Aquaculture in Southern Africa with special reference to site selection and carrying capacity issues

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Abstract

Growth in aquaculture production in Southern Africa has not kept pace with trends worldwide. Part of the reason for this decline includes significant barriers to entry for new aquaculture development, including problems with site selection and carrying capacity. Information on these constraints on aquaculture production in the region have so far been fragmented and this overview paper attempts to fill the gap through a desktop literature review of factors relevant to site selection and carrying capacity issues in southern Africa.The key regional and national factors for site selection are the degree of development, the need for favourable environmental conditions, the accessibility of sites, institutional constraints and the impacts of aquaculture of ecosystems in the region. Although environmental capacity is not a key concern yet on a regional level, several incidences of the impacts of pollution on freshwater aquaculture, bivalves and abalone are identified and remain a serious concern in certain aquaculture production systems in the region. The use of models and decisions support systems for better site selection and identification of carrying capacity issues are discussed in the developmental context of southern Africa and several recommendations are made. The expectation is that the results of this overview contribute to a better understanding on site selection and carrying capacity constraints to aquaculture production in southern Africa.

Introduction

With wild fish stocks declining at unprecedented rates worldwide, aquaculture production is seen as an important solution to provide food security and also meet protein and other dietary requirements. This is particularly important in Sub-Saharan Africa, with large portions of the population undernourished and dependent on both freshwater and marine fishing for livelihoods.

However, growth in aquaculture production in Southern Africa has not kept pace with trends worldwide. In fact, on the whole aquaculture production in the Southern African region has declined by on average 5 percent per annum over the past 5 years (Table 1). The two main producers in the region in 2003, namely the Republic of South Africa and the Republic of Namibia, have experienced significant declines in total production. Aquaculture production in the Republic of South Africa (the dominant producer in the region) has fallen from approximately 6 600 tonnes in 2003 to approximately 5 050 in 2008, a drop of more than 1 500 tonnes over 5 years. The Republic of Namibia's production has halved since 2003. The Kingdom of Lesotho by contrast has experienced strong growth, albeit from a low base.

TABLE 1
Total production (tonnes) for 2003 and 2008.

Country	2003		2008		Growth 2003–2008
	Tonnes	% share	Tonnes	%share	
Lesotho	4	0.1%	91	1.8%	86.8
Namibia	117	1.7%	58	1.1%	-13.1
South Africa	6 602	98.2%	5 049	97.1%	-5.2
	6 723	100.0%	5 198	100.0%	-5.0

Note: No aquaculture production was recorded for the Republic of Botswana and the Kingdom of Swaziland during this period.
Source: FAO Fishstat Plus

With the exception of the Kingdom of Lesotho, production does not appear to be positively affected by environment (Table 2). For the Republic of Namibia and the Republic of South Africa, both freshwater and marine aquaculture either stagnated or declined between 2003 and 2008.

At first glance indications are that the region has an abundance of potential aquaculture sites. For example, a recent bulletin indicated that in the Western Cape alone there are 2000 suitable dams that could produce up to 8 000 tonnes of fish per year. Furthermore, the Republic of South Africa's coastline is approximately 2 798 km long and the Republic of Namibia's coastline is 1 572 km which suggests ample scope for identifying coastal aquaculture sites. So why has production stagnated or declined in most parts of Southern Africa?

TABLE 2
Trends in aquaculture production (tonnes) per environment

Country	Environment	2003	2008	% growth
Lesotho	Freshwater	4	91	86.8
Namibia	Freshwater	15	15	0.0
	Marine	102	43	-15.9
South Africa	Freshwater	2 246	1 202	-11.8
	Marine	4 356	3 836	-2.5
	Brackish	-	11	
Total		6 723	5 198	-5.0

Source: FAO Fishstat Plus

Reasons for declines in aquaculture production

Identifying current and future issues and bottlenecks

There are a number of reasons why aquaculture potential has not been realized in Southern Africa. Part of the reason for the decline includes significant barriers to entry for new aquaculture development. These include the following:

1. Few individuals or communities have access to the capital needed to start up aquaculture projects, lack technical skills nor do they have links with the main players in the industry.

2. Difficulties in finding and acquiring an appropriate site for aquaculture production.
   a. Identification of freshwater aquaculture sites can be expensive and onerous. Traditional methods for site identification are haphazard and rely on word of mouth, visual inspections and follow up visits. Costs include the transportation costs and the time it takes to reach the sites. Geographic Information Systems (GIS) may help to reduce some of these site selection costs, but at the moment it is an underutilized resource (Steer, 2006).
   b. It can take years to rezone land for aquaculture activities, and in the sea there is no legal instrument for zoning offshore areas for aquaculture.

Typically, the development process may require an environmental impact assessment, land rezoning, public comment and meetings, and applications for various permits. Obtaining access to areas of water (outside of National Ports Authority controlled waters) for sea-based aquaculture is particularly difficult, as there is no legal instrument for the granting of a use right for this purpose.

3. With respect to land based aquaculture, access to land that has sufficient suitable water resources (fresh or sea water) for large-scale production may also be difficult to acquire. Even if the financing for a land-based operation is in place, finding suitable sites reasonably close to market exit points is often costly and difficult – this is particularly true for mariculture operations as a premium is placed on coastal land in the Republic of South Africa.

Value of aquaculture production

The value of aquaculture production in Southern Africa is dominated by a few key species (Table 3). For marine aquaculture, abalone production makes up almost 85 percent of the value of the Republic of South Africa's production, while for the Republic of Namibia it is approximately 50 percent. Bivalves make up an important minority, approximately 3.5 percent in the Republic of South Africa and 15 percent of value in the Republic of Namibia.

TABLE 3
Value of production by species, 2008

	Lesotho	Namibia	South Africa	South Africa % total
		Thousand US$		
Carps, barbels and other cyprinids	3	-	-	0
Salmons, trouts, smelts	630	-	3 470.0	8.3
Abalones, winkles, conchs		102	35 341.0	84.6
Miscellaneous freshwater fishes		28.5	453.6	1.1
Mussels			640.3	1.5
Oysters		35	854.3	2.0
Red seaweeds		27.9	247.7	0.6
Other	-	-	762.8	1.8
TOTAL	633	193.4	41 769.7	100.0

Source: FAO Fishstat Plus

In terms of freshwater production, the Republic of South Africa produced rainbow trout to the value of R44 million in 2003, the next highest being R11.8 million generated from freshwater shrimp (Steer, 2006). This high production value came from only 1750 metric tonnes of fish produced. In the Kingdom of Lesotho, aquaculture production includes trout and catfish, some for the tourist market and some exported to the Republic of South Africa for processing.

Regional and National factors relevant to site selection for aquaculture in southern Africa

A number of issues are relevant to aquaculture site selection in Southern Africa. Apart from the issues discussed below, Appendix A provides a checklist of criteria for aquaculture development.

Degree of development

Degree of coastal development has potential to conflict with mariculture development. Too much can conflict with aquaculture development (e.g. much of KZN coastline) although too little can also hinder aquaculture development (e.g. Wild coast). Furthermore, the absence of competing activities such as mining, tourism, polluting industries, domestic effluent, etc. that might conflict with aquaculture. Development can also bring the risk of poaching, vandalism and theft of equipment.

Favourable environmental conditions

These conditions determine the physical carrying capacity of an area (McKindsey *et al.*, 2006) – in other words the area of aquaculture activity that can occur in the available physical space.

Examples of geographic areas favourable for aquaculture production include:

1. Sheltered areas (harbours lees such as Port Elizabeth and Coega, lagoons such as Knysna, Langebaan). With the development of improved technology for sea cages, semi-sheltered area could also be considered for aquaculture (e.g. Walker Bay and Boegoeberg Bay near Alexander Bay). Deeper water is required for cage aquaculture of fin fish
2. Availability of kelp bed habitat (e.g. for abalone production)
3. Climatic and ocean conditions, including temperature, salinity, ocean depth and current flow
4. Availability of under-utilized coastline (e.g. Western Cape province)
5. For freshwater aquaculture, the availability of a suitable habitat for fish production. For example, trout farming requires a dam with surface area at least 15ha, a capacity of 150 000 m^3 or more, and a depth of 5 m or more (Steer, 2006). This is because if cages are not moved around during the season the water quality around the cages can deteriorate.
6. Furthermore, aquaculture farming will not be allowed in areas that are protected or environmentally sensitive (e.g. nurseries, bird sanctuaries, migration routes, etc.)
7. Area should be large enough to allow for rotation and for areas to lie fallow.

Accessibility

Accessibility includes:

1. The availability of transport infrastructure (such as a developed road network and proximity to airports)
2. Access to labour which includes proximity to urban settlements
3. Access to services such as freshwater, electricity, sewerage and communication infrastructure
4. Access to site specific requirements such as marine pumps, hatcheries, ponds, buildings, etc.
5. Access to major processors, major feed suppliers and major hatcheries

Institutional constraints

For example in the Republic of South Africa the only readily accessible waters for sea based aquaculture are the areas within the jurisdiction of Portnet which has total control of all activities in the waters surrounding its ports. Portnet leases water for aquaculture at Saldanha Bay and Port Elizabeth. At present (2007) parliamentary approval is required for zoning of sea space for aquaculture outside of the Portnet areas of jurisdiction. In some cases this includes the use of Strategic Environmental Assessment (SEA) to determine where best to site aquaculture zones (e.g. The East Cape Development Corporation recently completed an SEA to identify suitable offshore aquaculture sites in the Eastern Cape Province). In addition the development process may require an environmental impact assessment, land rezoning, public comment and meetings, and applications for various permits.

Ecosystem impacts

The natural environment not only plays an important role in the physical scale of farming operations, but conflicts can occur between objectives that seek to maximize production capabilities, and environmental thresholds (environmental impacts that exceed the ecological carrying capacity). Site selection should exclude sensitive areas, MPAs, and other areas of recreation or tourism. Legal and institutional efforts to ensure that ecological thresholds are not exceeded can also affect site selection. Major issues include conflicts between endemic and exotic species, impact of farming practices, and animal health.

The balance between indigenous and exotic species

A number of issues are relevant for site selection:

1. The risk assessments required by the National Environmental Management Biodiversity Act for the use of exotic species are expensive and time consuming.
2. Fishery managers within the DEAT are in principle against the sale of cultured indigenous species on the local market as they maintain they can be used as a front for the sale of wild poached product.
3. Permits are required for cultivation of freshwater species such as trout. These may be difficult to obtain.

Impact of species and farming practices on ecosystem balance, water quality and environmental health

The abalone industry funds its own water quality management programme and health management programme, but smaller aquaculture SMEs cannot afford this.

The SABS and government require frequent water quality and product testing. While the costs of this can be absorbed by large and medium size enterprises, the cost (typically over R 100 000 per year) is simply too high for small enterprises.

One way in which environmental impacts are mitigated is through integrated multi-trophic aquaculture (IMTA). An example where this is applied in the Republic of South Africa is through implementing IMTA with the seaweed *Ulva lactuca* L. and the abalone Haliotismidae L (Nobre *et al.*, 2010). IMTA results in improved productivity of abalone, allows for water recirculation and reduces abalone effluent discharge into the environment, and also allows farms to function without the need for access to the ocean for periods of time. The latter is particularly useful in cases of oil spills or red tides.

Health management of farmed stocks.

Aquaculture veterinary services are most rudimentary and most farms have stock (herd) health management schemes. Disease and drug free certification is a HACCP requirement for the export of products to the European Union. Aquaculture activities should avoid areas associated with algal blooms (if possible).

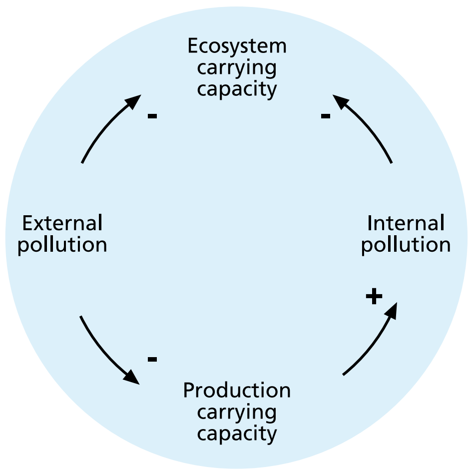
These and other issues indicate the importance of an ecosystem approach to aquaculture (Soto, Aguilar-Manjarrez and Hishamunda, 2008).

Environmental carrying capacity issues

An important relationship exists between pollution and carrying capacity (Figure 1). An increase in external pollution (pollution from non-aquaculture sources) reduces both ecosystem carrying capacity as well as production carrying capacity. An increase in production carrying capacity has the potential to increase aquaculture related pollution, which in turn reduces the ecosystem carrying capacity via impacts on ecological integrity.

In certain cases, however, an increase in external 'pollution' may have a positive impact on production carrying capacity. An example is the "culture based fishery" characteristic of many Southern African inland fisheries (Rouhani and Britz, 2004). This is a form of extensive aquaculture that resembles a fishery where the volume of fish produced per unit area is low but input running costs are also very low. Fish rely on natural production in a pond as their primary source of food (just as they would in a fishery); however, natural production in the pond may be enhanced by adding animal manure to the water, which increases the carrying capacity of the pond.

FIGURE 1
The relationship between ecosystem carrying capacity and pollution



A number of coastal ecosystems in Southern Africa are particularly vulnerable to both internal and external pollution, notably estuaries, which also provide favourable conditions for the establishment of aquaculture activities (e.g. Knysna). A number of indicators may be used to assess ecological integrity of marine ecosystems (Borja *et al.*, 2008): freshwater requirements of estuaries, fish, estuarine health or conservation significance. The emphasis is on developing technologies that improve production that also preserve the ecological integrity of the environment (Brummett and Williams, 2000).

Freshwater aquaculture

The introduction of trout, and especially rainbow trout in Southern Africa, is associated with a number of adverse effects. The first issue related to the impact of trout species themselves on endemic fish populations through competition and predation (Cowx, 2002). In Europe the introduction of rainbow trout has resulted in the reduction of native salmonid populations in Lake Ohrid, Macedonia. Furthermore, there are reports of rainbow trout escaping from farms into rivers and decimating the endemic fish stocks, particularly through predation of the juveniles. Secondly, *Oncorhyncus mykiss* displaces endemic species through aggressive behaviour and alters the fish community structure. In the Republic of South Africa there are problems on rivers where trout have been introduced and have resulted in degradation of the endemic species communities.

The second issue relates to the effects of trout farming practices on ecosystems. For example in a study in Southern California, effluent concentrations downstream of the trout farm were 1.7 times higher than the reference site (Pachon and Walton, 2008). Algal abundance, suspended particulate matter and ammonium nitrogen concentrations were also higher. It should be noted however that this was a small desert stream and conditions are likely to differ where runoff is higher.

Bivalves

Work on Bivalves indicates a number of adverse environmental impacts that can affect ecological carrying capacity. On the one hand these are associated with specific aquaculture activities (See Appendix B). A summary of some of the key issues is provided in Inglis, Hayden and Ross (2000). These include:

1. Organic enrichment of sediments below the farmed areas by faeces and pseudofaeces;
2. Shifts in benthic food webs from predominantly suspension-feeding to deposit-feeding faunas;
3. Shading of submerged plants and animals by surface infrastructure;
4. Drop of shells and other waste materials;
5. Localised depletion of phytoplankton from surface and sub-surface waters; and
6. Attraction of predators, such as starfish and fish.

The presence of mussels (*Mytilus galloprovinvialis*) and foulers associated aquaculture activities (such as the sea squirt, *Ciona intestinalis*) results in a high rate of sedimentation from faeces, pseudofaeces and fallen mussels. In a study conducted on an 80 hectare mussel farm in Saldanha Bay, the sedimentation rate within the farm was found to be high with 300 kg organic carbon/m^2/year (300 percent of ambient) and 45 kg nitrogen/m^2/year (200 percent of ambient) (Stenton-Dozey, Jackson and Busby, 1999).

Abalone

Although abalone farming represents an intensive flow-through system, it releases, compared to e.g. fish cage farming, only limited amounts of nutrient wastes (Troell *et al.*, 2006). The main reason for this is feeding mainly kelp or feeds with low fishmeal content. Due to the high-energy coasts of the Republic of South Africa, with massive mixing and naturally high levels of upwelled nutrients, nutrient effluents from farms most likely have insignificant effects on the coast.

However, the former Department of Water Affairs and Forestry has produced water quality guidelines for coastal marine waters that are intended for protection of the natural environment. A preliminary study characterising effluents from seven west coast abalone farms (Samsukal, 2004 cited in Troell *et al.*, 2006) concluded that dissolved nutrients were in accordance with the recommended standards outlined in the former Department of Water Affairs and Forestry water quality guidelines. The particulate loading (sizes less than 63 µm) was, however, found to be significant, as were the numbers of herbivorous crustaceans released from the farm during cleaning. The implications of this for the environment were, however, not studied. A preliminary study by Potgieter (2005, cited in Troell *et al.*, 2006) showed that approximately 100 kg of particulate waste per tonne of abalone is released annually from tank cleaning operations. This is a significant release but many times less than fish cage farming. Any effect from such release is probably of local nature.

The tube-dwelling polychaete worm *Terebrasabella heterounicinata* affects abalone growth negatively and it can occur in high densities at farms. It is not known if effluent from polychaete infested farms increase the infestation rate for wild abalone living in close proximity to the farm.

Use of models and decision support tools

GIS software can serve as a useful guide to site selection, and may reduce some of the costs associated with site selection. However, the human element associated with site selection cannot be eliminated. A study utilized GIS techniques to identify suitable sites for trout farming in the Western Cape. Of a total of almost 1500 dams, only 21 dams (1.4 percent) were found to be suitable (Steer, 2006). Furthermore, the study found that a number of successful aquaculture sites would have been screened out if based solely on this approach.

GIS is also widely used in carrying capacity model (McKindsey *et al.*, 2006). Decision support tools generally utilize an integrated approach that utilizes a combination of approaches such as fine scale circulation models, broader ecological models, databases such as GIS and individual based models (an example of this is the SIMILE project in Northern Ireland).

There are at least two problems with decision support models. The first is that these are often costly, complex and impractical. This is particularly problematic in a developing country context. A second problem with decisions support tools is that the carrying capacities are not precise values but are rather subject to large uncertainties.

The first problem is addressed through the use of an "Expert System," namely the development of a library of information and tools to provide the best possible advice to decision-makers even when experts in the relevant fields are not available. An Expert System is a computer package that contains a large database of information applicable to the problem at hand along with models and other programs for manipulating these data in order to provide meaningful advice to decision-makers. Expert Systems are designed through consultation with experts in the field in order to provide advice similar to what the experts would advise if they were available.

The problem of imprecise values is sometimes addressed through the use of a Fuzzy Expert System. The outputs in this case are not precise numbers but rather functional relations between production levels and acceptability. In other words, instead of saying that the carrying capacity has some value X, meaning that production levels below X are totally acceptable and levels above X are totally unacceptable, we say that a production level of X is 50 percent acceptable, while higher or lower values would be assigned acceptabilities of, say, 15 percent or 80 percent.

Fuzzy logic tools have been used to some extent in fisheries management in the Republic of South Africa (e.g. Paterson *et al.*, 2007).

Recommendations

A summary of issues and associated recommendations is included in Appendix C.

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Appendix A: Aquaculture site selection questionnaire

The following checklist of questions is provided as a self-guiding primer for the would-be farmer.

Economic Questions:
Do you have a realistic business plan containing all relevant information required by financial and government institutions for speedy approval?
Can you secure sufficient capital at a reasonable interest rate?
Does your management team have sufficient management and financial skills to help manage the farm?
Have you made a realistic assessment of the timing and scale of expected returns on your investments?
Do you have adequate cash reserves for unanticipated costs such as equipment and/or crop loss?
Are you aware of the various government grants/schemes available?
Site selection:
Is the proposed site in a region zoned as suitable for aquaculture?
Does the site have a site-topography suitable for proposed design?
Does the site have sufficient and acceptable water supply?
Is there adequate room for intended use plus future expansion?
Does the site have acceptable potential for effluent disposal?
Does the site have a climate suitable for the intended species (which should be natural to the area)?
Is the access to services, technical assistance and public infrastructure such as roads?
Species selection:
Is the species suited to the local climate conditions/extremes
Is it native to the area and have you consulted the authorities/Biodiversity Act?
Do you understand the basic needs of the species in order to build it into management plans?

Have you been in touch with an industry representative about information change?
Is there a market for your species (local or international)?
Have you explored the various production strategies available?
Do you or your business partner have the necessary technical experience? If not, are you prepared to employ someone who does?
Are you intending to spawn and grow? If not, are dependable sources of juveniles readily available locally?
Market intelligence:
Have you identified your market and will you be able to supply at demand the required quality?
Have you examined the existing situation with respect to market size and demand, along with the level of competition?
Have you determined the form in which you will market your product and are you aware of the required standards?
Can you supply product to your market on a regular basis throughout the year?
Do you have the means to harvest, handle hold and transport the product?
Socio-legal considerations:
Is the development of an aquaculture facility at your site acceptable to neighbours/ community and other who may use the region?
Have you discussed your plans with the relevant government authorities?
Are you aware of the required permits to be obtained, can you obtain the permits for an extended period of time or do they have to be renewed frequently?
Is the development of an aquaculture facility at your site acceptable to neighbours/ community and other who may use the region?
Have you discussed your plans with the relevant government authorities?
Are you aware of the required permits to be obtained, can you obtain the permits for an extended period of time or do they have to be renewed frequently?

Source: Aquaculture Institute (www.ai-sa.org.za)

Appendix B: Selection of activities related to bivalve culture that may influence the ecological carrying capacity of a coastal area

1. Seed collection

a. Dredging
- i. Disturbance of benthic communities, especially the removal of long-living species
- ii. Removal of juveniles from wild populations of target species
- iii. Collection of non-target species
- iv. Suspension of sediments
- v. Release of H2S and reduction of dissolved oxygen in the water due to oxygen-consuming substances, release of nutrients

b. Artificial collectors
- i. Removal of juveniles from wild population of target species
- ii. Increasing target and no-target species recruitment success
- iii. Alteration of the hydrodynamic regime
- iv. Acting as FAD
- v. Risk of entanglement for large vertebrates (e.g. marine mammals, sea birds, turtles, sharks).

c. Hatcheries
- i. Chemical pollution (e.g. pharmaceuticals)
- ii. Genetic selection
- iii. Spread of diseases

d. Importation
   i. Introduction of alien species
   ii. Genetic pollution
   iii. Spread of diseases

2. Ongrowing
a. Effects common to all techniques
   i. Organic enrichment of seafloor
   ii. Providing reef-like structures
   iii. Alteration of hydrodynamic regime (current speed, turbulence)
   iv. Food web effects: competition with other filter feeders, increasing recycling speed of nutrients, removal of eggs and larvae of fish and benthic organisms
   v. Spawning: release of mussel larvae
   vi. Providing food for predators of bivalves
   vii. Control of predators and pests
b. Bottom culture
   i. Activities to prepare the culture plots, e.g. dredging for predator removal
   ii. Removal of associated organisms by dredging and relaying
c. Artificial structures (trestles, poles, rafts, longlines)
   i. Acting as artificial reef or FAD (attraction/displacement or enhancement of animals)
   ii. Risk of entanglement for big vertebrates (e.g. marine mammals, sea birds, turtles, sharks)

3. Harvesting
a. Effects common to all techniques
   i. Removal of biomass, nutrients
   ii. Removal of non-target species
   iii. Competition with predators
b. Dredging
   i. Disturbance of benthos communities, especially removal of
   Long-living species
   ii. Suspension of sediments
   iii. Release of H_2S and decrease of dissolved oxygen in the water due to oxygen-consuming substances, release of nutrients
c. Collection of off-bottom structures

4. Processing
a. Dumping of by-catch
b. Relaying near auction houses
c. Depurating
d. Dumping of shells
e. Effluents from processing plant
f. Spread of alien species or diseases

Source: McKindsey et al., 2006.

Issue	Recommendation
Lack of st-art up capital	The establishment of Public-Private-Partnerships (PPPs) to involve SMMEs in sustainable forms of aquaculture. This model could also be utilized to develop aquaculture in rural areas (through CPPPs). The SMME development programme could be achieved in two ways; 1. A private investor contributes financial and technical skills while the community provides resources (land/water, labour etc); and 2. Government could provide funding for the community per cent share in the venture, the private company provides technical skills and some of the funding. The community will provide resources such as labour or land/water if possible.
Site selection expensive and time consuming	A key intervention by government should thus be facilitated access to suitable sites to stimulate investment into the sector. In in order to streamline and facilitate mariculture development in the Republic of South Africa, a sector planning process identified eight potential aquaculture development nodes. The potential mariculture nodes identified included Port Nolloth and Kleinsee in the Northern Cape Province, Toothrock, Saldanha Bay and Mossel Bay in the Western Cape, Coega (Port Elizabeth), the East London IDZ in the Eastern Cape, and Amatikulu in Kwa-Zulu Natal. Benefits accruing from the proposed clustering of mariculture projects into nodes would include: • Readily available, partially developed sites, which would minimize land preparation costs; • Basic on-site infrastructure (electricity and other municipal services); • Ready access to a source of seawater or fresh water; • Lower individual operating costs – through shared resources, marketing and support services, thereby achieving economies of scale; • On-site expertize, in the form of scientific support or practical experience from the other operations in the park; • On-site staff training programmes supported by R&D personnel; • A limited requirement for an environmental impact assessment (EIA), since a general assessment would have already been conducted for the park.
	In the freshwater arena, no sites for "aquaculture development zones" (ADZs) have as yet been identified, however it is expected that some of the old state run hatcheries such as Dzindi and Turfloop (Limpopo) and Lydenburg (Mpumalanga) could be developed into ADZs.
Ecosystem approach to aquaculture	The ecosystem approach to managing watersheds, with the rivers, wetlands, lakes, estuarine areas, and land viewed as part of a continuum, is fundamental to managing water for inland fisheries. This approach should consider not only water quantity and quality but also the connectivity of the system because many species of fish must be able to move between spawning, nursery, and feeding areas within a basin. This management approach needs to consider land-use practices, such as agriculture and forestry, as well as the needs of industry, urban areas, and waterborne transport that affect basin processes and the quality, quantity, and timing of flows. The approach is further complicated by the fact that many river basins are transboundary and may be located within several countries, necessitating international mechanisms to regulate and manage river flows.
Impact of trout on endemic species	The introduction of trout can be justified if the habitat it is introduced is isolated and holds no endemic or endangered species.
Impact of trout effluent on carrying capacity	Intensive running water culture systems need constant inputs of high-quality water to ensure sufficient oxygen for the fish and removal of wastes; sufficient flow is needed in rivers into which farm effluents are discharged to dilute wastes and nutrients without damaging ecosystems.
Risk assessments for the use of exotic species expensive. Permits difficult to obtain	Develop guidelines on the use of exotic species, which species are acceptable, where they can be farmed and under what conditions. Consideration should thus be given to a grant from government to undertake risk assessments in areas earmarked for strategic aquaculture development.
Cultured indigenous species may be used as a front for the sale of wild poached product	Traceability and certification schemes to market indigenous species on the local market. Government should be proactive in developing traceability schemes to open local markets for producers.
Fish health and the risk of diseases	Reduce fish stress as far as possible e.g. through maintaining correct stocking densities and environmental conditions Strict control over the importation and introduction of stock to reduce risk of disease accompanied by routine monitoring and application of disease management protocols