Issues in Entomology: Tephritid Pest Populations

To Repeat: Can Polyphagous Invasive Tephritid Pest Populations Remain Undetected For Years Under Favorable Climatic and Host Conditions?

T.E. SHELLY, D.R. LANCE, K.H. TAN, D.M. SUCKLING, K. BLOEM, W. ENKERLIN, K. HOFFMAN, N. BARR, R. RODRÍGUEZ, P.J. GOMES, AND J. HENDRICHS

In recent decades, there has been a dramatic increase in detections of invasive pest tephritid fruit flies in California as well as other regions. Two camps have offered divergent explanations. One maintains that numerous introductions of maggots in infested fruit found incipient populations, which are detected by the existing trapping network and eradicated or, less frequently, not completely eradicated, a circumstance which is then followed up with another full set of eradication procedures (McInnis et al. 2017). Frequent detections, in this view, reflect increasing international human traffic and arrival of infested hosts, particularly in the Los Angeles megalopolis. Increased global movement of people and goods is also likely responsible for the increasing number of different fruit fly species being detected in California (from one species in 1960 to 17 species in 2017). The alternate view is that populations of several species, including the Mediterranean and oriental fruit flies, *Ceratitis capitata* (Wiedemann) and *Bactrocera dorsalis* (Hendel), respectively, have been established in the state for many years (Carey 1991, 1996, 2010; Papadopoulos et al. 2013), and detections result from occasional population build-ups in particular locations to the point where they are detected in traps. Once discovered, eradication procedures reduce, but do not eliminate, such populations to small, sub-detectable levels, where in time they may again grow to a detectable size.

In the recent give-and-take, McInnis et al. (2017) challenged the validity of the "established population" argument by raising several obvious questions. If non-native pest fruit flies are established in California, why are they not trapped in rural areas, where the vast majority of commercial horticultural production is? Why have larvae never been detected in Californian produce by trading partners and foreign consumers? And why are detections in California so rare in spite of a continuously operating trapping network that includes more than 94,000 traps? Or, more precisely, what ecological or evolutionary factors act over long periods to maintain their populations at what Carey et al. (2017) now call "ultra-small" sizes as to be undetectable by trapping? Also, what are the specific conditions that trigger the sudden build-up of the populations that they claim remain undetectable for years? These fruit fly species are fecund, with relatively short generation times, and polyphagous, with hundreds of suitable host plants; they are highly mobile, and they have no apparent surfeit of natural enemies. In rebutting McInnis et al. (2017), Carey et al. (2017, hereafter referred to as the Carey Group) posited 10 rebuttal points that repeat previous arguments while failing to directly address the arguments of McInnis et al. (2017). We believe the Carey Group's position rests largely on three assumptions: 1) there are long post-invasion lag times in population growth; 2) the existing trapping system for detecting non-indigenous tephritid species is ineffective; and 3) operational or regulatory international guidelines regarding eradication are weak compared to strictly science-based criteria. Accordingly, this essay focuses on these assumptions and comments briefly on the San Diego oriental fruit fly case highlighted by the Carey Group. Remarks on the remaining rebuttal points appear in Table 1.

Excessively Long Lag Phases

Successful invasions manifest a common process involving a series of sequential phases, namely transport, colonization, establishment, and spread (e.g., Blackburn et al. 2015). While the duration of these phases may vary, a temporal gap, or lag time, may occur between establishment and rapid population growth and spatial spreading (e.g., Mack et al. 2000). The Carey Group derides the expectation that non-native fruit flies in California should display rapid population growth, because they assume these species, despite their r-selected nature, are still in the lag phase of the invasion process and hence undetectable.

However, lag phases, particularly for invasive insects, are generally not prolonged. The Carey Group noted that lag times may last decades or even centuries, but these extreme cases occur in long-lived, woody plants, such as certain oaks that do not produce acorns until 50+ years old (Kowarik 1995). Lag times vary substantially among taxa, being decades to centuries for woody plants (Kowarik 1995, Larkin 2012) and one to several decades for herbs (Pyšek and Prach 1993, Larkin 2012), birds (Aagaard and Lockwood 2014), and mammals (Crooks 2005), but only a few years for insects (Roques et al. 2016). Regarding insect invaders, Kenis et al. (2007) stated "In general, there is no obvious 'lag phase'...and when a lag phase is observed, it is usually of short duration." Examples of rapid population growth and spatial spreading are common for invading insects and include wasps (Bertolini et al. 2016), mosquitoes (Kaufman and Fonseca 2014), ladybird beetles (Lombaert et al. 2010), homopterans (Petit et al. 2008), and drosophilids (Roques et al. 2016), to mention a few.

Rapid growth and spread also characterize invasive pest tephritid species. For example, *B. dorsalis* was discovered in Africa in 2003, but within three years, it was a major pest throughout the sub-Saharan region (Ekesi et al. 2006) and is now present in 41 African countries (De Meyer et al. 2014). In Australia, this same species invaded Queensland and rapidly spread to 20,000 km^2 before an eradication program stopped the expansion and ultimately eliminated this very large infestation (Hancock et al. 2000). Rapid population growth and spread was also documented for medfly invading Guatemala and southern Mexico (Hendrichs et al. 1983). This same pest recently invaded the Dominican Republic, spreading in a few months to more than 2,000 km^2 (Marte et al. 2017). Even more germane, and as noted by McInnis et al. (2017), the largely monophagous olive fly, *Dacus oleae* (Gmelin), was first detected in California in 1988 and within five years had spread to all olive-growing areas in the state.

First discovery of medfly and oriental fruit fly in California occurred 42 (1975) and 57 (1960) years ago, respectively (Carey et al. 2017). To invoke the lag phase to explain the decades-long scarcity of these species in California is to propose delays in population growth of these highly fecund, mobile, and polyphagous insects that are, at minimum, several-fold longer than those typically observed for invasive arthropods and counter to documented cases in other parts of the world.

Apparently, the Carey Group assumes that, because the invading tephritids are largely tropical in origin, they face an inhospitable climate in California, which constrains population growth. In other words, the long lag times are thought to represent time required for local adaptation. Regarding the medfly, it is interesting to note that Carey (1996) previously identified the southern coastal region of California, including the Los Angeles Basin and San Diego County, with a climate similar to Greece and Israel, where medfly is abundant, as prime habitat for the medfly and predicted that "all backyard hosts would eventually be infested with medfly throughout much of the year and commercial fruit-growing areas would be under constant attack." It is not clear why this region of California, "with the most ideal conditions for medfly in the state" (Carey 1996), was previously considered eminently suitable for the medfly but now, apparently, is not. The high abundance of medfly in the Mediterranean region indicates that the species should similarly thrive in California. Regarding *Bactrocera*, the invasion history of the peach fruit fly, *B. zonata* (Saunders), to take one example, also casts doubt on the notion that California presents an "adaptive problem," as this species has a tropical origin (Southeast Asia), yet has become established in Egypt, where it has become a serious agricultural pest (Ni et al. 2012). Similarly, *B. dorsalis* has rapidly adapted to a wide range of ecological zones (semi-arid to humid tropical) across the African continent (Goergen et al. 2011).

Additionally, the strong likelihood (Barr et al. 2014) that non-native tephritids have been introduced to California on multiple occasions from multiple sources weakens the notion that "adaptive constraint" limits population growth. Repeated arrivals would serve to increase the genetic diversity of any established populations and thereby lessen the incidence and severity of genetic bottlenecks and increase the adaptive plasticity of the established populations (the "genetic rescue" effect, Carlson et al. 2014). Moreover, the theoretical expectation that adaptive potential is inversely related to population size may not be universally true (Hoffman et al. 2017), and indeed invading insects may evolve quickly to novel environments (e.g., Huey et al. 2000, Tanaka et al. 2015).

Ineffective Trapping Program

Assuming that populations of non-indigenous tephritids have existed in California for decades implies that these flies have escaped detection by the ongoing extensive trapping program in the vast majority of times and places (94,000 detection traps serviced biweekly yields 2,444,000 trap checks per year). It also rests on the unlikely assumption that these populations are consistently small over long periods under favorable climatic and host conditions; otherwise, they would be detected within a few generations. In any case, the possibility of a small population not being detected at a given point in space and time has little bearing on whether broadly distributed populations of non-native tephritids persist in California. That question relates more specifically to whether populations can be large enough to be viable, display the characteristic demography and ecology of polyphagous invasive tephritids, and still escape the general detection trapping system in the vast majority of places and times.

The maximum size that populations can achieve without being detected on a regular basis will depend on the sensitivity of the detection trapping system. Assessing that sensitivity requires an understanding of the relationship of trap capture to the numbers of flies in the field, and the latter can be difficult to measure, especially if populations are sparse. One approach is to release insects within a detection trapping network, such that the numbers of flies and their distances from traps are known, and then observe how many are caught. The proportions of flies captured can be used as estimates of the probability that a fly will be "detected" (caught) if present at a given distance from a trap (Lance and Gates 1994).

Distance/capture functions based on mark-recapture data have been used to directly calculate probabilities of detecting *C. capitata* and *Bactrocera* populations of various sizes (Lance and Gates 1994, Shelly et al. 2010) and to develop Monte Carlo simulations of incipient tephritid populations within detection trapping grids (Lance 2014). Results of these exercises suggest that the detection grids in California, which include more than 94,000 traps that are regularly relocated according to host phenology, are quite sensitive. In high-risk areas (monitored at two traps per km^2), the models predict that over half of the populations of *C. capitata* will be detected (at least one fly caught) by the time there are 250 males present, and more than 90% will be found at 2,000 males. For *B. dorsalis*, only about 30 males are required for a 50% detection probability, and the 90% level is reached at around 200 flies (Lance 2014). Because these estimates are based on probabilities of capture of individual flies, they apply across space and time. For example, assuming a population of *C. capitata* exists only in 10 "pockets" that are spread throughout "high-risk" areas of California—residential areas where the detections have historically occurred—we should expect to find at least one fly half of the time if the pockets average 25 males each, and 90% of the time if they average 200 males. To further illustrate, there have been many instances when two years have passed with no *C. capitata* detections in a given county. Assuming, conservatively, six to eight generations per year (Muñiz and Zalom 1997), these pockets of infestation would have to average two males or fewer per generation to avoid at least one system-wide detection 50% of the time, and 10 males or fewer per generation to escape 10% of the time. Given that populations in these size ranges are likely subject to Allee effects (Liebold and Tobin 2008) and will fluctuate both seasonally (Papadopoulos et al. 2001) and stochastically, we would argue that the long-term survival of a given population would be extremely unlikely under the scenario described here. A similar analysis with *B. dorsalis,* a species showing much higher attraction to traps, would show long-term survival of undetected populations to be even more unlikely when considering that *B. dorsalis* males seek out and ingest methyl eugenol, the bait used to trap these flies, in order to produce sex pheromone and to attract females for mating (Tan and Nishida 1996). Moreover, repeat captures of the same individuals in methyl eugenol traps (Tan and Jaal 1986) suggest that males may need to "re-fuel" on this pheromone precursor, which would increase the likelihood of detection.

The Carey Group, however, dismiss the entire approach of using mark-recapture data for these analyses and state that "Detectability estimates based on results of release-recapture studies using tens of thousands of factory-reared laboratory strains of oriental fruit flies have little relevance to the detectability of wild flies living in their natural habitats." Presumably, their argument would extend to similar studies with *C. capitata* (e.g., Lance and Gates 1994). In contrast, we argue that data from such tests are currently the best quantitative information available for estimating detection system sensitivity. First, evidence suggests that factory-reared males show similar (*Z. cucurbitae*; Manoukis and Gayle 2016) or lower (*C. capitata*; Shelly and Edu 2009) attraction to traps compared to wild males. Thus, if anything, use of factory-reared males is a conservative approach and yields underestimates of trapping sensitivity. In addition, the Carey Group's implication that the mark-release studies lose credibility because they were not conducted in natural fly habitat is illogical, especially considering that these assessments were conducted in the very areas where the Carey Group claims such flies are now established. What matters is the detection probability in the high-risk, suburban areas of California, not comparable data for the forests of sub-Saharan Africa or Southeast Asia. Finally, the Carey Group's statement implies that tens of thousands of flies are simply dumped into the field, resulting in dense clusters of highly agitated flies that are more likely to disperse and eventually locate a trap. However, even in a replicated test in which hundreds of thousands of *C. capitata* were eventually released, only a few hundred flies at most were released at any one point in any given trial by allowing flies to emerge from holding containers of their own volition (Lance 2014). The resulting overall density of flies in the field during all of the tests that were run in actual detection trapping grids would be considered very low relative to areas where these species are known to be established. In short, the only real "evidence" that the Carey Group has regarding the irrelevance of mark-recapture-based data is that the available information doesn't fit with their assertion of established, sub-detectable populations. Regardless, we would argue that available estimates of detection system sensitivity would have to be "off" by at least an order of magnitude—and, for *B. dorsalis* probably two orders of magnitude—to allow viable, broadly distributed populations of non-native tephritids to go undetected in

California. At present, we have no reason to believe that available estimates of detection sensitivity are inaccurate (Lance 2014, Meats 2014).

Decades of program experience (Programa Moscamed 2013, Rodríguez 2013) indicate that when delimitation trapping is implemented after a fly detection (ca. five to 10-fold increase in trapping density in arrays in the surrounding 64–81 km^2, together with fruit sampling, to determine the incursion's extent), in over half the cases no additional fly is found, instead of the expected infestation that would trigger an eradication effort. This also runs counter to the Carey Group concept that there is some fixed level below which even a very small population will not be detected (Lance 2014).

Weakness of Operational Guidelines for Declaring Eradication

The Carey Group criticized the operational definition of eradication for tephritid populations under the International Standard for Phytosanitary Measures (ISPM) No. 26 (FAO 2016). They argue that using a time period equivalent to a minimum of three consecutive generations without detections to declare eradication is scientifically unfounded, even though historically it has proven effective, and detailed agent-based simulations have confirmed its effectiveness (Manoukis and Hoffman 2014). They claim, "We do not accept regulatory criteria… as evidence of eradication" but emphasized only "zero individuals in a population," and not the lack of trap detections, as evidence of eradication (Carey 2017). This argument has several major faults. First, since trapping is a chief means of detecting flies, how does one conclude that a population has zero individuals without trapping records? Seemingly unaware of the irony, the Carey Group (2017) proposed that the answer requires "hard detection data" and an in-depth analysis of all trap detections in California over the past 65 years! So, on one hand, trapping records are insufficient to declare eradication but, on the other hand, are essential to identifying populations with zero individuals.

Second, by insisting on strict scientific criteria only, the Carey Group ignored the fact, evident day after day and year after year, that California-produced fruit and vegetable crops are accepted by international trade partners who would immediately refuse products if they detected or even perceived a risk of fruit fly infestation.

Third, the Carey Group essentially rejected international plant health (phytosanitary) standards, adopted by the contracting parties (CPs) of the International Plant Protection Convention (IPPC) (now 183 countries) and designed to effectively harmonize and facilitate international agricultural trade (Devorshak 2012, Jang et al. 2014). These international plant health standards or ISPMs become obligations for countries that are members of the World Trade Organization (WTO) (WTO 1994, FAO 1997). Even though the Carey Group disparaged this global regulatory framework as unscientific, the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) Agreement requires transparency and the use of scientific and technical evidence to support measures that manage risk (Devorshak 2012). IPPC standards are developed by Drafting Groups of internationally recognized subject matter experts and then reviewed and finally adopted by all national plant protection organizations that are CPs to the IPPC. This process ensures that ISPMs respect the appropriate level of protection of all countries, are consistently applied, and are reviewed and revised as the science advances (Jang et al. 2014), thereby allowing comparison and evidence obtained by fruit and vegetable industries overseas to inform similar decisions elsewhere. As a result, uncertainty is decreased by minimizing bias and error in international agricultural trade (Griffin 2012).

Finally, while insisting on a rigorous approach, the Carey Group itself has never provided any scientifically testable proposals in terms of how many trap zeros at what densities would be required, and for how many generations or years based on their academic analysis, to be able to reach what they call "true" eradication success.

San Diego Oriental Fruit Fly Case

The Carey Group highlighted this case as a special example of overwhelming evidence of establishment of a tephritid pest in California. However, several questions arise immediately. Why were the earliest *B. dorsalis* outbreaks the largest, expanding to more than 100 km^2 before they could be eradicated, even though, according to the Carey Group, tephritid pest species require long post-invasion lag times in population growth? Why were there a number of multi-year detection gaps when no oriental fruit flies were found? The most recent *B. dorsalis*-free period spanned three years (2009–2011), an interval encompassing approximately 16 generations of the pest during which 157,638 checks of methyl eugenol traps (2,021 traps serviced biweekly over three years) yielded zero oriental fruit fly finds in the San Diego area, a striking finding given the strong attractiveness of this lure to the oriental fruit fly. This is not counting the 2,021 food-baited traps that were also deployed in the San Diego area (serviced weekly for nine months and bi-weekly over the three winter months), which represent an additional 272,835 zero finds during those three years. As traps are relocated eight times per year, a total of 80 points are sampled per square mile, or 32,336 sampling points in the San Diego area each year.

Why has *B. dorsalis* not been detected on the nearby Mexican side of the border, where non-native fruit fly trap networks are maintained by the Mexican National Plant Protection Organization (SENASICA-SAGARPA) in collaboration with CDFA, USDA, and the Government of the State of Baja California? In 2004, an extensive medfly outbreak was detected in the Mexican city of Tijuana that required a nine-month bi-national effort to achieve eradication (Enkerlin et al. 2015). However, since then, in spite of continuous monitoring, there has been no medfly or other non-native fruit fly detection on the Mexican side, even though San Diego and Tijuana have merged into a large conurbation.

The Carey group stated that it is "illogical" that introductions of the oriental fruit fly into San Diego would

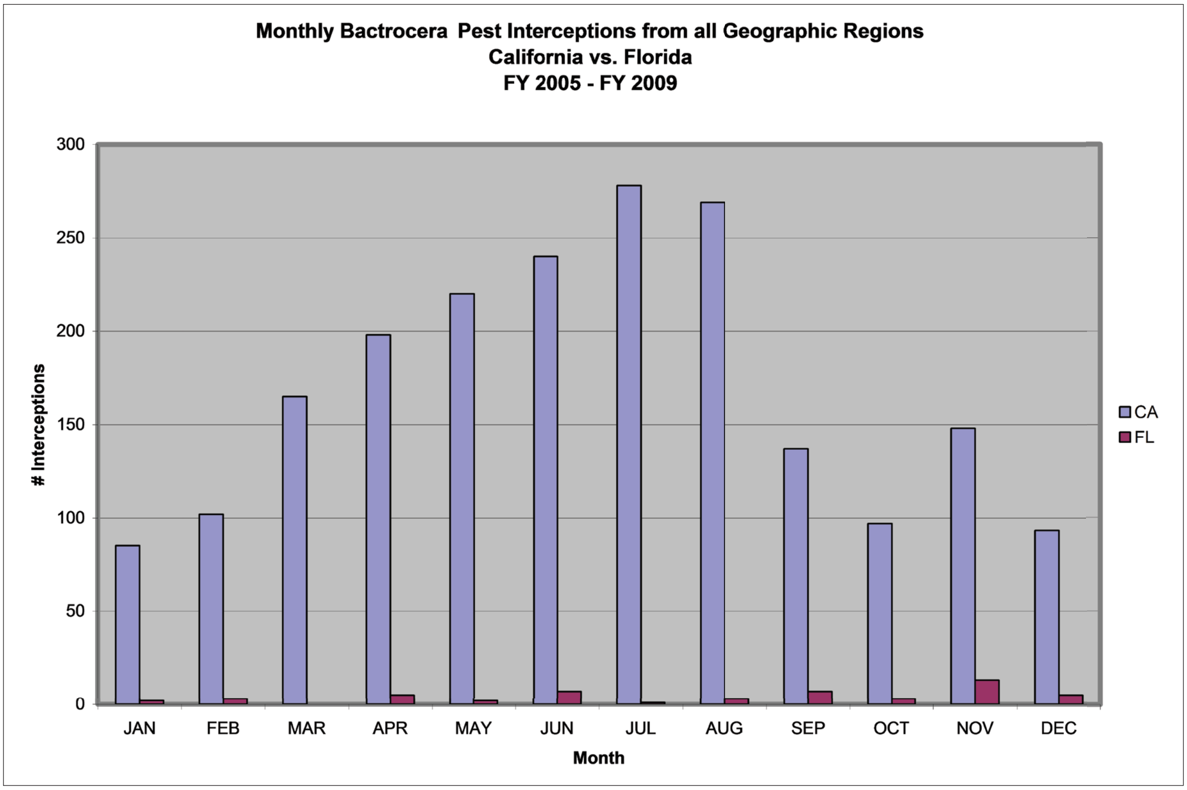

Fig. 1. Monthly comparison between California (CA) and Florida (FL) in terms of numbers of *Bactrocera* spp. interceptions at ports of entry from all geographic regions during fiscal years 2005–2009. (Source: USDA APHIS PPQ AQAS pest ID database.)

suddenly begin after no flies were detected for the previous 100+ years. The start of tephritid incursions in California coincides directly with the initiation of the jet age that began in the United States in the late 1950s with the introduction of Boeing 707 and Douglas DC-8 airliners. As jets became bigger, faster, and further-ranging, they established new levels of safety and passenger comfort that resulted in the development of mass commercial air travel overseas (both passenger and cargo), thereby drastically increasing the likelihood of introductions of non-native pests. The persistent arrival of alien insects in airline baggage and postal shipments originating from hundreds of countries can explain the repeated detections in years following eradication campaigns (Liebhold et al. 2006). As California has historically been a key entry point to travelers and trade coming from Asia, it is not a surprise that it has been so vulnerable to oriental fruit fly and other *Bactrocera* incursions when compared to other high-risk regions such as Florida (Fig. 1).

Carey Group Recommendations

One of the main recommendations of the Carey Group is to follow Australia as an example to address fruit flies in a more "thorough and comprehensive manner." However, Carey et al. (2017) and Australians themselves (Capon et al. 2017) admit that they have recently lost control in Australia's main "Tri-State" fruit production area (southern New South Wales, northern Victoria, and eastern South Australia), as Queensland fruit fly, *Bactrocera tryoni* (Froggatt), has invaded and recently become established there. In the Goulburn Valley (the easternmost part of what was the "Exclusion Zone"), the pest has already been declared endemic with negative effects, and in Sunraysia (the central part), the pest-free area had to be suspended. As a result, they are now preparing "to live with the pest" by permanent application of area-wide suppression measures and implementation of post-harvest treatments to be able to export from this area. Giving up their pest-free status, by following the "Australia model" as promoted by the Carey Group, would negatively affect productivity, employment, environments, and the advancement of sustainable technologies in California, Chile, Mexico, and other major fruit producers and exporters.

Concluding Remarks

The sustained arrival of non-native tephritids cannot be significantly reduced unless there is a major investment in improving exclusion efforts at ports of entry to increase interceptions without affecting travel and trade (Liebhold et al. 2006). There are also no optimal, risk-free methods of surveillance and eradication monitoring, and although trapping systems can be further refined to increase efficiencies, this may not lead to significant improvements in the timely detection and elimination of outbreaks (Meats 2014). Plant protection authorities overseeing agricultural exports and imports need to maintain a fine balance: they have to design exclusion and trapping systems that are not prohibitively expensive but still prevent incursions or allow their rapid detection so that subsequent eradication efforts are not too costly (Lance 2014).

Table 1. Carey et al.'s rebuttal points with corresponding responses.

REBUTTAL POINT #1

Regulatory databases do not contain scientific invasion data.

RESPONSE: GERDA, the Global Eradication and Response Database, compiles information on historical and current eradication programs to give biosecurity practitioners rapid access to international experience and expertise. Ultimately, the database aims to improve the success rate and efficiency of future eradication programs by improving transfer of knowledge between eradication practitioners (http://b3.net.nz/gerda/manual.php?topic=overview). GERDA data were not used unfairly, as claimed, for analysis of the specific situation in California, but only to discern global trends.

GERDA is based on volunteerism, logons are free, and therefore is not a comprehensive compilation of invasions and eradication efforts. Data have been entered by many individuals, who share the vision of getting better information on which to make better decisions about incursion responses. Professor Carey has a GERDA logon but has not chosen to enter any additional fruit fly data from California, merely using his logon to access the contents to try to deflect and weaken his opposition, rather than addressing the argument directly.

REBUTTAL POINT #2

Immediate explosive tephritid population growth is science fiction.

RESPONSE: Text contains section on the assumption of excessively long lag times.

REBUTTAL POINT #3

"Can tephritids escape detection?" is not falsifiable.

RESPONSE: This point re-states point 2 without explaining why explosive population growth under favorable conditions, seen normally in other parts of the world, is a "fictitious assumption" for California, but decades-long lag times for r-selected tephritid species is not. It is ironic that the Carey Group considers the question posed by McInnis et al. (2017) in their title as illegitimate, since for decades they have asserted the existence of undetectable populations of tephritid pests in California, which itself is unfalsifiable.

REBUTTAL POINT #4

Trap sensitivity claims have no basis in reality.

RESPONSE: Text contains a section on the assumption of ineffective traps.

REBUTTAL POINT #5

Genetic analysis implies multi-sourced established populations.

RESPONSE: The genetic data for medfly and oriental fruit fly fit a reintroduction model. The Carey Group does not dispute that, and they propose that multiple sources could have contributed to an established population either during the initial introduction event or over time (i.e., reintroductions over years). By using models based on predicted effective population size, dispersal, and population fragmentation of the purported established populations, it should be possible to determine how well the genetic data fit their interpretation and compare its likelihood to alternatives that incorporate greater impact or frequency of reintroductions. Until that work is completed, it is better to avoid claims that genetic data support the notion of established populations as such claims are misleading (Barr et al. 2014).

REBUTTAL POINT #6

"You can't prove a negative" is pseudologic.

RESPONSE: Tangents into scientific logic aside, claiming that populations of pest tephritids are established in California is, in and of itself, insufficient without specific data on their characteristics, such as size, location, and temporal dynamics. Populations are observable biological entities that are amenable to measurement; if established populations of non-indigenous pest tephritids exist in California, their parameters should be quantifiable. Yet, aside from referring to CDFA trap captures, some of which are separated by multi-year gaps, no further information is provided.

REBUTTAL POINT #7

Absence of eradication validation in other countries.

RESPONSE: Since no country or jurisdiction without pest fruit flies wants them, the continuation of trade is surely a recognition of pest-free areas (FAO 2017) and a validation of the widespread absence of larvae in fruit given the inspection protocols that exist in exporting and importing countries around the world. Cases where initial pest establishment is detected, as for instance in the Dominican Republic, where a medfly outbreak recently occurred, result in the immediate closure of export markets for horticultural products by trading partners (Marte et al. 2017).

REBUTTAL POINT #8

Bogus evidentiary demands.

RESPONSE: The analogy with the physician and cancer is appropriate: if they diagnose "fruit fly metastasis" for California, they need to prove it rather than asking the patient to do so. Claiming that gaps in detection are "incontrovertible signs" or "unequivocal evidence" of established fruit fly populations is opinion, not fact. The repeated claim that "willful ignorance" of the detection data blinds McInnis et al. (2017) to the truth of tephritid establishment is, again, opinion. These data, which are the official CDFA data, can be interpreted in different ways, and their belief that their interpretation is the only correct one is just that: a belief.

REBUTTAL POINT #9

Institutional solidarity is not scientific consensus.

RESPONSE: The characterization of agreement among dozens of tephritid workers from various countries as institutional conformity, driven by the threat of professional ostracism, is simplistic and questions the scientific integrity of each worker associated with the McInnis Group. None of us has witnessed pressure to adopt one view over another in this debate. The Carey Group's point is an opinion, seemingly buoyed more by cynicism than fact. Interactions between national plant protection organizations from exporting and importing countries, with the future of multi-billion dollar industries at stake, is where the "rubber meets the road." Importing country counterparts, with extensive operational experience, cannot be easily misled by hiding pest presence or by academic opinions that are ignorant of "regulatory" procedures and negotiations. To date, not a single one of California's trading partners has bought the Carey Group interpretation of CDFA detection data, even though they could misuse it for protectionist purposes.

REBUTTAL POINT #10

The statement "interpretation of the same data" is false.

RESPONSE: The Carey Group stated that they take strong, unmitigated exception to this statement in Suckling et al. (2016): "This interpretation of the same data for California is at odds with officially-comprised committees, a wide range of international experts and International Plant Protection Convention (IPPC) standards." The text strictly refers to the California detection data that the Carey Group has been obtaining courtesy of CDFA, and not to the GERDA database, as misleadingly claimed by the Carey Group. Also, in McInnis et al. (2017) only the following sentence can be found: "This re-interpretation of California Department of Agriculture (CDFA) detection data is at odds with the conclusions of most of the international tephritid fruit fly research community, including a wide range of international experts and official technical committee members."

The Carey Group states that they never asked the question "Can fruit fly populations remain sub-detectable for sustained periods?" and that the question was simply a straw man used by the McInnis Group. However, understanding how polyphagous invasive tephritid pest populations can remain undetected over years under favorable climatic and host conditions is critical to evaluate claims of their establishment in California. It is logical to expect advocates of the establishment hypothesis to provide details on the age, size, and distribution of these purportedly established populations so that the hypothesis can be tested objectively.

Acknowledgements

This essay is dedicated to the memory of Don McInnis and his many important contributions to the science and operations of control programs for screwworm and tephritid fruit flies. The authors also acknowledge conversations with colleagues around the world, who work directly with the scientific, regulatory, and political issues discussed herein.

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T.E. Shelly, USDA/APHIS/CPHST, Honolulu, HI, USA; **D.R. Lance**, USDA/APHIS/CPHST (retired); **K.H. Tan**, Academy of Sciences, Malaysia, Kuala Lumpur, Malaysia; **D.M. Suckling**, The New Zealand Institute for Plant & Food Research Limited and University of Auckland, Christchurch, New Zealand; **K. Bloem**, USDA/APHIS/CPHST, Raleigh, NC, USA; **W. Enkerlin**, FAO/IAEA, Vienna, Austria; **K. Hoffman**, CDFA, Sacramento, CA, USA; **N. Barr**, USDA/APHIS/CPHST, Edinburg, TX, USA; **R. Rodríguez**, SAG, Santiago, Chile; **P.J. Gomes**, USDA/APHIS/CPHST (retired); and **J. Hendrichs**, FAO/IAEA, Vienna, Austria.

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