

SESAMME: An iPad application for participatory systems modelling

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Abstract:

The CCRES project is focused on enhancing livelihoods and food security, improving community health and wellbeing, and sustaining coastal ecosystems in two case study areas (El Nido, Philippines and Selayar, Indonesia). A key activity is to understand how communities currently interact with coastal ecosystems and how these interactions, along with external factors, have led to current socio-ecological problems. This work is assisted by an iPad application (SESAMME – Socio-Ecological Systems App for Mental Model Elicitation). SESAMME provides a mechanism for eliciting the mental models of local stakeholders framed around specific problems at specific geographical locations. It uses a ‘drag and drop’ icon approach that provides a graphical and participatory means to mapping out socio-ecological systems. It is used in conjunction with a methodological script that guides participants through this process in a consistent and repeatable manner. Overall, we found the use of an interactive app to elicit mental models to be effective and engaging. This was based on comments received from the CMTs who facilitated the FGDs and the comments from many of the FGD participants. SESAMME has been developed for iPad and is planned to be available via the Apple App Store after further refinement and testing has taken place.

Keywords: SESAMME; iPad app; rich pictures; community based system dynamics; socio-ecological systems; mental models; focus group discussions

INTRODUCTION

Socio-ecological problems relate to the complex webs of relations between dynamic ecosystems and the many scales of social networks (e.g. fishers, households, regional institutions etc) that interact with them (Murray et al., 2009). They (socio-ecological problems) are often framed as ‘wicked’ problems (Davies et al., 2015), or as the stakes are raised, as ‘super wicked problems’ (Lazarus, 2009), characterised by multiple spatial (local, regional, national and/or international) and temporal (e.g. days, weeks, months, decades) scales, multiple dimensions (social, ecological, economics, political etc), complex interactions and feedback pathways and conflicting stakeholder interests. As such, there is an increasing awareness that these problems need to be contextualised from a ‘systems’ perspective that acknowledges the relationships between system structure and behaviour (Lazarus, 2009). This characterisation of socio-ecological problems therefore lends itself towards using a systems thinking and modelling approach (Sterman, 2000; Lazarus, 2009), which has underlying tenets of holism and model structure (including feedbacks and delays).

There is also an increasing awareness that, in conjunction with using a systems approach, active engagement with key stakeholders is needed when developing models for managing socio-ecological problems (Davies et al., 2015). Such ‘participatory modelling’ is known to increase the sense of ownership, place and trust in model outputs (McAllister et al., 2006) and help gain common understanding of a problem (Senge and Sterman, 1992). Participatory systems approaches are commonly applied in urban and regional planning and natural resource management with established techniques to capture information from stakeholder groups (Mendoza and Prabhu, 2006). This includes community-based system dynamics (CBSD) that draws upon, and engages with, the knowledge domain of a community (Nadkarni and Shenoy, 2004; Hovmand, 2014). Engaging with the community helps the community itself make decisions based on their assumptions and inferences (i.e. mental models) about how a system operates (Hovmand, 2014), building social capital in the process.

The application of participatory systems modelling is accelerating, however, the tools available to help practitioners implementing the participatory systems modelling process are limited. This is especially so for mental model elicitation where there appears to have been little development of tools beyond the use of white boards, butchers paper, marker pens and post-it notes (e.g. Richards et al., 2013). This is not to denigrate the use of these tools, which are readily available and do not suffer the ‘slings and arrows of outrageous fortunes’ associated with more sophisticated technology. However, the rapid emergence and near ubiquitous (as evidenced by social network software such as Facebook) use of computer tablets and smart phones (collectively termed here as ‘smart technology’) coupled with their increasing functionality provides an opportunity to harness this technology for participatory modelling.

In particular, there is capacity for developing and using mobile applications (apps) as tools for improving the mental modelling process. The processing power and capabilities of smart technology is increasing nonlinearly in a manner that parallels computer development to the point where they themselves resemble powerful computers. Furthermore, the availability of application programming interfaces (APIs) means that the functionality of these apps can be expanded to include features such as mapping (Apple, Google maps) and cloud database storage (e.g. Parse) that

cannot be provided by the traditional ‘pen and paper’ approaches. They (apps) can also help with the “strive for visual simplicity” (Andersen and Richardson, 1997) by providing active filtering of mental model components through hiding and un-hiding selected elements. In the work presented here, this is exemplified by the ability (of our developed app) to selectively show / hide parts of a system map, allowing this visual simplicity to be achieved quickly and cleanly during a workshop.

In this paper, we present an iPad application (SESAMME – Socio-Ecological Systems App for Mental Model Elicitation) that has been developed and used within the Capturing Coral Reef & Related Ecosystem Services project. The purpose of SESAMME is for eliciting rich picture mental models themed around specific socio-ecological problems from community members during focus group discussions (FGDs). The developed rich pictures are a precursor step in developing causal loop diagrams (CLDs) and ultimately stock and flow models to be used for decision support.

This paper is divided into the following sections:

- Brief description of the CCRES project
- Core modelling teams used to run the FGDs
- The FGD script used to guide the use of SESAMME
- Detailed description of SESAMME
- Summary of outputs derived from using SESAMME
- Conclusion

CCRES PROJECT

The CCRES project (www.ccre.net) is funded by the Global Environment Facility (GEF), the World Bank and The University of Queensland (UQ), Australia. CCRES is primarily focused on enhancing livelihoods and food security, improving community health and wellbeing, and sustaining coastal ecosystems in two case study areas (El Nido, Philippines and Selayar, Indonesia). One key activity of CCRES is the *Systems Analysis* activity, which aims to understand how communities currently use and interact with coastal ecosystems (i.e. coral reefs, mangrove forests, seagrass beds) and how these interactions, along with external factors, have led to current problems such as fish catch decline, mangrove loss, water pollution and food insecurity.

CORE MODELLING TEAMS

Central to the *Systems Analysis* activity of CCRES are the active engagement with in-country partners, formation of core modelling teams (CMTs) and specification of socio-ecological problems to be investigated by the CMTs.

In-country partners were engaged for both case study areas (El Nido, Philippines and Selayar, Indonesia) to help coordinate, design and implement the FGD conducting with community participants (Table 1). The partners were drawn from two universities (one in the Philippines, one in Indonesia), local authorities and a non-governmental organisation. Their involvement in the *Systems Analysis* activity was critical because of their knowledge of the local issues (including socio-ecological problems), values and the language of the local communities.

The in-country partner organisations formed CMTs, used to engage with the communities and lead the design and implementation of the FGDs. Hovmand (2014)

provides an overview of the range of roles that can be incorporated within a CMT. For the CCRES project, four key roles were identified for each CMT:

- Facilitator – leads the discussion during the FGD proper
- iPad operator – controls the SESAMME app during the FGD
- Recorder – takes notes during the FGD and manages the notes post FGD
- Runner – assists the other roles in running the workshop

Training workshops covering systems theory (systems thinking and system dynamics) and the FGD methodology (assignment of roles within the CMTs and role-specific training where required e.g. operating SESAMME; development of an accompanying script for the FGDs) were conducted before the FGDs. These parallel the requirements detailed in Hovmand (2014) and include:

- (1) Raising / normalising the CBSD skills across the CMTs (systems modelling capacity building);
- (2) Identifying the roles and requirements for each CMT member before, during and after FGDs;
- (3) Developing a common language to be used by the CMT during the FGDs;
- (4) Developing workplans (process maps) detailing the timing and location of FGDs;
- (5) Developing the script that methodically details the FGD process; and
- (6) FGD training and rehearsal.

The socio-ecological problems (Table 1) investigated in the CCRES project were selected after a series of site visits to Selayar and El Nido, consultations with the in-country partners and review of the results of prior community surveys.

Table 1. In-country partners used to form CMTs and the socio-ecological problem assigned to each. Note there are two CMTs formed at Palawan State University (PSUa and PSUb).

Socio-Ecological Problem	In-country Partner	Country
Food insecurity	El Nido Foundation (ENF)	Philippines
Mangrove loss	Palawan Council for Sustainable Development (PCSD)	Philippines
Water quality	Palawan State University (PSUa)	Philippines
Fish catch decline	Palawan State University (PSUb)	Philippines
Coral reef fisheries decline	Bogor Agricultural University (IPB)	Indonesia

SCRIPT

The FGDs are run according to a script, which is a logical and repeatable process that allows the results of multiple FGDs to be compared. Such scripts provide a scientific basis for group model building (Andersen and Richardson 1997, Hovmand, 2014). Table 2 provides a summary of the main steps in the script used to elicit socio-ecological systems information from FGD participants.

Table 2. Main steps in the script used to elicit socio-ecological systems information from FGD participants.

Step	Description
<i>Activity</i> identification	<i>Activities</i> related to the problem are identified e.g. fishing, mangrove cutting (for mangrove loss)
<i>Resource</i> identification	<i>Resources</i> affected by the <i>Activities</i> are identified e.g. reef fish, mangroves, coral reefs. The current condition (state) of each resource is also identified.
Trends in <i>Activities</i> and <i>Resources</i>	Past, Expected Future and Desired Future trends are assigned to each <i>Activity</i> and <i>Resource</i> .
<i>Pressures</i>	Pressures that have influenced the past trends in <i>Resources</i> and <i>Activities</i> are identified (e.g. population growth, commodity prices, climate change).
Trends in <i>Pressures</i>	Past, Expected Future and Desired Future trends are assigned to each <i>Pressure</i> .
<i>Interactions</i>	Direct interactions between <i>Resources</i> , <i>Activities</i> and <i>Pressures</i> are identified. These are elicited as interaction sets (i.e. Resource – Resource; Activity – Resource; Pressure – Activity; Pressure – Resource, Activity – Activity, Pressure – Pressure interactions)
<i>Decisions</i>	<i>Decisions</i> that stakeholders could make to address problematic trends in <i>Resources</i> , <i>Activities</i> or <i>Pressures</i> are identified.

THE SESAMME APP

SESAMME is an app developed for the CCRES project to aid the elicitation of local stakeholder mental models framed around specific socio-ecological problems at specific geographical locations.

SESAMME uses a ‘drag and drop’ icon approach (see Figure 3 for example icons used in SESAMME) coupled with the Apple maps application programming interface (API) (comparable to Google Maps). The rationale for using an icon-driven approach (as opposed to a text-driven one) is that it does not make assumptions about the level of literacy of the participants.

It is important to note that whilst SESAMME was developed as an interactive tool for creating rich picture representations of mental models for a given socio-ecological problem, operation of the app within the *Systems Analysis* activity is restricted to a trained operator (the iPad Operator in the CMT). This means that only the iPad Operator needs to know how to operate SESAMME. To make the app accessible to the FGD participants, the iPad that SESAMME is being run from is connected to a projector and the iPad screen area projected onto a viewing area where it is visible to all. The workshop participants provide the input regarding the rich picture map composition (e.g. which icons to use, where to place them on the map, how they are interconnected etc) via facilitated discussion.

App architecture

The base architecture of the SESAMME app is shown in Figure 1. SESAMME opens with a splash screen whilst the app is launching. The app then opens the title screen, which contains base information (app title, author names, development version). The

app is launched by touching the screen, taking the user to the log-in screen. Here, the user must enter a user-name and can elect to use the app in ‘local’ (draws upon data stored on the iPad) or ‘global’ (draws upon data stored on the ‘cloud’) mode. After successful log-in, the FGD details screen is launched. This provides an opportunity for the user to add details about the CMT (i.e. enter the names of the Facilitator, iPad Operator, Recorder and Runner), the workshop (date, location, stakeholder group) and up to 20 FGD participants. From here, the main interactive screen (Mapping area in Figure 1) is opened.

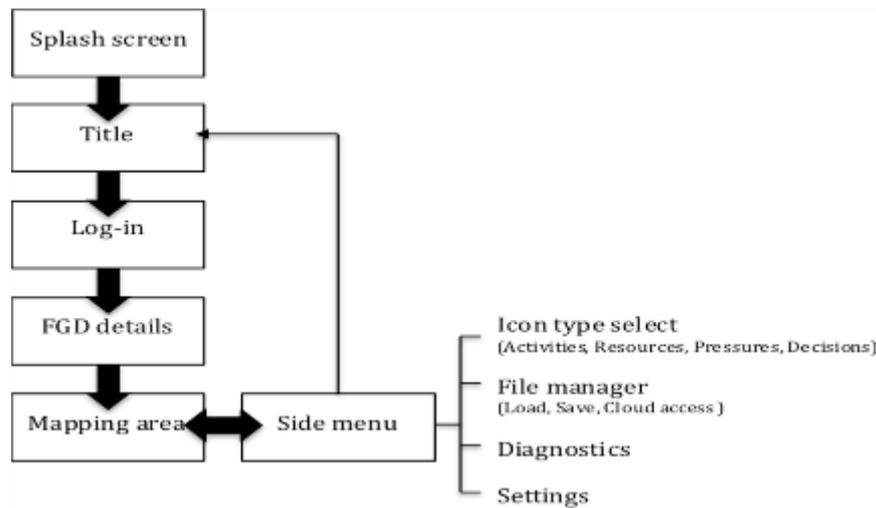


Figure 1. The architecture of SESAMME showing the main screens and the pathways between them

Mapping Area

The mapping area provides the main focus screen for rich picture development during the FGDs. As outlined earlier, the rich pictures are constructed according to a script (see Table 2). As the rich pictures are constructed, icons are used to represent *Activities, Resources, Pressures* and *Decision* and these linking these together with interactions to indicate causality. All icons, regardless of type, have a common range of attributes that can be set, facilitated by the object-oriented programming used to construct SESAMME (iPad apps are programmed within the object-oriented software platform of Objective-C using the software development kit of Xcode).

An example of the default layout for the map area is shown in Figure 2. This shows the map area and four menus that can be accessed, three of which are hidden (side menu, icon menu top, icon menu bottom).

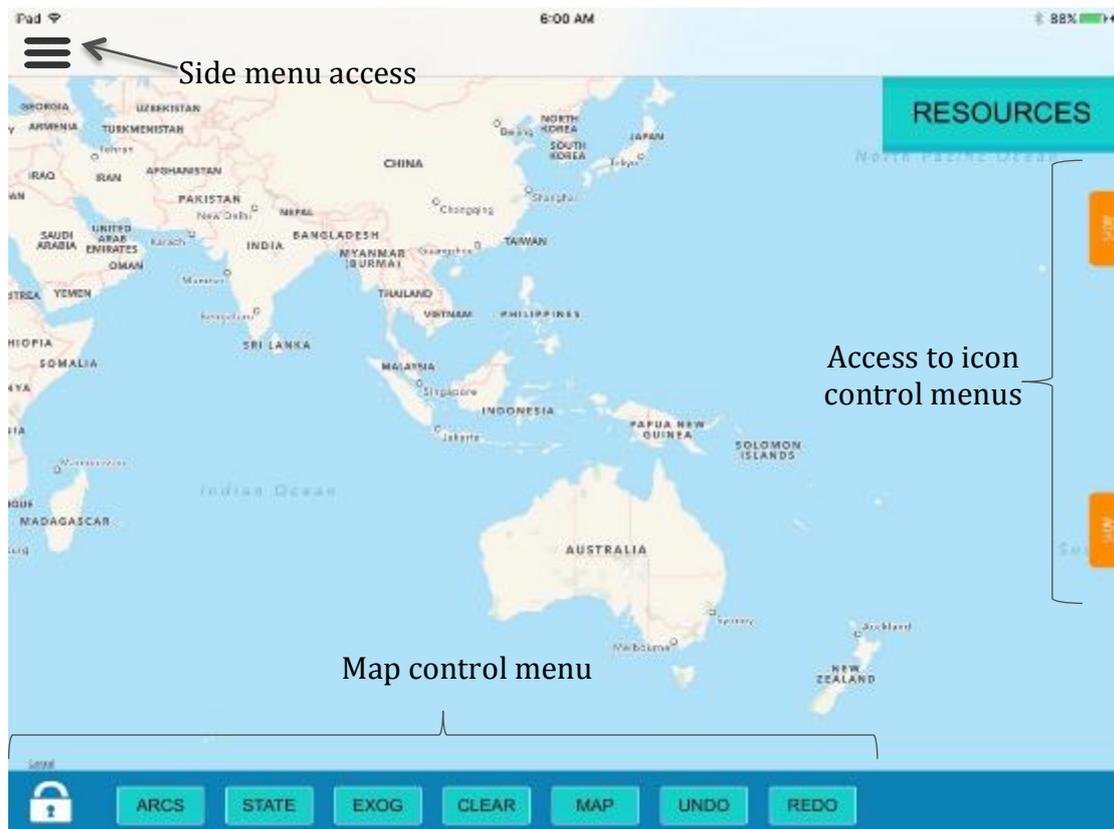


Figure 2. Mapping area screen

Side Menu

The side menu (Figure 3), which is accessed by pressing the top left of the screen, contains four types of options:

- Map building functions
- Rich picture diagnostics
- File management
- App settings

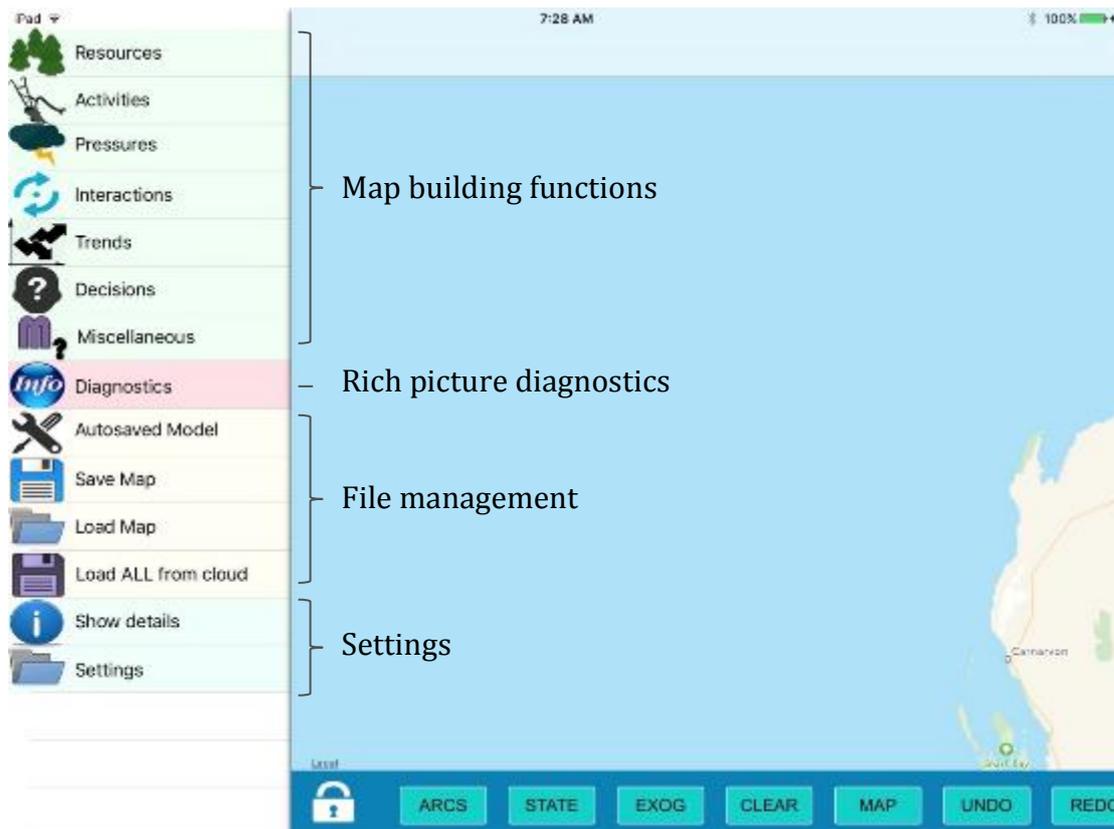


Figure 3. The side menu options that appear

Map building functions: The map building functions follow steps in the script used for rich picture development (Table 2).

Rich picture diagnosis: The diagnostics tool allows basic statistical summaries to be carried out on the rich pictures. Its intended purpose is to provide rapid assessment of one or more rich picture maps (e.g. across multiple rich pictures it can address questions like *how many times is an interaction between fish and fishing recorded?*). This tool is still under construction but the function (and current development status) of each of the components within it is as follows:

- Select maps (Figure 4): allows the user to select which maps saved on the iPad are to be used for diagnostic testing (this is limited to rich pictures saved on the iPad). This tool is fully functional.
- Summary statistics (Figure 5): Displays the bulk statistics for each of the icon types for each map. This tool is fully functional.
- Icon type diagnostics – This tool will allow (this tool is under construction and is not yet functional) a more in-depth analysis of a specific icon type (*Resource, Activity, Pressure, Decision*) across the selected maps. It is planned that this tool will identify and summarise for each selected rich picture map (using histograms and tables) which icons are connected to each other, the polarities of these connections, icon trends and icon states.



Figure 4. Select map function. Multiple maps can be ‘selected’ to be included in the diagnostic testing.

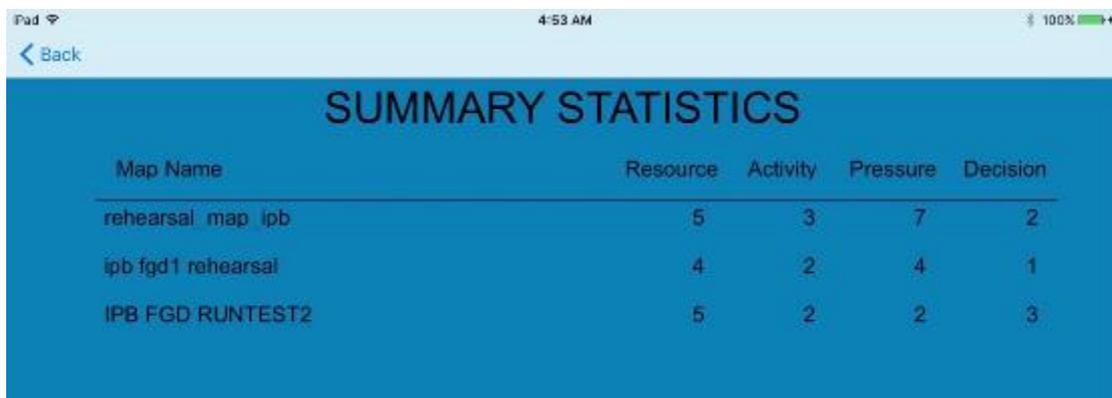


Figure 5. Summary statistics function. This shows a frequency count of the different icon types (Resource, Activity, Pressure, Decision) for each map.

File management: SESAMME has a basic file management system that allows rich picture maps to be saved to, and loaded from, the iPad and cloud storage (Parse). An early development requirement for SESAMME was that it be connected to cloud storage so that (1) rich picture maps could be backed up to a secondary storage unit (the primary storage is the iPad) to provide data security and (2) the rich pictures developed could be shared (upon upload to the cloud). The process of saving files to the iPad and cloud storage is outlined within the script.

Settings: This page is, to date, quite rudimentary in that the only setting that can be adjusted is whether the iPad is connected to the cloud (online) or not (offline). It was important that the iPad operator could purposely switch between online and offline modes, particularly in areas where Wi-Fi is intermittent. This situation (intermittent Wi-Fi) can cause SESAMME to make repeated attempts at connecting to the cloud database, essentially ‘locking’ up the iPad for several minutes. This issue of intermittent connection and searching is addressed in the script by requiring that SESAMME be used *offline* during the FGD.

Bottom Icon Control Menu

The bottom right hand *Icon Control Menu* is where the library of available icons is located. These icons are dependent on which icon type has been selected (e.g. if *Resources* has been selected then only resource-type icons will be shown – refer to Figure 6 for an example of icons for each type) and are hidden by default. Originally, this menu was always shown and feedback from early testing indicated that showing the icons biased participant responses.

Icon category	Icon examples				
Resources	 user-define	 coral	 cattle	 reef fish	 crops
Activities	 user-define	 fishing	 egg gathering	 ploughing	 tree clearing
Pressures	 user-define	 climate change	 population growth	 economy	 air pollution
Decisions	 user-define				

Figure 6. Examples of icons for each icon category (Resources, Activities, Pressures, Decisions) in SESAMME

When starting a new map, the default category is ‘RESOURCES’ (as shown in Figure 7). A sub-set of 12 icons from the total available icons is shown at any one time. Pressing the header of the icon menu (refer Figure 7) will replace this subset of visible icons with a different sub-set. Note that the first icon is a ‘user define’ icon that is available for use when it is deemed by the FGD participants that there is not an appropriate icon in the library. Also, note that the text label attached to any icon, which is also shown when the icon is dropped into the map view, is editable allowing the icon to be re-labelled.

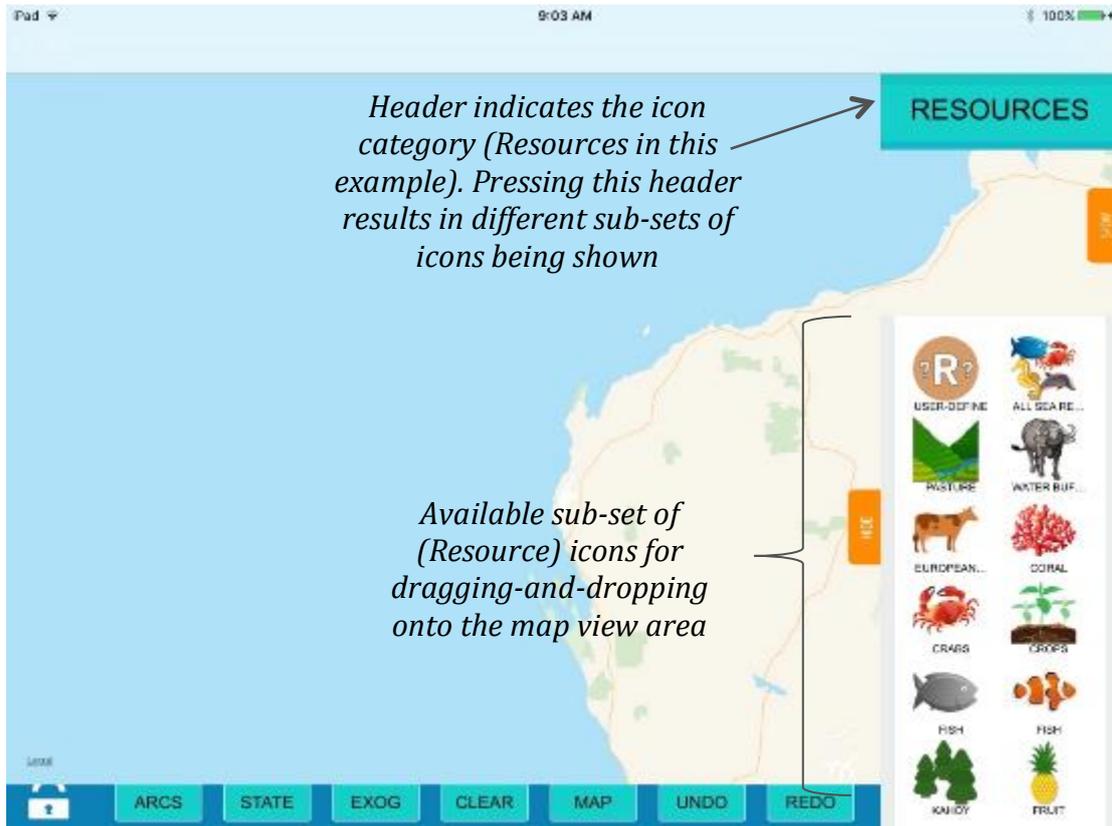


Figure 7. The icon menu after the ‘SHOW’ button is pressed. Note that the icon category header (i.e. the ‘RESOURCES’ tab) is a button that enables different sub-sets of the icons to be presented.

The bottom side menu can also be set to show a library of qualitative trend icons (Figure 8) when *Trends* has been selected from the side menu (Figure 3 – map building functions). These trend icons indicate the *past*, *expected future* and *desired future* trends for a particular icon.

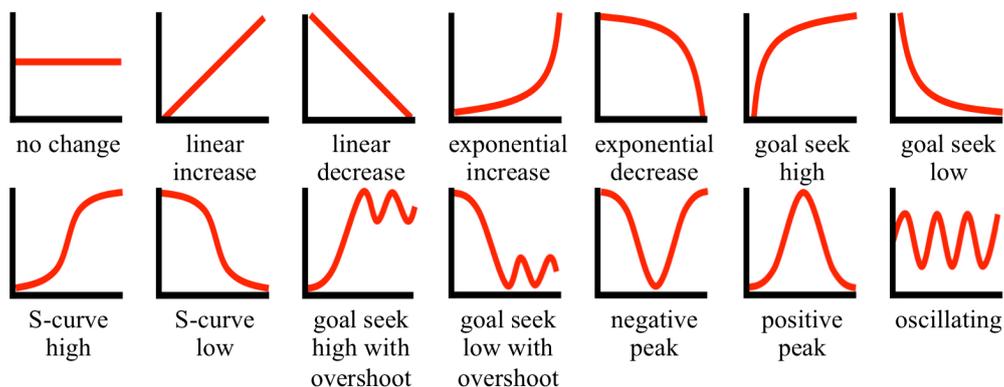


Figure 8. Trend available in SESAMME that can be assigned to an icon

Trends are attached to icons using sub-views so if the parent icon (the reef fish in Figure 9) is moved the sub-viewed trends will move with it. The trends are sub-viewed depending on whether they represent past (located upper left of the parent

icon), expected future (upper right) or desired future (extreme upper right) trends. Note that SESAMME does not require that all trends (past, expected future, desired future) be assigned to an icon i.e. just one of these trends can be assigned.

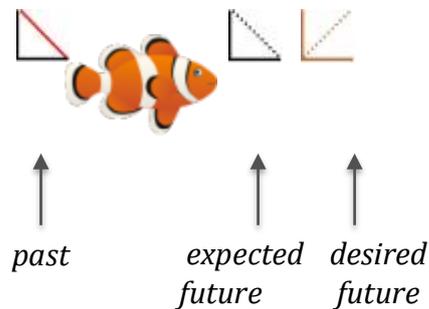


Figure 9. Example of how the trends assigned to an icon appear in SESAMME

Top Icon Control Menu

The top menu is for controlling how the icons are displayed within the map display. This includes a rubbish bin icon that is used for deleting icons and interactions (arcs) from the view map area, a note function so that comments can be added to the map and a set of view toggle buttons that can be used to hide and un-hide components of the rich picture (e.g. trends, labels and/or interactions can be hidden to de-clutter the map).

The top icon control menu can be used to enter into SESAMME's edit mode. Edit mode allows changes to an existing rich picture to be tracked (similar to Track Changes in Microsoft Word), so that if the rich picture is modified between FGDs, the changes can be recorded. SESAMME's edit mode has three modes (Figure 10):

- *edit* –reflects the updated rich picture and is where deletions (e.g. icon removed), additions (e.g. icon added) and modifications (e.g. polarity changed) are made.
- *highlight* –changes made to the original rich picture are highlighted.
- *original* –where the original form of the rich picture (i.e. before edits were made) is shown.

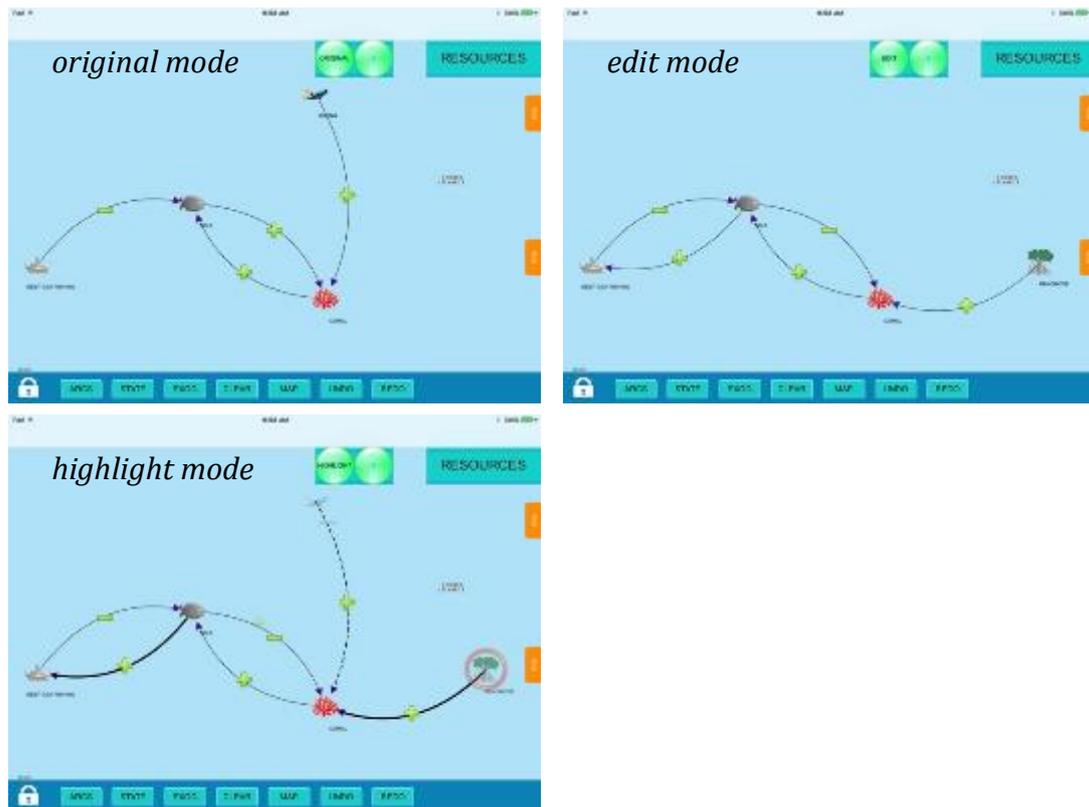


Figure 10. Example of how an edited map appears in each of the three edit modes (Original = pre-edited map; Edit = revised form of the map; Highlight = changes made to the map).

Map Control Menu

The menu bar located along the bottom of the screen contains several functions that can be applied to the map area. This section briefly describes the use of each function within this menu.

Map Padlock: A padlock icon located at the bottom left of the screen is used to lock the map when icons are being dragged onto it, otherwise the map will move when icons are dragged.

Arc / Interactions: This button allows arcs (interactions) to be added to the rich picture. Whilst this is enabled, neither the map nor the icons can be dragged (because SESAMME reserves the touch screen movements to drawing arcs on the map). The process for creating an arc between two icons is shown in Figure 11. To start an arc, an icon is touched (a gold rectangle around the icon indicates it is a valid icon¹ for developing an arc). Once tethered to a start icon (always contextualised as the ‘cause’ icon in a cause-effect relationship), the arc can be dragged to another valid icon (the ‘effect’ icon). A second gold rectangle around the destination icon indicates that the connection can be made and is completed by lifting the finger off the screen at this stage. The colour of the arc changes from red (signifying arc under construction) to

¹ The concept of a valid arc is used in the code to differentiate between touching a rich picture icon (resource, activity, pressure, decision) and a subsidiary icon (e.g. a trend icon – refer Figure 11)

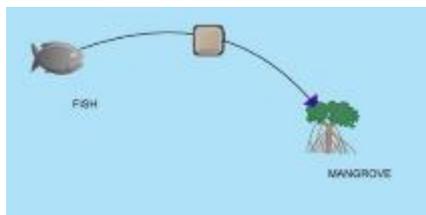
black (arc has been successfully constructed). The constructed arc also contains a grey box at the mid-point, which is used to set the polarity of the arc.



1. A red arc is tethered to a start (cause) icon



2. The arc is dragged to an end (effect) icon



3. A successfully constructed arc changes to black with a grey 'polarity' box appearing at the mid-point.

Figure 11. The process of creating an arc (interaction) in SESAMME. The gold rectangles shown for the start (top panel) and the end (middle panel) icons indicate that they are 'valid' icons for tethering the arc to.

State: This button is used to set the current state or condition of an icon. When state is enabled, touching any *Resource*, *Activity*, *Pressure* or *Decision* icon in the map view will sequentially cause it to change colour in the order shown in Figure 12. The colour scale legend is: red = poor condition, orange = moderate condition, green = good condition.

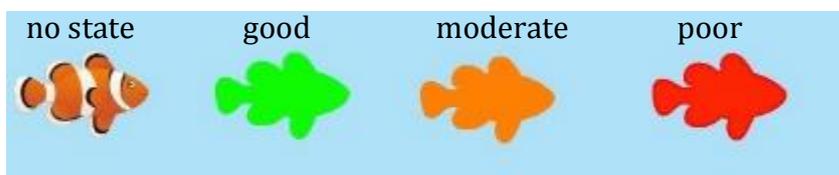


Figure 12. Example of the three state settings shown for the reef fish icon and how this changes the icon's appearance in the map view.

Exog: This button is used to allow individual *Resource*, *Activity*, *Pressure* or *Decision* icons to be specified as exogenous (external to the system) or endogenous (internal to the system). By default, any icon added to the map view area is endogenous and becomes automatically geo-located to the map (i.e. if the map is panned or zoomed then the icon will automatically move with it). Touching an icon within the map area when the *Exog* button has been set will change the icon from endogenous to exogenous (and back again if the same icon is pressed again). If an icon has been set

as exogenous, then its appearance will fade and it will no longer move with the map. Hence a rapid way of determining which icons are exogenous in a ‘crowded’ rich picture map is to move the map area and see which icons do not move.

Clear: This button is used to clear the entire map of all icons. Pressing this button instantiates an alert call-out window that checks this action (‘Clearing all icons. Are you sure’). If actioned, all icons and interactions are cleared from the map permanently.

Map: This button enables toggling between regular, satellite and hybrid (regular and satellite combined) map views.

Undo / Redo: These two buttons are edit buttons that allow sequential changes to be recovered (undo) or repeated (redo). However, these functions are still undergoing development and are not functional at this stage.

OUTPUTS FROM THE FGDs

The SESAMME app was recently used in over 166 FGDs in El Nido and Selayar. Observations and feedback from these FGDs indicated that SESAMME was a good mechanism for engaging with communities and capturing their mental models related to socio-ecological problems. Some issues with SESAMME were identified (bugs in the coding, usability of the app) during the FGDs with most resolved quickly because of clear communication with the CMTs and the use of the Internet to remotely update SESAMME.

An example of a rich picture developed from an FGD using SESAMME is presented in Figure 13. Features of this rich picture are:

- *Resource, Activity, Pressure* and *Decision* icons;
- ‘States’ assigned to *Resource* icons e.g. the fish icon in the middle of the map;
- Trends (past, expected future, desired future) assigned to *Resource, Activity* and *Pressure* icons;
- Interactions indicating causal relationships between icons;
- Polarities on the interactions indicating the direction of relationship between connected icons.

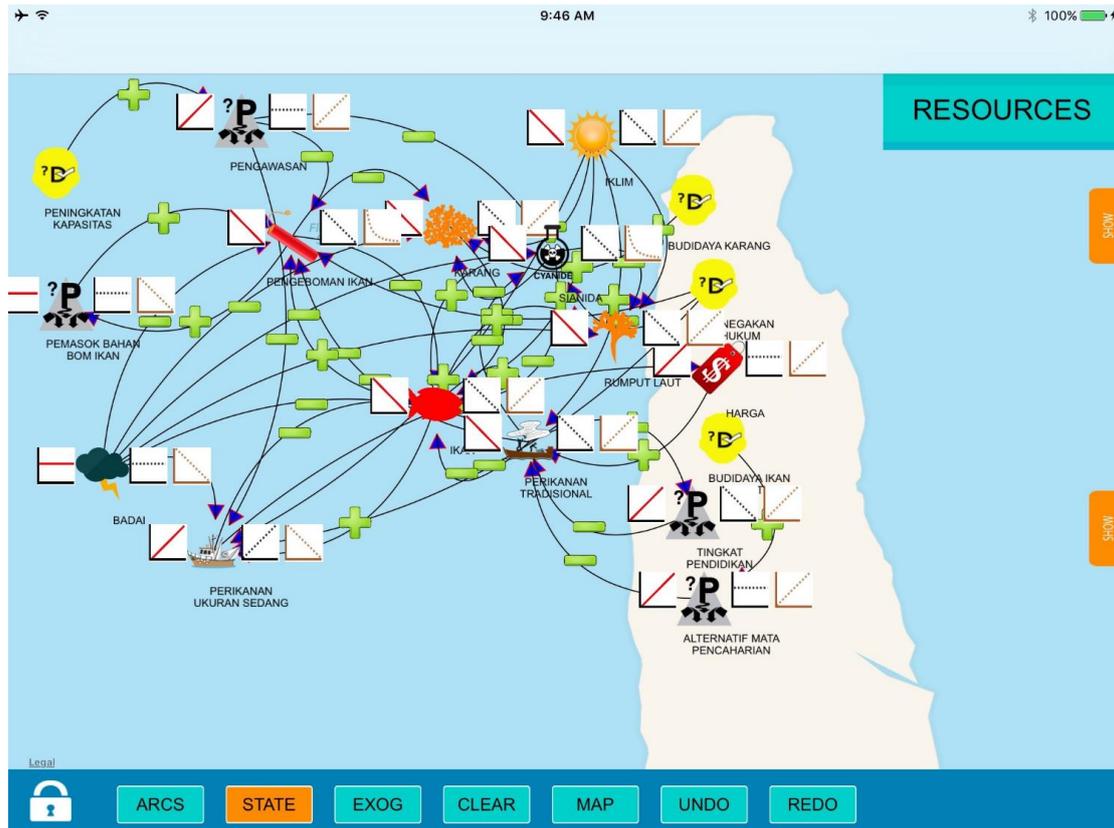


Figure 13. Example of rich picture developed using SESAMME for an FGD held in Selayar, Indonesia. Note that the ‘state’ button is enabled, causing icons that have been assigned states to be highlighted (e.g. the red fish icon in the middle of the map is red, indicating poor condition).

The following figures present summaries of some of the data elicited from 17 FGDs conducted in Selayar, Indonesia, using SESAMME. The focus problem for these FGDs was ‘Coral reef fisheries decline’.

Figure 14 summarises the percentage of FGDs in which different activities were identified. For example, ‘Coral Fishing’ was identified in all FGDs. Other forms of fishing (Poison fishing, Fish bombing) also featured frequently. Conversely, some *Activities* (e.g. Hobby fishing, Sea weed farming) were identified at a small number of FGDs, perhaps reflective of site-specific activities.

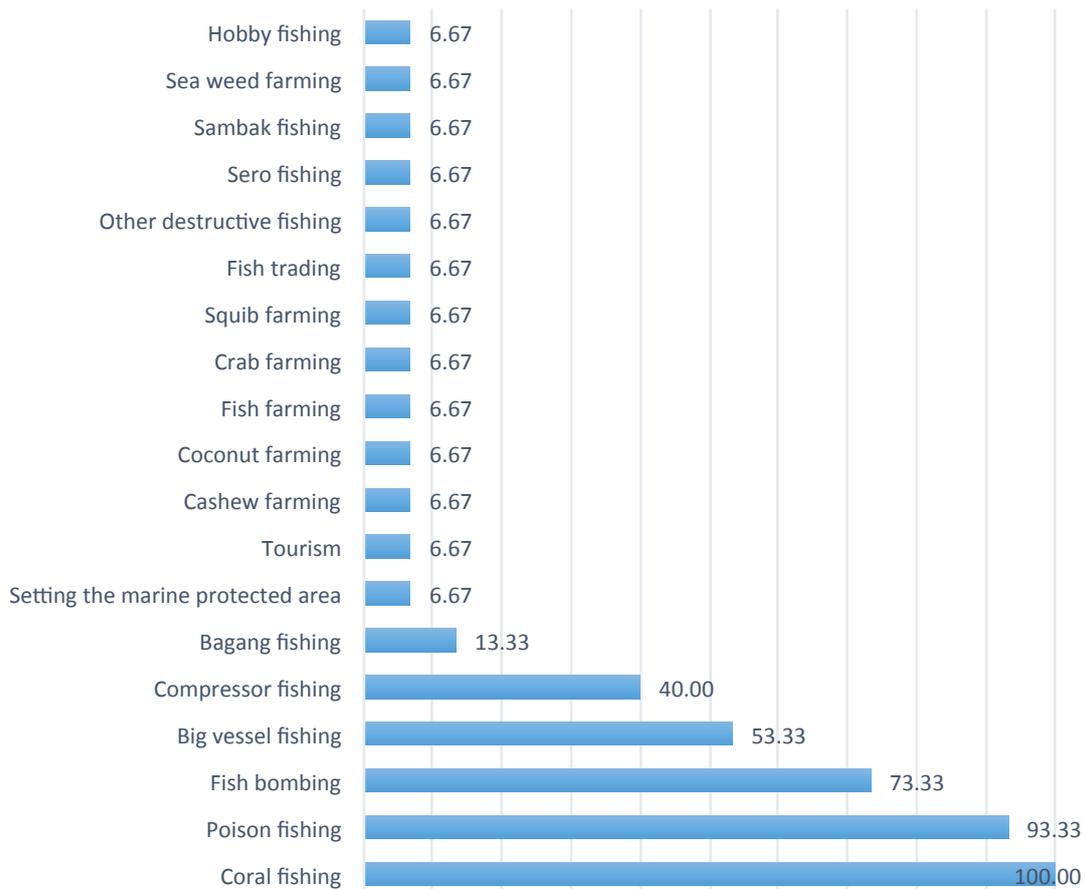


Figure 14. Summary of the *Activities* reported across the FGDs conducted in Selayar, Indonesia. The number at the end of the row indicates the % of FGDs in which an Activity was identified (Adrianto et al., 2015).

Figure 15 summaries the trends (past, expected future, desired future) assigned to *Activities* across the FGDs, e.g. 67% of the FGDs perceived that Coral fishing has been increasing (past trend) and will continue to increase (expected future trend). However, only a third (33%) of FGDs expressed a desire for fishing to continue to increase.

Activities	Trends	Percentage						
								
Coral fishing	Past	20	0	0	13	67	0	0
	Expected	26	0	0	7	67	0	0
	Desired	34	0	13	20	33	0	0
Poison fishing	Past	29	7	0	29	28	0	7
	Expected	36	0	0	36	28	0	0
	Desired	43	0	57	0	0	0	0
Fish bombing	Past	64	36	0	0	0	0	0
	Expected	64	0	0	27	9	0	0
	Desired	9	0	91	0	0	0	0
Big vessel fishing	Past	13	0	0	12	75	0	0
	Expected	25	0	0	12	63	0	0
	Desired	75	0	13	12	0	0	0
Compressor fishing	Past	67	17	0	0	16	0	0
	Expected	33	0	0	0	67	0	0
	Desired	67	0	17	0	16	0	0

Figure 15. Summary of the *Activity* trends reported by FGDs, Selayar, Indonesia (Adrianto et al., 2015).

The data extracted from the SESAMME rich pictures can also be used to summarise the frequency with which interactions between ‘icons’ were elicited. For example, Figure 16 highlights the *Activity – Resource* interactions across the FGDs and the nature of these interactions. This figure highlights that ca. 93% of the FGDs identified interactions between Coral fishing and Fish (negative polarity) and Fish and Coral fishing (positive polarity). This particular result highlights that most of the communities perceive a balancing feedback loop between the *Activity* (Coral fishing) and the *Resource* (Fish).

Nine balancing loops (the blue lines in Figure 16) between *Activities* and *Resources* were identified across the FGDs (Adrianto et al., 2015). These interactions (along with interactions that did not form loops e.g. the grey and orange lines in Figure 16) and interactions between other icon types (e.g. *Resource – Resource*) are being used to construct causal loop diagrams (CLDs). An example of a preliminary CLD that has been developed from the FGDs conducted in Selayar is presented in Figure 17. These CLDs provide a bridge between the rich picture maps elicited using SESAMME and stock and flow models that will be developed to simulate the effect of feedback loops on system dynamics.

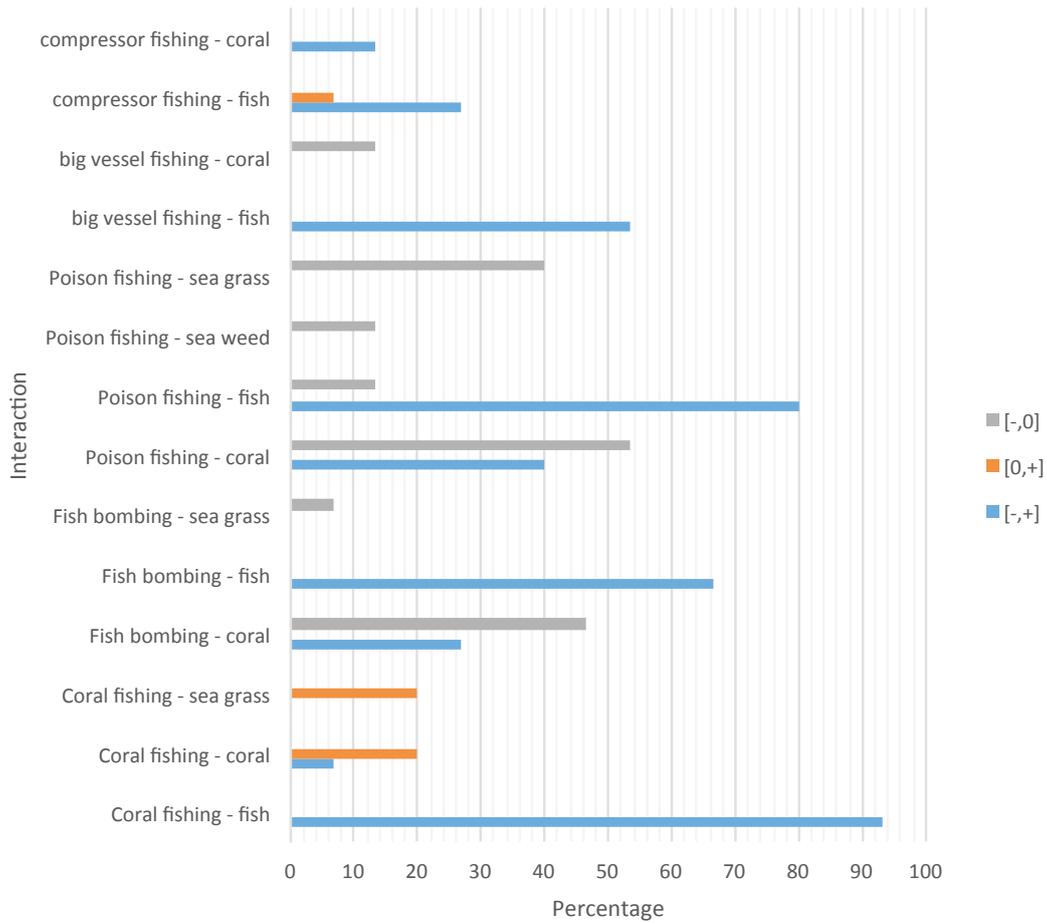


Figure 16. Summary of *Activity – Resource* interactions reported by FGDs conducted in Selayar, Indonesia (Adrianto et al., 2015). Note [-,0] means there was a negative relationship from the Activity to the Resource but no relationship from the Resource to the Activity. [0, +] means that there was no relationship from the Activity to the Resource but there was a positive relationship from the Resource to the Activity. [-,+] means that the Activity had a negative relationship with the Resource and the Resource had a positive relationship with the Activity (i.e. feedback loop exists).

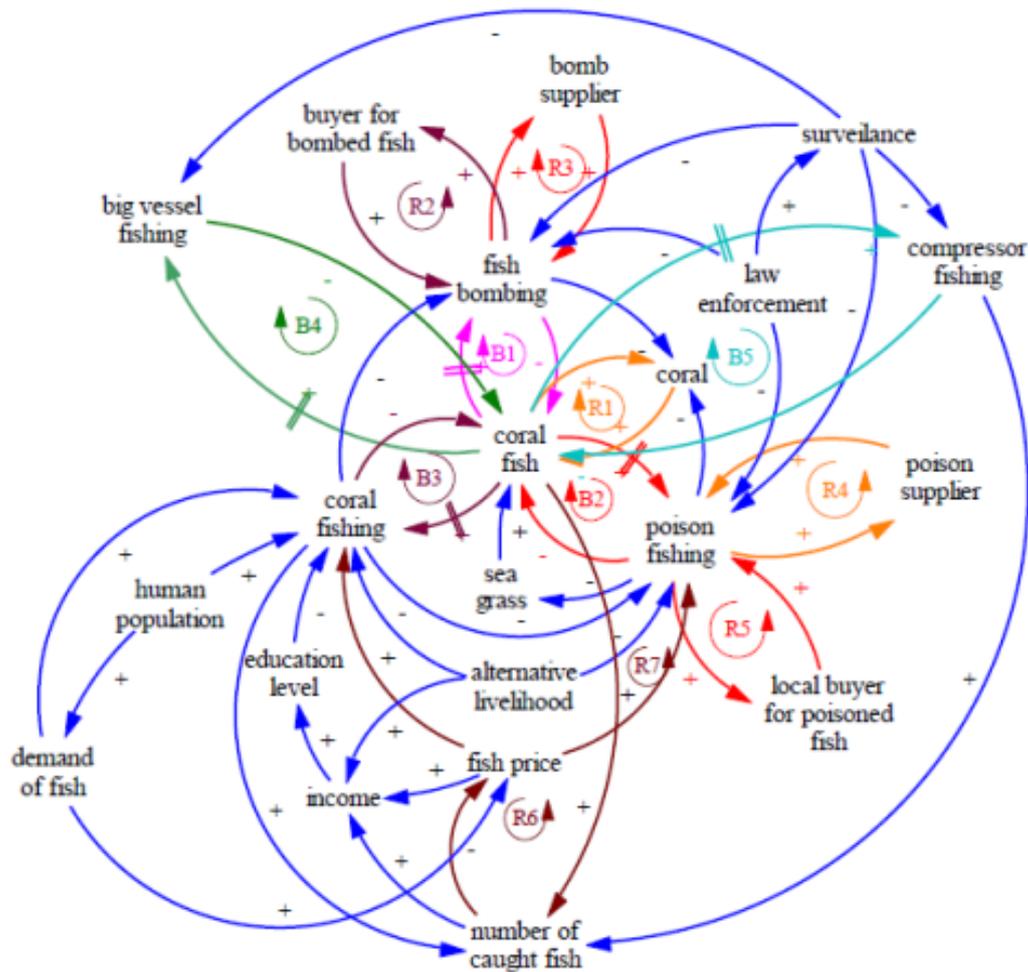


Figure 17. Common interactions among Activities, Resources, and Pressures reported by FGDs held in Selayar, Indonesia (Adrianto et al., 2015)

CONCLUDING REMARKS

Overall, we found the use of an interactive app in conjunction with a script eliciting rich picture maps from stakeholders to be effective and engaging. This was based on comments received from the in-country partners who facilitated the FGDs and the comments from many of the FGD participants. SESAMME is being developed for iPad and is only currently available through Apple ‘ad hoc’ distribution. However, it is planned to be available via the Apple App Store after further refinement and testing has taken place. These refinements include allowing the users to create their own icon categories and import their own icons into these categories. This will allow SESAMME to be applied to any problem.

REFERENCES

Adrianto, L., Setianto, N.A., Kusumo, S., Affata, S. (2015). Report on Scoping and First Round of Focus Group Discussions in Kabupaten Kepulauan Selayar, Indonesia. Capturing Coral Reef and Related Ecosystem Services draft report. December 2015.

Andersen, D.F., Richardson, G.P. (1997). Scripts for group model building. *System Dynamics Review*, 13 (2), 107–129.

Davies, K.K., Fisher, K.T., Dickson, M.E., Thrush, S.F., Le Heron, R. (2015). Improving ecosystem service frameworks to address wicked problems. *Ecology and Society* 20(2), 37.

Hovmand, P.S. (2014). *Community based system dynamics*. Springer, New York.

Lazarus, R.J. (2009). Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future, 94 *Cornell L. Rev.* 1153.

McAllister, R.R.J., Gordon, I.J., Janssen, M.A., Abel, N. (2006). Pastoralists' responses to variation of rangeland resources in time and space. *Ecol. Appl.* 16, 572–583.

Mendoza, G., Prabhu, R. (2006). Participatory modeling and analysis for sustainable forest management: overview of soft system dynamics models and applications. *Forest Policy and Economics* 9, 179–196.

Murray, G., Neis, B., Johnsen, J.P. (2006). Lessons Learned from Reconstructing Interactions Between Local Ecological Knowledge, Fisheries Science, and Fisheries Management in the Commercial Fisheries of Newfoundland and Labrador, Canada. *Human Ecology*, 34,(4), 549–571.

Nadkarni, S., Shenoy, P.P. (2004). A causal mapping approach to constructing Bayesian networks. *Decis. Support Syst.* 38, 259–281.

Richards, R., Sano, M., Roiko, A., Carter, R.W., Bussey, M., Matthews, J., Smith, T.F. (2013). Bayesian belief modeling of climate change impacts for informing regional adaptation options. *Environ. Modell. Softw.* 44, 113–121.

Senge, P.M., Sterman, J.D. (1992). Systems thinking and organizational learning: acting locally and thinking globally in the organization of the future. *Eur. J. Oper. Res.* 59, 137–150.