

Development and implementation of a monitoring programme for South African estuaries

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ABSTRACT

This study designed and implemented a national estuarine monitoring programme for South African estuaries. The National Water Act (Act No. 36 of 1998) mandates the Department of Water and Sanitation (DWS) to undertake monitoring for the protection of water resources. Monitoring also forms an integral component of estuarine management plans which are a requirement of the Integrated Coastal Management Act (Act No. 24 of 2008). The design of the programme was based on a review of international best practice, a critical evaluation of existing national monitoring programmes implemented by DWS and workshop input from a group of national experts. The National Estuary Monitoring Programme has three tiers. Tier 1 focuses on basic data, Tier 2 makes use of the methods used for determining estuarine freshwater inflow requirements, and Tier 3 is usually of a short temporal scale and dependent on the issue at hand, such as a sewage spill or fish kill. Tier 1 monitoring commenced on 21 priority estuaries between 2012 and 2014 in collaboration with government conservation authorities, conservation forums and local and district municipalities. Available financial and human resources guided the selection of the priority estuaries. Analysis of the implementation of the programme showed that collaboration between all relevant role-players was central to the successes achieved during the first 3 years of the programme and will continue to be critical for the success of the programme, although funding remains a challenge.

Keywords: estuaries, South Africa, monitoring, National Estuarine Monitoring Programme, collaboration.

INTRODUCTION

The National Biodiversity Assessment (NBA) classified 291 estuaries in South Africa into 46 estuarine ecosystem types (Nel et al., 2011). Estuaries constitute one of the most threatened habitats in South Africa (Turpie et al., 2002), with an estuarine functional zone that covers 171 046 ha (Van Niekerk and Turpie, 2012). This zone is seen as the entire area associated with an estuary that ensures its functionality, and therefore includes open water area as well as floodplain and salt marsh areas. Geographically South Africa's estuaries are situated in three biogeographical regions: subtropical, warm temperate and cool temperate (Day, 1981; Whitfield, 1992; Whitfield, 1998, Whitfield and Balewa, 2013). According to Van Niekerk and Turpie (2012), the functional zones for these three geographical regions are 102 746 ha (60% of total), 41 785 ha (24% of total) and 26 516 ha (16% of total), respectively. The South African coastal zone is an area of high population density, as a result of port and associated industrial, trade and residential development as well as tourism-related activities. Over the past four decades there has been substantial pressure on these productive ecosystems as a result of this anthropogenic activity.

Chapter 4 of the Integrated Coastal Management Act (Act No. 24 of 2008; ICM Act) makes provision for the drafting of estuary specific management plans. The National Estuarine Management Protocol (NEMP), gazetted in May 2013, specifically addresses integrated cross-sectoral planning and management of South African estuaries by setting strategic objectives which, inter alia, encompass sustainable use, maintenance of ecological integrity, protection and co-operative governance. The associated standards for estuarine management state

that management actions should be based on sound scientific evidence. A monitoring programme therefore forms an integral part of estuarine management plans as the data and resulting information will be used to facilitate informed management decisions. Currently, the Western Cape Province has made the most progress in drafting estuarine management plans, through the C.A.P.E. Estuaries Programme, thereby giving effect to the ICM Act. Various estuarine management plans are however also being implemented in the rest of South Africa.

The NEMP further addresses the institutional structures and arrangements necessary for co-operative coastal governance. The potential implementers for this long-term monitoring programme should be identified through the guidance of this specific section of the NEMP and working relationships established at an early phase of testing and implementation of the National Estuary Monitoring Programme (NESMP). The parties involved differ from estuary to estuary and may consist of NGOs (e.g. wildlife associations, conservation trusts, ratepayers association), conservation bodies (e.g. SANParks, Ezemvelo/KZN Wildlife, CapeNature, Eastern Cape Parks & Tourism Agency), and government institutions (e.g. South African Environmental Observation Network (SAEON), Department of Water and Sanitation (DWS), Department of Agriculture, Forestry and Fisheries (DAFF), Department of Environmental Affairs (DEA), local and/or district municipality).

The Department of Water and Sanitation (previously Department of Water Affairs) is responsible for the regulation of South Africa's water resources, which include estuaries as part of the 'source to sea' concept. This concept indicates that a river stretches from the headwaters to where it spills into the ocean, and that different functionalities and characteristics of rivers are interlinked with each other. The DWS, in accordance with the National Water Act (Act No. 36 of 1998) is mandated to, amongst others, attend to development of water management strategies and protection of water resources, undertake

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Received: 12 January 2015; accepted in revised form 9 March 2016

monitoring, and do assessments of and ensure information dissemination on the quantity and quality of water resources in South Africa.

The DWS has been responsible for monitoring of water resources over the past seven decades and has created a substantial knowledge base with regards to the design and implementation of national water resource monitoring programmes. The Department currently has 11 national water resource monitoring programmes (DWAF, 2004a), which are dependent on robust scientific data and aim to produce information that is used for water resource management. Most programmes are associated with the freshwater environment, with limited overlap with the estuarine environment. These programmes provide appropriate data and information necessary to assess, amongst others, the quantity, quality, use and rehabilitation of water resources, the compliance with water resource objectives, the health of aquatic ecosystems, and the atmospheric conditions that may influence water resources.

The National Aquatic Ecosystem Health Monitoring Programme and, specifically, the River Health Programme component thereof, are more recent examples of successful programmes undertaken by the Directorate: Resource Quality Information Services (RQIS) of DWS. In addition RQIS is also responsible for the testing and implementation of various additional monitoring programmes that overlap with the estuarine monitoring programme.

The objective of this study was to design a National Estuarine Monitoring Programme (NESMP) for South Africa, which ensures that the mandate of DWS as custodian of South African water resources, as entrenched in the National Water Act, is achieved, and is in support of integrated co-operative coastal governance as per the ICM Act.

MATERIALS AND METHODS

Design process

The process followed during the design of the National Estuary Monitoring Programme was based on the prescribed method of the DWS (DWAF, 2004b; DWAF, 2004c) and Bartram and Ballance (1996). The process consists of 6 steps as indicated in Fig. 1 and is expanded on specifically for the NESMP in Fig. 2.

A needs assessment for the NESMP was a precursor to its design. The needs assessment identified objectives, target users, criteria for choosing variables, and the general design considerations. A pilot testing phase followed the design phase and the design was revisited and refined to incorporate changes that were identified. Full-scale implementation will follow the pilot testing phase. Provision is made for adaptive management during the full-scale implementation, to accommodate changes in roles and responsibilities, priorities and financial support for the programme.

The design process was based on three components (Fig. 2). These components, although being independent entities, were linked through feedback paths to revisit existing views and refine these as design understanding was gained, opinions were formed and the design parameters established. The three components were a literature review of international monitoring practice pertaining to the estuarine environment in Europe, Australia and United States of America, followed by a critical evaluation of existing national monitoring programmes implemented by DWS within the context of the National Water Act (Act No. 36 of 1998), the Strategic Framework for National Water Resource Quality Monitoring (DWAF, 2004b), National Water Resource Strategy (DWAF, 2004c) and the 5 Year

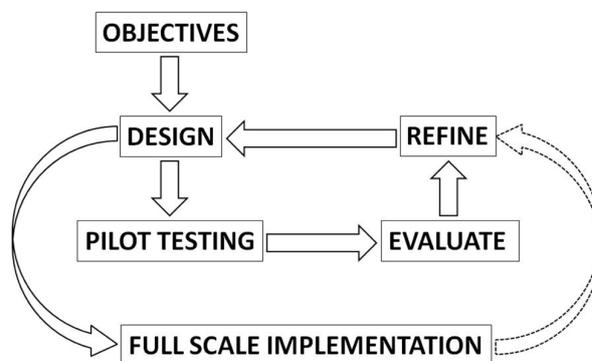


Figure 1

The process followed by the Department of Water and Sanitation during the design, testing and full-scale implementation of national water resource monitoring programmes

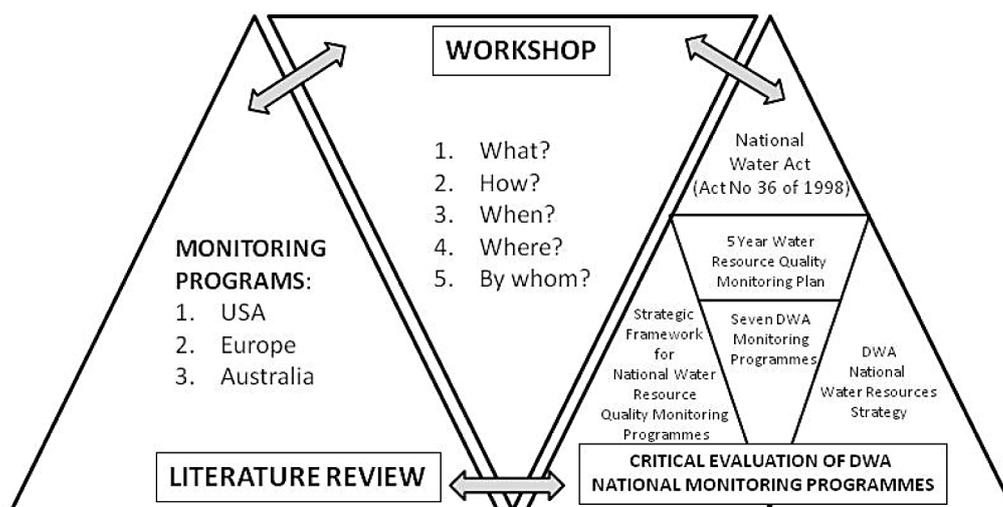


Figure 2

The design process for the National Estuarine Monitoring Programme consisted of three separate but interlinking components

Water Resource Quality Monitoring Plan of DWS (DWAF, 2004a). Finally, a workshop was convened, where South African estuarine ecologists and managers discussed and agreed on the requirements for a national programme. The objective of the workshop was to determine (i) what constituents need to be monitored, (ii) how these constituents should be monitored, (iii) where these constituents should be monitored, (iv) when these constituents should be monitored; and (v) by whom should these constituents be monitored?

Estuary prioritisation

Selecting estuaries for monitoring should be as objective as possible, to ensure that systems that are in need of monitoring, based on the DWS management mandate, are prioritised at a national level. The primary objective of the NESMP, being the collection of long-term data to inform future management decisions, should always be the focus of such a prioritisation effort. Six criteria (Table 1) were used to determine priority estuaries through a ranking system that is based on the application of a numerical equation. The overall priority (*P*) for the estuary is calculated using the following formula:

$$P = A(K + D + E + F) \quad (1)$$

where:

$$K = (B + 2C/3) \quad (2)$$

Practicality (*A*) is the main driver for the programme, and thus plays a key role as a common multiplier of the sum of all of the components (ecological, socio-economic and level of available data) of the equation. This value is multiplied with functions of the ecological components (*K*) and added to the

socio-economic importance (*D*), which is added as a separate value to the ecological components (*K*) as it is seen as an independent factor, based on social and associated development pressure. Through this a balance of priority is achieved between the ecological components and socio-economic importance, thus addressing sustainability in a broad context.

In terms of the calculation of the ecological component (*K*), ecological importance (*C*) is seen as having twice the weight of current state (*B*) and therefore multiplied by 2. In order to average the ecological importance (*C*) and the current state (*B*) contribution, the value is divided by 3. Future impacts (*E*) are added to this value as they are linked to and influence both the current state (*B*) and ecological importance (*C*). The level of available data (*F*) is also contextualised within the programme with its addition to the equation.

Those estuaries with the highest calculated *P* value (the maximum value being 42) are the 'high priority' estuaries and should be considered first for monitoring. It should be noted that this was applied on an estuarine-specific basis, and not on a water management area or catchment scale as the criteria used already integrate catchment-scale or water management area information at an estuarine-specific level.

Direct consultation with estuarine experts and water resource managers will solicit estuary-specific knowledge ensuring a balanced view based on objective criteria and subjective system-specific knowledge. For this approach, it is adequate for the programme manager of the NESMP to meet with relevant estuarine specialists, conservation bodies and representatives of the DWS regional office or catchment management agencies to determine their opinion on the list of priority estuaries based on the objective approach (Fig. 3). Using their local knowledge a refined list of estuaries should be identified that are likely to be most appropriate for monitoring based on the objective prioritisation criteria. A similar exercise was undertaken by the

TABLE 1
Criteria and rating used to prioritise estuaries for monitoring

Criteria	Rating
Practicality (A) The monitoring programme is volunteer-based and therefore depends on the availability of human resources on a specific estuary to undertake the sampling.	1 – Impractical 2 – Possible 3 – Highly practical
Current state (B) The estuary may be important to monitor because of its pristine state (current and/or historic ecological state) based on the ranking of Turpie et al. (2002) and Turpie et al. (2012).	1 – Highly degraded 2 – Fair/good 3 – Pristine
Ecological importance (C) The ecological importance of an estuary is based on a local, regional or national level. Based on the ranking of the National Freshwater Ecosystem Prioritisation Atlas (NFEP) by Nel et al. (2011) and Turpie et al. (2012).	1 – Low 2 – Medium 3 – High
Socio-economic importance (D) This entails the importance of estuaries to provide economic opportunity in the form of industry and associated harbour development (D1), tourism (D2), and subsistence fisheries (D3) on a national scale and is based on Turpie et al. (2002). The socio-economic importance is evaluated for each of these categories and averaged to provide the final rating used in the equation.	1 – Low 2 – Medium 3 – High
Future impacts (E) Future environmental impacts relate to the likelihood of development pressure increasing in the future on a specific estuary through urban development, tourism, industry and subsistence fisheries, and are based on professional opinion and Turpie et al. (2002).	1 – Low 2 – Medium 3 – High
Level of available data (F) Estuaries where a low level of data is available merit the establishment of a monitoring programme to address this inadequacy. In certain instances an estuary may have a high level of data available, but, due to current and future pressures (pollution, pending EFR's, development pressure) and/or its national importance (St. Lucia for example), there is merit in building on this existing data. In these instances separate motivation for prioritising a specific estuary should be provided, although it may have a lower calculated prioritisation as a result of the existence of historical data. The rating system used for level of available data is based on Whitfield and Baliwe (2013).	3 – Low 2 – Moderate 1 – Excellent

participants who attended the Estuaries Monitoring Workshop in Port Elizabeth in 2008 (DWAF, 2008a). Participants were asked to indicate the 10 priority estuaries per biogeographical region where monitoring should be initiated during the testing phase of the NESMP, based on their expert opinion. The estuaries were selected to cover a broad spectrum of estuarine types with different characteristics and management issues.

The prioritisation process therefore consisted of two steps with feedback loops to ensure the highest level of trustworthiness is ensured when choosing estuaries to monitor (Fig. 3). The subjective approach is in support of the objective approach.

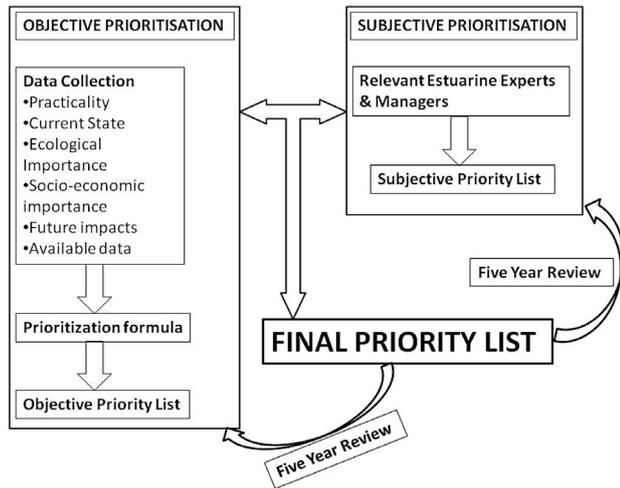


Figure 3

Two-step objective and subjective process followed to determine the priority estuaries for monitoring

The financial and human resources available for monitoring, already reflected in practicality (A) of the prioritisation calculation, will also guide which estuaries are selected for monitoring. Estuaries where there is a lack of available resources will receive lowest priority. Monitoring on these estuaries could take place in the future, as estuary-specific situations (impacts, knowledge, available resources) may change, paving the way for future monitoring. The stakeholders should reach consensus on the relative rankings. The priority list should be reviewed every 5 years to incorporate new knowledge/information on the selection criteria that may have developed since the initial prioritisation list was compiled.

RESULTS AND DISCUSSION

Objectives of the National Estuarine Monitoring Programme

The objectives of a monitoring programme define the reasons for its existence (DWAF, 2005) and provide the primary statement by which the success of the monitoring programme will ultimately be assessed. Based on the three design components (Fig. 2), the objectives of the NESMP were to measure, assess and report on a regular basis on the status and trends of the nature and extent of the condition of South African estuaries in a manner that will support strategic management decisions to ensure sustainable use of estuaries and ensure ecosystem integrity, being mindful of financial and capacity constraints, while also being scientifically sound.

The overall objective will result in an estuarine monitoring programme that will collect relevant, consistent and reproducible long-term data to facilitate information generation and dissemination for the future integrated national, regional and local management of South African estuaries (Fig. 4). It will also investigate the use and development of the Estuary Health

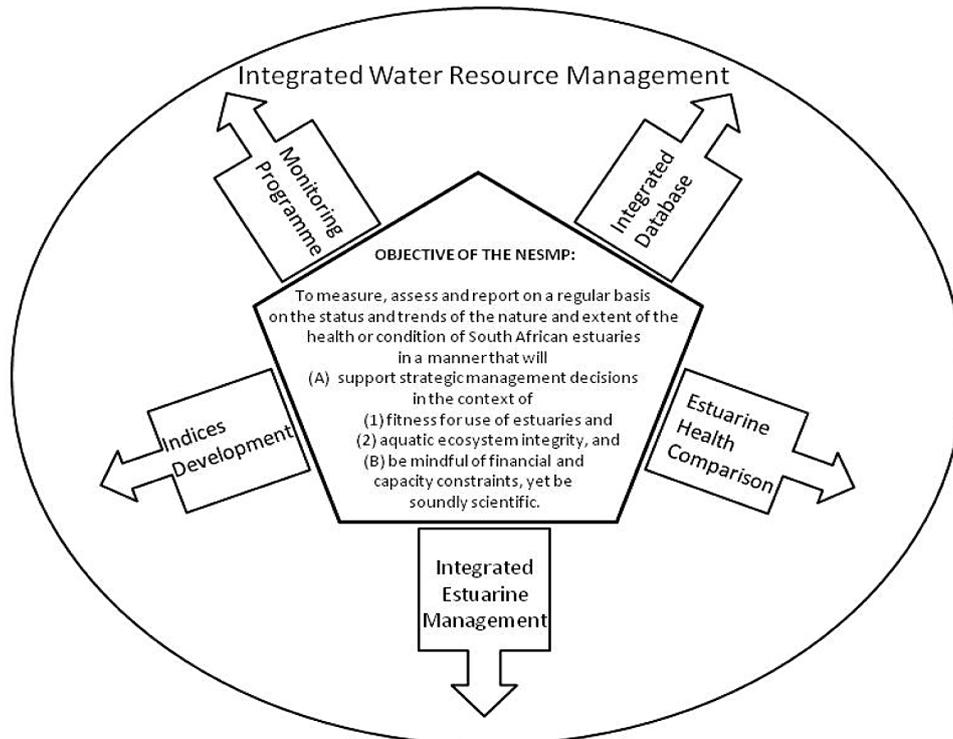


Figure 4

The objective of the NESMP will result in key outcomes that address aspects of integrated water resource management

Index (Turpie and MacKay, 1999) on a national scale within the eco-classification context, which is currently being developed for other South African water resources (Kleynhans and Louw, 2009). Eventually the NESMP will compare the health of South African estuaries on a temporal and spatial scale.

Design of the National Estuarine Monitoring Programme

A three-tiered approach forms the basis for this programme (Fig. 5). This ensures that the aims and objectives of the national monitoring programme are achieved and ensure the programme is robust enough to adapt to changing situations.

Tier 1 entails the collection of basic environmental data to develop a long-term database of the most important drivers within estuaries. Data on these drivers are needed to understand the functioning of a system and to determine the level of environmental perturbations as a result of human-induced activities and/or natural phenomena. The basic data are divided into an estuarine and a freshwater component. For the freshwater component, measurements are made at a point above the head of the estuary which represents a site above the furthest point of saline intrusion, while the estuarine component is collected along the length of the estuary up to the mouth of the estuary.

The rationale for the selection of the estuarine components of Tier 1 is based on Taljaard et al. (2003). The estuarine component entails the measurement of water quality variables within the estuary and includes fixed-point photography of the mouth and/or mouth state records.

The freshwater aspect of the programme is indicative of exogenous compounds and therefore the physico-chemical condition of the water entering from the catchment. The rationale

for the selection of the freshwater components is also based on Taljaard et al. (2003) and includes measurement of freshwater inflow if an operational flow-gauging weir is available.

Tier 2 make use of the methods employed for determining estuarine freshwater requirements (Taljaard et al., 2003; DWA, 2008b) and is divided into abiotic and biotic components. Only selected aspects of the RDM process will form part of this tier in view of its financial and practical implications. The protocol includes variables which provide an indication of the health of the system. The RDM protocol (DWA, 2008b) standardises the methods to be used for assessing estuarine freshwater requirements on a national scale. The Tier 1 assessment should be done concurrently with the Tier 2 assessments. Through the use of the estuarine freshwater requirements protocol, the NESMP will not only give an indication of the health of the system, but also provide important background information for future freshwater requirement studies, setting of resource quality objectives and associated Reserve auditing. These aspects are legal requirements of the National Water Act (Act No 36 of 1998). The abiotic components of Tier 2 are mostly drivers of the system and the same as the abiotic components of the Tier 1 assessment, while the biotic components, summarised in Table 2, are response indicators.

Tier 3 will be tailored monitoring to address specific management issues that may occur from time to time in a specific estuary. This may include, amongst others, pollution incidents, fish kills and specific developments that may influence the health of an estuary. This tailored assessment will be done as a focused short-term study in consultation with relevant estuary specialists. These experts will advise on which biotic and abiotic components should be included in the Tier 3 protocol

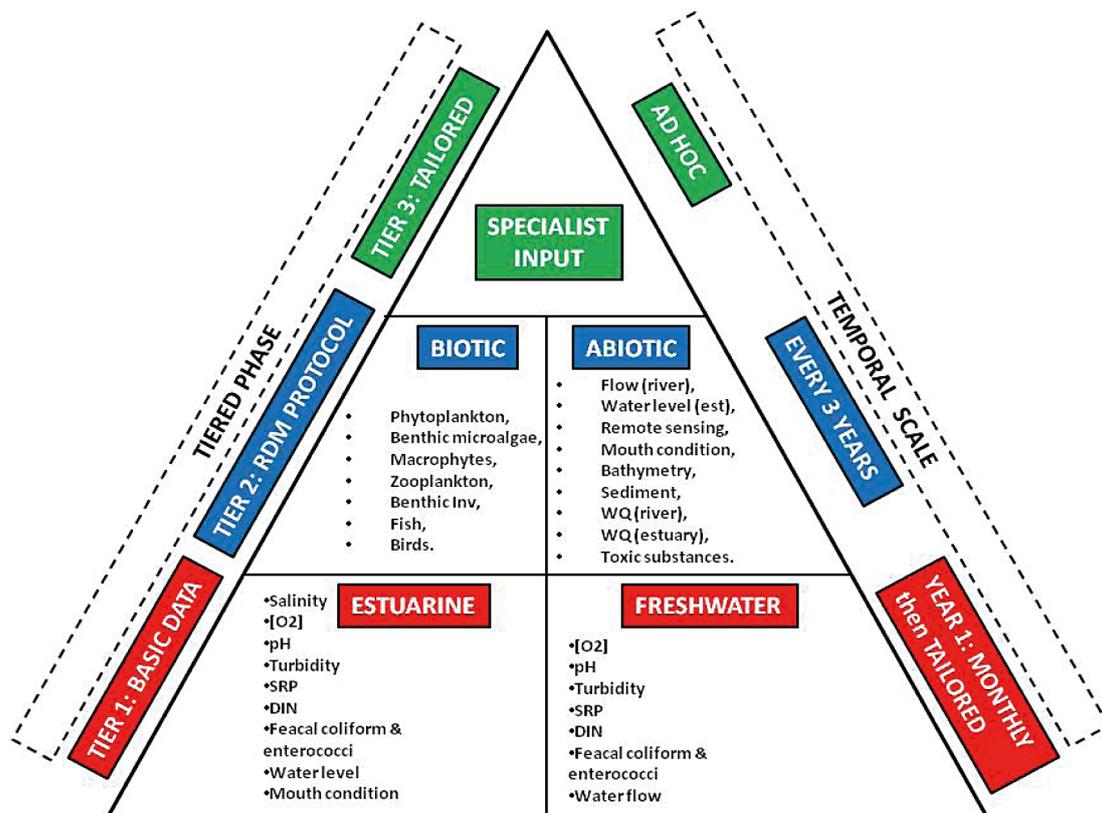


Figure 5
The National Estuarine Monitoring Programme for South Africa

TABLE 2
Rationale for the selection of specific biotic components of Tier 2 of the NESMP (Taljaard et al., 2003)

Component	Rationale for choice
Phytoplankton	Phytoplankton biomass is an indicator of nutrient loading and is assessed concurrently with nutrient analysis to provide a nutrient 'balance'. Changes in the phytoplankton assemblage are also an indication of changes in the water quality and quantity. Phytoplankton also act as important primary producers within permanently open systems.
Benthic microalgae	Changes in the microalgae composition are an indication of changes in the nutrient levels in an estuary and therefore water quality. Microalgae are important primary producers in shallower, non-turbid systems.
Macrophytes	Estuarine plant communities form the habitat for many estuarine species including birds, fish and invertebrates. The condition of the macrophyte habitat is therefore a direct indication of the health of an estuary.
Zooplankton	Zooplankton are an important aspect of the estuarine food web as they act as a food source to fish, birds and other invertebrates.
Benthic invertebrates	Benthic invertebrates are also important components of the estuarine food web as they serve as a food source for other invertebrates, birds and fish.
Fish	Fish form the apex of the water-based estuarine food web. They reflect what is happening with the biotic and abiotic component of the estuarine ecosystem.
Birds	Birds are part of the apex of the estuarine food web, and therefore also reflect the condition of the estuarine ecosystem.

to be used. These components will however need to be selected from the Tier 1 and/or Tier 2 protocol to ensure method consistency across the different tiers of the monitoring programmes, thereby ensuring usability of the data in the national programme, even though the focus of the Tier 3 assessment may be over a short temporal scale. In the instance where no historic data are available, the Tier 3 study may act/contribute to a future baseline study. The study does not need to be limited to the Tier 3 protocol, but may, depending on the specific situation, include constituents that do not form part of the NESMP.

Sampling methods

Method consistency when sampling is critical to the success of any monitoring programme. This ensures quality of the data and the credibility of the information generated and associated comparability of results. In order to ensure consistency, the methods stipulated for estuarine flow requirements (DWAF, 2008b) should be used for the NESMP. This will also ensure that the data from the NESMP can be used and compared in future estuarine flow requirements/assessments, Reserve audits and setting of resource quality objectives.

Estuary site selection

In order to increase the cost-effectiveness of the NESMP, high-priority estuaries were identified where monitoring could begin. Only 12 (40%) of the estuaries that fell within the 'top 30' estuaries (Table 3) according to the prioritisation or objective model were also selected during the 2008 workshop (DWAF, 2008a) in a subjective manner. This low number of subjectively-selected estuaries in the objective list, which is driven by the practicality of undertaking the monitoring, indicates that the subjective approach does not take into consideration the practicality and human resources required to undertake the monitoring. Monitoring commenced on 7 of the 12 (58%) subjectively-chosen estuaries during the first 3 years (2012 to 2014) of the programme, although monitoring commenced on only 16 (53%) of the 'top 30' estuaries according to the priority model. The subjective approach therefore assists to prioritise the monitoring effort to systems where it is most needed according to the objective prioritisation model. The subjective approach acts as a refinement step to the objective approach,

focusing the required monitoring to estuaries where monitoring is most needed based on professional opinion.

All 28 of the estuaries selected for the pilot testing between 2012 and 2015 have NFEPA priority rating and are of national importance. Human resources were available at all of these estuaries to undertake the sampling. Based on Turpie et al. (2002), Nel et al. (2011), Van Niekerk and Turpie (2012), and Turpie et al. (2012), 38% of these estuaries are in a relatively pristine state, while 52% and 10% are utilized and highly utilized, respectively; 29% of the estuaries are formally protected, 19% have active conservation forums and 36% have estuarine management plans in place. Only 16% of the estuaries do not have some sort of protection status or management intervention in place. Historic monitoring and/or research did take place on 52% of these estuaries before 2012. Monitoring and/or research, independent of this national monitoring programme, is currently (2012 to 2015) taking place on 45% of these estuaries, while only 3% of these estuaries did not have any form of monitoring and/or research.

In smaller systems (up to 30 km in length), at least 4 sites per estuary for Tier 1 and 2 sampling should be selected. These sites should, where possible, be sites that have been used for previous research and/or monitoring programmes in order to ensure comparability and consistency with historical data. The sites should be representative of the upper, middle and lower estuary and a site immediately upstream of the furthest point of tidal exchange; therefore at the point indicative of freshwater entering the estuary.

In the case of larger estuaries (>30 km) a rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between each site should be 3 km). This should only be used as a guideline and would depend on the estuary-specific conditions and specialist opinion for a particular estuary.

The sites selected for Tier 3 assessments will depend on the spatial orientation of the specific issue being investigated. It is advised that the sites should be representative of the above-stream and below-stream environment of the area of study. Where possible, these sites should also be representative of sites that have previously been monitored. The temporal scales for sampling vary between the different tiers and vary from monthly sampling for Tier 1 to 3–5 years for Tier 2. Tier 3 will depend on site-specific conditions (Table 4).

TABLE 3
Prioritisation of estuaries for monitoring based on the objective numerical model and the subjective outcomes of the monitoring workshop held in 2008. Estuaries where the programme is currently operational, with year of monitoring commencement indicated, are shaded. Estuaries where monitoring commenced but which lie outside the 'top 30' priorities, as well as estuaries where monitoring is to commence in 2015 and 2016, are also included.

Priority according to the numerical model	Estuary	Final score	Subjective prioritisation during 2008 workshop	Monitoring commenced				
				2012	2013	2014	2015	2016
1	Swartkops	38	Yes				X	
2	Knysna	37	Yes	X				
3	Berg	36	No	X				
4	St Lucia	35	No	X				
5	Durban Bay	35	No					X
6	Bot	34	No		X			
7	Olifants	34	No		X			
8	Kromme	33	No	X				
9	Richards	32	Yes					X
10	Mhlanga	32	Yes		X			
11	Swartvlei	32	Yes	X				
12	Wilderness	32	No					X
13	Mfolozi	31	No	X				
14	Bushma	31	Yes					X
15	Verlorenvlei	31	No		X			
16	Mgeni	31	No		X			
17	Gamtoos	30	No		x			
18	Breede	30	No	X				
19	Mtamvuna	29	Yes				X	
20	Keurbooms	29	No			X		
21	Piesang	29	No					X
22	Heuningnes	29	Yes				X	
23	Klein	29	Yes		X			
24	Mtanfufu	28	No				X	
25	Kowie	28	No					X
26	Groot	27	Yes				X	
27	Mlalazi	26	Yes		X			
28	Mpenjati	26	No		X			
29	Uilkraals	26	No				X	
30	Palmiet	26	Yes					X
33	Zinkwazi	25	No	X				
34	Mdlotane	25	No		X			
41	Nonoti	23	No	X				
53	Gouritz	19	No				X	
71	Mdloti	18	Yes				X	
99	Orange	16	Yes				X	

TABLE 4
Sampling frequency for different sampling tiers of the NESMP

Tier	Sampling frequency
Tier 1	Monthly during first year on a spring high tide, starting 1 to 3 h after the onset of high tide to determine the extent of the saline intrusion. Thereafter, dependent on findings of first year, a minimum of at least during high flow and low flow or stable open and stable closed phase, depending on the type of estuary. The temporal scale does however need to be as frequent as practically possible within the limitations of the available budget and human resources.
Tier 2	Twice every 3 to 5 years during the high and low flow or stable open and closed phase, dependent on the type of estuary. A minimum of once during a stable phase, should there be budget limitations.
Tier 3	Situation-specific dependent on the objective of the study. Usually more frequent sampling over a shorter period.

Roles and responsibilities

Collaboration is the foundation of the NESMP and ensures sharing of responsibilities for the programme, thereby making best use of available financial and human resources. Central to the successful implementation of the NESMP is programme management, funding and implementation (Fig. 6). The responsibility for these three main activities rests with different organizations and, in most instances, is overlapping.

Table 5 indicates the main participants in the estuaries monitoring programme for the initial 28 estuaries, as well as their roles and responsibilities. The provision of capital equipment, including

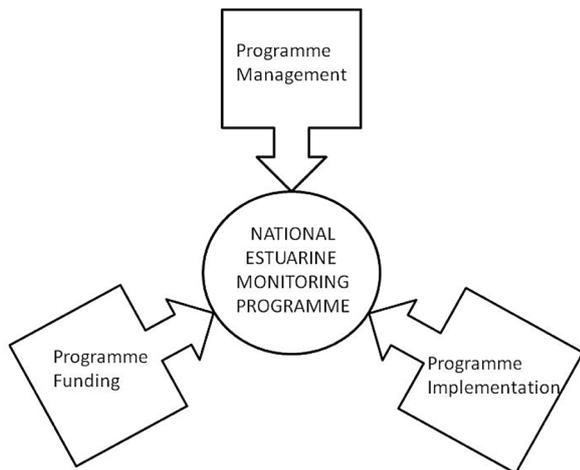


Figure 6

Three main activities form the core of the NESMP. Different parties have different and sometimes overlapping responsibilities within the NESMP framework.

boats, in-situ multiprobes and sampling material, is largely the responsibility of DWS, although it is shared in certain instances, where capital equipment is already available to the entities which are responsible for monitoring. Sampling is done by ground personnel of conservation bodies (e.g. Ezemvelo/KZN Wildlife, SANParks, CapeNature), volunteers from the different conservation forums (including Zinkwazi/Blythedale Conservancy, Lower Breede River Conservation Trust), local and district municipalities (including West Coast and Eden) and government departments (e.g. DST through SAEON, DAFF, DEA). In most instances the entities that are responsible for the sampling are also responsible for the operational costs (fuel, travel, subsistence). Water quality analysis, including nutrient analysis, is the responsibility of DWS, while microbial analysis is in most instances part of the mandate of the local authorities. Raw data are stored in the DWS national database, through the Water Management System (WMS) and HYDSTRA platforms in Pretoria. These data, as well as information products, will also be accessible via the South African Estuary Information System (SAEIS) housed at the SAEON Elwandle Node. Annual reporting will be the responsibility of DWS, although other authorities, including conservation bodies, government departments and municipalities, may also do ad-hoc and/or estuary-specific reporting based on the mutually collected data.

During the initial pilot testing phase of the programme the roles and responsibilities did change as a result of (i) limitation of the available manpower to do the sampling, (ii) a decrease in the available operational budget, (iii) changed mandates or priorities by entities involved, (iv) administrative complications as a result of these changed mandates or priorities, and (v) organizational and personal conflict.

Programme management

The management structure consists of a national, regional and local management level (Fig. 7). This is to ensure that the management

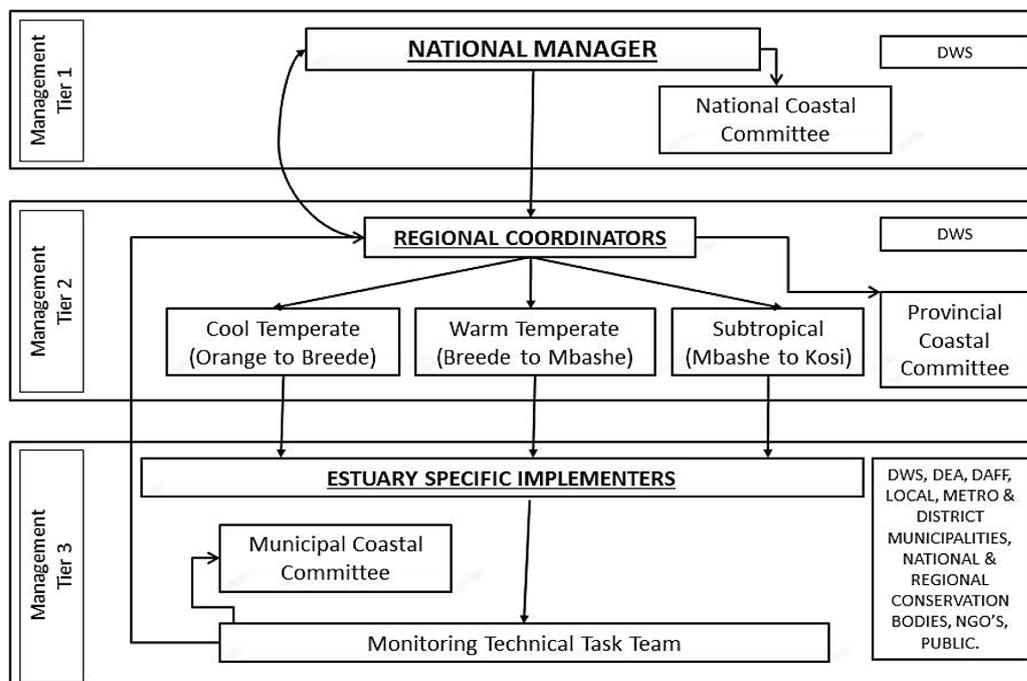


Figure 7

The management structure for the estuarine monitoring programme is divided into three distinguishable levels

TABLE 5					
Roles and responsibilities of the different organisations associated with the estuaries selected for pilot testing of the NESMP between 2012 and 2015					
	Capital equipment	Sampling	Water quality analysis	Data management	Reporting
Subtropical					
St Lucia, Mfolozi	DWS, Ezemvelo/KZN Wildlife	Ezemvelo/KZN Wildlife, SAEON	DWS, SAEON	DWS, SAEON	DWS, Ezemvelo/KZN Wildlife, iSimangaliso Wetland Park Authority
Mlalazi	DWS, Ezemvelo/KZN Wildlife	Ezemvelo/KZN Wildlife	DWS	DWS	DWS, Ezemvelo/KZN Wildlife
Nonoti, Zinkwazi, Mdlotane	DWS, Zinkwazi/Blythedale Conservancy	Zinkwazi/Blythedale Conservancy	DWS	DWS	DWS
Mhlanga, Mdloti, Mgeni, Mpenjati, Mtamvuna	DWS, Ezemvelo/KZN Wildlife	Ezemvelo/KZN Wildlife	DWS	DWS	DWS, Ezemvelo/KZN Wildlife
Mtafufu	DWS	Mtafufu estuary management forum	DWS	DWS	DWS
Warm temperate					
Swartkops	DWS, Nelson Mandela Bay Municipality, SAEON	Nelson Mandela Bay Municipality, SAEON	DWS, Nelson Mandela Bay Municipality	DWS	DWS
Kromme	DWS, SAEON	SAEON	DWS	DWS, SAEON	DWS
Keurbooms	DWS	DWS, Eden District Municipality	DWS, Eden District Municipality	DWS	DWS, Eden District Municipality
Knysna, Swartvlei	DWS, SANParks	SANParks	DWS	DWS	DWS
Gouritz	DWS	SAEON	DWS	DWS	DWS
Groot Brak	DWS, Eden District Municipality	Eden District Municipality	DWS, Eden District Municipality	DWS	DWS, Eden District Municipality
Breede	DWS, DAFF	Lower Breede River Conservation Trust	DWS	DWS, DAFF, Lower Breede River Conservation Trust	DWS, DAFF
Cool temperate					
Heuningnes, Uilkraals	DWS	Cape Nature	DWS, Overberg District Municipality	DWS	DWS
Klein Bot	DWS	Cape Nature, DAFF, The Shark Conservancy	DWS, Overstrand Local Municipality	DWS	DWS
Berg, Verlorenvlei, Olifants	DWS, West Coast District Municipality	West Coast District Municipality	DWS, West Coast District Municipality	DWS	DWS
Orange	DWS	DAFF, Endangered Wildlife Trust, Northern Cape Environmental Affairs	DWS	DWS	DWS

structure is simple and practical with a minimal chance for ambiguity in programme implementation and reporting.

National level management is the responsibility of Directorate: Resource Quality Information Services of the DWS, in Pretoria. This directorate is mandated to design and implement all DWS national water resource monitoring programmes in terms of the National Water Act (Act No. 36 of 1998). Although DWS is the national manager, other relevant government departments and parastatals are also consulted as part of the national management through a NESMP reference group. These government departments include DEA, DST through the SAEON, DAFF and the CSIR.

Currently, engagement with other national departments and institutions takes place through Parliamentary Working

Group 8, tasked specifically with Oceans and Coast. Working Group 8 also acts as the National Coastal Committee. This working group meets once a quarter and discuss issues of joint interest between the different role-players. During these meetings DWS provide feedback on the NESMP through the Working Group 8 chair.

Reporting to the national manager are the regional coordinators, who are responsible for the implementation and operation of the programme in the three biogeographical regions. The subtropical region covers Water Management Areas (WMA) 3 and 4 and part of WMA 7 (from Mzimvubu to Mbashe estuary). The warm temperate region covers part of WMA 7 (from Mbashe to Keiskama estuary) and part of WMA 9 (Keiskamme to Breede estuary). The cool temperate

region covers part of WMA 9 (Breede to Cape Point), WMA 8 and WMA 6. The regional coordinators are officials from the DWS based at the Directorate: Resource Quality Information Services and liaise with relevant regional role-players, including government departments, parastatals and NGOs, and report back to the provincial coastal committees when needed.

The estuary-specific implementers are responsible for undertaking the monitoring in line with the NESMP protocol, through a monitoring technical task team, which is responsible for overseeing the estuary-specific operational aspects of the monitoring programme. A core group forms the monitoring technical task team. They are responsible for co-ordinating the sampling on a specific estuary, addressing the logistical requirements including sampling equipment, sample collection and delivery, and liaison with the main funders including DWS. This task team comprises members from different organisations where possible, including government departments, parastatals, the private sector and volunteer civilians in their personal capacity. In most instances the monitoring team consists of two members, but ideally there should be at least four individuals, to ensure that there is an alternative team that can undertake the sampling should it be required. This group provides feedback to the regional coordinators and to the Municipal Coastal Committee on a quarterly basis. There is overlap of roles and responsibilities between the NESMP implementing organisations and coastal management organisations as required in terms of the ICM Act. In order to prevent a duplication of meetings and subsequent effort, the structure as proposed for integrated coastal management in terms of the ICM Act is synergized with the management structure for the NESMP (Table 6).

The largest difficulty with a national water quality monitoring programme is the availability of funding for water quality analysis, procurement of capital equipment and operational costs. In view of this being a DWS initiative, the bulk of the operational funding is budgeted for by DWS. However, in view of the scale of the programme, additional funding and support streams should be solicited though collaboration.

In view of various role-players' mandated involvement with water resource monitoring there is an opportunity to pool resources ensuring the most effective use of available funding and manpower. Different estuaries have different role-players, each with their own strengths and weaknesses. The success of the programme is based on making use of the available human and financial resources at each estuary and not applying a single stringent operational philosophy. This is achieved by coordinating the monitoring effort efficiently and ensuring constant open lines of communication between role-players. The national manager is critical in coordinating this collaboration and giving it effect through the

regional coordinators and the estuarine-specific implementers.

Data management is a critical pathway in the NESMP. Without proper data management all of the effort going into programme coordination, management and sample collection will be ineffectual. A simple two-way (bottom-up and top-down) data management process (Fig. 8) ensures that the data are collected and stored, and information generated and disseminated, in a seamless fashion. Four parties are involved with data collection, management and dissemination.

The implementing agency is responsible for collecting water samples, the associated physico-chemical variables and any other relevant data. The water samples are submitted to the analytical laboratory for analysis, whilst a simple standardised Excel-based database is kept by the implementing agency on a local computer for the physico-chemical variables and other relevant data. This Excel spreadsheet is submitted on a monthly basis to the DWS programme manager, who is responsible for loading the data into the appropriate DWS database. The data from the water sample analyses are directly submitted by the relevant analytical laboratory to the DWS programme manager. This data is also available to the implementing agency if requested. The information on this database is also submitted in parallel to SAEIS at the SAEON Elwandle Node by the DWS programme manager.

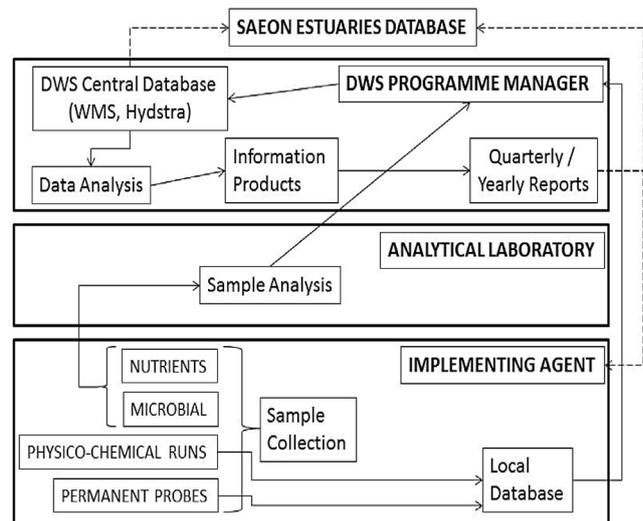


Figure 8

The data management process of the NESMP. Solid lines indicate data collection, data archiving and analysis. Dotted line indicates data and information product dissemination

Level	NESMP management structure	ICMA management structure
National	National manager	National Coastal Committee/Working Group 8
Regional	Regional coordinators <ul style="list-style-type: none"> • Subtropical – Kosi to Mbashe (WMA 3,4,7) • Warm Temperate – Mbashe to Breede (WMA 7, 9) • Cold Temperate – Breede to Orange (WMA 6, 8, 9) 	Provincial Coastal Committees <ul style="list-style-type: none"> • KZN • Eastern Cape • Western Cape • Northern Cape
Local	Estuary-specific implementers <ul style="list-style-type: none"> • Monitoring Technical Task team • Sampling team 	Municipal Coastal Committees (On district municipal level)

The DWS programme manager is responsible for ensuring the compilation of information products in the form of quarterly and annual reports that are submitted to the implementing agents. The implementing agents are then responsible for providing these to all the stakeholders. These reports are then also deposited in the SAEIS.

CONCLUSION AND RECOMMENDATIONS

A three-tiered monitoring approach is followed in the NESMP. This ensures that data collected are robust enough to provide relevant long-term information on the state of South African estuaries. This approach also ensures that the data can be used for other relevant management interventions, including estuarine flow requirement baseline studies and estuarine flow requirement audits. This approach further ensures that the data generated during ad-hoc assessments of specific issues, including pollution incidents and impacts associated with development pressure, can contribute to the long-term data sets for estuaries in South Africa.

The success of the National Estuary Monitoring Programme depends on the commitment by all parties to the collaboration which is the foundation of the NESMP. Linked to this is the commitment by all parties to the objectives and practical implementation of the programme. For this to happen there is a need that the necessary budget and human resource allocation to the programme is made by all the relevant parties. Efficient and simple communication channels are critical to ensure that momentum is built and maintained for the programme. Finally, there should be a willingness to share effort and information by all parties. This is in line with the revised National Water Resource Strategy (DWA, 2013) as is currently being implemented by DWS. Within this strategy the issue of leadership, cooperation and regulation are key focus points. The National Water Resource Strategy needs to be given practical effect as part of the NESMP. This is only possible if the Strategy is cascaded down to a practical implementation action plan as is the case with NESMP.

Central to this programme is the ICM Act which also has the collaborative management of coastal resources as a foundation and which guides the drafting of estuarine management plans. The implementation of an estuarine management plan by different stakeholders on a municipal level, through relevant management bodies, is central to the implementation and success of the estuarine-specific monitoring programmes. Estuarine management plans should therefore be drafted as soon as possible for estuaries where they do not exist.

The consistency in data collection and data quality is indicative of the success of a monitoring programme. Success during the pilot testing phase of the NESMP was achieved where conservation bodies, municipalities and other role-players understood the value of the monitoring programme in terms of their own mandates and therefore gave 'top-down' support to the initiative. In a similar fashion the 'bottom-up' approach of the sampling teams also strengthened this collaborative effort. This effort is most effective when formalising the sampling team's responsibilities through incorporating monitoring, scientific support and co-operative governance in the sampling team's workplans and providing the linkage with the mandate of each entity involved. Estuary monitoring should be a coordinated effort, managed through a single body to ensure effective communication and prevent duplication of effort. The estuary management forums fulfil this requirement.

The programme that commenced in 2012 should continue

with the further collection of Tier 1 data through expansion of the programme to other estuaries. The identified estuaries for 2015 to 2017 are Richards Bay, Mdloti, Durban Bay, Mtamvuna, Mtafufu, Kowie, Bushmans, Swartkops, Wilderness, Gouritz, Klein and Groot Brak, Piesang, Heuningnes, Uilkraal, Onrus, Palmiet and Orange. The collection of Tier 2 data should also commence as soon as possible. Financial support for this should be solicited by demonstrating the success of the pilot testing of Tier 1 monitoring, thereby keeping the existing momentum going through expansion of the Tier 1 and initiation of Tier 2 monitoring.

REFERENCES

- BERTAM J and BALLANCE R (1996) *Water Quality Monitoring. A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes*. E&FN Spon, London. 383 pp.
- DAY JH (1981) Summaries of current knowledge of 43 estuaries in southern Africa In: Day JH (ed) *Estuarine Ecology with Particular Reference to Southern Africa*. A.A. Balkema, Cape Town.
- DWA (DEPARTMENT OF WATER AFFAIRS, SOUTH AFRICA) (2013a) National Water Resource Strategy. June 2013 Second Edition. Department of Water Affairs, Pretoria. DWAF (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, SOUTH AFRICA) (2004a) A 5-Year Water Resource Quality Monitoring Plan. Directorate: Information Programmes, Department of Water Affairs and Forestry, Pretoria.
- DWAF (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, SOUTH AFRICA) (2004b) Strategic Framework for National Water Resource Quality Monitoring Programmes (1st edn). Report No. N/0000/REQ0204. ISBN 0-621-35069-9. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria.
- DWAF (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, SOUTH AFRICA) (2005) National Toxicity Monitoring Programme (NTMP) for Surface Waters Phase 2: Prototype Implementation Manual. Report No.: N/0000/REQ0605 ISBN No.: 0-621-36403-7. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria.
- DWAF (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, SOUTH AFRICA) (2008a) Proceedings of the National Estuarine Monitoring Workshop hosted by DWA. Unpublished report. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria.
- DWAF (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, SOUTH AFRICA) (2008b) Water Resource Protection and Assessment Policy Implementation Process. Resource Directed Measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries Version 2. Department of Water Affairs and Forestry, Pretoria.
- KLEYNHANS CJ and LOUW MD (2009) River EcoClassification: Manual for ecostatus determination (Version 2) Module A: EcoClassification and EcoStatus Determination. WRC Report No. TT 329/08. Water Research Commission, Pretoria.
- NEL JL, STRYDOM WF, MAHERRY A, PETERSEN C, HILL L, ROUX DJ, NIENABER S, VAN DEVENTER H, SWARTZ E and SMITH-ADAO LB (2011) Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. WRC Report No. TT 500/11. Water Research Commission, Pretoria.
- TALJAARD S, VAN NIEKERK L, HUIZINGA P and JOUBERT W (2003) Resource Monitoring Procedures for Estuaries for application in the Ecological Reserve Determination and Implementation Process. WRC Report No. 1308/1/03. Water Research Commission, Pretoria.
- TURPIE JK and MACKAY H (1999) Assessing Estuarine Health and assigning Present Ecological Status (PES). In: *Water Resource Protection and Assessment Policy Implementation Process – Resource Directed Measures for Protection of Water Resources: Estuarine Ecosystem Component*. Department of Water Affairs and Forestry, Pretoria.

- TURPIE JK, ADAMS JB, JOUBERT A, HARRISON T, COLLOTY BM, MAREE RC, WHITFIELD AK, WOOLDRIDGE TH, LAMBERTH SJ, TALJAARD S and co-authors (2002) Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA* **28** (2) 191–206. <http://dx.doi.org/10.4314/wsa.v28i2.4885>
- TURPIE JK, WILSON G and VAN NIEKERK L (2012) National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consultants Report No. AEC2012/01. Anchor Environmental, Cape Town.
- VAN NIEKERK L and TURPIE JK (eds) (2012) South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report No. CSIR/NRE/ECOS/ER/2011/0045/B. CSIR, Stellenbosch.
- WHITFIELD AK (1992) A characterization of South African estuaries. *S. Afr. J. Aquat. Sci.* **18** 89–103.
- WHITFIELD AK (1998) *Biology and Ecology of Fishes in South African Estuaries*. Ichthyological Monographs of the JLB Smith Institute of Ichthyology No 2. JLB Smith Institute of Ichthyology, Grahamstown. 223 pp.
- WHITFIELD AK and BALIWE NG (2013) A century of science in South African estuaries: Bibliography and review of research trends. SANCOR Occasional Report No. 7. South African Institute for Aquatic Biodiversity, Grahamstown.
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