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Designing local institutions for cooperative pest management to underpin market access: the case of industry-driven fruit fly area-wide management

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Abstract: Area-wide management of mobile pests offers advantages over uncoordinated farm-by-farm efforts through increased effectiveness of pest control and by reducing the need for pesticides. The literature about area-wide pest management focuses predominantly on the technical aspects of these programs, but tends to neglect the importance of social and institutional aspects. In this article the eight design principles for robust common-pool resource institutions are applied to industry-driven area-wide pest management. Three case studies are compared to gain insight about the social and institutional aspects that affect the success of these undertakings. These cases are focused on Queensland Fruit Fly control to underpin market access. Growers face a particular challenge to gain support from town residents, as backyard fruit trees can be pest breeding spots. The paper illustrates that social aspects – such as heterogeneous incentives, social capital and the ratio between town residents and main beneficiary growers – influence the ease of which the design principles can be applied. Market access opportunities impact the ratio of cost and benefits to different participants. The paper concludes that disconnecting the technical aspects of successful programs from the social and institutional aspects in which they are embedded can create unrealistic expectations in socially different regions that intend to replicate these programs.

Keywords: Biosecurity, market access, pest management, social ecological systems, sustainable agriculture

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1. Introduction

Pests have been a key challenge to sustainable agriculture since the days humans started to cultivate their own food. Nowadays pests are spreading at an increased rate due to rising international movement related to trade and tourism activities (Maye et al. 2012). Governments and agriculture industries in contemporary society use a relatively new term when they refer to this challenge, namely biosecurity. Biosecurity involves designing strategies and activities to minimise and manage the risks related to the spread and establishment of pests, diseases and other undesirable organisms impacting on plant, animal and human health (Outhwaite 2010).

International trade is a key driver for implementing national and international agricultural biosecurity strategies (Maye et al. 2012). International and national legal and regulatory biosecurity measures are in place for the prevention, eradication and control of pests (Outhwaite 2010). This means that the risk of particular pests being present either restricts access to certain overseas and domestic markets or necessitates preventative phytosanitary measures, often at substantial cost to the exporter (Dibden et al. 2011).

Despite the far-reaching implications of pests, they have received relatively little attention as a commons issue. Most biosecurity-related research centres around the economic and biophysical aspects of pest management, while focus on socio-institutional elements has only started to gain momentum during the last decade (Barker et al. 2013). Yet, as will be established, there are many commons-based issues when trying to successfully implement biosecurity measures.

This article explores the case of industry-driven fruit fly area-wide management as a commons issue. In particular, it uses Elinor Ostom's (Ostrom 1990) design principles for robust socio-ecological systems as a lens to better understand what promotes or hinders collective action. It concludes that the commons theory offer valuable insights to area-wide management. More broadly, it draws attention to the idea that the concept of biosecurity is situated in the world-view of neoliberalism and market supremacy.

2. Background

Fruit fly is one of the world's most significant commercial pests affecting horticulture. Several species of fruit fly cost Australia around a total of AUS$300 million a year in control and lost markets, with more than three quarters of fruit

and vegetable exports susceptible (Plant Biosecurity CRC 2014). In addition, fruit fly management has recently become more challenging in Australia following the restriction of key pesticides traditionally used to control the pest, such as fenthion and dimethoate (Florec et al. 2013), forcing industry to identify alternative measures. This study focuses on Queensland fruit fly (*Bactrocera tryoni* (Froggatt)) or in short, QFly.

In terms of its general biophysical features, QFly is geared for survival. A couple of flies can result in a large population in one season under favourable conditions. QFly has a preference for warmer and wetter weather. Proliferation is limited by extreme high or low temperatures and a lack of moisture. It becomes less active during winter, and in several areas fruit fly pressure in spring is related to whether the region had cold or mild winter conditions (Dominiak et al. 2006).

Traditional pest management typically involves growers reactively addressing pests on a farm-by-farm basis. The trouble with a mobile pest such as QFly is that re-infestation tends to occur from nearby untreated areas, such as backyards, derelict orchards and wild hosts (Klassen 2005; Vreysen et al. 2007b). Hence, proactive, uniform suppression of the total pest population across a region is more effective than the uncoordinated endeavours of individual growers (Hendrichs et al. 2007).

Area-wide management is increasingly in the spotlight as a QFly management solution as it promises a reduced need for pesticides (PHA 2008; Fay et al. 2011; White et al. 2011). It involves synchronised pest management strategies used over a wide geographical area with the aim to reduce QFly either to below economic threat levels or to eradicate it (Elliott et al. 2008). Strategies are applied to commercial horticulture operations and urban settings, such as backyard fruit trees. Area-wide management programs can have different aims, including achieving pest free status, where the pest is fully eradicated and/or excluded, or to maintain so-called areas of low pest prevalence. Several benefit-cost analyses have shown that area-wide fruit fly management can be cost effective (Kalang Consultancy Services 2013; Ha et al. 2010; Florec et al. 2013).

Area-wide management happens world-wide to manage mobile pests, often in combination with integrated pest management and other technologies (Klassen 2007). Fruit fly area-wide programs exist or have been trialled in Argentina, Australia, Brazil, Chile, Central America, Israel, Mexico, South Africa, Thailand, Tunisia and the United States (Vreysen et al. 2007b). Many such programs are instigated to underpin market access and are therefore embedded in the highly regulated, politicised and contested wider institutional context of national and international trade. The World Trade Organisation (WTO), in conjunction with the International Plant Protection Convention (IPPC), promotes international free trade whilst upholding a science-based approach to prevent agricultural trade causing biosecurity risks. The IPPC's international standards for phytosanitary measures (ISPMs) make allowance for fruit fly area-wide management systems, including 'ISPM 26 Establishment of pest free areas for fruit flies' and 'ISPM 30

Establishment of areas of low pest prevalence for fruit flies'. As well, the 'ISPM 35. Systems approach for pest risk management of fruit flies' is also relevant to area-wide management. Systems approaches involve two or more independent measures pre- and/or postharvest to achieve satisfactory phytosanitary outcomes. Areas of low pest prevalence are seen as good candidates to be used as part of systems approaches (PHA 2008).

Australian state governments have traditionally been key contributors in performing on-ground operations to control QFly, especially for pest free areas. However, there is increasingly an expectation that industry will take the lead in funding and managing QFly management programs.

Management of area-wide management programs is intensive and logistically complex. It requires the support and cooperation of a critical mass of owners of host plants. This ranges from high-value produce growers through to town residents with host plants in backyards (Hendrichs et al. 2007). Maintaining public participation is a key challenge (Mumford and Tan 2000). However, it is mostly the technical and economic aspects of QFly that receives most attention in the literature (Dyck et al. 2005). This paper attempts to broaden the problem-solving approach by shedding more light on the socio-institutional factors that influence the success of these undertakings.

This paper argues that low prevalence (or freedom) of a pest within any particular region is a resource presenting a commons issue. All inhabitants who otherwise would have experienced damage from higher pest prevalence enjoy benefits from this resource, whether through less crop damage or via improved marketing prospects. Overall, biosecurity is generally referred to as a public good resource (Perrings et al. 2010; Mumford 2013). However, on-ground mobile pest control resembles a common-pool resource, i.e. a resource with high substractability and low excludability (Ostrom 2005). Horticulture growers (and other host plant owners) who are not controlling the pest on their properties are reducing benefits to growers who are carrying-out pest control, as the former provides breeding spots for the pest which then harms the resource for all users (implying high substractability). It is difficult to exclude landholders who are not contributing to pest control from the benefits of low pest prevalence (low excludability).

Hence, the social dilemmas of free-riding and 'opting-out' also apply to mobile pest management. For example, if a critical mass of growers is following recommended practice, thereby reducing QFly pressure, those who are not following suit cannot be excluded from the benefits, i.e. from free-riding. This provides a perverse incentive not to invest in QFly management. Likewise, growers witnessing others doing little to address QFly on their properties could use this observation as an 'opt-out clause' by asking 'Why should I control QFly if they don't?

A lack of cooperation will result in 'the tragedy of the commons' (Hardin 1968). That is, as some people maximised their short-term benefits by underinvesting in QFly management, QFly has the opportunity to proliferate on their properties

resulting in increased QFly pressure in the region. This is to the detriment of all owners of horticulture crops in the region, regardless whether they are cooperating with recommended practice. The best way to overcome this dilemma associated with the commons is through well-considered local institutions (Ostrom 1990; Anderies, Janssen, and Ostrom 2004).

3. Methods

This study applies the design principles of robust common-pool resource institutions pioneered by Elinor Ostrom and others to three cases of industry-driven area-wide fruit fly management programs. Box 1 contains a short description of the case studies.

Box 1. Short case study description

Central Burnett, Queensland
Central Burnett was chosen as it is often held-up as a model case of successful industry-driven fruit fly area-wide management (PHA 2008; Lloyd et al. 2010; Davidson and Davidson 2012). Once a significant endemic pest that sometimes devastated crops, QFly is now considered a minor pest. Preliminary investigation suggested that Central Burnett has social factors that contribute to its success and which tend to be overlooked when the focus is on the program's technical aspects. There are around 60 commercial horticulture growers (predominantly citrus) in the region. One focus group and thirteen interviews were carried out in October 2013.

Riverina, New South Wales
Preliminary scoping revealed that this large, diversified horticulture region could be a particularly challenging case study. It also includes large rural centres, such as Griffith, that economically depends on a range of service and other industries, and not just horticulture. Traditionally, the region is not endemic to QFly and has a history of strong state government supported QFly management that has been significantly reduced since mid-2013. The citrus industry drives the recently introduced QFly management initiative. There are around 420 citrus growers in the region. One focus group and twenty interviews were carried out in March 2014.

Young-Harden, New South Wales
This case was chosen because local government is a key player in assisting forty local growers in a recently initiated effort to achieve area-wide management. QFly is increasingly a market access barrier to lucrative overseas markets, especially for cherry growers. One focus group and nine interviews were carried out in in September 2013.

The design principles, which are summarised in Box 2, facilitate overcoming the social dilemmas of 'opting out' and free-riding as they create the conditions required to sustain the trust and reciprocity that is needed to sustain collective action. In addition, the principles are used as a diagnostic tool to deepen understanding about what social and institutional factors contribute to or hinder the success of industry-driven area-wide management (Cox et al. 2010). The hypothesis is that the most successful case study, i.e. Central Burnett, will align closer to Ostrom's design principles than the Riverina and Young-Harden.

Box 2. A summary of the design principles for robust common-pool resource institutions (Ostrom 1990; Anderies et al. 2004; Cox et al. 2010; Poteete et al. 2010)

a. *Clearly defined boundaries*
The resource system's boundaries and the individuals who have rights to use the resource and need to contribute to its maintenance, are clearly articulated. This underpins the development and enforcement of rules.

b. *Congruence between appropriation and provision rules and local conditions*
The rules in play that allocate benefits to different participants are fair and equitable, that is, they ensure the benefits individuals derive from the resource are in proportion to the contributions they provide. Rules also conform to local resource conditions, such as fluctuations over time and space. If rules are seen as fair there is less chance that resource users will challenge or violate them.

c. *Collective choice arrangements*
Individuals affected by the rules have a say in their design and modification. This ensures greater support for the rules; rules are better understood, are more likely to fit local circumstances, norms and values, and are adjusted when needed. It provides locals with the opportunity to experiment and fine-tune rules over time.

d. *Monitoring*
The condition of the resource is regularly monitored as well as risk contributors' compliance with the system's rules. Monitoring is done in a way that complements trust and reciprocity, rather than causing antagonism.

e. *Graduated sanctions*
Users who do not abide by rules first receive a signal that their breach has been noticed followed by more onerous consequences if the breach continues. Such an approach makes allowance for exceptional circumstances, misunderstandings

or mistakes and focuses on encouraging the violator to resume compliance. It is also important for other participants to witness that rule breaches are followed up, to maintain trust in the system.

f. *Conflict resolution mechanisms*
Participants and officials have ready access to low-cost, local arenas to address conflicts between stakeholders and to get it resolved quickly with minimal impact on the trust between participants.

g. *Minimal recognition of rights to organise*
The rights of participants to develop their own rules are recognised and supported by external authorities, such as local or state governments, thereby contributing to the legitimacy and enforceability of these rules.

h. *Nested enterprises*
Where the resource is part of a larger scale system, institutions are developed in a nested approach, where different layers complement each other. Smaller units adapt rules to local circumstances and larger-scale institutions regulate the interdependencies between smaller units and address larger-scale issues.

Ostrom's design principles seemed suited for on-ground pest management, because they focus on both the local social and institutional processes as well as on how these are nested in and interact with higher hierarchical levels of governance (Armitage 2007; Ostrom 2007; Poteete et al. 2010). Of particular interest here is the wider political and economic setting of national and international trade in which area-wide management programs are embedded, including the role of the state. However, due to space restrictions, this paper will highlight only some key elements.

A qualitative research approach was chosen to achieve in-depth understanding of the processes occurring at local level (Denzin and Lincoln 2000). Case studies were selected using theoretical sampling as opposed to random sampling. That is, cases were chosen to maximise gaining insight (Flyvbjerg 2006; Eisenhardt and Graebner 2007) about the social and institutional aspects of area-wide management programs. Hence, cases were chosen to achieve maximum variation of social and institutional profiles (Flyvbjerg 2006). Cases that involve existing or coordinated attempts to achieve industry-driven fruit fly area-wide management programs were considered.

The main data source is face-to-face, in-depth, semi-structured interviews with key informants as well as a focus group with each case study's management committee. Purposive sampling were used to select interviewees, i.e. people were chosen based on their knowledge, position or characteristics (Morse et al. 2008), such as how well they know how growers and/or the broader

community respond to the area-wide fruit fly management program. A range of interviewees were chosen to ensure a diverse range of perspectives (Eisenhardt and Graebner 2007). Key informants typically included local program coordinators, key growers, on-farm consultants, as well as representatives of the programs' management committees, packhouses, local shire councils and local industry bodies and associations. Interview questions during the fieldwork were broad and open-ended in order to obtain an authentic representation of how respondents view the local area-wide management program 'from the inside' (Punch 2005). Interviews typically went for an hour, were audio-recorded and transcribed verbatim. Data was coded using the qualitative research analysis tool NVivo. A summary of each case study's key findings was distributed amongst the cases' participants. They were asked to identify gaps or provide other viewpoints to documented findings, which led to a few more updates to the results.

4. Results

This section provides a more detailed overview of each case study, followed by jointly applying Ostrom's design principles across the cases.

4.1. Central Burnett

The area-wide management program started in 2003 as a trial led by the Queensland government in collaboration with three local crop consultants to strengthen fruit fly control and improve market access opportunities (Lloyd et al. 2010). In the past there were some peak trap catches of 240 flies/trap/day, which were dramatically reduced to 1 fly/trap/day by 2010. Likewise, backyard fruit infestation levels in towns dropped from 60.8% to 21.8% (Fay et al. 2011).

Area-wide management builds on a successful integrated pest management (IPM) program implemented by the crop consultants. IPM had already significantly reduced QFly pressure before area-wide management started (Lloyd et al. 2010). The state department for agriculture has carried out a number of QFly-related research activities in the region since the 1990s. Hence, local fruit fly activity was well understood and provided important baseline data for area-wide management (Lloyd 2007). It also resulted in an amicable and trust-based relationship between growers, the consultants and state government staff. The crop consultants have serviced around 90% of growers for twenty years or more.

Growers make voluntary contributions to fund QFly treatments in towns. Over the years the number of contributing growers has reduced considerably, with the most frequently mentioned reason for opting-out being that other growers do not contribute, yet still enjoy the same benefits. This was followed by disappointment that the program has failed to deliver the anticipated market access.

Between 1999 and 2007, Central Burnett was able to secure access to a number of domestic markets, without the need for post-harvest treatments, through the establishment of protocol ICA-28 Pre-Harvest Bait Spraying and Inspection of

Citrus (Fay et al. 2011). However, access to international markets without the need for costly cold sterilisation has not yet been obtained.

4.2. Riverina, New South Wales

This area presents a socially challenging case to achieving area-wide management, despite being traditionally not endemic to QFly. The key drivers for QFly management are to reduce pest numbers, prevent post-harvest treatments and to minimise impacts on market access opportunities (Davidson and Davidson 2012). The citrus industry is the main horticulture group pursuing coordinated QFly management. The region used to be part of the Fruit Fly Exclusion Zone (FFEZ), a formal interstate trade zone involving prevention and eradication activities co-funded and managed by state governments and industries (Voullaire and Dominiak 2003; Dominiak et al. 2006). However, New South Wales Department of Primary Industries (NSW DPI) abolished its on-ground operations after unprecedented QFly detections left the NSW FFEZ unviable (NSW DPI 2015).

The local management committee, Riverina Biosecurity, started in September 2012 to oversee biosecurity issues across all horticulture industries in the Riverina, using QFly as a starting point. This follows the demise of Riverina Citrus in 2012, a grower-funded local industry body which had a large involvement in regional QFly management.

4.3. Young-Harden, New South Wales

In September 2012, horticulture growers and local government started a local management committee called the Fruit Fly Action Group to address the challenge of QFly, as the pest increasingly impedes market access. The group is grower-driven and includes representatives from two shire councils, an on-farm consultant from a chemical company and a NSW DPI representative.

Intermittent QFly management and research activities by the state and local government have occurred in the region. For example, between 2003 and 2006, state government research revealed a strong case for the possibility of developing a QFly-related protocol for cherry market access, such as an area of low pest prevalence (Marte 2007).

Respondents report that QFly breeding in town backyards is a major concern. Some mentioned an increase in derelict orchards, lifestyle blocks and absentee landholders on land that used to be commercial orchards. Some exiting growers sold their land as a number of lifestyle blocks to maximise their capital gain.

4.4. Applying the design principles

a. *Clearly defined boundaries*

In Central Burnett, the geographical boundaries of the area-wide management program lies within the North Burnett Region local government area. It includes all commercial horticulture operations, including predominantly citrus (mainly

mandarines), and some table grape and mangoes, reportedly involving around 60 commercial growers. The area includes the towns of Gayndah and Mundubbera, and a production area of around 2000 ha along the Burnett River (Fay et al. 2011). Signs have recently been erected along major roads in the region to discourage travellers from bringing fresh produce into the region.

Strong on-farm support for QFly management results from the majority of growers being export-focused or else supplying to QFly-sensitive domestic markets. Being located within the endemic QFly region, growers are well aware that on-farm QFly management is imperative. Having relatively small towns, means that town residents – who generally have less incentive to invest in backyard QFly management – can be dealt with as an externality. This makes it achievable for growers to fund regular backyard QFly management.

The Riverina covers the local government areas of Carrathool, Griffith, Leeton, Murrumbidgee, and Narrandera (Davidson and Davidson 2012). Varying levels of incentives to control QFly complicates securing support from all people with host plants on their land, even amongst the estimated 420 citrus growers. Most are part-time growers who run low-input production systems focused on the juice market. A smaller proportion of growers supplies to the export market. At the time of the fieldwork juice companies carried-out fruit inspections on arrival for signs of QFly infestation. For export-oriented growers, to achieve access to lucrative overseas markets without applying costly, postharvest cold sterilisation, regular monitoring of an extensive QFly trap grid across the region is required to supply hard evidence of low QFly prevalence. There are also several other horticultural industries, that, despite being declared hosts, are not economically affected by QFly. Likewise, many town residents and lifestyle landholders have little incentive to control QFly. Road signs to discourage travellers from bringing fresh produce into the Riverina were still in place from the FFEZ period. The Riverina Biosecurity was negotiating with NSW DPI to retain at least some of the signage.

The Young-Harden geographical boundaries include the two shire regions of Young and Harden. Setting achievable boundaries around who needs to comply with certain recommended practices is complicated through the varying levels of incentives, especially as many peri-urban landholders and town residents have little direct incentive to actively address QFly concerns.

b. *Congruence between appropriation and provision rules and local conditions*
Naturally, Central Burnett growers' on-farm QFly investment is related to the size of their operations. In addition, the voluntary contribution that the management committee requests from each commercial grower to fund town treatments is based on the number of hectares that each grower has under horticulture production. In order to maximise the cost-effectiveness of QFly management, the frequency of QFly baiting depends on the crop under production and time of harvest. Citrus growers increase to weekly baiting from January to harvest (around August)

whereas mango and stonefruit growers apply baiting between half fruit growth to harvest (Lloyd 2007). Control is further intensified if QFly catches in monitoring traps increase above certain thresholds.

In the Riverina, export citrus growers would benefit most from successful area-wide management. Apart from already implementing onerous QFly management programs on-farm, one export grower mentioned that he is willing to spray for his neighbours if area-wide management would eliminate the need for costly cold sterilisation. However, there is no incentive for growers like him to invest in a much challenged area-wide management initiative beyond rigorous on-farm practices while they still have to invest in cold sterilisation.

Likewise, most export-oriented Young-Harden growers are reported as generally applying rigorous QFly management on-farm; yet there is little evidence of those benefiting most contributing most to this recently-initiated program. The local government tries to get the best output for input by applying bait sprays in towns during two periods per year when QFly numbers spike.

c. *Collective choice arrangements*

The Central Burnett pilot program was co-funded by growers and a grant from the national research and development body, Horticulture Australia Limited. Growers, crop consultants and the state department research staff set the research agenda for the area-wide management pilot program, thereby responding to growers' self-identified needs. The management committee, called the Central Burnett Area-Wide Management Committee was formed in 2003. Until today it comprises the three crop consultants, citrus and non-citrus grower representatives, staff from the state government department for agriculture, a local shire council representative and a few other stakeholders (Lloyd et al. 2010). Growers tested new technologies such as male annihilation on-farm with the support of crop consultants and participated in an evaluation at the end of the pilot program. A grower survey carried out in 2005 showed one hundred per cent of growers were in favour of continuing the program (Lloyd 2007). As many growers employ a crop consultant, who serves on the management committee, most growers continue to have ample opportunity for two-way discussions with key decision-makers.

Extensive engagement with Central Burnett town residents commenced six months before the pilot program. Public meetings were held with the local crop consultants who explained the importance of, and the science behind, area-wide management. These interactions gave residents an opportunity to respond if they had concerns or questions. Residents were asked to give permission for QFly management activities to be carried out in their backyards on a regular basis. Key messages were reinforced with the distribution of flyers and posters through local shops. Respondents talked about town people remarking that they can now enjoy maggot-free backyard produce. At the end of the pilot program, 89% of residents supported the program (Lloyd 2007) and respondents reported that support remains high.

In the Riverina, no strongly established communication channels exists between Riverina Biosecurity and all horticulture growers in the region. Some horticultural industries have no local representative bodies, which complicates communication with these growers. Generally speaking, grower meeting attendance is low. Solidarity amongst citrus growers has also been damaged following a troubled past involving the demise of Riverina Citrus.

Communication with town people in the Riverina involves predominantly one-way communication, requesting town residents to maintain pest-free backyard hosts, this being done by media releases and radio talks. A number of workshops were planned to demonstrate to town residents and growers how to best manage QFly.

Young-Harden respondents mentioned that commercial growers are well-connected with each other, including connections with those serving on the Fruit Fly Action Group. However, connections with newer horticulture groups, such as a local Lebanese community, are weaker. Some growers on the Fruit Fly Action Group have amicable relationships and informally engage with Lebanese growers about the importance of QFly management, contributing to trust and communication channels between them.

Current communication with Young-Harden town residents, including two public meetings and various media releases, involves mainly one-way promotion of maintaining pest-free backyard hosts.

d. *Monitoring*

Monitoring of on-farm practices in Central Burnett happens when crop consultants visit farms. Crop consultants provide the management committee with up-to-date information on seasonal QFly activity, incidence of crop infestation, and the level of adoption of recommended practices.

Good financial record management ensures the management committee knows who contributes to the town treatments and who has ceased paying the levy. The reduced contributions has forced less intense town QFly treatments and monitoring. The management committee keeps a close eye on the effectiveness of the revised procedures to ensure QFly is still satisfactorily managed.

QFly prevalence in the Riverina is monitored through traps on growers' properties, in towns and other rural areas. Riverina Biosecurity has had some success with encouraging packhouses to insist on proof of QFly management from growers. Legislation requires Riverina residents to maintain QFly-free hosts. According to the Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order No. 45, 2011 under the Plant Diseases Act 1924, owners and occupiers of land or premises in the Riverina area are required to treat citrus and prune plants for QFly using specified bait sprays and to maintain a treatment record. Many interviewees expressed frustration that the state government does not enforce this legislation, several ascribing it to a lack of state government resources. A state government representative pointed to a moral constraint

preventing them from fining ordinary citizens for not maintaining fruit trees if they lacked resources or were not able-bodied, such as retirees. Enforced regulation requiring regular backyard maintenance might also be unpopular with voters.

Most Young-Harden growers monitor QFly pressure on-farm. The Young and Harden shire councils conduct monitoring in towns through a number of traps. NSW DPI also conducts some trapping in the region.

e. *Graduated sanctions*

There was no evidence of formal graduated sanctions for non-compliance with recommended QFly management practice in any of the case studies. In Central Burnett such growers might get a personal word from a crop consultant. Soft sanctioning is applied to Central Burnett growers who do not contribute to town treatments. They are indirectly identified by publically listing and thanking contributors in newspapers and providing them with gate signs. This has reportedly led to some growers resuming their contributions. One respondent called it a 'blame and shame system in disguise' and said that if the management committee was authentic about thanking contributors, they should have done it from the start.

f. *Conflict resolution mechanisms*

No formal conflict resolution mechanisms were identified in any of the case studies. The management committees would be the first point of call to resolve QFly-related conflict.

g. *Minimal recognition of rights to organise*

Government agencies across state and federal levels are supportive of all three case studies to organise themselves to achieve and maintain area-wide management.

h. *Nested enterprises*

The pilot Central Burnett area-wide management program and the research leading up to it are evident of complementary nested systems. This is how a crop consultant described it:

> '*We used to have the Central Burnett Horticultural Committee. Growers were paying a levy for regional R&D and marketing. We had two meetings a year. [Two specific QDPI&F staff] would come along, we would say we have problem with this, they'd say we will apply with HAL if you contribute. And then we got involved in the fruit fly stuff. The project was driven by [the three crop consultants]. This is the issues we found, we would call on DPI [state government Department of Primary Industries] people and they come up with project and get on with it.'*

Nowadays, the Queensland state government still provides some support through representation on the management committee and identifying insects caught in

traps. However, a lack of resources was mentioned as a barrier to receiving further government support.

Despite spectacular QFly management in Central Burnett, area-wide management has failed to translate into formally supporting international market access without the need for cold sterilisation. Attaining international market access is a complicated, sometimes politicised process and growers are to a great extent dependent on government representatives and industry bodies to pave the way and provide needed support. The reduction in growers making voluntary contributions to the town treatments partly results from disappointing market access outcomes. A grower no longer supporting town treatments explained it as follows:

> *'The concept is correct by lowering the general fruit fly population in the whole district …The goals were correct at the start for market access, that is what it could do for getting access to Victoria, South Australia and internationally. But in reality we have been showing good results for five to six years now and still we need to cold treat for export. New markets all require cold disinfestation too. So, it [area-wide management] is not paying back. It misses the mark in what they said it would do. For us to fund it [the town treatments] without seeing any real benefits…we are already spending lots of money on fruit fly management [on-farm], including MAT, baiting and cover sprays if we need to.'*

The NSW state government and the peak industry body, Citrus Australia, provide support to the Riverina initiative through their involvement in Riverina Biosecurity. However, there was little devolution of power beyond state government, such as enforcement powers, to back-up softer engagement activities with people who have little incentive to manage QFly on their properties.

In Young-Harden, the NSW state government also provides valuable input, although respondents were disappointed with the difficulty of securing support from the NSW Minister responsible for agriculture. Respondents were also frustrated with a lack of feedback from the Australian Department of Agriculture – as the responsible body for international market access negotiations – about what is required on-farm to achieve access to certain markets. Some respondents suggested that the Australian Government does not appreciate the cost of impractical on-farm requirements that are the result of government-to-government negotiations. As with the Riverina, there was little devolution of power beyond state government, to bolster the softer engagement activities with town residents. Local government was investigating what it could do within its powers, such as requiring removal of trees or a management plan for fruit trees when land is sold.

5. Discussion

This section provides a synthesis of the main lessons learned from applying Ostrom's design principles to area-wide management of QFly. In terms of the need for clearly defined boundaries (principle 1), geographical boundaries are overall

well-demarcated. However, these boundaries are porous, especially in areas that are located on major travelling routes, as travellers can bring QFly-infected fruit into the regions. In the Central Burnett and Riverina cases management committees use road signs to discourage travellers from bringing fresh produce into the region.

Most challenging here, due to the varying incentive levels for QFly management, is determining who needs to implement QFly management strategies, what is required from them and how to secure their commitment. In the Riverina and Young-Harden this is complicated due to the heterogeneity amongst risk contributors. Even within the Riverina citrus industry, most growers would in principle agree that collective QFly management has value, but the different market requirements imposed on them (e.g. juice versus export growers) complicates finding a shared vision for QFly management. In addition, many part-time growers have other sources of income. Cox et al. (2010) point out that the dependence of risk contributors on a resource is directly related to the incentive they have to support cooperative behaviour. The findings suggest that collective action is easier to achieve when horticulture growers have fairly homogenous on-farm objectives, such as in Central Burnett. To address QFly risk from non-commercial land, the Central Burnett shows that small town communities are helpful as it is more feasible to implement QFly management for them.

Although there is some ambiguity in literature about the impact of hetereogeneity, generally speaking, it is seen as presenting challenges to collective action (Ostrom 2010). Heterogeneity complicates achieving proportional equivalence between benefits and costs, i.e. congruence between appropriation and provision rules (principle 2). When participants' investments are not proportionate to the distribution of eventual benefits, incentives for cooperation is diminished. This challenges decision-making (Valentinov 2007) and adds to the transaction cost of achieving consensus (Ostrom 2010; Chaddad and Iliopoulos 2013). It affects whether locals perceive rules as fair, an important condition for gaining support for local institutions. Identifying who is gaining from biosecurity measures, to what extent and therefore who ought to contribute most, is not always evident (Donaldson 2013). For example, the ratio of who benefits most from area-wide management depends on whether the scheme is accepted by international markets to the point that it makes post-harvest treatments, such as cold sterilisation, obsolete. The willingness of a Riverina export grower to undertake some QFly management activities on his neighbours' land if area-wide management eliminate the need for cold sterilisation confirms findings elsewhere. That is, wealthy members sometimes accept a disproportionate economic responsibility to ensure the success of collective action provided the benefit they gain from it justifies their actions (Jones 2004).

If the number of risk contributors who have little to benefit from QFly management greatly outweighs the number of main beneficiaries – usually full-time, commercial growers – it is not feasible for these growers to pick-up the cost of QFly management for other risk contributors. For example, in Central Burnett

there are around 60 growers keen to export. The towns are relatively small with Gayndah having 1789 residents and Munduberra 1042 residents in 2011 (ABS 2015). In the Riverina, by contrast, growers focused on the export market form a minority of the total of 420 citrus growers. This area includes the large regional centre of Griffith with a population of 17,616 residents in 2011, as well as Leeton with 8414 residents and Hillston with 1430 residents (ABS 2015).

There was also evidence of congruence of appropriation and provision rules with local social and environmental conditions, the second part of principle 2 (Cox et al. 2010). In all case studies those involved in QFly management intensified control activities at certain times of the year in conjunction with times of peak QFly pressure, or when the pest can cause most damage. The deployment of traps to monitor of QFly pressure plays a key role here.

Finding and implementing ways where most of those affected by the local institutions have their views represented can be challenging (principle 3 – collective choice arrangements). As demonstrated in the case studies, relationships play a facilitating role. Informal relationships between commercial growers in Young-Harden assist in two-way discussions between those who are on the management committee and others affected by the group's decisions. In Central Burnett, engagement with those affected by decisions happens in a number of ways. First, the area-wide management program was developed in a participatory fashion with significant input and involvement of growers. Hence, the program was designed in a way that was appropriate for local socio-economic, cultural and political contexts (Pretty 1995; Gonsalves 2005). Second, existing relationships between growers and crop consultants imply strong ties between growers and the management committee. The transaction cost to achieve similar engagement in, for example, the Riverina, would be much higher as the grower population is far bigger, more fragmented, and there is less evidence of an existing effective 'communication infrastructure'. Collective choice arrangements also mean that management committees need to enjoy legitimacy and credibility with different local groups in order to influence their behaviour. This is again obscured in the Riverina, due to fragmentation resulting from the large variety of horticulture industries and tension within the citrus industry relating to the demise of Riverina Citrus. This implies that Riverina Biosecurity as a start might benefit from greater representation across different sections within the local citrus industry to consolidate industry support, as opposed to the current high representation of external bodies.

The fact that Central Burnett town residents receive 'free' QFly management makes it unsurprising that such a high percentage support the program. In contrast, town residents are more likely to feel QFly requirements are imposed on them when they are being asked to purchase treatments and invest time and effort indefinitely to maintain their fruit trees. The true cost of effective community and grower engagement to underpin collective choice arrangement can be easily underestimated. Pest management presents the added challenge that when control activities are most cost-effective, i.e. when the pest is not present yet or at very

low numbers, it is difficult to secure interest from stakeholders, such as town residents and even local government. This has been the past experience in the Young-Harden case study.

The importance of monitoring (principle 4) has been described in the area-wide management literature (Vreysen et al. 2007a). Monitoring of QFly pressure was evident in all case studies, with varying numbers of traps under surveillance on-farm and in towns. Sharing and collating data from different traps can assist in developing a clearer picture of QFly behaviour across the region. However, some respondents reported that information generated by state government traps did not reach all interested parties.

More challenging is monitoring people's compliance with recommended practice. The case studies reveal a number of ways of using existing channels that could be helpful. In Central Burnett, the crop consultants' visits to farms give a good insight into compliance levels. In the Riverina, some packhouses insist on proof of QFly management. Some believed that other reluctant packhouses might follow suit if QFly pressure increased and started to affect their supply. State government-issued legislation that enforces compliance was complicated for a number of reasons. The Treatment and Eradication of Queensland Fruit Fly Order in the Riverina requires QFly host owners to implement pest management strategies. However, enforcement is thwarted by a lack of resources for consistent compliance monitoring. NSW DPI representative also pointed out that a heavy-handed approach of imposing fines on non-complying residents poses a moral dilemma, especially when people have limited ability to comply. This also conflicts with the need for implementing graduated sanctions.

Overall there was limited evidence of graduated sanctions (principle 5). Dyck et al. (2005), in their review of area-wide management programs involving the sterile insect technique, recommend that penalties for poor performance need to be negotiated before the program commences. These requirements should form part of an official agreement between stakeholders, rather than an agreement between friends. In Central Burnett, the indirect tactic to publicly thank contributing growers and thereby expose non-contributors had some success in gaining renewed commitment from some to support the town treatments. This system represents a second-order reward or a positive sanction, where those who are cooperating are rewarded in order to provide an incentive for defectors to also cooperate. Rewards work better than punishment as they increase the average payoff for the group, whereas punishment lowers the average payoff for the group (Kiyonari and Barclay 2008). However, as this tactic was not built into the program early-on there is a risk that violators will perceive it as a punishment, as the feedback from one respondent reflects.

Support from state government agencies and peak industry bodies go some way in meeting the principle of nested enterprises (principle 8). However, it seems that with international market access the nested approach become unstuck. Market integration can impede successful collective action due to its influence on local incentive structures and power relations (Cox et al. 2010). Findings from

the case studies suggest that abiding by national and international trade rules represents a 'top-down' element to on-ground QFly management strategies. For example, trade protocols provide detailed requirements to manage pest risks on-farm and throughout the supply chain. Several growers lamented that protocols by importing countries sometimes present impractical and not necessarily effective ways to prevent pest infestation, but they need to abide by them in order to be permitted to access export markets. This can interfere with adaptive management on the ground, i.e. the inclusive process where key stakeholders, including growers and researchers, learn from doing in their own context, rather than mere implementing management activities (Allan and Curtis 2005; Folke 2007; Berkes 2010).

In the area of pest management for market access the state plays many institutional roles that widen the power differential between the state and growers. As regulator, the state increasingly shapes national and state biosecurity policies to reflect international trade regulations, such as those set by the WTO, rather than solely basing policies on the needs of growers (Wissemann et al. 2003). The state enforces many of the national and international trade requirements, including inspections, auditing and accreditations. However, it is also a partner in assisting growers to overcome pest issues; for example, by providing resources for research and on-ground activities, advice about the technical aspects of QFly management and market access requirements.

Unsurprisingly, many respondents mentioned that government needed to play an enabling role in achieving industry-driven area-wide management. In particular, respondents want government to actively promote area-wide management as a suitable phytosanitary measure as part of a systems approach during market access negotiations, in order to overcome the need for cold sterilisation. Industry representatives are not allowed to participate in negotiations between importing and exporting countries' governments, so respondents saw it as government's role to champion area-wide management. However, market access experts explained that, despite formal allowance in the ISPMs for systems approaches, in reality these are problematic. In particular, demonstrating the combined efficacy of different QFly management techniques throughout the supply chain is difficult. Markets therefore continue to show preference for 'one kill step' measures, such as cold sterilisation, or previously, the now restricted chemicals.

Other government roles and actions that were mentioned as being helpful in the context of QFly management included enforcing compliance with QFly management practices; advice about how to strengthen market access opportunities; establishing network opportunities with different government departments and groups; overcoming regulatory challenges and 'red tape'; and negotiations with other government departments on issues such as erecting road signs. Factors mentioned that hamper progress on the ground included high government staff turnover, slow government processes, the difficulty of reaching the right government official to talk to and apathy to grower needs, such as government officials who may attend meetings but are not truly engaged.

This work shows that, unlike the age-old concept of pest control, the concept of biosecurity and the related national and international plant protection institutional frameworks are attached to certain worldviews (Donaldson and Wood 2004). These are embedded in paradigms of neoliberalism, the dominance of market forces, standardisation (Dibden et al. 2011) and heavy reliance on scientific expertise. It involves the belief that processes of categorisation, ordering and accompanying rules can stem the flow of unwanted organisms from 'unclean' infested areas to 'clean(er)' controlled areas and provide assurances that produce is free of unwanted organisms. In particular, control of human behaviour is seen as the key mechanism to achieve desired outcomes (Donaldson and Wood 2004) in a realm that, in practice involves a complex interplay between the environment, host plants, humans and the problematic organism, here QFly (Hinchliffe et al. 2013). Although this status-quo clearly has weaknesses and is increasingly critiqued (Donaldson and Wood 2004; Dibden et et al. 2011; Hinchliffe et al. 2013), for commercial horticulture growers these are the realities that they need to deal with in order to maintain their livelihoods. Moreover, in the worldview of those who do not need to respond to these national and international institutions, QFly present a mere nuisance, the level of which is related to how much they value their home-grown produce. In the context of the commons, this discord between worldviews is likely to challenge the ability to achieve collective action.

6. Conclusion

The case studies illustrate that there are no 'one size fits all' local institutions that will be ideal for all area-wide management programs (Carlsson and Sandström 2007). There are certain traits of commercial pest management that shape the abilities of ventures such as area-wide management to align with the design principles. First, these initiatives can involve a large number of risk contributors who have little incentive to manage the pest. Second, there is a large power differential between growers and the state as international and national biosecurity institutions present top-down elements to pest control for market access. Growers are to a great extent dependent on state negotiations with prospective importing countries or states to achieve market access. If anticipated market access fails, local support for all aspects of an area-wide management program is likely to decline. Three, the onerous requirements set by international biosecurity institutions and QFly-sensitive markets contribute to more heterogeneous objectives amongst growers about what a regional QFly management program should involve.

Apart from certain biophysical traits within a region, the social profile of local industries and town communities play a key role in achieving compliance with the Ostrom design principles. In Central Burnett, the long-term presence of the three crop consultants, a relatively homogenous industry, small sympathetic towns and a participatory research-based lead-up to the program, are major contributing factors to the success of this area-wide program. The Riverina and Young-Harden are challenged by the heterogeneous incentives for the different landholders who

range from full-time commercial growers to lifestyle and absentee landholders and town residents. These findings suggest that industry-driven area-wide management will be hampered in regions where different types of landholders co-exist.

There is a key message from this work to horticultural industries contemplating industry-driven area-wide management. Despite the fact that the QFly management technologies developed in successful cases such as Central Burnett provide a great exemplar for other areas, disconnecting them from the socio-institutional context in which they emerged, is likely to result in unrealistic expectations elsewhere.

This study demonstrates that the commons can make a significant contribution to gaining insight into maintaining sustainable agriculture. It also confirms the finding of Agrawal (2001), that there is a need to investigate the impact of markets on the commons and how to apply socio-ecological systems thinking in a market-based environment.

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