CHAPTER 5.3.

MANAGEMENT OF AREA-WIDE PEST MANAGEMENT PROGRAMMES THAT INTEGRATE THE STERILE INSECT TECHNIQUE

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TABLE OF CONTENTS

1. INTRODUCTION	782
2. FEASIBILITY ASSESSMENT	783
3. PROGRAMME PLANNING	783
4. MANAGEMENT STRUCTURE	784
4.1. Government Management	785
4.2. Private Management	786
5. OPERATIONAL FLEXIBILITY AND INDEPENDENCE	787
6. PROGRAMME STAFF	789
6.1. Training	793
6.2. Risks	794
7. PROGRAMME MANAGER	795

Pages 781–814

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8. FINANCIAL SUPPORT	796
8.1. <i>Financial Support from Various Levels of Government and/or Private Sources</i>	796
8.2. <i>Financial Support from Donors and Foreign-Aid Programmes</i>	799
9. MANAGING FINANCES	800
10. LOGISTICAL AND PHYSICAL SUPPORT	801
11. EXPORTING/IMPORTING STERILE INSECTS	802
12. PROGRAMME EVALUATIONS AND INDEPENDENT ASSESSMENTS	806
13. PROGRAMME SUCCESS OR FAILURE	806
14. ACKNOWLEDGEMENTS	808
15. REFERENCES	808

SUMMARY

Effective management of area-wide integrated pest management (AW-IPM) programmes that integrate the sterile insect technique (SIT) is key to their success. Programme planning includes collection of baseline data and technical and financial feasibility assessments. Programmes should be initiated only if there is strong stakeholder support and political long-term commitment. The optimal management structure permits the programme to be implemented effectively and flexibly, as independent as possible of government politics and routine bureaucracy that can impede timely goal achievement. At the same time, high-level oversight is required to avoid corruption and to benefit from expert committees that provide independent technical advice. Ideally, programmes include a mixture of public management and the outsourcing of some routine tasks to private management. They require strong and steady financial support. Governments and donors are the most common sources of funds, but a mixture of public, community, and private funds is now the trend. Interrupted cash flow severely restrains programme performance. Physical support of programme infrastructure and operations must be reliable, and led by a maintenance professional. It is essential to have full-time, well-paid, and motivated staff led by a programme manager with technical and management experience. Poor management and inadequate support often result in programme failure.

1. INTRODUCTION

Even though the technical elements of area-wide integrated pest management (AW-IPM) programmes that include the sterile insect technique (SIT) are critical to their success, the management components are of equal importance. However, more emphasis is usually placed on getting the “science right” than getting the “management right”. Failure of an area-wide programme is usually due to poor management and inadequate support and not to how well the scientific technology is implemented.

Management is important for AW-IPM programmes with an SIT component because, firstly, these programmes affect large segments of the community, as do other more generally accepted area-wide activities such as police protection, electricity supply, or other services, where virtually everyone within the concerned area is involved (Knippling 1980; Lindquist 2001; Hendrichs et al. 2007; Klassen and Vreysen, this volume). This necessarily involves public financing, public accountability, legislation, enforcement, community participation, substantial infrastructure and organization, long-term support, and high levels of managerial skill. Secondly, as the SIT requires the successful handling of live insects, which have a very short “shelf life”, as well as a number of other activities that need to be carried out in a defined time and space sequence, flexibility and high levels of technical responsibility to conduct and coordinate operations effectively and in a timely manner are essential.

Reyes et al. (1988) described the general organization and structure of an AW-IPM campaign involving the use of the SIT. This chapter discusses generic aspects of programme management and its impact on programme success or failure.

2. FEASIBILITY ASSESSMENT

Technical and economic feasibility assessments are essential, e.g. DeBiasio (1988) on the codling moth *Cydia pomonella* (L.). They address financial issues such as funding and budgets (costs and benefits) (Rhode 1975; Mumford, this volume), expected benefits other than financial, the biological and practical feasibility of achieving the goal of pest suppression or eradication (Rhode 1970), details of the proposed organization and administration, and activities needed to conduct the programme. Also, the pest situation, current control methods, impact of the pest on agriculture, the environment and human health, and the complexity of the human, biological and physical environments must be assessed. An assessment of the political and fiscal stability of a country, government priorities, governance, public and programme security, social and economic values, and economic development all impact on how feasible it would be to conduct an AW-IPM programme that applies the SIT.

The baseline data needed for a feasibility assessment are: (1) data on the area and commodities (for domestic consumption or export) or livestock/human population to protect, (2) data on population ecology, dynamics, and distribution of the insect pest in the proposed area using geo-referenced data, and an assessment of potential immigration of the insect into the area, (3) assessment of the pest problem (Tween 1993) — losses, both direct and indirect, caused by the pest, and the impact of the pest on human health, agriculture and the economy, (4) cost and effectiveness of current pest control methods, and their disadvantages, and (5) impact of the pest and of current control methods on the environment (Tween 1993; Vreysen et al. 1999; Nagel and Peveling, this volume; Vreysen, this volume). Decision-support tools, such as geographic information systems (GIS), remote sensing (RS), population genetics (Krafsur and Ouma, this volume), and mathematical modelling (Bouyer et al. 2010; Barclay, this volume; Bouyer et al., this volume) can greatly assist in feasibility assessment and planning of these programmes.

3. PROGRAMME PLANNING

A programme can be planned properly only if the baseline data are available, and all required feasibility assessments have been carried out.

If such assessments show that a programme is technically feasible, economically viable, and socio-politically acceptable, detailed plans can then be made and incorporated into a programme document or business plan (FAO/IAEA 2008). Such a document provides details of programme strategy, milestones, operational procedures (including standard operational procedures (SOPs)), budgets, plan for public relations activities, and management policies and procedures.

A legal agreement between the programme organization and commercial farmer associations, other stakeholder groups, and local and regional authorities, may be needed (Lindquist 2000). This agreement would describe responsibilities and authorities of all parties, in terms of financial and in-kind contributions, monitoring activities, the required level of pre-release suppression, sterile insect quality, expected insect deliveries, identification and handling protocols, expected degree of insect control, penalties for lack of compliance or poor results, and insurance coverage (Nelson et al. 2021).

Unfortunately, there is a tendency to begin implementation before planning is complete (Vreysen et al. 2000; Itô et al., this volume). A premature start can easily cause the programme to fail, or at least perform poorly, leading to discouragement, and possibly to abandonment of the programme. All components of the programme must be ready and harmonized, including a carefully selected and properly trained staff, before operations can begin. Sometimes programmes can begin on a pilot scale, to provide hands-on training for staff and to test all components, or start with areas in which success can be more easily achieved, and then move on to larger or more difficult areas. The lessons learned in the pilot programme are useful in making plans for the large-scale programme, and in any case flexibility (Norton 1986) is always needed as programmes proceed. In cases where a pest emergency occurs, such as an invasion or introduction of a new pest (Patton 1984; Hendrichs, Enkerlin et al., this volume), a rapid response is essential and proper planning is usually not done, and ad hoc procedures have to be adopted with the attendant high risk of failure. However, in spite of the crisis of the New World screwworm *Cochliomyia hominivorax* (Coquerel) invasion into Libya, the appropriate time was still taken to develop a plan of action for an AW-IPM programme (Lindquist et al. 1992).

If programmes are aimed at eradication, especially of pests that attack export crops, plans to continue the appropriate activities indefinitely, e.g. pest monitoring, quarantine, and contingency plans and readiness to re-eradicate outbreaks if needed, should be included (Krafsur et al. 1987; Reyes et al. 1988; Lindquist et al. 1992; Barclay et al., this volume; Hendrichs, Vreysen et al., this volume; Vreysen, this volume).

4. MANAGEMENT STRUCTURE

AW-IPM programmes tend to be large in size, complex, comprehensive, flexible, dynamic, intense, and demanding, and are relatively long-term. They require multidisciplinary teams of technically knowledgeable people with special skills to integrate different control methods, an organization involving whole communities and thus needing public and political support at many levels, and significant facilities and equipment. It is a real challenge to conduct such programmes, and both public and private sectors of society need to be educated and encouraged to play their essential roles in the programmes (Dyck, Regidor Fernández et al., this volume; Enkerlin, this volume).

AW-IPM programmes cannot be conducted by individual beneficiaries such as a farmer on a single farm or one individual in a community. Instead, an organized

group, in the area defined by the distribution of the pest population, must be formed that coordinates the implementation of harmonized activities on an area-wide basis (Tweddle 2002; Vreysen et al. 2007; Klassen and Vreysen, this volume). Therefore, it is essential that coordination among all stakeholders is effective, and that tasks and procedures are well described and clear responsibilities shown.

4.1. Government Management

Traditionally, SIT-related programmes have been managed “top-down”, where the planning and directing is done by hired programme managers, usually government employees such as was the case in the melon fly *Zeugodacus cucurbitae* (Coquillett) programme in Japan (Yamagishi et al. 1993), where national and prefectural technical specialists directed the activities. The eradication programme for the New World screwworm in Libya (FAO 1992) was strongly supported by the national government and international donors, and managed by a team of international technical specialists and their Libyan counterparts. Strong support for a programme from its stakeholders is essential for its success (Hendrichs 1986).

A government-led programme has the advantage of political, social, and legal authority in the programme area, and therefore persons in the public sector appropriately may be programme staff members. This may involve provincial and/or federal laws which can authorize the appropriate office and personnel to direct the programme, and also provide a revenue source and budget. For example, in Mendoza, Argentina, the provincial law number 6333 (1995) determines responsibility for plant and animal protection. A self-governing institute, ISCAMen, was created to deal especially with the Mediterranean fruit fly *Ceratitis capitata* (Wiedemann). Each year ISCAMen receives a budget provided by law through the Provincial Congress; its economic independence permits funds to be dispersed without diversions elsewhere and enable it to fulfil its legal commitments.

Political independence and power in the hands of a few managers, even though usually an advantage for an action programme where some flexibility in decision-making is essential and operations are time-critical, can nevertheless under certain conditions become a disadvantage. Empowerment of people can become a real detriment to success if the programme then becomes burdened by political concerns and vested interests. Those not accustomed to having access to large amounts of money and authority may be tempted to use it unwisely, jeopardizing the programme. Therefore, empowerment needs to be accompanied by some oversight regime and should not be granted unilaterally, but only after individuals and groups have demonstrated the ability to manage resources in the best interests of the programme.

However, AW-IPM programmes almost always require both “top-down” and “bottom-up” elements for effective management. The local community and direct clients can influence the programme from the “bottom-up”, such as the initiative shown by ranchers in the USA to get screwworm flies eradicated (Baumhover 2001), and by fruit growers in Canada to study the feasibility of a sterile insect release programme for the codling moth (Dyck et al. 1993). Community participation, at some level, is also essential to obtain the cooperation of farmers

(and sometimes the community at large) for pest suppression activities prior to the release of sterile insects, pest monitoring, quarantine, and publicity. Where pest suppression has to be carried out in residential areas, e.g. in the case of *Aedes* spp. mosquitoes, the active participation of homeowners is essential. When an outbreak of the New World screwworm was discovered in the Florida Keys, the travelling public was required to stop at roadside checkpoints to permit pets to be inspected in case they were infected (Robles 2016; USDA/APHIS 2017).

Nevertheless, the area-wide nature of programmes, and the technical activities of sterile insect production and release, almost always need a centralized organization led by experienced and knowledgeable managers. For transboundary programmes involving more than one country (where the pest distribution range includes areas in two or more adjacent countries), a multinational or international organization is required to coordinate the activities (FAO 1992). Such an organization may introduce cost savings that are not feasible if there is only a national programme, and a regional approach to pest control often has technical benefits (Enkerlin et al., 2017). Selection of a management structure for a programme must be made carefully since, once it has started, it will probably be impossible to change it.

4.2. Private Management

Ideally, AW-IPM programmes include a mix of public and private management, but the balance depends on the local situation, and each case is different. Private companies are often cost-effective and dependable for routine tasks, e.g. maintenance and security of a rearing facility, purchase of materials, insecticide applications, aerial release of insects, and research contracts, but supervision of any out-sourced activity is essential to maintain the quality of the programme (Barnes 2007; Bassi et al. 2007; T. Matsuyama, personal communication). However, the final cost to the community may be high if there is not enough competition among companies, and private firms may take a large profit. In Mexico, an international institute contracts with the government to provide administrative services (with an 8% overhead charge) in the *Anastrepha* spp. rearing facility, resulting in an efficient work force and no labour union conflicts. In Argentina, a public-private foundation, hired by ISCAMen, provides contracts to personnel for the programme.

Another option is for a private firm to manage a programme, especially a permanent suppression programme, and where there is a continuous demand for sterile insects. A private company in The Netherlands (de Groene Vlieg Bio Control b. v.) (DGVBC 2018) produces and releases sterile *Delia antiqua* (Meigen) flies as a suppression pest control method for onion growers who request this; these growers pay for the monitoring and release of sterile flies on their fields (Loosjes 2000; DGVBC 2018). This programme now covers about 40% of the onion production area in The Netherlands (M. Loosjes, personal communication). In South Africa, FruitFly Africa (Pty) Ltd. handles insect rearing, sterile fly distribution to release areas, coordination of aerial baiting, and technical support for a Mediterranean fruit fly suppression programme (Barnes et al. 2015; Barnes 2016), and another company, Xsit (Pty) Ltd., was created to produce and release sterile false codling moths *Thaumatotibia leucotreta* (Meyrick) (Hofmeyr et al. 2015). A private company

established to produce and release sterile codling moths in South Africa operated on a pilot scale for several years, but closed down in 2014 (Barnes et al. 2015).

Interest is increasing for private companies to supply sterile Mediterranean fruit flies in Israel and Croatia (FAO/IAEA 2012a; Bio-Fly 2018), and tsetse flies *Glossina* spp. in Slovakia. The risks of a business based on biology, and of matching correctly the demand for, and production of, sterile insects, are a significant challenge for private business (Barnes 2007; Bassi et al. 2007). Production contracts must specify the required quality of the insects. Nevertheless, commercialization of sterile insect production, with the potential cost reductions (as already shown by successful companies producing biological control agents), is likely to become increasingly common (Quinlan and Enkerlin 2003; FAO/IAEA 2008). Companies involved in the SIT strengthen the local economy because they produce value-added products and create jobs (Hofmeyr et al. 2015). However, the area-wide nature of SIT field operations, with the consequent involvement of various stakeholders and the public, complicates privatization of these activities. To attract private investors, the industry supporting an AW-IPM programme must be robust and strong.

If insect rearing and field operations are managed by two or more different organizations, it is important that misunderstandings and poor coordination between them do not develop. A lack of coordination would be awkward at best, and disastrous at worst, for a programme. One organization with all programme components is the easiest to manage — the programme manager has authority over, and can coordinate, all components. However, when this is not the case — such as a programme that purchases sterile insects from another, possibly distant, organization, and a third one is contracted to release them (Quinlan and Enkerlin 2003; Cayol et al. 2004; Enkerlin and Quinlan 2004; Dowell et al., this volume) — ways must be found to ensure strong cooperation between the organizations. If a programme is implemented by more than one agency in a joint undertaking, the roles of each agency must be clearly defined. To maximize effectiveness and efficiency, it is essential that the authority for day-to-day operations be held by the executing organization (Rhode 1969).

Corruption can be a significant problem for programme managers, and AW-IPM programmes with large budgets, such as those that use the SIT, are especially vulnerable to it. Examples of corruption are: (1) diversion of funds and materials for personal use or for other units of government, (2) personal use of equipment such as vehicles, and (3) personal or political favouritism or nepotism in selecting or rewarding staff, and in selecting (or obtaining kickbacks from) suppliers or companies providing services. Paying bribes, e.g. to customs personnel, cannot be done officially, but sometimes for the sake of programme efficiency it is possible to reward cooperators in a culturally acceptable way. Political disturbances and civil unrest are also a threat to programme operations (Rhode 1969).

5. OPERATIONAL FLEXIBILITY AND INDEPENDENCE

Due to the rather unique challenges of managing an AW-IPM programme, there will almost always be better results if the organization is politically and financially autonomous, and independent of the usual government bureaucracies, and politics,

and sometimes corruption, that reduce efficiency and block progress (Hendrichs 1986; Box 1). Insufficient operational independence, and the burden of stifling administrative restrictions, can cause programme failure.

Box 1. Tsetse Eradication Programme in the Niayes Region of Senegal (Vreysen et al. 2021)

The programme adopted an “adaptive management” approach (which included monthly project coordination meetings with the various stakeholders, including researchers) that, as stated in EXPO 2015 (2015), ensured transparency and decision-making by consensus. Decisions were based on scientific (not political, personal or emotional) principles, and were guided by analysed field or other data. Day-to-day operational and financial problems were openly discussed and solutions found. Any decision that required follow-up action by the different actors was immediately implemented according to project plans. The collaboration between internal stakeholders and international partners, and a policy of “non-interference” by government ministries, enabled a smooth implementation of the programme.

Operational independence, with a focused and goal-directed agenda, can produce stability and remarkable achievements. The melon fly programme in Japan was conducted through a special organization, the Okinawa Prefectural Fruit Fly Eradication Project Office. This office was independent, like a trust, and had considerable flexibility and freedom to conduct operations and follow procedures conducive to programme success. The prefecture also provided administrative support. The Mexico–United States Commission for the Eradication of the Screwworm, established in 1972 for the AW-IPM programme on screwworm flies (Krafsur et al. 1987; Vargas-Terán 1991; Wyss 2000; Baumhover 2001), represented such an independent but legal body that had the authority but also the flexibility to “get the job done” effectively and efficiently. This commission, or its current follow-up, the Panama–United States Commission for the Eradication and Prevention of the Screwworm (COPEG), was exempt from the usual bureaucratic rules, and decentralized from government with an independent management, with its own regulations, accountability, and financial audits (Tweddle 2002). Another example is the Programa Moscamed, which implements a trinational (Guatemala/Mexico/USA) Mediterranean fruit fly programme (Enkerlin et al. 2017). The eradication programme for the New World screwworm in Libya (FAO 1991, 1992; Lindquist et al. 1992) was operated under a specially created organization, Screwworm Emergency Centre for North Africa (SECNA), which had the required independence and authority to achieve its objectives. The same is true for programmes operated by ISCAMen in Argentina – Mediterranean fruit fly, codling moth, European grapevine moth *Lobesia botrana* (Denis and Schiffermüller), and other species (section 4.1.).

On-site programme managers have not only the responsibility to make a programme successful, but also require the authority to make management decisions in a timely manner so that the programme can achieve its goals. This should include authority to dismiss an employee for unproductive or disruptive performance (Rhode 1969).

6. PROGRAMME STAFF

An adequate number of qualified, competent, responsible, goal-oriented, motivated, dedicated, and hard-working staff members, having a high level of performance and morale, are essential to programme success (Lorraine and Meltsner 1987). Employees must have “can do” and “do it today, not tomorrow” attitudes. Staff recruitment should be done well in advance of the time when employees will be needed.

Staff, especially the managers, ideally must be full-time workers to encourage a high level of commitment and provide strong leadership, preventing other interests or responsibilities from diverting attention away from the programme (Hendrichs 1986). In the past, some programmes have suffered greatly because the leading professional staff could not spend the required time on the programme due to other duties or insufficient government salaries (Box 2). In the programme in Senegal (Box 1), project staffing (managers and technical personnel) was stable, with little turnover in 12 years. This created a staffing culture of reliability, transparency, and trust, ensuring the necessary institutional memory (Vreysen et al. 2021). To prevent the loss of accumulated knowledge about programme operations, competent staff must be encouraged to remain in the job and not be subject to staff rotation for bureaucratic reasons.

It is important to provide incentives for staff to maximize job commitment and continuity, and to improve their performance on the job. For example, higher than normal salaries, or special incentive pay based on performance, can be given to prevent staff taking on competing extra jobs to earn more money. High salaries also attract the best workers and discourage resignations to take more lucrative positions elsewhere. Staff members taking higher risks than usual, such as persons supervising the release of sterile insects from aircraft, should receive appropriate compensation and life insurance coverage. If the organization is unique or independent of government, promotion and the accumulation of pension benefits may not have much relevance to employees of the programme, and therefore a high salary is justifiable.

Job security and opportunities for promotion help to maintain job satisfaction. To make workers feel comfortable and able to concentrate on their tasks, safe practices in the work environment should always be a priority. It is vital that there be a high level of *esprit de corps*, using various forms of recognition and reward for good performance to encourage employees and make them feel proud to be a part of the programme; a positive work environment also discourages thoughts of sabotage. A biological programme has a high degree of dependence on the good performance of the programme’s workers; sloppy work from one employee can negatively impact the whole programme.

The appropriate expertise needed for all of the various operations must be available among the programme staff, not only biological and scientific but also engineering and managerial expertise. This is especially true of the management of insect production (Fisher 1984; Leppla 1984; Schwalbe and Forrester 1984; Fisher 2009). If the appropriate persons needed to operate a programme are not available, it

is better not to start than to start and fail. Incompetent management leads to programme failure.

Box 2. New World Screwworm Eradication Programme in Jamaica — Lessons Learned (Vreysen et al. 2007)

The programme began releasing sterile flies in 1999, but by mid-2004 little progress had been made. A special management configuration, which could operate independently of existing inflexible regulations of the government, was never established. Instead, the programme was embedded in existing government structures, and senior staff continued with their normal animal health responsibilities. It was technically and financially supported by several “outside” stakeholders. The Government of Jamaica purchased the sterile flies from the Mexico-US Commission that, at that time, operated the only screwworm mass-rearing facility in the world (located in Tuxtla Gutiérrez, Mexico).

The programme was implemented on the premise that the screwworm SIT technology was infallible. Consequently, emphasis was placed on operational procedures rather than on strategic considerations that took local conditions into account. Most of the problems encountered in the programme were not related to the SIT technology *per se*, but were due to a reluctance to address problems in a scientific way. Although there were many factors that contributed to the lack of programme progress, the following were the most significant:

- The importance of collecting appropriate and sufficient baseline data on screwworm population ecology and dynamics prior to the initiation of sterile insect releases was not recognized. Sterile insects were dispersed using long-established protocols (which proved their usefulness in other countries under different environmental conditions) that did not take into account the distribution, and spatial and temporal fluctuations in density, of the local screwworm population. Consequently, the density of the screwworm population was greatly underestimated, and insufficient attention was given to adequate population suppression prior to and during the releases. The programme adhered to a dogmatic belief in the “supremacy” of the sterile flies, and ignored an important lesson from history, i.e. screwworm SIT cannot succeed without efficient field operations that continuously suppress the native fly population.
- Appropriate field data to monitor programme progress (Vreysen, this volume) were not collected. Evaluation of the programme was based solely on the number of reported positive screwworm cases, a very crude parameter influenced more by the willingness of farmers to collaborate and submit samples than by the effect of sterile flies. No attempts were made to systematically collect information on mating frequencies between sterile male and wild female flies. It was always assumed that the released sterile insects would perform adequately, and any potential inferior competitiveness was not considered. Many decisions were based on assumptions, the underlying causes of the lack of progress were never identified, the real problems were never rectified, and the programme was allowed to “drift along” for several years.
- Privatization of the veterinary services created a conflict of interest for veterinarians working for the screwworm programme. The more animals they treated against screwworms, the more money they received; this discouraged the veterinarians from working towards screwworm eradication.
- AW-IPM programmes that integrate the SIT are inherently complex, and require flexibility to react swiftly to changing pest population distributions and densities, and to solve emerging problems. A flexible and proactive management style is required to ensure continuity in the implementation of all important programme components. Any interruption in a critical component will automatically result in severe setbacks. This is especially true in programmes against the New World screwworm fly (which has a very short life cycle — 21 days in optimal conditions). Fig. 1 shows that, for the Jamaica programme in 2003, optimal implementation conditions, i.e. continuity in all important components, were achieved only 52% of the time (during 27 of 52 weeks). Although some of the problems such as the interruption in the dispersal of sterile flies, or the accidental release of fertile flies, were beyond the control of the programme, the malfunctioning of the chilled fly unit (which reduced both fly quality and the number of sterile flies released), and the interruption in the employment of all or at least some temporary field inspectors, could have been avoided.

Box 2. Continued

- The lack of an independent centralized management structure, with the responsibility, authority and flexibility to implement all programme components, was a major constraint and at the core of many persistent problems:
 - o Programme staff members were usually civil servants, and especially the senior persons were assigned many other duties and responsibilities outside of the screwworm programme. The complex nature of AW-IPM programmes demands the full commitment and complete dedication of senior staff, and the many diversions caused by the other duties were detrimental to the programme.
 - o Due to the absence of locally available SIT-related expertise at the onset of the programme, expert advice had to be provided continuously by internationally recruited technical advisors. However, these scientists were authorized only to give advice and thus could not play a significant role in programme decision-making. Many management decisions were unduly influenced by political concerns instead of scientific principles and field data.
 - o Government regulations, that imposed severe restrictions on programme implementation, had to be followed, e.g. the programme could not employ temporary field staff according to the changing needs of the programme over time.
 - o Some critical components of the programme were beyond the control of the managers. For example, there was only one source of sterile screwworm flies, the screwworm production facility in Mexico. Delivery of sterile insects to Jamaica was interrupted twice due to labour unrest at the facility. The second interruption (in 2001) lasted for 38 days, a time equal to almost two screwworm generations, and as a result all progress made earlier was lost. Another catastrophe occurred in January 2003 when, due to a malfunctioning irradiator at the production facility (Merrell 2003), a batch of at least 400 000 fertile insects (potentially 200 000 fertile female flies) was delivered to Jamaica. The upsurge in screwworm cases after this incident is hardly surprising in view of the very large potential for female screwworm flies to proliferate (each fertile female can, in her lifetime, produce several egg masses, each with up to 400 eggs). A third disaster occurred when a hurricane passed through the area, causing damage to the fly release facility and interrupting sterile fly releases.
- The importance of culturally determined factors, such as the attitude of the public and farmers towards animals, was severely underestimated. The rough handling of pets and livestock, creating small wounds (and oviposition sites for flies), generated ideal and persistent opportunities for the fly population to sustain itself. Obviously, the public education activities were not enough to change this attitude. This problem could have been circumvented by not relying on farmer participation, but instead employing more permanent or temporary field staff to proactively screen animals and treat both infested and uninfested wounds with insecticide; government regulations and a tight budget prevented such actions.
- The programme was impaired by having too many stakeholders, each with a slightly different interest and agenda. Often the result was political and diplomatic dithering rather than firm and focussed decision-making. As a consequence, an attitude of “getting the job done”, a prerequisite for programme success, was never developed.

If there is a conflict of interest, such as between insect production and field work, or between insect production and quality control, the lines of authority must permit staff to report their results to managers who will not be biased, e.g. product quality control activities should be done by an organizational unit that is not responsible for sterile insect production (FAO/IAEA/USDA 2019; Parker, Mamai et al., this volume; Parker, Vreysen et al., this volume).

In addition to producing a quality product, applying quality management practices in field operations, releases and administration, based on the implementation and certification of standards from the ISO (International Organization for Standardization), ensure the best and systematic procedures

without using subjective standards. Therefore, written procedures for all strategic steps in the various processes should be followed, e.g. field operations, mass-rearing, sterile insect release, etc.

Figure 1. Diagram showing, during one year, the weeks with suboptimal and with optimal implementation of the sterile fly releases and field activities in the New World screwworm programme in Jamaica.

Labour-management relations must be kept positive to maintain staff morale (H. Hofmeyr, personal communication). Refusal to accede to union demands can lead to strikes or work sabotage, while capitulation results in the programme becoming a hostage and subject to blackmail. A labour strike, and the consequent failure to operate a biologically robust programme, can severely retard and even jeopardize the programme's success. Labour strikes at the New World screwworm production plant in Tuxtla Gutiérrez, Mexico, caused delays in the progress of the Jamaican screwworm eradication programme because it depended on this sole source of sterile screwworms (Box 2).

Especially if staff motivation is low, negative personal habits, attitudes, and values, and even local customs, can create significant problems. If not taken into account and creative solutions found, holidays, religious practices, personal behaviour patterns and conflict among staff members can reduce programme efficiency, and lead to programme losses. Rearing and handling sterile insects is a

24-hours-per-day and 365-days-per-year job. In ways that do not offend individuals and local customs, the insects must somehow be given the first priority. After a clear explanation of the reason for timely actions, properly motivated workers will usually respond with the kind of behaviour that is good for the programme, especially if recognition and compensation for exceptional work are being given.

The need for timely action is not only true for the biological elements of a programme, but managerial actions must also be carried out at the appropriate time (Kakinohana et al. 1993). A delayed management decision, just like a delayed biological activity, could result in programme termination. In the Jamaica New World screwworm eradication programme (Grant et al. 2000), interruptions in critical programme components, such as the employment of temporary field inspectors, resulted in severe programme setbacks (Box 2, Fig. 1).

In addition to holding training courses on the specific skills needed in the various tasks in the programme, e.g. field operations, mass-rearing, sterile insect release, etc. (section 6.1.), a Human Resource Management team in the programme or “parent institution” is needed to provide onsite training on all aspects of management and decision-making.

Due to a shortage of funds, or for convenience, volunteers such as local farmers may be recruited to perform certain tasks, e.g. set up insect traps or distribute a lure-toxicant (Teruya 2000; T. Matsuyama, personal communication). The screwworm programme in Central America developed an honorary-inspector scheme that effectively complemented the activities of programme field workers. However, experience has shown that sometimes volunteers do not perform properly, and therefore close supervision is indispensable; the critical operations of a programme should not be assigned to volunteers.

6.1. Training

Specialized training for the various tasks related to SIT implementation is essential; it improves performance directly, and also represents an incentive for staff. It is important to train back-up employees so that the work usually done by a person who is absent can continue.

There are many national training programmes on insect pests, e.g. Florida State Agricultural Response Team (FSART 2012), as well as degrees in entomology offered by universities, but virtually none focuses on aspects of area-wide pest control and SIT application (one example is the specialized course “International Insect Rearing Workshop” (MSU 2018) offered periodically by Mississippi State University). Therefore, on-the-job training often has to be provided internally by the programmes themselves. For example, in the tsetse mass-rearing insectary in Ethiopia, the colony’s performance improved substantially after the implementation of a permanent training programme. This programme was conditioned on the performance of the project and aimed at motivating the staff in two ways: by delivering specialized training on the SOPs in the different activities of the project, and by stimulating the staff to attend training sessions after the regular working time with an overtime compensation fee. Another powerful motivation tool is to offer deserving staff (those who have shown an outstanding aptitude and level of

performance) the possibility of enrolling in flexible postgraduate studies (MSc, PhD) in local universities, as long as this doesn't interfere in the performance of their daily activities in the programme and the topic of the research component is on an operational aspect of the programme. This requires an additional effort on the part of the student and on that of the programme, but benefits both the student's personal career and the programme's technical capacity (R. Argilés Herrero, personal communication).

Over many decades the FAO/IAEA (Food and Agriculture Organization of the United Nations/International Atomic Energy Agency) has been providing specialized national and regional training courses on various aspects related to implementing the SIT. Such courses provide opportunities to accommodate specific language and local issues, e.g. training courses on applying the SIT against insect pests in Brazil, Asia and Africa (IAEA 2016). Training courses may include a wide range of subjects: insect biology and mass-rearing, induction of sterility, field operations -- monitoring and sterile insect release, and management issues such as economics, financial planning, staff management, project implementation, public relations (Nature 1975; Jayaraman 1997; Dyck, Regidor Fernández et al., this volume), import/export requirements, and risk management. Most importantly are specialized training opportunities and in particular comprehensive interregional training courses for managers that are organized periodically by the FAO/IAEA at sites of operational programmes (FAO/IAEA 2018a).

If a programme results in pest eradication, there would appear to be little need in the future for the acquired knowledge and skills on that pest in that area. Nevertheless, experience shows that the knowledge and generic skills on AW-IPM acquired in a successful programme can be used by animal and plant health authorities in area-wide programmes against other pests or the same pest in other areas.

6.2. *Risks*

There are significant risks associated with the manned aerial release of sterile insects. Every effort must be made to employ (or contract companies with) experienced and skilled pilots, and competent maintenance workers, and to use the best available equipment and facilities. Nevertheless, aircraft accidents do occur.

There were ongoing fatalities due to aircraft accidents in the New World screwworm eradication programme in Mexico and Guatemala from 1972 to 1992. However, for more than 25 years now, there have been no aircraft-related fatalities during the Central America and Panama programmes (J. H. Wyss, personal communication). Also, the aerial release of sterile false codling moths using gyrocopters in South Africa was not accident-free -- three pilots were lost in accidents. Subsequently, releases were made using fixed-wing aircraft (S. Groenewald, personal communication). To avoid risk to the lives of pilots and accompanying personnel, a significant effort is now being made in several programmes to test remotely operated drones for releasing sterile insects; this is a welcome development (PFR 2018; Boersma 2021; Dowell et al., this volume).

Also, workers using irradiators must face risks, even though extensive safety features are built into modern irradiation equipment (Bakri et al., this volume). In most countries, the use of irradiators is not permitted by national nuclear authorities unless programme operators have been thoroughly trained in regulatory and safety procedures, using written guidelines and supervised by an instructor certified by the national nuclear authority.

7. PROGRAMME MANAGER

The management of AW-IPM programmes that integrate the SIT is multifaceted and intensive. Administrative tasks can be done by persons with a business orientation, but the senior managers have a much larger responsibility — to give overall leadership to the programme! Ideally, besides being able to manage personnel, infrastructure, finances, and the political side of the programme, and to make difficult decisions, managers should also have theoretical and practical knowledge about relevant technical matters, and have experience in conducting area-wide and complex insect control programmes. Many of the day-to-day decisions in a programme require sensitivity to critical biological issues, including environmental issues (Kinney 1993). Managers must be convinced that the technology being used will achieve the programme's objectives. Area-wide programmes require strong and persuasive leadership. Managers must be able to communicate effectively with the programme's stakeholders (Patton 1984; Dyck, Regidor Fernández et al., this volume), but still promise only realistic deliverables (Barnes et al. 2015).

An “ideal programme manager”, i.e. a person who has all of the qualifications needed in a programme manager, is difficult to find. In science-related institutions the senior manager is usually a scientist, and all of the other needed skills and knowledge are acquired secondarily. However, sometimes the senior manager is an administrator, and the scientific skills and knowledge are acquired secondarily. Both situations can function satisfactorily, but most often there is a need for additional personnel to be hired to complement the programme manager in the subject areas that need strengthening, e.g. administration or technical matters. Such a team-approach is the one most likely to manage a programme successfully.

Quite often the nomination of programme managers is done at the political level. Although there is an undeniable political dimension to large operational programmes, and strong links to political authorities is an important asset, it is also true that such programmes can be logistically complex and technically demanding, requiring an adaptive management to be successful. Therefore, it is essential to have a technical manager with knowledge and experience in all SIT-related activities (including field activities, sterile insect releases and mass-rearing) and with an executive capacity for decision-making at the technical level (R. Argilés Herrero, personal communication).

The programme manager, and similar senior positions in the management structure, must be chosen subsequent to official competitions that really provide for fair, thorough, and unbiased assessment and selection procedures.

Since there are relatively few persons in the world who have all of these required qualifications, hiring an experienced manager from outside the country may, at least

initially, be appropriate (FAO/IAEA/TANZANIA 1994). In fact, due to cultural norms, an “outsider” can sometimes achieve things more efficiently than a local person. However, for a number of local reasons, an external expert is often only accepted as a co-director (FAO 1992) or as an advisor to the national director, which can have negative consequences (Box 2). Normally, a programme manager operates under the guidelines and oversight of a board drawn from the official supporting agencies.

If a government takes a leadership role in programme management, it can produce mixed results, since standards of good governance vary tremendously among countries. A risk of government-run programmes is that senior management positions may be seen as political rewards, independent of managerial and technical competence. Also, if a government changes, there is the potential for staff changes, and this lack of continuity could disrupt a programme (Rhode 1969).

The suggestions made by Lorraine and Chambers (1989) in the context of the 1980–1982 California Mediterranean Fruit Fly Programme are worth noting. In urban entomology, with today’s increased participation of community activists and special-interest groups, it is a major challenge to deal with complex public policies and programme activities that are not derived from experimental sciences. In modern life, there is no longer a “best solution” but only bargained negotiated compromises that more or less balance competing interests. Coping with the public’s desire to participate in decision-making, and even having public confrontations over technical issues, are rather new experiences for most managers of AW-IPM programmes.

8. FINANCIAL SUPPORT

AW-IPM programmes using the SIT may operate over large areas, and sometimes involve major facilities and equipment. The financial resources required may also be large. Even though a programme might be economical on a benefit/cost basis (Mumford, this volume), it is not always affordable, and obtaining start-up and operating funds can be the most important issue facing a programme. The type of financing used affects programme strategy and operations, the duration of programme support, and the reliability of this support.

Enkerlin (this volume, section 3.1.) provides an extensive summary of various funding options for AW-IPM programmes that apply the SIT, and discusses the strengths and weaknesses of the various options. Table 1 shows the various complexities of different funding arrangements (J. Hendrichs, personal communication).

8.1. Financial Support from Various Levels of Government and/or Private Sources

AW-IPM programmes can be financed through a variety of funding sources and financial operating systems. Many programmes are funded from one or another level of government, or a mix of levels, ranging from national governments, state/provincial governments, and regional/district/local governments. In many cases this support is essential to the stability and success of the programme, e.g. melon fly

in Japan (Kakinohana et al. 1993), New World screwworm in the USA, Mexico and Central America, oriental fruit fly *Bactrocera dorsalis* (Hendel) in Thailand, Mediterranean fruit fly in Latin America (Rhode 1975; Patton 1984; Dowell et al., this volume), and codling moth in Canada (Nelson et al. 2021). However, sometimes government support is unreliable or not delivered in a timely manner; delays create uncertainty for managers (especially if political considerations become dominant), unnecessary repetition of work, and even programme failure (Hendrichs 1986). Convincing government officials (who may reside far from, and have very different concerns than, the people in the programme area) to support a programme is often a huge challenge.

Table 1. Funding Situation for Various Types of Programmes¹

Funding Situation	AREA-WIDE PROGRAMMES (with central coordination and government involvement)		NON-AREA-WIDE PROGRAMMES
	Federal and State Government Programmes	Local Community Government Programmes	Local Individual Stakeholders Programmes
Programme managed and implemented as government service (including contracting out some services)	Yes	Yes	No
All citizens, including non-beneficiaries, contribute indirectly to programme funding through generic government taxes	Yes	No	No
Only local beneficiaries contribute directly to the programme, mostly through local taxes, and sometimes also through other in-kind or cash contributions	No	Yes	No
Local beneficiaries are involved in the decision-making on programme funding and governance	No	Yes	Yes
Beneficiaries contract and fund services individually, without any local coordination or government involvement	No	No	Yes

¹ Source: J. Hendrichs (personal communication)

In one way or another, taxation provides the resource that governments use to support their activities. Sometimes citizens have no direct influence on how money is spent. However, all government-based funding systems have some level of accountability to the stakeholders, and if a programme is largely funded by a local government, then the stakeholders will probably have a greater influence on the programme activities than a programme funded by a national or state government.

Community involvement usually benefits a programme; stakeholder participation can improve programme delivery and effectiveness. If the tax base used to support a programme is drawn from a specific community that includes programme beneficiaries, e.g. farmers or members of a larger community (Dyck et al. 1993; OKSIR 2018; Seymour 2018; Nelson et al. 2021; Mumford, this volume; Simmons et al., this volume), then residents of a community can influence local government decisions, e.g. decisions on support for an AW-IPM programme, through elections and support of, or opposition to, a particular feature of the programme or a change in the tax rate. Mosquito abatement districts are the most common examples of such locally organized, managed and taxed programmes, with Florida alone having currently 61 local mosquito control programmes (UF 2018). This involvement of the community creates an opportunity to obtain broad public support, but also for uninformed people to influence the programme; therefore, the role of public education becomes very important in such cases (Dyck, Regidor Fernández et al., this volume).

If governments provide the finances to operate a programme, this can foster a culture of dependence and reduce the incentive for stakeholders, e.g. farmers in an agricultural setting, or citizens in public health campaigns, to be involved actively. If stakeholders do not contribute in some way to the pest control programme, e.g. managing pest “hot spots”, eliminating mosquito breeding areas, or checking insect traps or pest damage to crops, their lack of supportive actions could reduce the effectiveness of the whole programme. Therefore, to ensure programme success, it is usually essential to keep stakeholders involved in programme activities, even if most funding comes from governments or donors (I. Pla Mora, personal communication). In area-wide programmes, the participation of farmers is essential in view of their first-hand knowledge of the pest situation on their farms, and their cooperation is necessary even if they are reluctant, for whatever reason, to take advice from programme staff.

Direct programme beneficiaries, such as growers, orchardists, and ranchers, are goal-oriented, and the pest or its control directly affect their livelihoods, environment, or even health. They have a personal stake in the programme’s success. Such stakeholders are usually supportive of the programmes since they will reap many of the benefits of success, but often are also “cash poor”, even if sometimes “asset rich”, and tend to offer quite limited financial resources to a programme. Those farmers whose products for export must be residue-free, or even completely free of quarantine pests, are often very supportive. Even though in some programmes there is little or no contribution from the direct beneficiaries, many programmes obtain contributions “in cash” or “in kind” from stakeholders, e.g. fruit growers in Argentina and South Africa (Barnes et al. 2004, 2015) support the field operations of Mediterranean fruit fly programmes, cotton growers in California, USA, helped fund the pink bollworm *Pectinophora gossypiella* (Saunders) eradication programme, and cattlemen in the south-western United States made contributions to a New World screwworm programme (Wyss 2000; Baumhover 2001).

Support from programme beneficiaries is good from an operational point of view, but the financial aspects are often less stable than government funding.

Contributions need to be reliable, and therefore probably compulsory. If market returns are low, or the economic health of an industry is poor, the participants in that industry will be reluctant to continue supporting a programme. In addition, as in many AW-IPM programmes, not all beneficiaries tend to be supportive and educated in technical matters. They are also sometimes poorly organized, and reluctant or even opposed to cooperating in joint area-wide activities.

There are good reasons for a community to contribute financially to an AW-IPM programme that applies the SIT, especially if the insects for release are reared locally -- quantifiable economic and social benefits to the region, e.g. employment, purchase of locally produced materials, increased tourism because of a safer environment, and a potential for higher market returns of the commodity, such as fruit, being produced largely insecticide-free (Mumford, this volume).

A mix of public and private funds seems to work best in some programmes, and this is now the trend (Barnes et al. 2015; IAEA 2015; I. Pla Mora, personal communication). For example, the successful *Anastrepha* spp. fruit fly programme in northern Mexico is funded one-third by grower associations, one-third by state authorities, and one-third by the national government. However, the larger the number of funding sources, the greater the complexity of financial management, but probably also the greater the funding stability.

A few programmes are largely or completely operated through the direct payment by stakeholders and members of a community to a commercial company. The onion maggot programme in The Netherlands is conducted entirely with funds from individual growers that contract for the service of pest monitoring and suppression in their onion fields, including the release of sterile flies (Loosjes 2000). In the case of mosquitoes, it is quite common for citizens of a county or community to fund their mosquito-abatement districts, including the recruitment of professional managers and entomologists. However, in cases where individual farmers have sterile insects applied but not as a part of a coordinated area-wide approach, as in the example of the onion maggot, such support would mainly benefit the farmers who contracted to have the SIT applied. Neighbouring farmers, who are “free riders”, obtain benefits from dispersing sterile flies without paying for them, while farmers that pay for the SIT suffer when mated fertile female flies enter their land from nearby farms that are not part of the programme (Klassen et al., this volume).

8.2. Financial Support from Donors and Foreign-Aid Programmes

In developing countries, it is common for donor organizations and government-sponsored foreign-aid programmes to provide some support to national governments in area-wide pest control programmes, e.g. the New World screwworm programme in Libya (FAO 1992; Lindquist et al. 1992), and the tsetse fly *Glossina austeni* Newstead programme in Unguja Island, Zanzibar, United Republic of Tanzania (FAO/IAEA/TANZANIA 1994; Dyck et al. 1999). In Ethiopia, non-governmental organizations (NGOs) provide some financial support for the control of tsetse flies, although most funds are received from the government. It is also common, at the request of developing countries, for international organizations to provide some multilateral support to national governments (LaChance 1993), such as in the

screwworm programme in Libya (FAO 1991, 1992; Lindquist et al. 1992), and the tsetse fly programme in Zanzibar (FAO/IAEA/TANZANIA 1994; Dyck et al. 1999). Most such support is provided “in kind”, and focused on important expert services for training, capacity building, and feasibility studies, as well as the provision of special equipment. However, sometimes the equipment provided is not appropriate to the practical operations, or difficult to maintain locally, and may therefore become unusable. Thus, some “in cash” support, although not common, is also very useful to a programme for some local purchases and to overcome local constraints and cover needs not foreseen in inflexible government budgets.

In many countries the FAO/IAEA has provided financial support for some applied research activities, capacity building, and pilot operational programmes related to applying the SIT, e.g. South Africa (Barnes et al. 2015).

9. MANAGING FINANCES

Often the biggest problem in managing finances is interrupted cash flow due to delays in receiving funds from financial supporters of a programme, be it from government or other sources. Budget cuts, caused by economic downturns or political decisions, especially if unexpected, have a strong negative impact on the progress of a programme (Patton 1984). Sometimes a shortage of money is caused simply by bureaucratic delays. If there is no money or money is delayed, usually the programme activities have to be restructured, curtailed, or even stopped, and this can be disastrous for a biological programme that requires continuity and where “timing is everything” (Lorraine and Meltsner 1987). Insect rearing and release activities cannot be “put on hold” and resumed later when money becomes available. Failure to sustain activities can result in a total loss of previous achievements and the necessity to start the programme again (Box 2). On the other hand, if a programme suddenly receives an excess of funds shortly before the end of the fiscal year, panic spending could lead to the inefficient use of money. One way to minimize the problem of local cash flow is for the funding organization to regularly advance money to the programme manager, who can anticipate expenses and budget these funds accurately.

A back-up plan must be included in the programme planning document so that, when a programme supporter fails to deliver promised money, funds can still be made available, and the programme can proceed on schedule. A possible mechanism to solve this problem would be for one financial supporter to agree, in advance, to provide contingency funds. In any case, a contingency fund is needed to cope with emergencies.

Reliability in funding and cash flow, and also the provision of larger amounts of money at those times of year when biological operations require it, are essential for an AW-IPM programme involving the SIT. In the case of seasonality of programme implementation, financial planning is further complicated. This emphasizes the need for a separate organization (section 5.), located at the site of the programme, with its own financial accounting system and audits, which can control cash flow and prevent unauthorized use of money.

Especially in poor countries, payment of incentive bonuses to complement on a regular basis the low staff salaries is important for maintaining staff morale and a high level of performance, both of which are essential for effective field operations and the production of high-quality sterile insects for release.

Declining exchange rates between local and foreign currencies can be a major problem for programmes that have some of their expenses in foreign currencies. Under these conditions the conversion of funds has to be carefully managed, as a rapid decline makes it more difficult for a programme to purchase foreign-produced goods such as technical equipment or aircraft services.

10. LOGISTICAL AND PHYSICAL SUPPORT

Even though the quality of the human input into an SIT-related AW-IPM programme is a top priority, programme staff cannot do the work alone, and logistical support and the physical infrastructure are essential to achieve a programme's objectives. Materials and equipment must be of appropriate specifications and quality, cost-effective, procured in a timely manner, and properly maintained. A well-executed procurement plan should take into account that biological processes, once started, must be completed, and that the lack of even one item could mean disaster. Stability in the supply of critical materials, and an adequate stock of essential items, are required. For example, in mass-rearing, tested diet ingredients for at least 3–6 months operation are required, and warehouses have to be sized accordingly (Parker, Mamai et al., this volume).

Local rather than foreign procurement would appear, at first glance, to be the best policy, and can be advantageous in terms of availability, lower costs, and reduced transport expenditures. However, purchasing products from another country may be necessary in some cases to obtain a high-enough quality or items that simply are not available locally. Flexibility in procurement procedures is required to enable the correct materials to be purchased, and to permit quick action when biological events demand it. The lowest bid on an item is often not the correct criterion on which to base a purchase decision. Diet ingredients require especially stringent quality control procedures (Parker, Mamai et al., this volume).

The location of a mass-rearing facility has an impact on operational efficiency, and on the availability of materials and appropriate staff (Rhode 1969; Hendrichs 1986; Phillimore 2002; FAO/IAEA 2004, 2012b; Cáceres et al. 2012; Dowell et al., this volume; Parker, Mamai et al., this volume). If the programme is located in a difficult-to-access place, procurement must be done long before items are needed. This applies especially to insect rearing and release materials and equipment, and to field monitoring supplies.

To protect the environment and maintain respect for nearby communities, diet should be biodegradable and the disposal of spent diet through treatment of waste solids and water is an essential activity in facilities mass-rearing fruit flies, moths and screwworms, requiring appropriate infrastructure (Wyss 2002; Nagel and Peveling, this volume).

The production and release of a perishable product like sterile insects need a strong support system to ensure that investments are not wasted by the absence of,

or having low-quality, materials and equipment. Proper maintenance of equipment is essential so that mechanical failures do not result in the production of fewer or low-quality insects. Equipment should not be more complex than necessary (Rhode 1969), but of good quality to minimize breakdowns that lead to inefficient operations. Back-up equipment and plans for all critical operations, and a stock of spare parts for essential equipment to minimize equipment downtime, are necessary. Accidents and emergencies do happen, and therefore redundancy is needed to avoid negatively affecting field operations or to prevent declines in quality insect production. For example, even though several smaller independently operated rearing rooms cost more to build and operate than one large room, the smaller rooms provide much more production security than one large room (Tween 1987; Dyck et al. 1993; Phillimore 2002; Dowell et al., this volume; Parker, Mamai et al., this volume). For the sake of maximizing efficiencies and productivity, competition among workers responsible for the performance of different rooms can be fostered.

Ideally, utilities must be reliable, but back-up systems, e.g. electricity generator, should always be available so that temperature controls and other essential activities can continue operating.

Vehicles, including release aircraft, must be adequate in number and maintained properly to provide reliable and safe service. The aerial release of sterile insects has sometimes been done from aircraft owned by the programme. However, it may often be appropriate to contract out aerial release activities to private or government aircraft companies (Dowell et al., this volume). Nevertheless, to maximize programme effectiveness, programme staff must still supervise release operations. The high cost of aerial release necessitates a careful assessment of operational procedures to accommodate any concerns with economic, efficiency or technical issues (Teruya 2000).

In selected cases it may be realistic and appropriate for a large regional mass-rearing facility to produce enough sterile insects for the needs of a whole region, from where sterile insects are sent to the various emergence and release centres for handling and release. Sometimes it is more efficient and economical to construct a regional facility than for each programme to have its own facility (Dowell et al., this volume). However, this is risky in view of unforeseen catastrophic or political events, and can lead to complete dependence on the supply of insects, especially if there is only one production facility in the world, as is currently the case for the New World screwworm, currently in Panama (Vargas-Terán et al., this volume). Such a monopoly situation had a negative impact on the Jamaica New World screwworm programme (Box 2). In the absence of competition, dependence on the operating procedures and policies of, and the cost charged by, the only external source of sterile insects might not be in the interest of a particular programme; therefore, such a system is “the exception rather than the rule”.

11. EXPORTING/IMPORTING STERILE INSECTS

Sterile insects have routinely been shipped across borders for decades (see Table 2 for history of transboundary shipments), which is facilitated by the fact that sterile insects are non-invasive agents that leave no “ecological footprint” because they

cannot become established due to their sterility. In 2005 the shipment of sterile insects across national borders was facilitated further by a decision of the International Plant Protection Convention (to which most countries are parties), formally categorizing sterile insects among beneficial organisms (IPPC 2017; Klassen et al., this volume).

Table 2. History of transboundary shipments of sterile insects¹

Year	Tephritid species	Site of production	Approximate amount shipped (million pupae)	Recipient	Observations
1963–1990	Mexican fruit fly <i>Anastrepha ludens</i>	Monterrey, Mexico	Unknown	Texas, USA	
1970/1971	Mediterranean fruit fly	Seibersdorf, Austria	Unknown	Procida, Italy, and Greece	Relatively small amount since sterile flies were used for field trials
1970	Mediterranean fruit fly	Costa Rica	Unknown	Nicaragua	Relatively small amount since sterile flies were used for field trials
1975–1977	Mediterranean fruit fly	Madrid, Spain	302	Canary Islands	
1978	Mediterranean fruit fly	Seibersdorf, Austria	Unknown	Guatemala	Sterile pupae shipped from the IAEA laboratories (Seibersdorf) to a packing and emergence facility in Guatemala for field trials and staff training in SIT techniques
1979–2017	Mediterranean fruit fly	Metapa, Chiapas, Mexico	357 600	Guatemala	Transboundary shipments have been carried out periodically for the past 36 years
1989–1994	Mediterranean fruit fly	Metapa, Chiapas, Mexico	6670	California, USA	To assist the CDFA in eradication of medfly outbreaks
1989–1990	Mediterranean fruit fly	Seibersdorf, Austria	Unknown	Israel	Pilot trials
1990	Mediterranean fruit fly	Metapa, Chiapas, Mexico	552	Chile	Sterile flies donated by the Mexican government to Chile
1990–1991	New World screwworm (NWS)	Tuxtla Gutierrez, Chiapas, Mexico	1800	Tripoli, Libya	To assist the eradication of a NWS outbreak
1993–2006	New World screwworm	Tuxtla Gutierrez, Chiapas, Mexico	107 000	Central American countries	To assist NWS eradication in Central America

Table 2. Continued¹

Year	Tephritid species	Site of production	Approximate amount shipped (million pupae)	Recipient	Observations
1990–1998	Tsetse fly <i>Glossina</i> spp.	Seibersdorf, Austria	8	Tanga, Tanzania	To assist tsetse eradication in Zanzibar
1994	Mediterranean fruit fly	Seibersdorf, Austria	60	Tunisia	Pilot trials
1996–2000	Mexican fruit fly	Metapa, Chiapas, Mexico	2511	California, USA	To assist the CDFA in eradication of Mexican fruit fly outbreaks
1994–2017	Mediterranean fruit fly	El Pino, Guatemala	152 100	California, USA	Preventive Release Programme and to eradicate medfly outbreaks
1997/1998	Mediterranean fruit fly	Madeira, Portugal	206	Israel	In support of pilot suppression programme
1997–2000	Mediterranean fruit fly	El Pino, Guatemala	3700	Israel	In support of pilot suppression programme
1998–2017	Mediterranean fruit fly	El Pino, Guatemala	97 720	Florida, USA	Preventive Release Programme and to eradicate medfly outbreaks
1999–2000	Mediterranean fruit fly	El Pino, Guatemala	720	South Africa	In support of pilot suppression programme
2003–2006	Mediterranean fruit fly	Mendoza, Argentina	1681	Valencia, Spain	In support of suppression programme
2011–2013	Mediterranean fruit fly	Valencia, Spain	425	Croatia	In support of suppression programme
2008–2017	Mediterranean fruit fly	Bio-Fly Israel	650	Jordan	In support of suppression programme
2010, 2012, and 2014 to 2017	Mediterranean fruit fly	Bio-Fly Israel	3289	Croatia	In support of suppression programme
2010–2018	Tsetse fly	Slovakia	9	Senegal	To assist tsetse eradication in Senegal
2014–2017	Mediterranean fruit fly	Valencia, Spain	600	Morocco	In support of suppression programme
2015–2017	Mediterranean fruit fly	El Pino, Guatemala	4000	Dominican Republic	In support of eradication programme
2016–2017	New World screwworm	COPEG, Panama	194	Florida, USA	To assist the eradication of a NWS outbreak
2008–2017	Mediterranean fruit fly	El Pino, Guatemala	260 000 ²	Metapa, Chiapas, Mexico	In support of eradication and containment programme
TOTAL			1 001 797		

¹ Data from FAO/IAEA (2018b), reproduced with permission² Only in this case, insects shipped as eggs

There is a long history of successful shipments of live sterile insects across national borders, especially insects in the pupal stage, e.g. Mediterranean fruit fly, New World screwworm. In future, there is no doubt that this practice will continue (Dyck 2010; Blomefield et al. 2011; Seck et al. 2015; FAO/IAEA 2017). As stated in FAO/IAEA (2018b),

The transboundary shipment of sterile insects has taken place on a continuous basis for 55 years. The total number of sterile insects shipped has been estimated at more than 1 trillion [thousand thousand million] in thousands of shipments across borders to 23 recipient countries from 50 sterile insect factories in 25 countries. During this long period and many precedents, no problems associated with possible hazards have been identified, and thus the shipment of sterile insects has never been subjected to any regulatory action. The table shows the history of transboundary shipments which started in 1963 with the shipments of sterile Mexican fruit flies *Anastrepha ludens* (Loew) from Monterrey, Mexico, to Texas, USA.

The Okanagan-Kootenay Sterile Insect Release (OKSIR) Program in British Columbia, Canada (OKSIR 2018), has during the winter season in Canada shipped sterile adult codling moths to South Africa and New Zealand for use in both research and field control programmes (Taret et al. 2010; Blomefield et al. 2011; Horner et al., 2016; Suckling et al. 2017; Fries 2018; Nelson et al. 2021). However, recently there was a delay in shipments to New Zealand because of quarantine concerns (in New Zealand an Import Health Standard and permit to import live animals is necessary under the Biosecurity Act) (R. M. Horner, personal communication). Eventually, the requirement for a veterinary certificate was revised; an official letter of verification from the OKSIR (declaring that the shipped live insects are sterile codling moths produced at the OKSIR mass-rearing facility) was deemed acceptable, and shipments were allowed to resume. Nevertheless, even though such problems can usually be resolved, this illustrates the potential for difficulties in shipping sterile insects across borders (Quinlan and Larcher-Carvalho 2007; C. Nelson, personal communication; Klassen et al., this volume).

Shipments from the OKSIR to researchers in the USA, which initially would appear to be a simple matter given the proximity of supplier to the users, has become complicated. Hand-carried shipments work well, but such arrangements are always ad hoc and not sustainable. Alternatively, import fees, official inspections, and difficulties in finding carriers that can transport live insects quickly can be barriers to cross-border shipments. Export shipments sold at a profit are a vital component of the financial plan of mass-rearing facilities that operate year-round but need the produced sterile insects only during the growing season (Fries 2018; C. Nelson, personal communication).

The Nagoya Protocol (2018) was established in 2014 under the Convention of Biological Diversity as an organized system to permit the fair exchange of biological control organisms among countries, and to share the benefits of such exchanges with all involved. This system now exists in principle, but it is so restrictive that it has recently brought about an almost complete stop to natural enemy exploration for classical biological control programmes (van Lenteren 2021). In future, it could affect the free movement of sterile insects across some national borders.

12. PROGRAMME EVALUATIONS AND INDEPENDENT ASSESSMENTS

Programme managers, and even standing advisory committees and associated research scientists and institutions, need regularly to invite independent external experts and consultants to evaluate a programme and then give constructive advice and guidance. Both national and international consultants play valuable roles. External reviews of a programme reduce the likelihood of failure due to the “cannot fail syndrome”, the unreasonable confidence that a process done correctly cannot fail to achieve the goal, and success does not need to be monitored (Dowell and Wange 1986). Experience gained in other programmes using the SIT can provide invaluable information and ideas to resolve problems and help achieve the programme’s goals as efficiently as possible. Advice is often available, but usually at a cost, from university professors and other technically trained persons that are not affiliated with the programme’s organization. The advice should be impartial, unbiased, and given “at arm’s length”. Sometimes it is appropriate to bring in full-time experts to advise the programme manager, especially on technical issues. If a programme claims to have eradicated an insect pest in a given region, it is important to obtain an in-depth assessment from a group of experts (Barclay et al., this volume).

There are numerous examples of good and helpful advice obtained from short-term consultants in many AW-IPM programmes. One is the international Technical Advisory Panel that recommended in 1994 an area-wide preventive release programme to deal with the recurring Mediterranean fruit fly outbreaks in the Los Angeles basin (Dowell et al. 2000). A more recent example is the Technical Advisory Committee (also composed of international experts) that advised the Dominican Republic on eradicating the Mediterranean fruit fly (Zavala-López et al. 2021).

However, there are also examples of bad advice that have damaged programmes (Box 3) (Klassen et al., this volume). Some caution in selecting consultants is needed since persons with no stake in a programme might in fact be biased, unrealistic, or too theoretical. External reviewers are not always correct in their assessments or recommendations, but it is extremely difficult politically for a programme manager to reject them. It is also difficult for non-technical managers, and representatives of donor organizations who hire technical consultants, to know if a consultant is biased or not, and has the required practical field experience. Therefore, external reviews need to be managed carefully, but on balance in most cases they are very valuable.

13. PROGRAMME SUCCESS OR FAILURE

Even though often blamed for programme failure, problems with technical issues in fact usually only delay the successful achievement of a programme’s objectives, and rarely lead to failure. However, several programmes have failed because of bad management, and inadequate funding and political support.

Box 3. Mediterranean Fruit Fly Invasion of Central America

In Costa Rica, the Mediterranean fruit fly was first found in 1955, and by 1962 it had spread to southern Nicaragua. Field trials to contain the northwards invasion of the fly demonstrated that the technology (including the use of the SIT) was adequate, but that more funds, a vision to achieve the goal, and an organization were required (FAO/IAEA 1970). However, the advice given in 1970 by a three-person review panel of university professors (with no experience in managing area-wide programmes) was to abandon any containment efforts in Nicaragua. The panel did not accept that eradication should be the goal, questioned the cost and feasibility of the programme, and instead recommended to “live with the pest” with a focus on enhancing biological control. Preconceived conservative notions against AW-IPM, and the economics and politics of the situation, evidently “ruled the day”; an opportunity to eradicate, or at least contain, the invasive fly was lost. Abandoning all containment efforts resulted in the fly rapidly invading the next three neighbouring countries (Honduras, El Salvador, and Guatemala), and reaching southern Mexico by 1977. A costly trilateral emergency programme had to be initiated to prevent the Mediterranean fruit fly from invading Mexico and the USA (Enkerlin et al. 2017). Since then, the great amount of effort and money that has had to be spent each year (currently over USD 40 million), to prevent this invasion from continuing and to reverse the trend, is at least an order of magnitude larger than the budget (USD 1.5 million for 4 years) that the experts had rejected for the Nicaragua programme (FAO/IAEA 1970). The economic problems caused by the fly invasion are still present in Central America, with significant losses and conventional control costs, and representing the major limitation of countries in the subregion, i.e. developing a tropical fruit industry and access to the nearby US export market. In comparison, Mexico recently celebrated 40 years of keeping the country free of the Mediterranean fruit fly, as a result of which the fruit and vegetable exports have exploded to over USD 4000 million per year. Thus, in the case of the Central American region, the recommendation of the external panel turned out to be bad advice. Meanwhile, the trilateral Moscamed Programme has resulted in major economic and other benefits for Belize, Guatemala, Mexico, and the USA (Enkerlin, this volume).

Many lessons about programme management have been learned from past and ongoing AW-IPM programmes that integrate the SIT (Vreysen et al. 2007). Programmes have a high probability of success if:

- Thorough baseline data collection and feasibility studies are implemented for proper programme planning.
- They are managed by a flexible, independent and efficient management structure.
- They have carefully selected technical staff that work full-time for the programme, and also offer specialized training for the different tasks related to implementing the SIT.
- They have strong and reliable financial support, and also strong political stakeholder support.
- They have adequate and appropriate logistical support and physical infrastructure.
- They seek expert advice, especially technical advice where needed. Even when pilot programmes encounter problems, eventual success can be achieved if adequate applied research support (probably provided from outside the operational AW-IPM programme), good cooperation, and international technical support and consultation are available.

However, other lessons show that programmes will risk failure, or have significant difficulties, if:

- They have unrealistic objectives and expectations.

- They are immature, based on inadequate knowledge, patterned after other programmes without recognizing unique local characteristics, or are started too soon or with too little advance planning.
- They lack operational flexibility and independence, and carry the burden of stifling administrative restrictions.
- Their managers have inadequate (especially scientific and SIT-relevant) knowledge and experience, have a predominantly profit-oriented attitude (where the programme is a commercial enterprise), or do not work full-time in the programme.
- They have inadequate funding (Chinvinijkul et al. 2016), and staff lacks training or technical support.
- They have inadequate communications with the stakeholders, political leaders and the general public (Dyck, Regidor Fernández et al., this volume).

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