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# Brian Herbert Kay 1944–2017

*Michael F. Good*[A,E], *Scott A. Ritchie*[B], *Darryl McGinn*[C] *and Richard C. Russell*[D]

[A]Institute for Glycomics, Griffith University, Gold Coast, Qld 4215, Australia.
[B]Australian Institute of Tropical Health & Medicine, McGregor Rd, James Cook University, Smithfield, Qld 4878, Australia.
[C]Mosquito Consulting Services Pty Ltd, Seventeen Mile Rocks, Qld 4073, Australia.
[D]School of Public Health, University of Sydney, NSW 2006, Australia.
[E]Corresponding author. Email: michael.good@griffith.edu.au

Brian Kay was a renowned entomologist and arbovirologist who worked in academia and with local and international governments to make major and lasting improvements in public health. Particular highlights were the first ever elimination of a saltmarsh mosquito in the world and elimination of dengue from many hamlets and villages in Vietnam. He is also remembered for the development of the careers of many young researchers in Australia and overseas. When thinking of Brian Kay, three things come to mind immediately. First, Brian was a great character—a man of fun and passion and always good to be around. He had a great cheeky smile. Second, Brian was deeply committed to the careers and well-being of those around him—exemplified no better than how he acted so caringly for the Queensland Institute of Medical Research (QIMR) staff when he served for several years as Chairman of the QIMR Staff Association; and third, Brian was an outstanding entomologist, biologist, scientist. Here, we give a little history of his background and attempt to distil a few of Brian's many scientific achievements and paint a picture of a man who was greatly admired and loved by those who worked alongside him in various parts of the world, but predominantly in Australia and the Asia Pacific Region.

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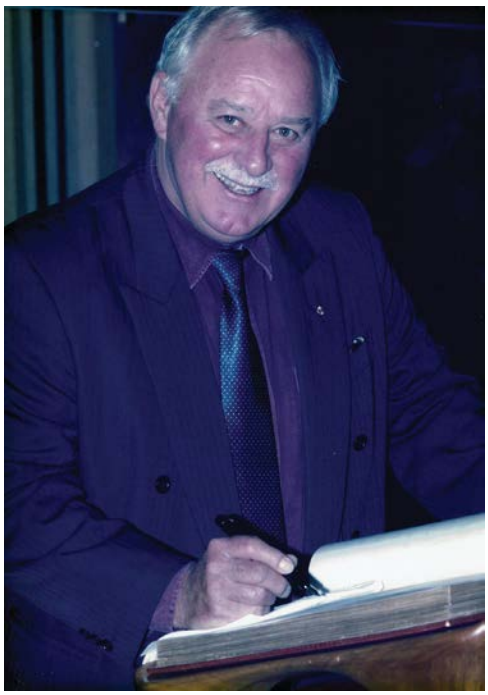
## The Early Years

Brian was the son of Herbert and Mary Ann Kay and was born in Prestwich, Lancashire, England on 2 May 1944. He arrived with his family in Brisbane in 1949. His father was an automotive engineer. In Brisbane Brian was a student at the Church of England Grammar School where he excelled in sport, becoming captain of the gymnastics team in 1962, although rugby was his real passion. He also played cricket from his school years to the age of 46. The love of sports stayed with him throughout his life and after he left school he also developed a passion for surfing and fishing, particularly around Noosa.

After leaving school, Brian started work at the Queensland Institute of Medical Research (QIMR) in 1963 as a cadet scientist. The cadet system was common throughout the public service and was used as a method of obtaining graduates by training them on the job while at the same time they were required to study for their degree at night. About two cadets were taken on each year. When they began as cadets at QIMR they were assigned to work in either the wash-up kitchen or the mouse room—in Brian's case, the mouse room. Following that, cadets were filtered through a series of laboratories until they settled in one. From 1963 he studied part-time at the University of Queensland while working as a cadet at QIMR. Brian began a long association with QIMR entomologist, Harry Standfast, and also learned from Alan Dyce at CSIRO. The entomology laboratory was responsible for collecting and identifying mosquitoes before they were passed onto Ralph Doherty's arbovirus group for virus antibody screens. Brian learned much of his virology from Ralph Doherty's team. Six months after receiving his first degree in 1969, he was promoted to laboratory head, an appointment that showed the foresight of director, Ralph Doherty. In 1978 Brian completed a doctorate from the University of Queensland where his principal supervisor was Dr D. S. Kettle. He also became an Australian citizen that year.



Post-graduation, Brian's research career focused primarily on investigating local arboviruses. This involved field investigations into ecology and laboratory studies on vector competence for viruses such as Murray Valley Encephalitis Virus, Ross River Virus and

others. Brian continued working with these and other arboviruses, including dengue viruses, throughout his long career. Much of what we now understand about the role of mosquito vectors and vertebrate hosts for these viruses that affect human health in Australia, particularly in Queensland, we owe to the ground-breaking work of Brian and his students.

## North Queensland

Brian Kay would go on to make significant national and international contributions to dengue control and natural history, particularly on its vector the mosquito *Aedes aegypti*. Some of his early important research was with Elizabeth (Pat) Marks with whom he published an observation of *Ae. aegypti* biting within the new international airport terminal in Townsville.[1] With the advent of international travellers arriving in a city with large populations of *Ae. aegypti*, they predicted a dengue outbreak in the not-too-distant future. And they were right! At the time, there had not been a dengue outbreak in Australia since the 1956 outbreak in Townsville that affected approximately one-third of the population. In 1981 a large epidemic of dengue occurred on Thursday Island in the Torres Strait, with transmission also found throughout much of northern Queensland. Brian Kay and his co-workers published a landmark paper on the reappearance of dengue after 26 years in the *Medical Journal of Australia*[2] describing the epidemic and speculating that while only 260 cases were serologically confirmed, the total transmission may have been as high as 3000 cases.

As a result of the 1982 outbreak both the Commonwealth Department of Health and the Queensland Government funded a vector control program based in North Queensland. Brian Kay was given the role of director while holding a joint position at QIMR. This program involved hiring local staff to do house-to-house surveys in North Queensland and the removal of water-holding containers that could produce *Ae. aegypti*. The mosquito, *Ae. aegypti* is a 'container mosquito' and the larvae utilize artificial containers such as pot plant bases, tyres, ice cream containers, rainwater tanks and so on in which to lay their eggs and complete their larval stage. Brian collated the data and published reports on the distribution and container types used by the vector.[3] Unfortunately, the *Aedes* control program was not sustainable.[4] The Commonwealth, after several years of funding, pulled out and as a result *Ae. aegypti* infestations rebounded. Indeed, Brian pointed out that *Ae. aegypti* rebounded extremely rapidly in Townsville, and the area was at risk for a significant outbreak of dengue. In 1992 a large epidemic of dengue 2 began in Townsville and subsequently spread to Charters Towers. This outbreak taxed most of the health workers in the area and resulted in Queensland Health developing the Dengue Fever Management Plan for north Queensland with local, national and international experts. It still operates to this day.

This led to an active period of research on dengue in North Queensland. Brian Kay's Mosquito Control Laboratory at QIMR led the charge, publishing a variety of articles on the biology, ecology and surveillance of *Ae. aegypti* in North Queensland. In particular, they investigated the relationship between larval habitat and the amount of *Ae. aegypti* that were produced. A Burmese PhD student of Brian's, Willoughby Tun-Lin, conducted important research on mosquito productivity and its relationship to container volume—a significant improvement on the 'container indices' used to describe dengue risk at the time. They expanded this work to describe the most productive container type, 'key containers' and even 'key premises' that produced the highest numbers of *Ae. aegypti*. He developed an index[5] called the 'premise condition index' as a way to rapidly assess the potential for a house and its yard to produce mosquitoes based on yard shade, the condition of the house and the condition of the yard. Bruce Russell, a PhD student of Brian's, quantified *Ae. aegypti* production in cryptic subterranean cavities such as telecommunication pits, wells and mine shafts in Charters Towers.[6] These habitats have been shown to be extremely productive, particularly in otherwise dry areas where most of the surface containers are dry. Brian applied this knowledge to knock out 'overwintering refugia' and improve overall control.[7]

## Mosquito Control

Brian's passion for studying arboviruses and their mosquitoes naturally led him to mosquito control research and he developed long-term relationships with local governments in South East Queensland that had control programs against the saltmarsh mosquito *Aedes vigilax*. Coastal Australia contains vast areas of wetlands and saltmarshes inundated by tides and the rainfall runoff or surges produced by seasonal storms. Much of the saltmarsh retains surface pools after the initial inundation subsides. The commonly known 'saltmarsh' mosquito *Aedes vigilax* and the cooler climate southern saltmarsh mosquito *Aedes camptorhynchus*, lay desiccation-resistant eggs in dry pool mud cracks and attached to the base of saltmarsh grasses and shrubs. The synchronous hatching of saltmarsh *Aedes* spp. eggs, on subsequent tidal flooding, and rapid larval development over just a few days (*Ae vigilax* in summer), produces a mass emergence of these aggressive human-biting mosquitoes across a wide area. The more important species, *Aedes vigilax* has an impressive pest flight range of several tens of kilometres and if major saltmarsh breeding sites are adjacent to highly populated urban centres, the resulting exposure of the public to aggressive mosquito biting and threat of Ross River Virus and Barmah Forest Virus transmission becomes highly political. In Queensland, there is historically very strong public health legislation aimed at reducing the risk of mosquito-borne disease to the community.

## Local Government

A significant legal obligation is placed on Queensland local governments to manage mosquito risks in areas under their direct control and to provide anti-mosquito regulation enforcement in private lands within their jurisdiction. This means that large scale operational aerial and ground-based mosquito control programs are commonly provided by Local Governments, particularly in South East Queensland. It is therefore no surprise that Brian, as Head of the QIMR Mosquito Control Laboratory based in Brisbane, should become very involved in supporting the Local Governments' approaches to efficient and effective mosquito control in Queensland.

His involvement working directly with local government in Queensland started in the 1970s with early trials of larvicide applications using the recently developed Abate 5G sand granule to control saltmarsh breeding mosquitoes for the council of the City of Gold Coast.[8] Prior to the larvicide trials, nearly all saltmarsh mosquito control was aimed at the adult stage using broad spectrum

adulticides. Indeed, the Abate sand granule that Brian helped developed was the mainstay of Australian saltmarsh mosquito control for 30 years. Later, in the 1980s, Brian was seconded to Cairns City Council supervising *Ae. aegypti* control efforts as part of the commonwealth *Ae. aegypti* control program described earlier. Brian also worked with Pat Dale of Griffith University in the 1980s on trials of the environmental manipulation of saltmarsh drainage (known as 'runnelling') to reduce availability of surface water for *Aedes vigilax* breeding in saltmarshes. Almost all the early involvement by Brian in local government mosquito control efforts was either situation-based or with defined project-based objectives.

In early 1991 a mosquito research strategy working meeting was convened in Brian's QIMR office and attended by Dave Allaway and Roy Durre (Gold Coast City Council), Harry Standfast (then working as Brisbane's Medical Entomologist Consultant), John Mothershaw and Darryl McGinn (Brisbane City Council). During that meeting, the Local Authority Research Committee (LARC) was proposed as a formal body to fund independent applied scientific research directly to the participating local mosquito control programs. The commitment that Brian was seeking was for some certainty of financial research contributions by the member local government outside of the traditional Australian scientific research-funding bodies such as the National Health and Medical Research Council (NHMRC), which would specifically be used for applied research directly beneficial to their operational mosquito control programs. With subsequent local government political and administrative agreement reached on appropriate membership contributions for each member local government, the LARC was formalized and research priorities were developed that could be the basis for seeking locally based research proposals for consideration by LARC members. In 1992–3 the LARC had two stated objectives: (i) to stimulate and evaluate research carried out with respect to saltmarsh mosquito control; and (ii) to act as a coordinating unit and as a technically sound discussion body with respect to development of operational issues. The LARC developed collaborations beyond QIMR and initially included The University of Queensland Centre for Pesticide Application and Safety (CPAS) and Griffith University School of Environmental Science. LARC also developed a collaboration with the American Mosquito Control Association (AMCA) and Florida Mosquito Control Association promoting and financially supporting working visit exchanges between mosquito control program personnel to strengthen professional development within local government officers.

A crowning achievement of the early LARC was Brian's efforts to secure a dedicated Local Government Research Committee Entomologist. Brian had met Dr Scott Ritchie, then employed by Collier Mosquito Control District in Florida, at a meeting of the AMCA before the creation of the LARC. Brian identified Scott as someone with extensive relevant scientific qualification and operational experience who could positively support the LARC's research objectives in Australia. Brian was responsible for facilitating Scott's successful immigration application process with the Australian Federal Government and also supported with letters from Brisbane City Council identifying the need for specialist medical entomology resources (as there were no suitably qualified and operationally experienced personnel then available in Australia) to support local mosquito management. Scott Ritchie's contribution to mosquito control research in Australia has extended well beyond his initial appointment as the first LARC Entomologist. Perhaps the key outcome from this period was the testing and operational development of new 'biorational' pesticides—*Bacillus thurengiensis israelensis* and the insect growth regulator methoprene—to replace organophosphate insecticides for control of saltmarsh mosquitoes.

The LARC continued to evolve under Brian's chairmanship and work conducted under its auspices has resulted in significant contributions to the scientific literature as well as direct operational control improvements. From the year 2000, the LARC was more broadly renamed the Mosquito and Arbovirus Research Committee (MARC). Its geographical coverage has extended to include much more local government territory in Queensland and now also has membership from the Queensland State Government and from local and state governments in Western Australia where similar saltmarsh mosquito problems exist. Starting with Scott Ritchie in the early 1990s, a succession of LARC/MARC scientists (Drs Michael Brown, Tim Hurst and Jon Darbro) and very many post-graduate students have contributed, and will continue to contribute, to Brian's legacy of applied research into the local mosquito control mission of local government in Australia.

We don't know if Brian Kay's vision for supporting local government mosquito control in the early 1990s extended to the now decades of intensive scientific research into local mosquito control in Queensland that followed and still continues, or the extension of Scott Ritchie's reach beyond LARC. However, we do know that Brian was deeply proud of the local achievements and wider extensions of the body of scientific work that started during that meeting in his office in early 1991.

## The *Mesocyclops* Story

Brian pioneered the use of the copepod predator, *Mesocyclops*, in integrated control programs against dengue vectors in north Queensland and overseas, especially Vietnam.

During the late 1980s and early 1990s he initiated a program to use these copepods as a biological control agent for *Ae. aegypti* larvae. Members of the copepod genus, *Mesocyclops*, are predacious, ravenously consuming freshly hatched mosquito larvae in containers. Brian and his research team worked out that copepods could be isolated from local freshwater waterways and then reared and released into large freshwater containers such as concrete water tanks and wells to provide long-term control of *Ae. aegypti*. This work would prove to be extremely fruitful. Initially he applied this strategy to control of *Aedes polynesiensis* in French Polynesia,[9] then targeted *Ae. aegypti* in the Torres Strait, North Queensland[10] and in Brazil. Eventually the program matured into a successful government-backed strategic initiative in Vietnam. In Hanoi, so the story goes, Brian was teaching a vector biology and control course sponsored by the World Health Organization (WHO) for the Vietnamese government in 1989. There he met an ambitious local named Dr Vu Sinh Nam, who would ultimately lead the national dengue control program and champion Brian's work. During the course, he introduced *Mesocyclops* for dengue vector control, and said that they could find *Mesocyclops* in the lakes in the city. Vu Sinh Nam adds:

> During the practice section, he took us to the Hoan Kiem lake at the centre of Hanoi city and we did collect *Mesocyclops* from the lake. After the course, we continued to collect *Mesocyclops* from different

localities in Vietnam and send samples to Brian for identification, and this ultimately led the development our successful collaboration, friendship and dengue vector control program.

He achieved world-first eradication first in hamlets and villages,[11] culminating in successful cessation of dengue transmission in the entire region,[12] emphasizing in a significant paper the importance of community control.[13] In addition, the Kay laboratory quantified mosquito production in concrete tanks and ceramic jars that are ubiquitous in Southeast Asia.[14]

When Michael Good was speaking to Brian a couple of months before his passing, he mentioned this as one of his proudest scientific achievements, a sentiment echoed by the governor general who said:

> Amongst our many brilliant scientists and researchers, those working at the Queensland Institute of Medical Research using tiny micro-crustaceans have, in a world-first, successfully eliminated the breeding of dengue fever-carrying mosquitos in 42 Vietnamese communities.

## The *Wolbachia* Program

The 2000s heralded significant change in the research career of Brian Kay. He continued to expand the copepod program in Vietnam, but he also became involved as a principal investigator in a new program headed by Professor Scott O'Neill (then of the University of Queensland) that investigated the use of the bacteria, *Wolbachia*, as a method to control dengue and other *Ae. aegypti*-borne viruses. The Bill and Melinda Gates Foundation funded this work in 2003 through their Grand Challenges in Global Health program. Brian Kay was instrumental in establishing Vietnam as the first site outside of Australia for *Wolbachia* releases. As a part of this program Brian, who emphasized fundamental 'first principles' research, initiated investigations into the mosquito populations in a small island off central Vietnam. Brian, with Peter Ryan and Jason Jeffrey, catalogued the mosquito production of different container types as well as the dynamics of the adult mosquito population.[15] Initially, the *Wolbachia* program used the life-shortening *w*MelPop strain that killed *Ae. aegypti* mosquitoes before they were able to transmit dengue viruses. Field estimates of mosquito age were needed to measure this impact, and Brian's laboratory was involved in testing novel gene expression methods to quantify the age of mosquitoes.[16] He was also involved in subsequent work using a less virulent strain of *Wolbachia* (*w*Mel) that was more successfully established in the wild. In a large collaborative effort, Brian's laboratory was involved in vector competence trials to confirm that *Ae. aegypti* infected with *w*Mel had a significantly reduced capacity to transmit dengue and chikungunya viruses.[17] This program has subsequently been rolled out throughout North Queensland. Indeed, *w*Mel infected *Ae. aegypti* have been established in most urban areas of North Queensland such as Cairns, Townsville and Charters Towers where Brian Kay initiated his dengue research studies in the 1980s.

## Saltmarsh Mosquito Elimination in New Zealand

The story of the *Ae camptorhynchus* eradication program is told in Brian and Richard Russell's book published in 2013.[18] There is, however, very much more that could be written just on the way that program evolved and was shaped and the many seat-of-the-pants ways to invent something that hasn't been done before. The collaboration between Brian, Darryl McGinn and others was a very productive one. They served on the NZ Ministry of Health Southern Saltmarsh Mosquito Technical Advisory Group (SSM TAG), Brian from January 1999 and Darryl McGinn from 2001, both until its wind-up mid-2006. TAG meetings were relatively frequent and located either in Wellington at Ministry of Health venues or at locations associated with current field operations to allow first hand observations before formal meetings. Brian usually attended the field sites and operations for a day or two before formal meetings. Evenings were usually spent consuming good wine, beer and food while engaging in good conservation strategizing about how the program could and would overcome the technical problems of the day. In consultation with industry partners Dave Sullivan from Zanus and Doug van Gundy from Zoecon, they developed a unique strategy to eliminate this noxious pest mosquito from New Zealand. Typically, mosquito control relies upon detection of active target mosquitoes that are then treated. But for eradication, it can't be assumed that very low levels that can avoid control and blossom into large populations can be detected. Thus positive sites were retreated for up to two years using the safe insect growth hormone, methoprene, which Brian launched in Queensland. Following Brian and Darryl McGinn's involvement, the program continued for another four years with Richard Russell, Scott Ritchie and others advising the New Zealand authorities and the culmination of this work was the first ever elimination of a saltmarsh mosquito in the world—a major tribute to Brian's foresight and dedication to the task.

## Awards

As a result of his many achievements, Brian's laboratory was ranked as a WHO Collaborating Centre, and he had recognition as President of the Mosquito and Arbovirus Research Committee, Inc., that effectively is a consortium of 20 local governments and industry members dedicated to better mosquito control in Australia. The WHO has acknowledged this program as one of the most successful ever implemented. Amongst his many major contributions to his colleagues and discipline, Brian also served as Deputy Director of the Queensland Tropical Health Alliance and a Director and Deputy Director of the Australian Centre for International and Tropical Health and Nutrition.

Brian was awarded many prestigious honours and prizes. These included a Winston Churchill Memorial Fellowship (1978), the Medallion of the Academy of Military Medical Sciences of Beijing (1987), the Shandong Medical University Medal (1994) and he was included in the Cambridge Edition of Who's Who in Medicine (1995). In 1999, he was one of a select few globally to be awarded the DI Ivanovsky Centenary Medallion from the Russian Academy of Medical Science for his achievements. Then in 2000, he received QIMR's top honour, the Bancroft Medal along with promotion to Senior Principal Research Fellow. In 2005 Brian was made a Member of the Order of Australia (AM) in the Queen's Birthday honours list 'for service to medical science and public health, particularly for research into the control and elimination of mosquito-borne arbovirus diseases in northern Australia and Asia'. In the same year he was awarded the Ralph Doherty QIMR Science Prize and in 2006, he was elected as a Fellow of the Australian Academy of Science. The photo is of Brian at the award of his Fellowship.

Brian was passionate about building up a talented post-graduate workforce—supervising up to twenty people at any one time—mainly for PhD degrees (mostly through the University of Queensland) as well as a strong public health network in the Asia Pacific Region, fostering students particularly in Vietnam.

Brian retired in mid-2014 after fifty one years at QIMR Berghofer's Mosquito Control Laboratory, but not before receiving an Australian Museum Eureka Award for Excellence in Science. He was part of the Eliminate Dengue team, and their game-changing use of *Wolbachia* bacteria to inhibit the mosquitoes' ability to spread Dengue. Brian published over 280 scientific papers (mainly on mosquito-borne virus diseases and their vectors, their surveillance, risk management and control), reviews and a book (see Supplementary Material).

Besides Australia, Brian had worked in French Polynesia, Fiji, Tonga, Samoa, Brazil, Indonesia, Laos, Cambodia and Vietnam and New Zealand and acted as short-term consultant or advisor to government, the United Nations and industry.

In Brian's last weeks and months, he was a man who had not lost his spirit, who was still a raconteur with a cheeky smile, who was still very interested in science and who was concerned about those around him. He was a very brave man who accepted his fate without complaint. He was a man who was very much in love with Jane, and a man who was a very proud father to his three daughters, Sarah, Emma and Lucy. It was the Brian that we had always known.

It is fitting to conclude with words from Brian himself:

> When I look at my career and 44 years at QIMR, I remember the wonderful opportunity afforded me by the Winston Churchill Memorial Trust, to visit key laboratories in England, USA and Asia to effectively 'dip my toes into the ocean'. Much to my relief, I found that I was not swallowed up and this gave me the initial confidence to build a career. In those days, international travel was a novelty but now as a Platinum frequent flyer, it simply is 'going to work with a longer journey'.

He will be greatly missed by all.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Acknowledgements

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