# ECSA 37 – ERF 2004

## ESTUARIES & CHANGE

# WORKSHOP ON SETTING FRESHWATER ALLOCATIONS FOR ESTUARIES

## BALLINA, 20 – 24 JUNE 2004

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***REPORT COMPILED BY:***

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# 1. PURPOSE

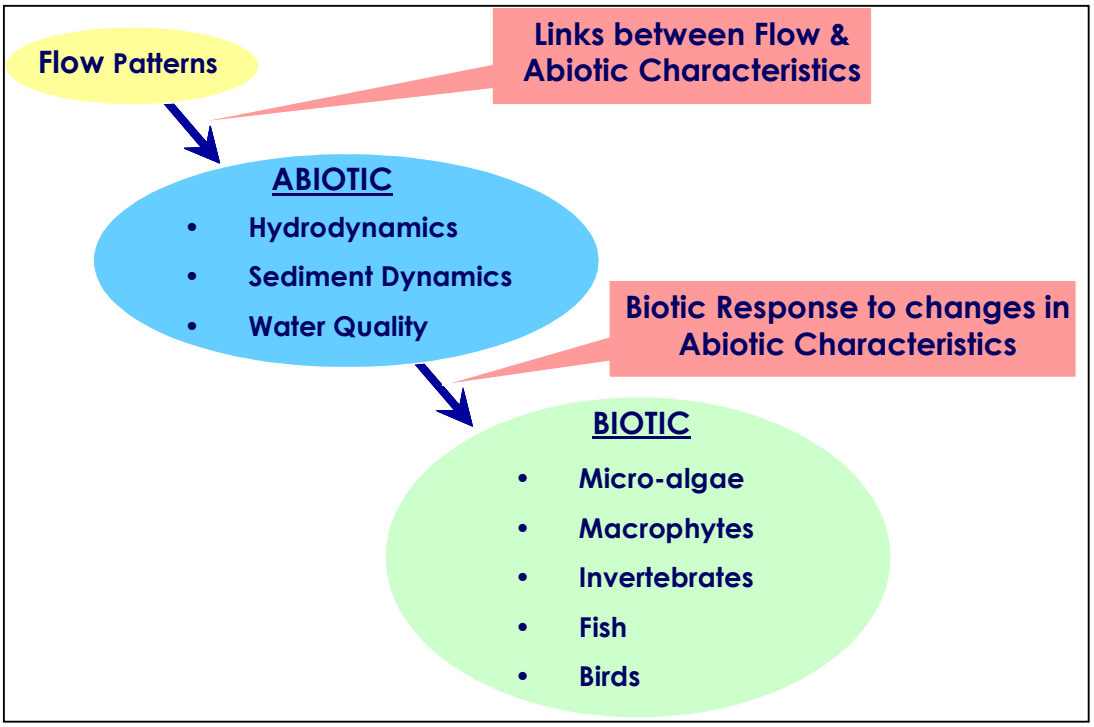
The purpose of the workshop was to share collective knowledge on practical methods that are currently being used to set freshwater allocations to estuaries.

The discussions were initiated using the current methods applied in South Africa as a departure point.

# 2. OVERVIEW OF THE SOUTH AFRICA METHODS

## 2.1 Approach and Method

South Africa follows an ecosystem approach in setting freshwater requirements for estuaries. In essence, this requires an understanding of the effect of changes in river inflow on abiotic components (e.g. hydrodynamics, sediment dynamics and water quality) and subsequently, the response of biotic components (e.g. micro-algae, macrophytes, invertebrates, fish and birds) to changes in those abiotic components:




*Linking flow to Abiotic Characteristics*

The South African approach broadly categorises river inflows into:

- Floods
- Seasonal flows.

Floods typically influence the sediment dynamics of an estuary, most importantly the sediment erosion/deposition equilibrium and the sand/mud distribution patterns within a system.

Seasonal flow patterns primarily affect hydrodynamic aspects such as state of the mouth (in the case of temporarily open/closed estuaries) and the extent of salinity penetration (in the case of permanently open systems).

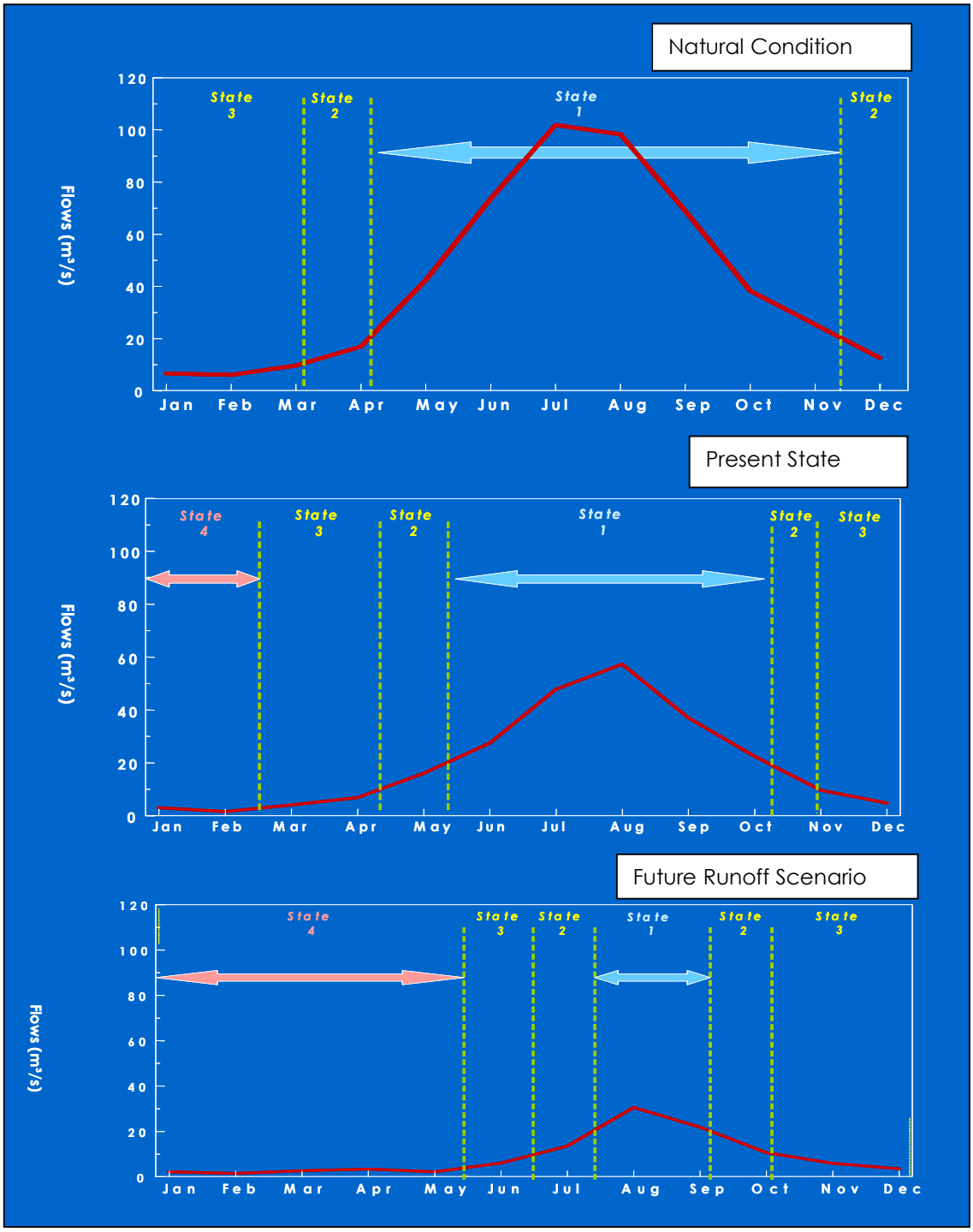
In order to establish links between seasonal flow patterns and abiotic characteristics, measured (as well as simulated) data on river inflow, water levels and salinity profiles are used to define typical 'Abiotic States'. Abiotic States are primarily linked to characteristic flow ranges. The relationships between Abiotic states and flow ranges are site-specific. An example of such relationships is provided below:

| Flow range | Abiotic State |
|---|---|
| **> 20 $m^3/s$** | **Strongly freshwater dominated** |
| **10 - 20 $m^3/s$** | **Freshwater dominated, significant saline intrusion in lower reaches** |
| **10 - 3 $m^3/s$** | **Marine dominated, freshwater only present in upper reaches** |
| **< 3 $m^3/s$** | **Mouth closed off to sea** |
| | |

In addition to flow ranges, each Abiotic State is also characterised in terms of:

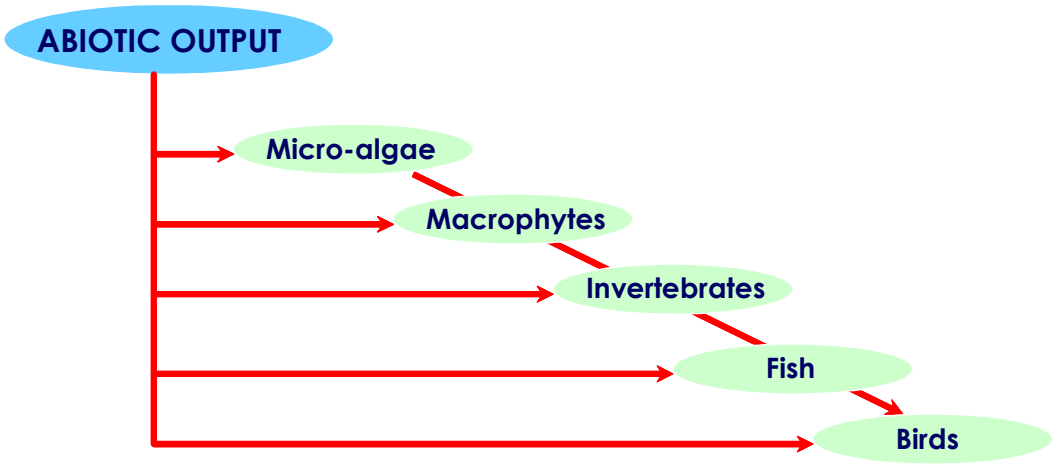
- State of the mouth
- Tidal amplitude and floodplain inundation
- Retention times
- Tidal velocities
- Salinity distribution patterns
- Physico-chemical characteristics (temperature, pH, dissolved oxygen, turbidity/suspended solids)
- Nutrient distribution patterns.

As input to the biotic assessments, the variation in the occurrence and frequency of Abiotic States under different river inflow scenarios are determined using simulated monthly flows, generated for a 50 – 70 year period. The change in the occurrence and distribution of Abiotic States under the Natural Condition, the Present State and a Future Flow Scenario (using the median monthly flows over a 50 – 70 year period) is illustrated in the example below:



*ii. Biotic Response to changes in Abiotic Characteristics*

To ensure that the biotic response to predicted changes in the abiotic characteristics of a particular estuary is addressed in an integrated manner, biotic assessment studies are carried out in a phased approach, to ensure that responses in lower trophic levels are incorporated in the assessment of higher trophic levels:




Within each of the biotic components the response to changes in abiotic characteristics is predicted in terms of:

- Species richness
- Abundance
- Community composition.

In order to provide such predictions, information is required on the biotic character of a particular system, as well as the response of sensitive or important species to:

- Change in abiotic characteristics, e.g. Salinity
- Change in habitat and food source.

## 2.1 Tools to assist in setting freshwater allocations

*i. Desired future state*

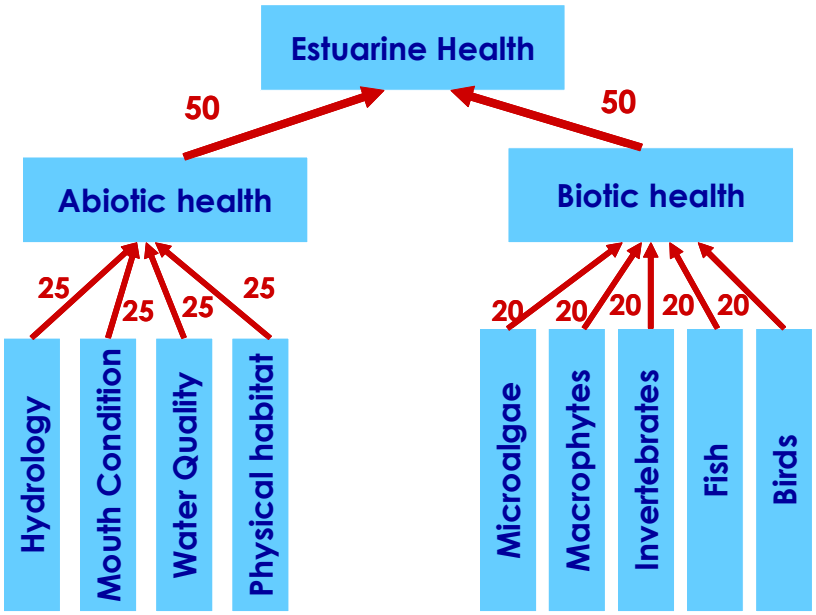
Key to setting freshwater allocations is to define the (recommended) desired future state of a particular estuary and associated resource quality objectives. In South Africa, the (recommended) desired future state of an estuary is primarily based on its:

- Present health
- Ecological importance.

The Present health of an estuary is defined as the extent to which the present state of an estuary differs from the natural state. Because this is often quite difficult to

quantify for complex systems like an estuary, an Estuarine Health Index was designed to assist in determining the present health of an estuary.

The structure of the health index is summarised below (weightings of different components are also indicated):



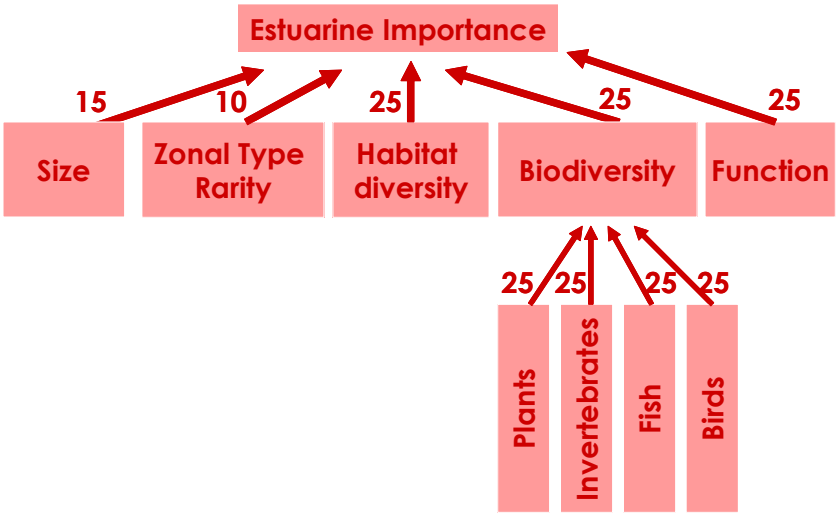

To determine the Present Health, each of the above components is scored in terms of 'similarity to the natural condition'.

Based on the final score, one of six estuarine health categories can be allocated, namely:

| State | Description |
|---|---|
| A | Unmodified, natural |
| B | Largely natural |
| C | Moderately modified |
| D | Largely modified |
| E | Highly degraded |
| F | Extremely degraded |

To provide a unified approach in determining the importance of an estuary, an Estuarine Importance Index was developed. The importance of South Africa's estuaries, using this index, has been determined on a national scale and is revised as and when new information becomes available (Turpie *et al,* 2002).

The structure of the estuarine importance is summarised below (weightings of different components are also indicated):




Depending on the final score, the importance of an estuary can be categorised as follows:

| Importance Score | Description |
|---|---|
| Protected status | Protected |
| 80 - 100 | Highly Important |
| 60 - 80 | Important |
| 0 - 60 | Of Average Importance |

The following guidelines are then used in setting the (recommended) desired future state for a particular estuary:

| Importance Score | Description | Recommended State |
|---|---|---|
| Protected status | Protected | A or BAS |
| 80 - 100 | Highly Important | Present State + 1, min B |
| 60 - 80 | Important | Present State +1, min C |
| 0 - 60 | Of Average Importance | Present State, min D |

**BAS = Best Attainable**

*ii. Setting freshwater allocations*

In setting the freshwater allocation for the desired future state of a particular estuary, a range of future flow regimes (or future runoff scenarios) are evaluated. Ideally these scenarios should be based on realistic water resource development plans, representing incremental modifications to river inflow to the estuary. The effect of each of these scenarios on the health of the estuary is assessed using the estuarine health index (EHI):

| Variable | Present | Flow 1 | Flow 2 | ..... |
|---|---|---|---|---|
| Hydrology | 66 | 62 | 58 | |
| Hydrodynamics | 100 | 100 | 100 | |
| Water Quality | 78 | 76 | 71 | |
| Physical habitat | 92 | 92 | 92 | |
| Human disturbance | 18 | 18 | 18 | |
| HABITAT HEALTH | 73 | 72 | 70 | |
| Micro algae | 90 | 90 | 70 | |
| Macrophytes | 80 | 80 | 70 | |
| Invertebrates | 80 | 80 | 60 | |
| Fish | 80 | 80 | 60 | |
| Birds | 95 | 85 | 75 | |
| BIOLOGICAL HEALTH | 83 | 83 | 67 | |
| EHI SCORE | 78=B | 77= B | 68 = C | |

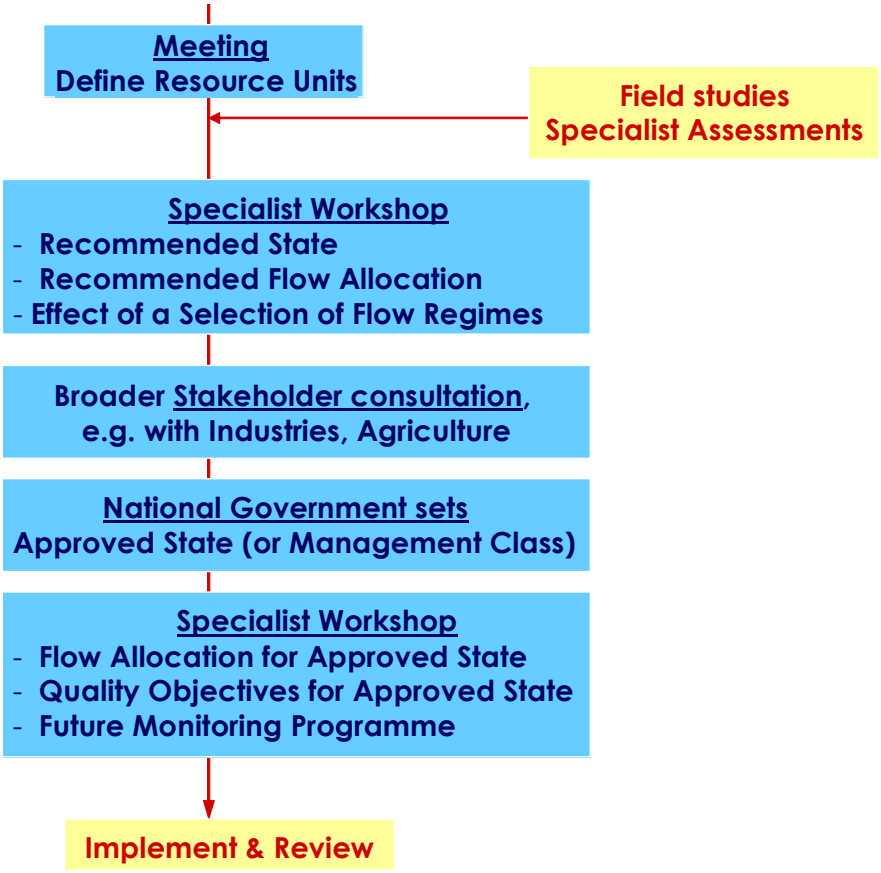
**Flow regime representing largest modification in flow, but still within 'Recommended State'**

In essence, the future scenario representing the largest modification in river inflow, but where the estuarine health index score still falls within the category allocated to the desired future state, is set as the 'freshwater allocation'.

The freshwater allocation is therefore set as a scenario (over a 50 – 70 year period), rather than single flow values so as to take into account natural variability in river flow patterns.

### 2.3 Process for Setting Freshwater Allocation

The overall process followed in setting freshwater allocations for South Africa's estuaries is summarised below:




## 3. KEY ISSUES FROM WORKSHOP DISCUSSIONS

### 3.1 Approach and Methods

If scientists want to be taken seriously (i.e. if we want to ensure that freshwater allocation policies are implemented) allocations must be realistic and results must be communicated in an easily understandable manner to the wider community (e.g. managers and politicians) by using, for example, indices. This is, for example, achieved by explaining allocation in terms of key, practical aspects such as the risk assessment approach (Marc Russell, Texas).

In setting freshwater allocations for estuaries, one of the important steps is to determine the present state (health) of an estuary. Although the objective may not be to return a system to its 'natural state', it is important to measure the present health relative to the 'natural or reference condition'. "Change from natural" provides a basis for auditing the degree of modification to a country's estuarine systems and can provide strategic insights into fluctuations in the biological components that depend on them, e.g. dwindling fish stocks (Lara van Niekerk, South Africa). However, the definition of the reference condition must be done

carefully as these are often not static. Omission of natural variability as part of a reference condition, could result in an over (or under)-estimation of freshwater requirements.

It is also important that developments in the catchment (watershed), such as those affecting water quality, be taken into account when setting allocations to estuaries (Marc Russell, Texas, USA).

A shortcoming in setting freshwater allocations to estuaries, that seems to be true for a number of countries, is the fact that historical data may not always be that useful, because:

- Data may not be representative of the present state any longer
- Data sets are 'discipline orientated' and did not measure influencing parameters (links that need to be understood to set freshwater allocations).
- Data are only available for a limited number of systems.

However, despite limited data and information, generic thresholds or tolerance ranges can often be extracted from such data sets for wider application in freshwater allocation studies, even if supplemented by expert judgement (Keith Bishop, NSW).

Based on discussions at the workshop, approaches in setting freshwater allocations for estuaries can broadly be divided into:

- Holistic, ecosystem approach
- Resource-based approach (e.g. where an important fishery drives the environmental flow requirement)
- Risk assessment approach, where abiotic (hydrodynamic) aspects are investigated and the inclusion of biotic components (if at all) is determined through a risk assessment approach.

### i. Ecosystem approach

The ecosystem approach aims at integrating processes throughout the different trophic levels in the assessment.

This approach is currently followed in South Africa. The abiotic assessment provides the 'driver' inputs to the biotic assessment that is done in a staggered manner, moving up the trophic levels. Confirmation of inter-linked processes between different components, as well as setting the freshwater allocation, is done at a specialist workshop.

To incorporate both long and short-term variability in freshwater (river) inflow, the South African method uses 50-70 year simulated monthly runoff scenarios to assess the modification in flows for different development regimes. This requirement is also identified in the methods used in NSW (Pierson et al, 2002) (Keith Bishop, NSW).

A shortcoming of the South African method, identified at the workshop, was that it does not explicitly incorporate predator/prey relationships, i.e. feedback loops where the impact of higher trophic levels on lower trophic levels is assessed (Daniel

Roelke, Texas USA). Although these are addressed at the specialist workshop it needs to become formally part of the method.

Also stressed, as part of the ecosystems approach, was that functional groups rather than just species lists, need to betaken into account (Marc Russell, Texas, USA). This is incorporated in the South Africa method where different biotic components are assessed in terms of species richness, abundance and community composition.

A very useful comment was that as part of the ecosystem approach, a conceptual model should be constructed to clearly illustrate/communicate key interactions between different trophic levels. This will provide a 'user-friendly' means of communicating complex system interaction to the wider community (e.g. managers and politicians) (Mick Howland, Tasmania). The use of ecological models (e.g. Ecopath) in preparing such conceptual models should be investigated. At present the setup and calibration/verification of such models requires comprehensive studies and exhaustive datasets (i.e. models are data hungry), but the possibility of using ecosystems models in a more 'conceptual mode' should be investigated (Bruce Pease, NSW).

The method used in New South Wales (Pierson et al, 2002) also follows an ecosystems approach, but their method uses a risk assessment component to determine the scope of the investigation. It primarily differs from the South African approach as follows (Keith Bishop, NSW):

- Preliminary evaluation phase to decide on the issues to be investigated, the components to be included and the level of detail required in the study, while the South African approach automatically assess the ecosystem as a whole, i.e. all components are evaluated from hydrology to birds.

- Checklists are used to ensure that specialists address key processes as part of their investigations.

Another important aspect identified at the workshop, was that 'estuaries do not stop at the mouth', estuarine type habitats often extend beyond the mouth of a system and offshore habitats in the marine environment may also require input (e.g. nutrient and sediment) from catchments (watersheds). In any freshwater allocation study this is an important aspect that needs to be identified at the onset of the study. In this context, Tasmania now requires that freshwater allocations be determined for freshwater dependent ecosystems (Mick Howland, Tasmania). South Africa also recognised the importance of this and is currently undertaking research studies to evaluate the various approaches to set freshwater allocations to the marine environment. The omission of the marine environment from the current South African methods is the result of the fragmented sectoral management of water resources in South Africa. In South Africa, government departments tend to only focus on their specific legal mandate (in this case the Department of Water Affairs and Forestry's jurisdiction stops at the mouth of estuaries, while the (coastal and offshore) marine environment is mainly the responsibility of the Department of Environmental Affairs and Tourism. Another important point raised in this context was that the impact of reduced freshwater inflow from catchments (watersheds) to the marine environment must not be seen in isolation, but rather be assessed on an eco-regional scale, e.g. the Thukela Estuary study in South Africa (Steve Lamberth, Department of

Environmental Affairs and Tourism, Marine and Coastal Management, South Africa). Understanding the relationship between freshwater inflow and effects on the marine environment is very complex and we must be aware to not oversell our abilities to predict change. In this regard a correlation approach, e.g. between river flow and specific biotic components may be more appropriate in the absence of sufficient knowledge to run the ecosystem (process driven) approach (Thomas Schlacher, Queensland).

### ii. Resource-based approach

The resource-based approach is followed in certain areas of Queensland, e.g. by the Department of Primary Industries (Julie Robins, Southern Fisheries Centre, Queensland). This approach focuses on optimising the harvesting of a specific living resource in the allocation of freshwater (Julie Robins, Queensland). In Queensland the allocation is derived from correlations between flow and estuarine fisheries (e.g. Barramandi) catches.

An advantage of the resourced-based approach is that it is links freshwater requirements to an economic resource, which makes motivation of such requirements to politicians much easier.

However, a limitation of the resources based approach is that it does not link to the lower food web. In this context, the Texas Water Board is moving away from the resource-based approach for the following reasons (Marc Russell, Texas, USA):

- Does not account for variability in recruitment
- Disjoined from other lower trophic levels that often respond faster to changes in flow than higher trophic levels (e.g. fish).

### iii. Risk Assessment Approach

In this approach, potential impacts on biotic components are taken into account by following a risk assessment approach. Marc Russell and Paul Montagna from the University of Texas Marine Science Institute have been working on this topic for some time and can be contacted for further details on their specific approach. Where answers need to be provided in the short-term, physical (abiotic) parameters, (mouth conditions and salinity distribution), for example provide a rapid means of setting freshwater allocations (John Sherwood, Victoria).

## 3.2 Tools to Assist in Setting Freshwater Allocations

Fundamental in the allocating freshwater for estuaries is:

- Determine the present health status
- Determine the 'desired' future state
- Determine the freshwater allocation to meet the desired state.

To determine the present state, South Africa uses an estuarine health index that expresses the present state (health) as 'similarity to the reference state' (see above).

However, such indexes may be subject to specialist interpretation. A useful way in which to test the robustness of such indexes to individual interpretation would be to have two to three groups of scientists applying the index to the South African system (Keith Bishop, NSW).

As health assessments cannot be conducted on all of Queensland estuaries in the short term, priority catchments for freshwater allocations have been determined and a monitoring programme is being launched to gather data for future studies and to assess the impact of future reductions in stream flow. A similar prioritisation of stressed catchments was conducted in South Africa and studies are systematically being conducted on them at present. Unfortunately, stressed ecosystems did not form part of the criteria for the prioritisation exercise (Lara van Niekerk, Cape Town).

The workshop also emphasised the need for good indicators because comprehensive data collection is costly and time consuming. South Africa has very successfully used vegetation and mud prawns in the Great Brak Estuary to monitor the success of the mouth management and the flow release policy (Piet Huizinga, Cape Town). Due to the paucity of data on invertebrates in South Africa, two additional developments with regards to indicators include:

- Investigate the potential for using zooplankton species, three in total, composition and abundance as an indicator for fluctuations between marine v.s. freshwater dominance in an estuary. Depending on the dominant salinity regime, the abundance of certain species can change by an order of magnitude (Tris Wooldridge, University of Port Elizabeth).

- Fiona McKay, CRUZ, is also developing an index focusing on the benthic invertebrate compliment of species as an indicator of flow change.

### 3.3 Overall Process

South Africa follows a stepped approach in setting freshwater allocations (see above). In the case of a comprehensive determination, the process includes a stakeholder consultation process, although the Department of Water Affairs and Forestry is ultimately responsible for setting the desired future state and its freshwater allocation.

In Tasmania, community consultation is used to scope key issues to be addressed and to identify, for example, potential impacts that can be caused by industry. A feed-back loop is in place to determine whether the indicated desired state is achievable, using a cost benefit analysis (Mick Howland, Tasmania). The cost-benefit analysis sometime indicates that the "desired state" cannot be achieved through flow manipulation and often a more cost effective management action, e.g. artificial breaching, is used to compensate for flow.

Freshwater allocation studies undertaken by the Department of Primary Industries, Queensland (using a resource-based approach) typically takes between 2 to 3 years to complete, with a review every 7 years (Julie Robins, Queensland).

In South Africa the duration of the process varies, depending on the level at which it is conducted, e.g.:

- Rapid level assessment: 2 – 3 months
- Intermediated level assessment: 1 – 2 years
- Comprehensive level assessment: 3 – 4 years.

## 4. THE WAY FORWARD

Following the Workshop, scientists and managers from South Africa and Australia had further discussions pertaining to future collaboration in developing methods for setting freshwater allocations for estuaries.

It was felt that the most appropriate manner in which to provide critique on the methods and to improve/refine existing approaches was through joint participation in freshwater allocation studies, e.g. one in South Africa and one in Australia.

On South Africa's side, this collaboration initiative will be facilitated by Susan Taljaard, Lara van Niekerk & Janine Adams, while Julie Robins (Queensland) and Keith Bishop (NSW) will be the key coordinators on the Australian side.

Phase 1: Collaboration on a South African study

Currently there are two detailed freshwater allocation studies underway in South Africa, namely the Olifants Estuary and Seekoei/Kromme estuaries studies. Key to each of these studies is a specialist workshop where the information and data are integrated into a format as per the freshwater allocation methods. The workshop on the Olifants Estuary, to be held in Stellenbosch, South Africa (planned for May 2005) is probably the most suitable for such collaboration. [Reason: It is organised by CSIR (i.e. S Taljaard & L van Niekerk) which will make logistical arrangements much easier].

It was proposed that a core team from Australia (including scientists and managers that have been involved in freshwater allocation studies) attend the workshop (watching the South African team in action!). A field visit to the Olifants Estuary can also be arranged prior to the workshop. Thereafter, a 2-3 day work session will be used to communicate critique and to propose modifications/refinements to methods. This will also include discussions on the different approaches, e.g. ecosystem approach versus resourced-based approach. It is envisaged that the output from the work session will then be submitted to the responsible authorities in the different countries/states for consideration – in the case of South Africa this will be the Department of Water Affairs and Forestry.

Representation needs to be as inclusive as possible. In the case of Australia, the following has been proposed:

- New South Wales – Keith Bishop & Bill Pierson
- Queensland – Julie Robins and others (to be confirmed by Julie)
- Tasmania – Christine Crawford, (Mick Howland)
- Western Australia – Paul Close
- South Australia – to be confirmed by Julie Robins

In the case of South Africa, most of the Consortium for Estuarine Management and Research (CERM) team members that attended the ECSA 37 and that are involved in freshwater allocation studies will be involved in the Olifants Estuary Study. Those that are currently not involved include Fiona MacKay and Digby Cyrus (CRUZ) and Alan Whitfield (SAIAB), but it is proposed that funding be sourced for them to also attend.

At this stage it is envisaged that the funding to attend this workshop and work session will need to be secured by individuals (or as a team) within each of the two countries.

Phase 2: Collaboration on a study in Australia

Depending on the outcome of Phase 1, it was proposed that the refined methods then be tested on an Australian system, e.g. the Hunt River Estuary in New South Wales.

Again, it is envisaged that the funding to partake in such as study will need to be secured by the teams within each of the two countries, although the possibility of joint funding opportunities should be investigated. This, however, could be further discussed during Phase 1.

In order to establish a free-flow of ideas and information it was decide to start an e-mail group where information could be exchange and interested parties can be kept abreast of developments in the Estuarine Freshwater Allocation field.

**NOTE: Anyone who wants to partake in this initiative or who wants to be 'kept in the loop' please reply in response to this e-mail to the 'coordinators' in either South Africa or Australia.**

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