The larva reaches its maximum size and weight after it has undergone two moults.

It is then ready to change its body into that of an adult. This process is called "metamorphosis". The larva moves away from its food and finds an area of soft ground in which it can burrow. Here it is safe from predators. Once buried, the larva pupates. Its body contracts until it is short and stumpy in appearance, and the outer skin or 'cuticle' hardens and turns reddish brown in colour. The inside of the larva is broken down by special enzymes into a sort of soup. The body and organs of the adult fly are then constructed by other enzymes. This process can take several days, depending upon the species of blowfly and the temperature of the earth in which the pupa is buried.

When the metamorphosis is complete, the adult fly breaks open the pupal case and crawls up through the earth. It may settle on the surface for several minutes, until its wings have dried, before flying away. The adults are usually sexually mature within approximately 10 days of emerging from the pupal case, and so the cycle is repeated.

Fish is an ideal food source for larvae and traditional methods of curing offer blowflies plenty of opportunities to attack the fish. Infestation occurs through two modes:

- Direct infestation where the larvae feeding upon the fish have hatched from eggs laid upon or adjacent to the fish.
- Indirect infestation where the larvae crawl onto the fish from the ground or another food source.

The two modes of infestation are illustrated in Plate 3a.

1.1.1 Direct Infestation

In direct infestation, adult flies are attracted to the fish both visually, by the large amounts of fish spread out to dry, and chemically, by the odours or 'volatile compounds' released from the fish, which we detect by smell and taste. Plate 3b shows a pile of fish pieces attracting large numbers of blowflies.

The fish is most attractive to the adult blowflies when its moisture content is high. This is probably because the moisture content must be high enough to enable the larvae to feed upon the fish, and because the eggs are more likely to develop if the surface on which they are laid is not too dry. This means that the fish is at most risk from ovipositing female flies during the preparation and salting stages of processing, and the early stages of sun drying. Because of this, small fish, which dry quickly, are not usually attacked after the first day of drying, unless the weather conditions prevent the fish from drying, or cause it to become wet again. Larger fish, which take longer to dry, are at risk of infestation for much longer, in some cases for four or more days of sun-drying. Sometimes, fish may be directly infested during the early period of storage.

Adults usually lay their eggs on the gills, mouth, and the underside of the fish, although egg batches are also seen in the crevices between muscle bands, and in bony cavities in split, beheaded fish (Plate 4a).

These are all sites where the eggs are protected from the weather and are hidden from predators. Upon hatching, the larvae burrow into the flesh and form feeding packs. Once the fish is too dry for the larvae to feed upon, they will leave the fish either to pupate, or to search for another food source. If the fish is not fully dried, the larvae will continue to feed upon the flesh until they are ready to pupate.

1.1.2 Indirect infestation

In indirect infestation, the larvae hatch from eggs laid upon another food source, sometimes another fish. The larvae leave this food, and move onto the fish where they gather to form new feeding packs. They will remain here until either the fish is too dry, or they are ready to pupate. As the larvae cannot move far to search out food, indirect infestation will occur only when the fish are placed in areas where larvae are present. The most common places to find larvae are within fish waste, which has been discarded under processing tables (Plate 4b), or on densely woven drying mats, where they may move between the drying fish (Plate 4c).

1.2 Factors influencing blowfly infestation levels

Some factors, associated either with the processing methods used, or external conditions at the processing site, increase the likelihood of blowflies attacking the fish. This may be because the conditions favour the survival of the eggs or larvae, or because the fish is more attractive to the female blowflies. Such factors simply cause more blowflies to be present at the fish-processing site, which means that more fish will be infested.

The most important of these factors are described below.

1.2.1 Factors associated with the processing methods

Raw Fish Quality

☹ **Processing partially spoiled fish will increase the likelihood that the fish will be attacked by blowflies.**

☺ **If possible, only fresh fish should be processed.**

Fish which are already partially spoiled before processing are much more attractive to blowflies than are fresh fish, which have been held in ice. This is because some of the compounds produced during microbial spoilage act as attractants to blowflies. Amongst these are trimethylamine (TMA), ammonia, and hydrogen sulphide. Many of these compounds are only attractive at low concentrations, and may even repel flies when present at higher concentrations. This may explain why many processors report that fish are most attractive to blowflies when partially spoiled, and cease to be attractive when spoilage is advanced.

Case Study 2: Current systems and practices in Timmapuram, Andhra Pradesh, India

Processors in Timmapuram routinely calculate a loss of 15-20% into each processing cycle. They purchase fish from Visakhapatnam fishing harbour, which is located 25 km from their processing area. To achieve economies of scale, the processors wait until sufficient quantity of raw material has been purchased before hiring a vehicle to transport it to their village. By the time the fish reaches the village, the combined effects of time and temperature result in them becoming spoiled. The smell attracts large numbers of blowflies and losses due to infestation are high. Ten years ago, when the processing site was situated close to the fishing harbour, approximately 80% of the processors produced fish for human consumption. Since the processing site was relocated to Timmapuram, the same proportion of processors now has to sell the fish as low value poultry feed because of spoilage resulting from the delay between fish landing and processing. Even those processors who continue to dry fish for human consumption frequently end up selling their product as poultry feed because of the poor quality of the raw material, which invariably becomes infested yielding a poor quality product. In an attempt to overcome this, the processors have recently begun to carry salt to the fishing harbour itself, where they salt the fish immediately after purchase.

Handling

☹ **Fresh fish, which was previously of good quality and not attractive to blowflies, may quickly become attractive if it is not handled hygienically.**

☺ **Always handle fish hygienically.**

Hygienic handling of the fish is important to ensure that the rate of spoilage is kept to a minimum. Contamination of the flesh with bacteria, which cause spoilage, will increase the rate at which the fish spoils, and so increase the rate at which the compounds attractive to blowflies are produced.

Case Study 3: Improved handling at Uppada, Andhra Pradesh, India

Processors in Uppada buy fish at the local landing centre in small batches, and in the past would wait until sufficient fish had been bought before carrying it to the processing site. At times when landings were slow, earlier batches of fish lost their freshness and became vulnerable to infestation. Nowadays, Appayamma arranges for the fish to be sent to the processing site as soon as she purchases them. At the processing site, her partner, Yellayyamma, begins pre-salting operations (washing, de-scaling, gilling, scoring and gutting) as soon as the fish arrive, unlike previously when she would wait for all fish to be brought to the processing yard before beginning the work. She takes care to conduct all these operations on a plastic sheet (Plate 5a), to keep the fish from coming into direct contact with the soil.

Gutting

- ☹ **Fish processed with their guts in may be highly attractive to blowflies.**
- ☺ **Whenever possible, gut fish prior to processing.**

The guts of fish naturally contain many anaerobic microorganisms. Anaerobic organisms are organisms which can live when oxygen is not present. When the fish die, these organisms will feed upon, and so break down the gut walls and invade other tissues. Again, attractant compounds, in particular TMA, will be products of microbial growth. Fish processed with their guts left in are likely to be more attractive to blowflies than fish which have been gutted immediately after capture.

Beheading/De-gilling

- ☹ **The head, gills and fins of the fish are important egg laying sites for blowflies.**
- ☺ **Whenever possible, remove head, gills and fins of fish.**

Blowflies often choose to lay their eggs in the mouth and gills of the fish, and under the fins (see earlier). If the egg batches remain unnoticed by the processor, the larvae will hatch and form feeding packs within the flesh of the fish. In some countries, fish processors remove the head or gills of the fish (Plate 5b) before sun-drying in order to reduce the risk of the fish becoming infested by blowflies through this route.

Splitting

- ☺ **Medium to large size fish should be split. Care should be taken, however, to split the fish so that the surfaces are smooth, or to smooth the surfaces by hand. This may help to stop blowfly eggs from hatching. If fish are to be de-gilled and gutted but not split, they need to be protected from blowflies during sun-drying with screens or nets.**
- ☺ **Ensure split surfaces are smooth.**
- ☺ **Screen or net gutted, unsplit fish during sun-drying.**

Splitting fish (Plate 5c) increases surface area. This increases the rate at which water can evaporate from the flesh. In salted fish, more salt is in contact with the fish, and so the rate of salt penetration into the flesh increases. If fish dry rapidly, there is less opportunity for blowflies to attack them. However, it seems likely that the way in which fish are split is also likely to be important in influencing whether blowflies will successfully infest them. If the exposed surfaces are rough after splitting, water can become trapped in the crevices. When the blowflies lay their eggs on the split surfaces, this water can help prevent the eggs from drying up in the heat of the sun. In contrast, when the fish are split so that the exposed surfaces are smooth, any eggs that are laid on these surfaces dry very quickly and die.

In some countries, fish may be de-gilled and gutted, but not split. The body cavity provides an ideal environment for blowflies to lay their eggs. The body cavity remains moist for longer than the outer surfaces of the fish, and it is protected from the intense heat of the sun. Fish which are processed in this way are much more likely to become infested than split fish.

Scoring

- ☺ **If it is necessary to score the fish, it is preferable to make slits, which can be held open with sticks. This prevents crevices from being formed in which the blowflies will lay their eggs. Alternatively, sprinkle plenty of salt into the crevices.**
- ☺ **Hold score marks open to stop blowflies laying eggs in the crevices, or apply salt to the crevice.**

Large fish often have slits, or scores, made in the side flesh. This, again, is done to increase the exposed surface area of the fish, in order to increase the rate of water evaporation and salt penetration. However, these slits provide ideal crevices for blowflies to lay their eggs in. The eggs are protected from the sun and wind and the larvae can hatch undisturbed. In some countries, the fish are split longitudinally (from the gills to the tail fin) and the splits are held open with sticks (Plate 6a). This practice also increases the surface area of the fish, but does not provide sites for egg laying.

Case Study 4: Current practice in Paradeep, Orissa, India

Garikina Lakshmi is a small-scale processor in Paradeep. She usually processes small fish whole, whereas medium sized fish are gutted and de-gilled, and large fish are split and scored. Fish are generally washed once before processing begins, but not afterwards, resulting in fish becoming soiled during processing. Fish are generally prepared on the ground, though some processors have begun to use plastic sheets for this purpose. Guts are removed by being pulled through the gill openings, which often results in the gut contents contaminating the body cavity of the fish. The unwashed fish are immediately put into the salting vat after gutting. No care is taken to dispose of the guts properly; they are discarded around the processing area, attracting large numbers of blowflies. Beheading is not generally favoured by the processors because the consumers want to buy their fish whole, and are suspicious of beheaded fish. Some fish are de-gilled, but this is not followed by washing. Larger fish are split, but the knives used are crudely made and are not often sharp enough to make clean cuts, thus leaving jagged edges. Larger fish are scored and large clusters of eggs or packs of larvae feeding on the fish are frequently observed in the scored areas.

Whenever large quantities of fish are bought, it takes a long time to prepare all of them. During this period, both fresh and prepared fish lay alongside each other, often exposed to the sun, providing many opportunities for both direct and indirect infestation to take place. Because the fish are not cleaned after preparation, and the brine in the vats is of low quality, infestation continues. Lakshmi usually loses about 5–10 % of her fish to infestation. Losses may exceed 50% during monsoons.

Case Study 5: Improved fish preparation in Timmapuram, Andhra Pradesh, India

Ganagalla Yerramma is a small-scale fish processor in Timmapuram. In the past, she washed her fish only once, before beginning the processing operations. More recently, she has been washing her fish twice, firstly on arrival at the site and once more before salting (Plate 6b). At times when she finds it difficult to obtain sufficient water for two washes, she prefers to wash the fish after completion of the pre-salting operations i.e. gutting, de-gilling, splitting and scoring, in order to wash off contaminants that affect fish quality and make them attractive to blowflies. She uses a waste disposal basket in which she keeps the fish offal before disposing of it at a distance from the processing area. She uses sharp knives, which not only split the fish more smoothly, but also need less effort on her part. She does not generally buy large fish that require scoring, but when she does, she tries to keep the score marks open. Using these measures, the quality of her fish has improved, as has its marketability.

Pre-salting fermentation

☹ **Pre-fermented fish is highly attractive to female blowflies. As pre-salting fermentation is a necessary part of processing these fish, blowflies will need to be physically excluded from the fish, with screens or by covering the fermenting tanks, if the fish is to be protected.**

☺ **Fit blowfly proof covers to pre-salting fermentation tanks.**

Before salting or sun-drying, some species of fish are fermented in water for several hours, so that desirable flavour compounds can be produced. Some of these compounds are known to be very attractive to female blowflies.

Salting

☹ **If salting is to be used to protect the fish from feeding larvae, salt penetration must be almost complete before the blowflies gain access to the fish. In large or oily fish, this may take several days. A minimum salt content of around 8% wet weight basis (w.w.b.) is needed to prevent newly hatched larvae from infesting the fish, and a concentration above this will be needed to stop older larvae. As older larvae are more salt-tolerant, extra care should be taken to protect the fish from indirect infestation. Salt crystals applied to egg batches may help to kill the eggs or hatching larvae.**

☺ **Salt fish thoroughly until the salt content throughout the flesh is at least 8% w.w.b.**

☺ **Prevent older larvae from infesting fish.**

☺ **Help stop egg batches from hatching by covering them with salt crystals.**

The tolerance of blowfly larvae to salted fish varies according to:

- Species of blowfly
- Geographic location of the fish processing site
- Age of the larva at the time it begins to infest the fish.

In laboratory studies it has been shown that some species of blowfly larvae are more tolerant to salt than others. It is not clear why this should be, but it may be associated with differences in body size, or the ability of the larva to regulate the concentration of salt in its body.

Studies have also shown that larvae from the same species of blowfly, but found in different geographic areas, have different levels of salt-tolerance. It is probable that a blowfly species will become more tolerant to salt if it is continuously exposed to salted fish. This means that any larvae that can feed and survive on highly salted fish are more likely to have offspring that can also survive upon highly salted fish. Those larvae that cannot tolerate the highly salted fish will die and will not breed. In this way, salt-tolerant blowflies are selected for. This shows how important it is to prevent blowflies from infesting fish which are salted below a level that kills the larvae.

Laboratory studies have also shown that older larvae are much more tolerant to salted fish. This is important when fish are infested through indirect infestation. The larvae infesting fish through indirect routes are usually older, as they are more able to survive moving between the fish. These larvae are therefore more tolerant of highly salted fish than are larvae hatching from eggs.

It is not possible to state exactly how much salt is needed to prevent any blowfly larvae from feeding upon the fish. A value of around 8g of salt per 100g of fish on a **wet weight basis** has been suggested, based upon laboratory studies and calculations. This amount should prevent all newly hatched larvae from surviving on the fish. It is likely that more salt would be needed to prevent older larvae from infesting the fish. To be effective, however, the salt must be evenly distributed throughout the fish flesh. The larvae are able to identify any areas where the salt content is low and will choose to feed in these areas. This means that salt penetration must be advanced if the salt is to protect the fish from infestation.

It is not clear whether adult blowflies will lay their eggs on highly salted fish at fish processing sites. Under laboratory conditions, they were willing to lay eggs on heavily salted fish if there was no alternative. However, if there was a choice of salted and unsalted fish, they chose the unsalted fish to lay their eggs upon. This suggests that salting the fish will protect it from blowfly attack if there are unsalted fish being processed at the same time. It may be possible to use unsalted fish as baits to attract the egg-laying blowflies away from the salted fish.

Fish processors sometimes put salt onto egg batches that are laid upon the fish, as they believe it will help to stop the eggs from hatching. How effective this practice is under field conditions is not known, but under laboratory conditions, it appeared to be successful in killing eggs and hatching larvae.

Case Study 6: Current salting practices in Uppada, Andhra Pradesh, India

Kare Nookalamma typically added salt in excess quantities, about 8-10% more than generally required. This represented an added cost to her, which could be reduced by standardising the optimum quantities used. When a team of researchers suggested that she should reduce the quantity of salt, she followed their advice, only to discover that the researchers had based their calculations on laboratory data alone, with the result that her fish were infested by the next day. When the researchers subsequently calculated the costs and benefits of excessive salting, it was discovered that the benefits of increased saltang in terms of reduced infestation risk, far outweighed the cost of the additional salt, particularly during the monsoon season.

However, in three aspects in Kare's salting practice needed improvement:

(a) Repeated use of the same brine over a large number of cycles. This allowed spoilage agents to build up which affected the quality of the fish and made them more attractive to blowflies. Many processors continue using the same brine over long periods, so much so that the brine acquires the texture and colour of mud. Such poor quality brine is often infested with maggots (Plate 6c).

(b) Using large stones to submerge the fish below the brine surface. This invariably results in some fish floating to the surface and being exposed to blowfly attack.

(c) Failing to exclude rainwater from the salting tank. Seepage of rainwater into the tank dilutes the brine concentration, thereby reducing salt penetration into the fish making them more susceptible to infestation.

Case Study 7 : Improved salting practice

Yellayyamma understands that the quality of salting can influence levels of blowfly infestation. She now uses good quality salt for brine preparation, and the brine is used for a maximum of five or six cycles before being thrown away. Whilst she was initially resistant to throwing away the brine after a few cycles, Yellayyamma realises that it pays dividends, and has made it her regular practice.

She now submerges the fish under the brine using a bamboo frame held in place with one or two large (and clean) stones so no fish float to the surface where they may become infested. A wooden lid, modified to better suit her needs, covers the vat entrance. This effectively prevents entry of blowflies and rainwater.

Drying

- ☹ **Fish, which are dried upon the ground, are more likely to be infested than similar fish, which are dried upon raised racks. Where it is not possible to dry the fish off the ground, clean mats or sheeting should always be placed beneath the fish to protect it from indirect infestation, and to prevent the larvae from burrowing into the earth beneath to escape from the heat or to pupate. Drying fish on mats will also prevent the fish from becoming contaminated with additional microorganisms. When drying fish on raised racks, mesh trays should be used if possible to avoid indirect infestation. Fish should not overlap one another.**
- ☺ **Wherever possible, dry fish on raised racks and use mesh trays.**
- ☺ **Always spread fish on a clean mat when drying fish on the ground.**
- ☺ **Never overlap fish during drying.**
- ☺ **Nets or screens will protect fish from blowflies during sun-drying.**

Fish are very susceptible to blowfly infestation during sun-drying. Blowflies are attracted to the large areas of fish spread out to dry, and will lay their eggs upon the fish unless they are protected with screens or mesh. The method of drying used by the processor can, however, influence the amount of infestation suffered.

Fish, which are spread on the ground to dry:

- ☹ **May become indirectly infested with larvae already present on the ground.**
- ☹ **May become contaminated with microorganisms on the ground, unless it is dried upon clean matting or a similar material.**
- ☹ **Will spoil more quickly and so will become more attractive to female blowflies**.
- ☹ **May be infested through both direct and indirect modes.**
- ☹ **Will dry more slowly as only the upper surface of the fish is exposed to the sun and wind.**
- ☹ **Will be attractive to the blowflies for longer, as the moisture content will be high enough to support the feeding larvae.**

Drying fish directly on sand or loose earth is an even greater problem because:

- ☹ **Larvae are able to burrow into the sand or earth when temperatures are high and move back onto the fish again once the temperature begins to fall. Drying fish on sand or loose earth therefore actually helps the larvae to continue infesting the fish.**
- ☹ **Once the larvae are ready to pupate, they will burrow into the sand beneath the drying fish. The adult flies will therefore emerge from the sand in the same area as the fish are dried, and so the cycle of infestation will be repeated.**

Drying the fish upon raised racks:

- ☺ **Improves the rate of drying, as the air can circulate around the fish.**
- ☺ **Reduces the period of time when the moisture content of the fish is high enough to be attractive to blowflies. The fish are still likely to be attacked by female blowflies though until this time.**
- ☺ **Can reduce indirect infestation when a) suitable drying trays are used, and b) fish do not overlap. Trays made of chicken wire or fishing net allow rapid drying and do not provide hiding places for the larvae unlike trays made from split bamboo or woven leaves. When fish overlap one another, larvae can easily move from fish to fish.**

The best way to dry fish is on mesh trays (Plate 7b) placed on raised racks (Plate 7c). The fish should be evenly spaced on the rack and turned over many times during drying.

Case Study 8: Current drying practice in Paradeep, Orissa, India

Koda Poleramma dries her fish on the ground around her house. When fish quantities are low, she spreads the fish on coir or bamboo mats placed on the ground (Plate 7a). When fish quantities exceed the capacity of the mats, she simply dries them on the sand. When there are very good landings of small fish, she dries them on the beach. Invariably, a percentage of the fish dried on the sand are infested by maggots. When the signs of infestation or damage are visible in a large number of fish, the fish buyers pay her a very low price. Even the fish dried on coir mats are affected by infestation because the mat itself provides a safe haven for blowfly larvae. Consequently, whenever she buys large quantities of fish, they will invariably be sold at a low price as poultry feed, because she does not have the capacity to adequately process such quantities. Thus, she buys large quantities of fish only when they are so cheap that even selling as poultry feed is viable.

During the monsoon, it is almost certain that one out of every two cycles of operations will result in product that is fit only for poultry-feed. She tries to cover the fish with a polythene sheet during light showers, but sudden bursts of rain cannot be foreseen and the polythene sheet is useless when it rains continuously because water seeps in from the sides and underneath, wetting the fish and making them more vulnerable to infestation. Also, in order to optimise drying space on the mat, she often places fish closely together, resulting in lower drying rates and increased infestation.

Case Study 9: Improved drying practice in Timmapuram

Garikina Ernamma began using a government constructed cement drying platform in the mid-1980s. The platform initially offered her an opportunity to dry her fish more effectively than drying on the ground, which had been her practice until then. However, the cement platform eventually began to crumble and lose its usefulness. As is generally the case with communally owned infrastructure, there was little effort to maintain it, although all the processors continued to use it.

Garikina found that a raised drying rack, supporting trays on which the fish were placed, was found by Ernamma to be an effective alternative to the concrete platform or drying the fish on the ground. She could personally own the rack; hence its repair and maintenance were under her control. It was also not very expensive to set up and maintain, and could easily be dismantled during periods when not in use. The fish on the rack dried faster because wind could flow over both sides of the fish. She also found that blowfly infestation of fish drying on the racks was much lower than when dried on the ground. Earlier, she would often observe infestation occurring well into the second day of drying, but because the fish on the rack dry faster, she says the opportunities for infestation have halved. Her only concern now is being able to set up sufficient numbers of drying racks to accommodate all her fish, for without access to affordable credit, the investment required is beyond her.

1.2.2 External factors having an influence on infestation

Season

- **Fish processed in the rainy season usually take longer to dry, and are therefore more likely to become infested with blowfly larvae. When fish are to be processed during the rainy season without the use of artificial dryers, blowflies should be excluded from the fish at all times, with the use of screens or netting. Wherever possible, fish should be covered at times of rainfall to reduce the risk of spoilage. Spoiled fish and waste should be removed from the processing site. This will reduce the risk of infestation in the unspoiled fish.**
- **Screens will protect fish from blowflies during the extended drying period.**
- **Always cover fish with waterproof sheeting during rainfall.**
- **Store salted fish carefully to prevent it from regaining moisture.**

During the rainy season, air humidity is high and the fish will take longer to dry. In addition, fish may be rained upon during the drying stage if unprotected. These factors can influence infestation in several ways:

- **The prolonged high moisture content in the fish will mean that it is attractive to the female blowflies for longer. This will increase the risk of direct infestation.**
- **The high moisture content also means that the texture of the fish remains acceptable to the feeding larvae for longer. Infestation by feeding larvae will therefore continue beyond the period normally expected and more of the flesh will be eaten or damaged.**
- **The fish is likely to spoil rapidly under these conditions, particularly if it is rained upon. As has already been discussed, partially spoiled fish is much more attractive to egg-laying blowflies than is fresh fish, and so the fish will be more susceptible to attack.**
- **The high air humidity, and the prolonged presence of free water on the surface of the fish will allow any eggs laid upon the fish to develop without the risk of desiccation. (Eggs are very susceptible to desiccation under conditions of low air humidity). This means that more larvae will hatch successfully and infest the fish.**

It is possible that these factors together will help the blowfly population to increase during the rainy season. Some studies have suggested that blowfly numbers peak just before the heavy rains. This coincides with the time when the air humidity is high and the fish are still being caught and processed in large numbers.

A further problem is that salted fish are 'hygroscopic'. This means that they will take up moisture from the air if the air humidity is higher than the humidity of the salted fish. The humidity of fish which has been salted as much as is possible is 75% (this is the same as a water activity value of 0.75). If the air humidity is greater than 75%, as it is during the rainy season, the fish will regain some moisture from the air until their humidity equals that of the air. In other words, they begin to rehydrate. This means that the salt content of the fish **on a wet weight basis** will decrease. If the salt content becomes less than around 8% w.w.b., the blowfly larvae will be able to feed upon the salted fish again. Fish, which had been salted and dried sufficiently to stop any infestation by blowfly larvae, may therefore be at risk again from infestation.

Environmental conditions

- ☹ **Fish is commonly infested whilst drying. Fish should be turned regularly during drying so that a uniform temperature can be maintained throughout the flesh of the fish. At high enough temperatures, this will help to deter feeding larvae, and destroy developing eggs.**
- ☺ **Fish should be protected from blowflies, with screens or nets, when processed during times of high air humidity. When the air humidity is low, fish should be dried in the shade to reduce the risk of case hardening.**
- ☺ **It may be possible to reduce the risk of infestation by only placing the fish out to dry at times when the blowfly activity is low, or by temporarily covering the fish when blowfly activity is high.**
- ☺ **Turn fish regularly to maintain a high temperature on both sides.**
- ☺ **Screen or net fish during drying if air humidity is high.**
- ☺ **Only dry fish at times of low blowfly activity.**

Environmental conditions, such as air temperature, temperature of the fish, relative humidity and sunlight intensity or 'lux', can affect levels of blowfly infestation suffered.

Temperatures of around 45^{0}C and above are lethal to blowfly adults, larvae and eggs. Fish which are dried in artificial dryers or under polythene covers, are therefore unlikely to become infested during drying. Unfortunately, at temperatures of around 50^{0}C, the texture of the fish flesh is irreversibly changed. In other words, the fish is partially cooked. This is usually unacceptable to the processor and consumer and so using very high temperatures to control infestation can be difficult, unless the temperature can be very well controlled. Fish, which are being sun-dried, should be turned many times during drying to expose any larvae and eggs to the heat of the sun.

The importance of high air humidity has been discussed above (see Season). However, if the air humidity is very low, or if the air temperature is very high, the fish may be susceptible to indirect infestation. This is because of 'case hardening'. The low air humidity and high air temperature mean that water is evaporated from the outer tissues of the fish very quickly. The water-soluble components or 'solutes' in the cells of the fish are dragged to the surface cells of the fish by the water which is moving to the surface in order to evaporate. As the solutes cannot leave the tissues by evaporating, they form a layer at the surface, which quickly hardens. This layer stops any more water from reaching the surface of the fish from where it can evaporate. In this way, water becomes trapped in the deeper tissues of the fish.

In fish, which are casehardened, the moisture content of the processed fish is still high enough to support feeding larvae. Larvae may therefore infest the fish during storage.

Adult blowflies are usually most active in the early morning and late afternoon. These times correspond to the coolest times of the day, when the sun is at its least intense. During the middle of the day, when the sun is at its strongest and hottest, blowflies are often found sheltering in buildings or amongst vegetation. Where this pattern of activity occurs, infestation of the fish may be reduced if the fish are placed out to dry slightly later in the morning and brought back in slightly earlier in the afternoon. This will avoid the fish being exposed to the blowflies at the time of greatest activity.

1.2.3 Hygiene standards at processing sites

Allowing fish waste and other refuse to accumulate at processing sites increases the chances of the fish becoming infested with blowflies. The number of blowflies at the site will increase because blowflies are attracted into dirty sites, and will breed in the waste.

Fish may suffer indirect infestation as larvae feeding in the waste may move onto the fish. Processing sites should be kept free of fish waste and other waste at all times. Fish waste should be collected up and disposed of away from the processing area. Ways of dealing with fish waste produced by small-scale sites include burial, drying for fish meal or disposal at sea.

Dispose of all fish and other waste away from the processing area.

The hygiene practices followed at fish processing sites are important in influencing the level of blowfly infestation occurring in the fish. Where processors follow good hygiene practices, and dispose of fish waste away from the processing area, the number of blowflies present at the site is normally very low. In contrast, at sites where fish waste (and in some cases household and human waste) is allowed to accumulate, blowflies are attracted into the area and lay their eggs upon the waste. The larvae which hatch from these eggs can feed upon the waste and eventually pupate in the ground where the waste has been discarded. In this way, the blowfly population at the site remains large, and can even increase. A further problem is that the larvae are able to move from the waste to any fish that may be stacked on the ground near the waste. The fish will then become infested through indirect infestation. Finally, as the presence of the fish waste attracts blowflies to the site, adult females will also lay their eggs on any fish, which are unprotected, and so the fish will become infested through direct infestation.

1.2.4 Socio-economic conditions

Despite many processors understanding the negative impacts of blowfly infestation and being aware of simple ways of reducing it, other than using insecticides, few take steps to control the problem. The failure of processors to adopt other remedial measures may be due to lack of technical knowledge or could be a considered response to the socio-economic environment within which they operate. If control measures are to be successfully introduced it is essential that any socio-economic constraints to their implementation are fully understood and taken into account. This section examines the socio-economic conditions which facilitate or handicap the introduction of improved technology.

The most immediate consideration is the costs and revenues associated with improved techniques. The revenues are associated with the quantity and price of the product sold. If there is any blowfly infestation there will be a loss of quantity during processing, so reducing infestation is certain to result in a gain in the quantity of the product. The average price per unit weight at which the fish is sold is also likely to be higher since there will be less low quality and more high quality product in the total output. This depends on the premium that consumers place on good quality fish. The purchasing