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Source: Journal of the American Mosquito Control Association, 30(2):106-115. 2014.
Published By: The American Mosquito Control Association
DOI: http://dx.doi.org/10.2987/13-6393.1
URL: http://www.bioone.org/doi/full/10.2987/13-6393.1

Journal of the American Mosquito Control Association, 30(2):106–115, 2014

MULTI-AGENCY PERSPECTIVES ON MANAGING MANGROVE WETLANDS AND THE MOSQUITOES THEY PRODUCE

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ABSTRACT. A group of researchers, mosquito and coastal managers, and consultants joined together to explore issues of concern to coastal and mosquito management in mangrove forests. At a 1-day workshop in Florida, participants identified issues that are important for their roles. The issues were subsequently compiled into a matrix and the participants were asked to individually assess the importance and urgency of each. The most important issues for everyone included habitat responses to management, community attitude, public education, interaction between agencies, local connectivity, sea-level rise (SLR) loss of wetlands, and conservation. Most urgent were public education, conservation easements, local connectivity, SLR, loss of wetland, restoration, and conservation. There were differing viewpoints among the roles that appeared to be related to responsibility for and ability to influence on-ground outcomes. This is reflected in mosquito and coastal managers who viewed issues broadly and ascribed higher levels of importance and urgency to them than did researchers and consultants. We concluded that collaboration is a key issue. Barriers to collaboration include knowledge differences between agencies. Facilitators of collaboration include interaction, trust, and shared goals.

KEY WORDS Coast, wetland, management, collaboration, mosquito control

INTRODUCTION

This paper addresses the issue of multiple-agency management of mangroves. It uses an iterative approach to identify and assess key issues from the perspective of various agencies with an interest in mangrove forests. Management and conservation of mangroves (the trees) or mangals (mangrove forest systems) is important because they provide important environmental services (Duke 1992, Ellison 2000). They provide physical, biological, and social services (Vo et al. 2012). From a human perspective, mangroves may also provide disservices in the form of pest mosquitoes. Mangroves need careful management as their values are threatened worldwide by both natural and anthropogenic processes (Duke et al. 2007).

Mosquitoes are only a problem in places where human settlement is within range of the mosquito and its habitat. This is often the case in coastal areas. In the USA, almost 40% of the population lives in coastal counties, but these counties represent less than 10% of the land area (Brockmeyer et al. 1997, NOAA 2013). Worldwide, it is estimated that 44% of people are located within 150 km of the ocean and most of the world's megacities are located near the coast (Brockmeyer 1997). This leads to a demand for mosquito control.

Mosquito control can damage wetlands and their values. In Florida, by the mid-20th century, mangroves had been adversely impacted as a result of habitat alterations for mosquito control. This was reviewed by Dale and Hulsman (1990) and referred to more recently by Brockmeyer et al. (1997) and Rey et al. (2012a). The key aim now is to restore natural functions without also restoring mosquito production. This was the premise for the work included in Brockmeyer et al. (1997). It was also an underlying aim of the Subcommittee on Managed Marshes (SOMM) (Carlson et al. 1991, Carlson 2006, Rey et al. 2012a). Thus, in USA the emphasis is on mitigation of negative impacts while restoring an important habitat, despite conflicts with other uses such as development in nearby areas (Taylor

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2012). In Australia, the issue is how to conserve wetland values in a changing environment without enhancing mosquito habitats. Mosquito control in Australia only became established in the 1980s, mainly in the Queensland subtropics. Dale et al. (2008) described and compared the historical and recent mosquito control activities in Florida and Queensland, noting the importance of collaboration between agencies.

In both the USA and Australia, holistic and integrated management of mosquitoes and their habitats is needed to maximize ecosystem value while minimizing health risks. One barrier to this is the often-limited interactions between experts in mosquito management and experts in wetlands (especially in mangrove ecology). This is manifested as a disconnect between various "research" communities, with the overlap between wetland science and mosquito control being relatively narrow. For example, mosquito managers may be resourced to attend specialist conferences for mosquito control but not for wetland-specific conferences, and vice versa for wetland managers. There is thus the potential for conflict between mosquito managers and groups or agencies that prioritize wetland conservation and restoration but who may have little knowledge of modern mosquito control approaches. Conversely, those who promote mosquito control may have limited knowledge of the ecology and functional values of wetlands. Such a lack of knowledge may result in ignoring or downplaying mosquito control issues or issues of ecosystem services. The various groups include researchers, land managers, health and pest control experts, politicians, governmental agency personnel, nongovernment organizations, and private citizens. The disjunct also extends to regulatory agencies involved in permitting activities in wetlands, although SOMM plays an integrating role among the agencies involved in mosquito control in Florida.

The aim here was to explore issues of concern for a range of experienced practitioners and experts in their particular domains. To start a dialogue among diverse interested parties, a Mosquito and Mangrove Workshop was held on March 6, 2013, at the Florida Medical Entomology Laboratory, Institute of Food and Agricultural Sciences, University of Florida, Vero Beach, FL. The meeting included mangrove experts, mosquito control agency expert personnel, coastal managers, consultants, and researchers from the USA, and 3 mangrove/mosquito researchers from Australia (part of the organizing team). The overarching aim was to nurture dialogue and advance the aim to optimize mangrove management, minimize mosquito problems, and develop best practices via collaborations and discussions between experts in the USA and Australia. The process started with participants making short presentations on issues of particular concern. These were discussed informally and then compiled into a table or matrix summarizing the issues raised. The subsequent dialogue activity and outcomes are described in the methods section that follows.

MATERIALS AND METHODS

Identifying the issues

A draft matrix of issues was developed from the face-to-face meeting notes. The issues were grouped into sections or categories including information gaps, participation, control of land, external factors, and sea-level rise (SLR). The draft matrix and meeting notes were distributed on April 16, 2013, to the 15 participants for comment and also to several who had recently discussed the issues in the field with the Australian team, but who could not attend the workshop. The rationale was that, in the weeks since the meeting, there had been an opportunity for everyone to reflect and to identify if additional issues should be raised. This resulted in the addition of several issues broadly related to management as noted in the results.

Assessing the issues

As a way to bring expert knowledge and opinion together, the US participants were asked, as individuals, to add information to the matrix from the perspective of their role. They were asked to consider the issues in the list in 2 ways: 1) for their importance and 2) for their urgency for action. They were provided with 2 matrices to facilitate this and to avoid confusion. A 5-point scale was used: 1, very low; 2, low; 3, average; 4, high; and 5, very high; allowance was made for a "don't know" response. Because the 3 Australians did not represent a range of interests and were involved administering the process, they did not actively participate in this stage.

Analysis

Analysis was a qualitative and largely descriptive activity. To obtain a general indication of importance and urgency for the issues, the information was examined for the participants as a whole. Inspection of the frequency of responses at this general level led to a decision to reduce the 5-point scale to 3 categories. These were very low to low (levels 1 + 2), medium (level 3), and high to very high (levels 4 + 5). The results were recorded as a percentage of responses for each category for each issue. To identify the most important or urgent issues, we highlighted those with at least 80% agreement. The cutoff value was selected as it approximated to the upper quartile (82.2% for importance and 80.5% for urgency).

Table 1. Importance and urgency matrix—all respondents (boldface values indicate ≥80%).

Variables	Very low–low (%)		Medium (%)		High–very high (%)	
	Important	Urgent	Important	Urgent	Important	Urgent
Information						
Habitat response	10.0	9.1	10.0	18.2	**80.0**	72.7
Extreme events	30.0	36.4	40.0	27.3	30.0	36.4
Mosquito habitats	9.1	9.1	27.3	36.4	63.6	54.5
Predation on mosquitoes	9.1	**81.8**	27.3	0.0	63.6	18.2
Potential environmental harm	72.7	30.0	18.2	40.0	9.1	30.0
Insecticide resistance	20.0	36.4	40.0	36.4	40.0	27.3
Participation						
Community participation	16.7	27.3	16.7	18.2	66.7	54.5
Community attitude	0.0	18.2	8.3	27.3	**91.7**	54.5
Public education	9.1	10.0	9.1	10.0	**81.8**	**80.0**
Interaction between agencies	16.7	33.3	0	0.0	**83.3**	66.7
Control of land						
Land ownership	20.0	20.0	10.0	20.0	70.0	60.0
Land stewardship	0.0	20.0	18.2	20.0	**81.8**	60.0
Conservation easements	18.2	9.1	36.4	9.1	45.5	**81.8**
External factors						
Local connectivity	0.0	9.1	9.1	9.1	**90.9**	**81.8**
International connectivity	20.0	22.2	0	0.0	**80.0**	77.8
SLR[1]						
SLR effect on mosquito management	16.7	10.0	25.0	30.0	58.3	60.0
SLR loss of wetland	8.3	9.1	0	0.0	**91.7**	**90.9**
Management-related						
Restoration	0.0	0.0	25.0	9.1	75.0	**90.9**
Conservation	8.3	8.3	8.3	8.3	**83.3**	**83.3**
Management	25.0	30.0	8.3	10.0	66.7	60.0
Public health	16.7	27.3	16.7	18.2	66.7	54.5
Historical legacy of land use	27.3	25.0	18.2	37.5	54.5	37.5

[1] SLR, sea-level rise.

At the individual level, data were recorded using only the respondent role (i.e., anonymity was preserved). The responses were averaged for each role, for importance and urgency, using the 5-point scale. To indicate a high level of importance or urgency an average value of 4 or greater was used. The tables, along with draft text, were circulated to all participants for comment. The comments were used to inform the discussion.

RESULTS

Identifying the issues

Responses to the April 16 communication led to the addition of several issues to the matrix in a category that was identified as "management-related" as it included restoration, conservation, management, public health, and historical legacy of land use.

Assessing the issues

Assessing the importance and urgency of the issues resulted in 12 responses including all roles: researcher, $n = 6$; mosquito manager, $n = 2$; coastal manager, $n = 2$; and consultant, $n = 2$. This included those who reported separately for 2 roles. The responses were tabulated at the general level (Table 1) and then by role (Table 2).

Analyzing the issues: general level

Table 1 shows the issues that were of high importance and/or were urgent (≥80.0% agreement). The key issues identified as important were habitat responses, community attitude, public education, interaction between agencies, land stewardship, local and international connectivity, SLR loss of wetlands, and conservation. Key issues of urgency were public education, conservation easements, local connectivity, SLR loss of wetlands, restoration, and conservation. Most respondents (81.8%) agreed that predation on mosquitoes was less urgent. Several were generally assessed as high–very high for both importance and for urgency. These were public education, local connectivity, SLR loss of wetlands, and conservation. The key issues and their intersection are illustrated in Fig. 1.

Table 2. Importance and urgency matrix by role of respondents (average values ≥4 in boldface).

	Researcher		Mosquito manager		Coastal manager		Consultant	
Issue	Important	Urgent	Important	Urgent	Important	Urgent	Important	Urgent
Information								
Habitat response	**4.0**	**4.0**	**4.0**	**4.0**	**5.0**	**5.0**	**5.0**	**5.0**
Extreme events	1.8	1.5	3.0	2.5	3.5	2.0	2.5	2.5
Mosquito habitats	3.3	3.3	**4.0**	**4.0**	3.5	5.0	**5.0**	**5.0**
Predation on mosquitoes	2.0	1.8	1.5	1.5	1.5	1.0	2.5	2.5
Potential environmental harm	2.7	2.5	3.5	2.5	2.5	1.0	**4.0**	3.5
Insecticide resistance	1.8	1.8	**4.5**	3.5	3.5	3.0	3.0	2.5
Participation								
Community participation	3.0	2.5	2.5	**4.5**	**4.5**	**5.0**	2.5	**4.5**
Community attitude	**4.2**	3.0	**4.0**	**4.0**	**5.0**	**5.0**	**4.5**	**4.5**
Public education	2.8	2.8	**4.5**	**4.5**	**4.5**	**5.0**	**4.5**	**4.5**
Interaction between agencies	3.7	3.2	5.0	**5**	**5.0**	**5.0**	3.0	2.5
Control of land								
Land ownership	2.7	1.7	**5.0**	**5**	**5.0**	**5.0**	1.5	**4.5**
Land stewardship	3.2	2.7	**5.0**	**5**	**4.5**	**5.0**	2.0	**4.0**
Conservation easements	2.2	2.3	**4.5**	**4.5**	**4.0**	**5.0**	**4.0**	**5.0**
External factors								
Local connectivity	3.7	3.8	**4.5**	**4.5**	**5.0**	**5.0**	**5.0**	**5.0**
International connectivity	2.2	2.0	**4.5**	**4.5**	**5.0**	**5.0**	**5.0**	**5.0**
SLR[1]								
SLR effect on mosquito management	3.3	3.2	**4.0**	**4.0**	**4.0**	**5.0**	2.5	**4.0**
SLR loss of wetland	**4.0**	**4.0**	**4.5**	**4.5**	**5.0**	**5.0**	2.5	**4.5**
Management-related								
Restoration	3.7	**4.0**	**4.5**	**4.5**	**5.0**	**5.0**	2.5	**4.5**
Conservation	3.3	3.7	**4.5**	**4.5**	**5.0**	**5.0**	5.0	**4.5**
Management	2.5	3.2	**4.5**	2.0	**4.5**	**5.0**	2.0	0.5
Public health	2.7	3.3	**4.0**	1.5	**4.5**	**5.0**	2.0	3.0
Historical legacy of land use	2.2	2.7	2.0	0.5	3.0	3.0	2.0	1.5

[1] SLR, sea-level rise.

Analyzing the issues: role-specific responses

When the roles were considered separately there was broad agreement on some issues (Table 2). All agreed that habitat response was both important and urgent; coastal and mosquito managers generally agreed that participation, control of land, external factors, and SLR were both important and urgent; consultants saw many issues as less important, but nevertheless urgent (e.g., community participation, land ownership, land stewardship, restoration); the researchers generally assigned lower values to most issues, though habitat response, community attitude and SLR loss of wetland, and restoration were important and urgent.

Figure 2 illustrates for each role the important and urgent issues (values ≥ 4) and their intersection. Mosquito managers and coastal managers were largely in agreement, with the coastal managers' perspective that, if an issue is important it is also urgent. Mosquito managers were similar but allowed that some issues were important, but perhaps not so urgent (insecticide resistance, management, and public health), whereas others were urgent though of lower importance (interaction between agencies). Consultants viewed issues related to community, control of land, effects of SLR and restoration, and conservation as particularly urgent, whereas potential environmental harm was important but not as highly regarded as urgent. There was considerable overlap of issues that fitted both importance and urgency. The researchers were apparently less concerned, noting the importance and/or urgency of only 4 issues: habitat response, SLR and loss of wetlands, restoration, and community attitude.

DISCUSSION

General issues

Information gaps: At the workshop the greatest barrier to integrated and holistic management of mangrove forests was considered to be a lack of information or knowledge. Although this was discussed at length at the workshop it did not rank as highly as other issues in the final results at either the general level (Table 1) or for individuals

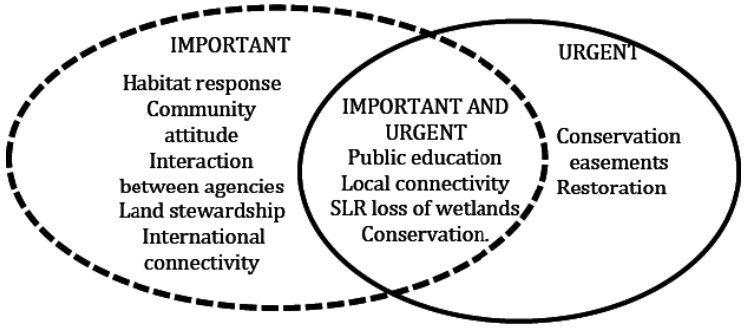

Fig. 1. Key issues: importance, urgency, and their intersection. SLR, sea-level rise.

(Table 2). The workshop participants acknowledged that knowledge barriers can be real gaps or can be an issue of access to information (Lewis 2005, 2009).

The real knowledge gaps that were identified at the workshop included the following:

1) Climate change information:
   a) Sea-level change is predicted to accelerate over the next several decades. Mangroves are particularly sensitive to this, and knowledge of the impact of SLR is only slowly emerging in the academic literature. There seems to be some way to go before this is made accessible to the wider community.
   b) Climate-change–related events, such as higher temperatures and extreme storms (producing storm surges and anomalous tidal events, changing water quality and acidity, causing damage to and loss of coastal vegetation) are potential/predicted consequences of climate change that have little practical translation from the academic literature.
   c) There is uncertainty about the actual effect of sea level change at the local level and about changing geomorphic processes (sedimentation and erosion) and how resultant change will affect mangrove distributions.
2) Mosquito habitat information:
   a) How mosquito habitats are distributed in heterogeneous mangrove systems is an information gap.

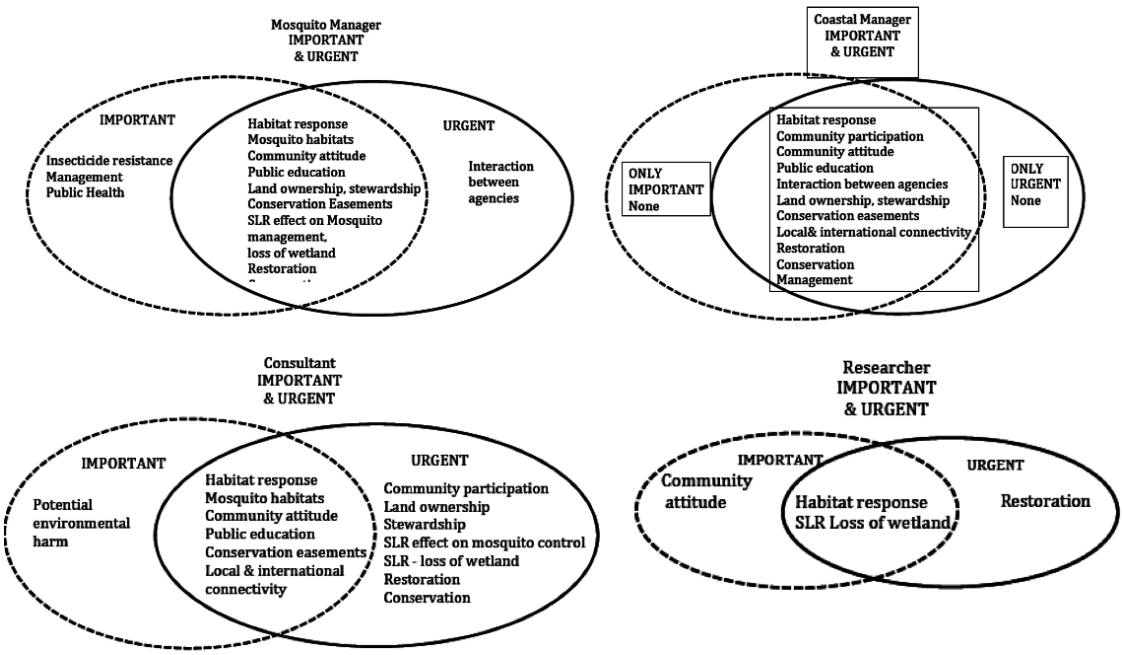

Fig. 2. Key issues for each role: importance, urgency, and their intersection. SLR, sea-level rise.

b) The heterogeneity of mangrove systems creates information gaps, especially at the local level—each site is different from others (and there is heterogeneity within sites also). Mosquito populations are variable within systems.

The mentioned points constitute information gaps at a local level, which would be difficult to address at a coarser level of resolution. At a more general level there are information gaps that include the following:

3) Predation by fish in mangroves is not well known.

a) We need hard data on actual predation rates by different species under different circumstances.
b) Knowledge (projections/models) of effects of predation on mosquito populations is needed.

4) The potential for mosquito control to cause environmental harm should be assessed.

Addressing knowledge gaps is difficult and is a role for research, but it is one that needs to be resourced, communicated to and integrated with management. Managers are often not resourced to conduct much, if any, research. There are models that focus on wetlands management and information, but they may be limited in their practical application. For example, Xing et al. (2009) proposed a model that had the potential to address management issues, but which may be difficult to put into practice.

Even if knowledge does exist there may be a barrier for some because they do not have easy access to the refereed literature. There is a theoretical literature on this aspect, which is outside the scope of this paper. However, Bendoly and Swink (2007) provided evidence that access to information does have an effect on project outcomes. The workshop reported here took a pragmatic approach and suggested that information could be shared among the various interest groups, for example by accessing the Robin Lewis website (2014) as a starting point. This would provide access to both refereed and grey literature that is specifically useful for coastal managers. Another view expressed in the later communications is that access to reliable information is inhibited by the proliferation of ''publish for a fee'' journals that may not conduct stringent reviews. The public, media, politicians, government agency personnel, etc. cannot be expected to discriminate between these and high-quality, peer-reviewed scientific journals. There is also the pressure to publish from within research-focused institutions that makes material accessible to academics, but not easily available to others.

Participation: The meeting noted that community perspectives are important in recognizing the values of wetlands. In this area, public information (education) was noted. Interagency collaboration is important. Existing collaborations include SOMM in Florida, which focuses on marsh management and the Mosquito and Arbovirus Research Committee (MARC) in Australia, which focuses on mosquito and disease management. The results confirmed the view on the importance of public participation, especially at the level of individual roles of managers or advisers (e.g., coastal and mosquito managers and consultants). However, it did not appear to be an urgent issue and that may be because it is already embedded in decision frameworks or because of the time needed to develop this aspect. Participation in decision making has received much attention in the literature. In a recent paper, Celino and Concilio (2011) discuss this in the context of a wetland example in southern Italy. They note that it is possible for participation to initially increase conflict. However, although the process began with conflict, it culminated in final collaboration. This demonstrates that participation can resolve conflict and ultimately lead to improved decision making.

Control of land: The issue of ownership was raised and distinguished from what might be seen as a greater challenge: that is, stewardship. This is supported by the results, as control of land was seen as both important and urgent by coastal and mosquito managers. Both of these roles have on-ground management obligations. The meeting noted that often, if owners allow management at all, they may impose restrictions so that the most effective or efficient management may not be implemented for a specific wetland. This has implications not only for the wetland in question, but also for surrounding areas. This relates to both private and public ownership. Although private landowners must obtain federal, state, and sometimes local permits to make modifications or develop their lands, frequently they do have some say as to what type of management is conducted there. In particular, in Florida, saltmarsh impoundments can often be privately owned, sometimes by multiple individuals or companies, and having even 1 of the owners object to some type of management activity can influence management of the entire impoundment. For example, in the late 1960s and early 1970s, some property owners were under the impression that having their saltmarsh property diked and flooded for mosquito control made it into a wetland. Consequently, some demanded breaching the dikes on their impoundment properties, thus ending the possibility of controlling saltmarsh mosquitoes there by summer flooding. More recently, this has happened even where only 1 owner in a multiply owned

impoundment objected to summer flooding. In that case the mosquito control office complied, for political reasons, even though this ended control by summer flooding at the time. Thus, mosquito production on that unflooded marsh during the summer had to be controlled with aerial larviciding.

This can also be an issue with some public ownerships such as refuges and parks owned federally, state-owned parks, water management district lands, and local land owned by the county. Public landowners' objectives can differ from those of public health entities and can limit activities, even those that can provide combined restoration benefits and public health benefits. There are also practical considerations, such as which agency will be charged with management and where funding will come from, as well as more complex issues such as conflicting management mandates for different agencies, public access, compliance with applicable laws and regulations, and many others. This is an important issue for Florida as identified in Dale et al. (2008), referring to multiple land ownerships leading to challenges for mosquito control as noted above. The meeting was of the view that achieving ownership did confer potential protection, but that good stewardship required resources.

Broader issues: These included external issues, SLR, and other management-related issues. Most participants indicated that external factors and SLR, especially loss of wetland, are both important and urgent (Tables 1 and 2). This is reflected in the literature (Traill et al. 2011) and is consistent with the workshop discussion, which noted that mangroves and saltmarshes are intermediate between land and sea and so connectivity among saltmarsh, mangroves, and seagrass communities is important. As well, management of the upland edge or zone, which connects to saltmarsh and mangroves is also important and becoming urgent as sea level changes (this relates to SLR too).

Connectivity at an international level is important for sustaining migratory birds and was discussed at the workshop and shown in the assessments (Tables 1 and 2). This is also recognized in the literature; for example, Lee (2012) stressed the importance of coastal soft-sediment communities (though not specifically mangroves) for migratory birds. The workshop identified the significance of the flyways: for example, the Atlantic Flyway in the USA that is protected under the Migratory Bird Program (US Fish and Wildlife Service 2012). Similarly, Australia has the Japan–Australia Migratory Bird Agreement and a similar agreement with China. These agreements impose a liability on the signatories to protect the migratory bird habitats, and this would need to be taken into account when managing mosquito larval habitats. Protection is also embedded in the Ramsar Convention and its strategic plan (Ramsar 2011) with both the USA and Australia as contracting parties. The general and individual-level responses indicated that local connectivity was both important and urgent. However, international connectivity was identified as only important (though some 77.8% responses considered it urgent). The researcher responses did not rank it highly as important or urgent. This may relate to their lack of specific regulatory power at the national level, as international connectivity is advanced by treaties and conventions, and local managers and researchers may have inputs but cannot direct outcomes.

Conservation and restoration of mangroves were both considered important. This is reflected in the literature. A search using the Web of Science (November 15, 2013) and the terms "management," "restoration," or "conservation" and "mangrove" yielded 122 refereed research papers dating from 1978, with 39 (32%) published between 2010 and 2013. The matrix responses after the workshop identified conservation as urgent and regarded restoration as both important and urgent. This was especially so for the roles with hands-on management responsibilities (mosquito managers and coastal managers). At the workshop, barriers to restoration/management included a lack of clarity in goals. Restoring to a past state may no longer be possible or advisable as everything surrounding (and ecologically connected to) the wetland in question most likely would have changed considerably from the not-too-distant past. In many cases, attempts to restore to a past state will be wasteful of resources that could be better utilized in other ways. A clear understanding of (functional) management/restoration goals that carefully consider surrounding habitats and management of surrounding wetlands is essential, but very complicated. In some cases, it may be more beneficial to aim to restore ecosystem function rather than a historic past state.

Roles distinguished

To clarify key differences between roles, the following section discusses the several roles. When we examine the views of the roles some differences may be related to how much responsibility and power each role has in actually affecting environmental outcomes. This is especially illustrated for mosquito and coastal managers. The mosquito and coastal managers were most similar to each other and that may reflect their responsibilities and active on-ground management role compared to observation-based activity (researchers or consultants). The managers considered most issues to be both important and urgent, including some that the group as a whole did not see as so important (e.g., part of the

participation issues and all of the land control issues and insecticide resistance). Predation on mosquitoes was not seen as important or urgent (nor was it in any of the role responses). This may reflect the efficacy of current larvicides and the lack of reliable biological control by predators.

One participant reflected that the views:

> … reflect an ecosystem management perspective; low public health risk from arbovirus transmission due to management processes is already implemented (although that may change over time, that time has not yet occurred); other missing categories are the loss of wetland value due to runoff impacts on estuaries resulting in estuarine acidification impacts (amplified by near shore ocean acidification) and harmful algal blooms, which eradicate marine life in short and medium term.

The reference in the quote above to time and change is pertinent. Reflecting that mosquito management was destructive in the early 20th century, it is clear that managers now consider a broader range of issues than just mosquitoes, as evidenced in Fig. 2. Similarly, concern for environment appears to have led to the current broad view coastal managers also take of issues.

When considering the observation-based roles of research and consultancy there was less apparent concern, especially by researchers. They did not appear to be as concerned about as many issues as the other roles. This may be explained by researchers having less direct influence over land management. The low importance for extreme events may also reflect an inability to address these issues and insecticide resistance, which may be seen to be the role of other agencies.

One participant noted the following:

> We should not place restrictions on research. Strictly basic research should not be discouraged, but in this context we do not see much chance of any contemporary wetlands research having practical applications. Researchers conducting strictly basic academic research may not have the inclination to interact closely with land managers and consultants and this should call into question their expertise in management issues. The important relationships are between researchers who are interested in practical applications of their work, or who are conducting strictly applied research on wetlands ecology, management, mosquito biology, and mosquito control, and land managers, politicians, mosquito control workers, and interested citizens. With a healthy dialog, a research-based balance between management and mosquito control requirements, as well as between basic and applied research can become a goal in some groups of the respective research–management–restoration–control communities.

Consultants tended to see issues as more urgent than important (Fig. 2). This may reflect a perceived need for action to which they can contribute, or they may have contacts in other areas that can put pressure for action on the agencies with power and responsibility in the area.

The outcomes at the role level demonstrate that differences between roles reflect the compartmentalization issue raised at the workshop. Where authority is limited, gaps in responsibility are reflected in diverging attitudes. This is exemplified by managers' differences from researchers or consultants, indicating that there may not be agreement on priorities when these groups get together on an issue, despite general agreement on some issues when taken as a whole.

Barriers to expert interaction

Although interaction between agencies is important there are barriers to its achievement. One barrier to holistically and collaboratively managing mangroves in order to minimize mosquito problems is the limited interactions between experts in mosquito management and experts in wetlands (especially mangrove ecology). This leads to the potential for conflict between "wetland people" and "mosquito people" such as was happening in Florida in the 1980s. In the longer term, however, there has been a broadening of approaches with wildlife agencies in the USA becoming involved in wetlands–mosquito issues. As an example, the Wetlands Initiative at the Merritt Island National Wildlife Refuge in the late 1990s included a focus on wildlife management issues supported by, for example, state and federal government agencies, community organizations, and universities (Brockmeyer et al. 2005). See also the references to Florida impoundment management (Dale et al. 2008) and the SOMM referred to above and in Carlson et al. (1991), Carlson (2006) and Rey et al. (2012a).

In Australia the situation is similar, though researchers often come from a wetland science background and, though researching in the area of mosquito control, are not themselves directly responsible for mosquito control. However, the MARC in Queensland brings some agencies together, though they are generally focused on health issues rather than the environment (mosquito management and state government health department). There is a more basic problem in the fragmentation of governance and management in Australia, especially for coastal lands. These lands are under a variety of jurisdictions with disparate

boundaries that themselves do not necessarily reflect ecosystem boundaries (Sporne and Dale 2009, Dale et al. 2010, Dale and Knight 2012).

The situation appears to be improving with a broadening of the field. This is demonstrated by recent research papers addressing both mosquito issues and wetlands, for example, Rey et al. (2012a) and Rey et al. (2012b), with the latter comprehensively describing North American wetlands, their associated mosquitoes, and mosquito management. In Australia, Dale and Knight (2008) reviewed wetlands and mosquito issues from a wetland perspective and Dale and Knight (2012) addressed intertidal wetland issues—mosquitoes and human health. These are, however, limited examples. A recent example of an interdisciplinary multi-agency approach is illustrated by Farley et al. (2010).

A key requirement for effective communication and integration is trust and common goal-sharing among agency personnel. This cannot be legislated for, though it can be facilitated by rule structures that encourage collaboration. Collaboration between agencies, developed over time, was a key strength underpinning the success of mosquito management programs in both Indian River Lagoon (Florida) and southeast Queensland, Australia (Dale et al. 2008), and was enhanced by trust (Dale and Knight 2012).

In conclusion, the meeting brought together a range of interests. It was noted that collaboration and long-term relationships are strengths underpinning good management outcomes. In collaborations with other agencies, mosquito control is a crucial component of coastal management. The importance and urgency of issues raised and later assessed reflected the roles of the various participants, with on-ground managers indicating great importance and urgency for the issues. Those with less direct influence (consultants and researchers) were apparently less concerned and this may reflect that they have less power and/or responsibility to affect environmental outcomes. The results also reflected an evolution of approach from one that damaged wetlands in order to control mosquitoes in the first half of 20th century in Florida, to one in which mosquito managers have concern for the environment and coastal managers understand mosquito control issues. This common understanding is a strong foundation for ongoing collaboration. However, there remains a barrier beyond the control of the relevant agencies whereby the potential benefits of integrated multi-agency and interdisciplinary approaches to mangrove management are limited by scarcity of resources. This includes resources for research, restoration, mosquito management, and education.

Finally, there can be multiple benefits from collaborative wetland management by articulating the benefits to policy makers and by taking an holistic ecosystem approach, including integrated mosquito and coastal management, with inputs from multiple agencies. It is important to facilitate collaboration to achieve optimal benefits for public health and the environment. Without such an overarching perspective, compartmentalization and fragmentation can potentially limit achievement.

ACKNOWLEDGMENTS

We acknowledge the support provided by the Florida Medical Entomology Laboratory at Vero Beach and by Griffith University. The Australians (JK, PD, and LG) thank the following for their valuable inputs prior to the workshop, setting the Florida scene in the field: Barbara Roberts (Gamble Rogers Memorial State Recreation Area), Jeff Beal (Florida Fish and Wildlife Conservation Commission), and Stan Howarter (US Fish and Wildlife Service [Merritt Island]). We also thank the anonymous reviewers for their helpful comments and suggestions.

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