An overview on desert aquaculture in Southern Africa

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SUMMARY

Southern Africa is a 15-member country block, located south of the equator and often referred to as the Southern Africa Development Community (SADC) Region. The SADC, which comprises the Republic of Angola, the Republic of Botswana, the Democratic Republic of the Congo, the Kingdom of Lesotho, the Republic of Madagascar, the Republic of Malawi, the Republic of Mauritius, the Republic of Mozambique, the Republic of Namibia, the Republic of Seychelles, the Republic of South Africa, the Kingdom of Swaziland, the United Republic of Tanzania, the Republic of Zambia and the Republic of Zimbabwe, has a favourable environment and the necessary natural resources for aquaculture production. Although the aquaculture sector in this subregion is generally regarded as being in its infancy, significant growth has been noted in a number of countries over the past 20 years. Aquaculture development has recently become a priority topic in all of the countries in Southern Africa, as dwindling traditional supplies of fish (capture fisheries) and the potentially positive economic gains that aquaculture can generate (in terms of food security, employment creation, poverty alleviation, improved national economies and other associated socio-economic gains). Namibia, for example, through its Ministry of Fisheries and Marine Resources (MFMR) is spearheading the development of national aquaculture at the community level in order to empower rural communities to be self-sufficient in food production, and to derive income through fish production integrated with existing and potential agricultural practices wherever natural conditions permit. Similarly, the Government of South Africa, through its national Department of Agriculture, Forestry and Fisheries (DAFF) and other support sectors is taking steps to accelerate the development of aquaculture production at a commercial level. Other countries in the region, such as Mauritius, Mozambique, United Republic of Tanzania and Zambia (including countries with limited surface water resources such as Botswana), have begun drafting specific aquaculture-oriented legal frameworks and are developing strategic plans to support the sector. Until now, very little has been achieved with regard to developing aquaculture in the deserts and arid lands of Southern Africa. A lack of available technical information has caused the concept to be relatively unknown. This fact is probably due to the general belief that aquaculture can only be practised where abundant surface water is guaranteed. This belief has led to the idea that erecting a fish farm in arid lands is costly, risky and, therefore, unsustainable in

the long term. Ongoing innovations, through research and development, are gradually modifying this attitude. Potential areas for arid land aquaculture are being identified through the examination of water availability and quality, environmental suitability and provision of technical know-how. Competition for land use in deserts and arid lands is limited since these lands are considered unsuitable for crop production except where irrigation facilities are available or livestock ranching is practised. The ever-rising prices of fish, caused by increasing demand and diminishing supplies, are encouraging private commercial farmers to consider developing aquaculture wherever feasible, including in arid locations where adequate surface or subsurface water is available and easily extractable. Naturally, commercial farmers always seek to establish and operate ventures that realize a sustainable return on investment; their operations are therefore, strongly market-oriented.

RÉSUMÉ

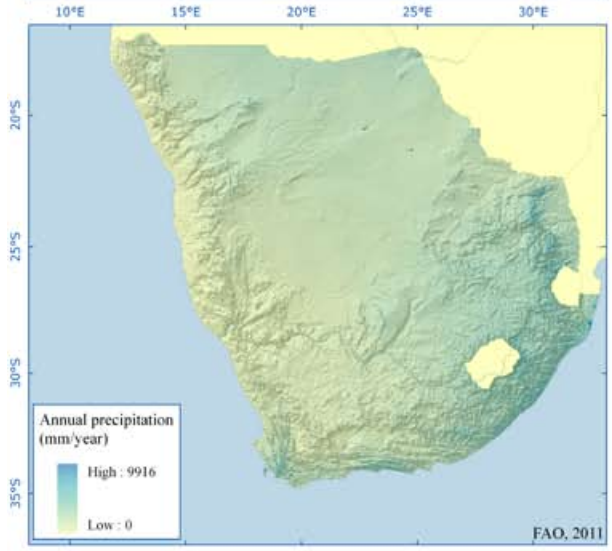
L'Afrique australe est un ensemble de 15 pays situés au sud de l'équateur. Souvent évoqué sous le nom de Communauté de développement de l'Afrique australe (SADC), cette région rassemble la République d'Angola, la République du Botswana, la République démocratique du Congo, le Royaume du Lesotho, la République de Madagascar, la République du Malawi, la République de Maurice, la République du Mozambique, la République de Namibie, la République des Seychelles, la République sud-africaine, le Royaume du Swaziland, la République-Unie de Tanzanie, la République de Zambie et la République du Zimbabwe. L'Afrique australe jouit d'un environnement favorable et des ressources naturelles nécessaires à la production aquacole. Même si l'on considère en général que l'aquaculture y est encore à ses débuts, on a noté une croissance importante de ce secteur dans plusieurs pays de la région au cours des vingt dernières années. Le développement de l'aquaculture est récemment devenu une question prioritaire dans tous les pays d'Afrique australe, surtout à un moment où l'approvisionnement traditionnel en poissons (la pêche de capture) baisse et alors que l'on constate que ce secteur peut avoir des conséquences positives dans différents domaines (du point de vue de la sécurité alimentaire, de la création d'emplois, de la lutte contre la pauvreté, de l'amélioration des comptes nationaux ou encore de bénéfices sur le plan social et économique). La Namibie, par l'intermédiaire de son ministère de la Pêche et des ressources marines, développe ainsi une aquaculture nationale au niveau communautaire, qui vise l'autosuffisance des communautés rurales en matière de production alimentaire et la création de revenus, grâce à une production piscicole intégrée aux pratiques agricoles existantes et potentielles, là où les conditions naturelles le permettent. De la même façon, le gouvernement sud-africain, par l'intermédiaire de son ministère de l'Agriculture, des forêts et de la pêche, et d'autres secteurs d'appui, est en train de prendre des mesures visant à accélérer le développement de la production aquacole à un niveau commercial. D'autres pays de la région, comme Maurice, le Mozambique, la Tanzanie et la Zambie (ainsi que des pays ayant des ressources limitées en eau, en termes de superficie, comme le Botswana), ont commencé à élaborer des projets de cadres juridiques spécifiques destinés à l'aquaculture et mettent au point des plans stratégiques pour appuyer le secteur. Jusqu'à présent, très peu de résultats concrets ont été obtenus en matière de développement de l'aquaculture dans les zones désertiques et arides d'Afrique australe. Il s'agit d'un concept encore relativement peu connu à cause d'un manque d'informations techniques disponibles. On pense en effet généralement que l'aquaculture ne peut être pratiquée que là où de grandes surfaces d'eau sont garanties. Cette conviction est telle que l'on estime qu'il est très coûteux et très risqué de créer une exploitation piscicole dans une zone aride et qu'une telle entreprise n'est pas viable à long terme. Les innovations en cours, grâce à la recherche-développement, invitent progressivement à revoir cette idée. Les espaces susceptibles

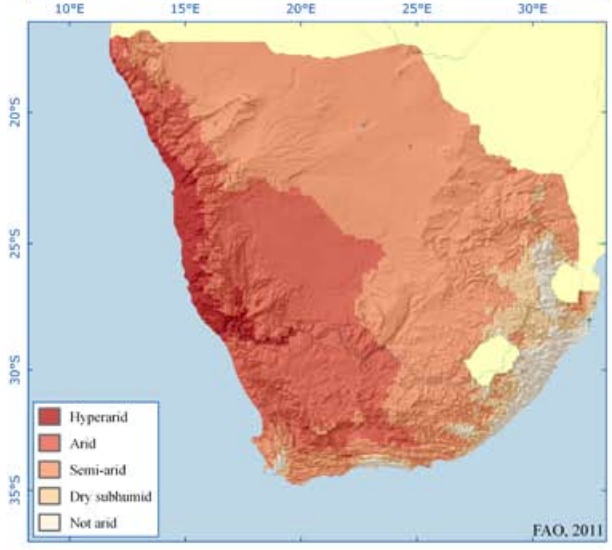
d'accueillir des activités aquacoles en milieu aride sont en cours de repérage grâce à l'examen des ressources en eau et de leur qualité, de leur environnement approprié ou non et de l'existence d'un éventuel savoir-faire technique. La pression exercée sur les terres désertiques et arides reste faible car elles ne sont pas considérées comme appropriés pour la production agricole, mis à part là où il existe des systèmes d'irrigation ou pour l'élevage. L'augmentation ininterrompue du prix du poisson, due à une demande croissante et à des approvisionnements en baisse, encourage les exploitants commerciaux privés à prendre en compte le développement de l'aquaculture la où c'est possible, notamment dans des milieux arides où des eaux appropriées, de surface ou souterraines, sont disponibles et faciles à extraire. Les exploitants commerciaux cherchent évidemment toujours à créer et à gérer des entreprises qui assurent un bon retour sur investissement et leurs activités sont par conséquent nettement orientées vers le marché.

ملخص

تتألف افريقيا الجنوبية من مجموعة خمسة عشر بلد عضو، والتي تقع جنوب خط الاستواء وغالبا ما يشار اليها بمنطقة مجتمع تنمية افريقيا الجنوبية (SADC). ان هذه المنطقة التي تتألف من جمهورية أنجولا، وجمهورية بتسوانا، وجمهورية الكونغو الديمقراطية، ومملكة ليسوثو، وجمهورية مدغشقر، وجمهورية مالاوي، وجمهورية موريشيوس، وجمهورية موزمبيق، وجمهورية ناميبيا، وجمهورية سيشل، وجمهورية جنوب افريقيا، ومملكة سوازيلاند، وجمهورية تنزانيا المتحدة، وجمهورية زامبيا وجمهورية زيمبابوي (الشكل 1)، لديها البيئة المناسبة والموارد الطبيعية الضرورية لإنتاج تربية الأحياء المائية. وعلى الرغم من اعتبار قطاع تربية الأحياء المائية في هذه المنطقة الفرعية بشكل عام في بداياته، فانه قد تمت ملاحظة نمو هام في عدد من البلدان خلال العشرون سنة الأخيرة. وقد أصبحت تنمية تربية الأحياء المائية مؤخرا موضوع ذو أولوية في جميع البلدان في افريقيا الجنوبية، وذلك لكون المعروض التقليدي المنخفض من الأسماك (المصايد التقليدية) والأرباح الاقتصادية الايجابية المحتملة التي يمكن ان توفرها تربية الأحياء المائية (من ناحية الأمن الغذائي، وإيجاد الوظائف، ومحاربة الفقر، وتحسين الاقتصاديات الوطنية والأرباح الأخرى الاجتماعية الاقتصادية المرتبطة) قد تم إدراكه. وناميبيا على سبيل المثال، من خلال وزارتها للثروة السمكية والموارد البحرية فإنها تقود تنمية تربية الأحياء الوطنية على مستوى المجتمع وذلك بهدف تمكين المجتمعات الريفية من ان تكون مكتفية ذاتيا من الإنتاج الغذائي، وللحصول على دخل من إنتاج الأسماك التي يمكن التكامل بينها وبين الممارسات الزراعية الموجودة والمحتملة حيثما تسمح الظروف الطبيعية. وبالمثل، فان حكومة جنوب افريقيا، ومن خلال إدارتها الوطنية للغابات الزراعية والمصايد السمكية (DAFF) والقطاعات الأخرى الداعمة تقوم بخطوات لتسريع تنمية انتاج تربية الأحياء المائية على المستوى التجاري. والبلدان الأخرى في المنطقة، مثل موريشيوس، والموزمبيق، وتنزانيا وزامبيا (وتتضمن البلدان ذات الموارد المحدودة من المياه السطحية مثل بتسوانا)، قد بدأت بصياغة إطارات قانونية موجهة وخاصة بتربية الأحياء المائية وتقوم بتطوير خطط إستراتيجية لدعم هذا القطاع. وحتى الآن، تم تحقيق القليل جدا من الانجازات فيما يخص تطوير تربية الأحياء المائية في الأراضي الصحراوية والجافة في منطقة افريقيا الجنوبية. ان النقص في المعلومات التقنية المتوفرة قد أدى الى ان يكون المبدأ غير معروف نسبيا. وهذه الحقيقة من المحتمل ان تكون بسبب الاعتقاد العام بأن تربية الأحياء المائية يمكن ان تمارس فقط في حالة ضمان وجود كميات وفيرة من المياه السطحية. وهذا الاعتقاد أدى الى وجود فكرة بأن إقامة مزرعة سمكية في الأراضي الصحراوية هو أمر مكلف وخطر وبالتالي هو غير مستدام على المدى الطويل. ان الابتكارات المستمرة من خلال البحوث والتطوير تقوم بتعديل هذا الاتجاه بشكل تدريجي. ويتم تحديد المناطق المحتملة لتربية الاحياء المائية في الأراضي الجافة من خلال فحص وفرة وجودة المياه، والاستدامة البيئية، والتزود بالمعرفة التقنية. ان المنافسة محدودة حول استخدام الأراضي في الصحاري والمناطق الجافة وذلك لكونها تعتبر أراضي غير مناسبة لإنتاج المحاصيل باستثناء في حالة توفر تسهيلات الري او عند ممارسة تربية الماشية. ان الأسعار المرتفعة دائما للأسماك، والتي يسببها الطلب المتزايد والمعروض المتناقص، تشجع المزارعين التجاريين الخاصين على الأخذ في الاعتبار تطوير تربية الأحياء المائية كلما كان ملائما، وتتضمن المواقع الجافة عند توفر مياه سطحية او شبه سطحية كافية وسهلة الاستخراج. وطبيعيا، فان المزارعين التجاريين يقومون دائما بالبحث عن تأسيس وتشغيل المشاريع التي تحقق ربح او استثمار مستديم؛ وبالتالي فان عملياتهم هي بشكل قوي باتجاه السوق.

FIGURE 1
Maps of Southern Africa





Botswana, Namibia and South Africa

Countries area: 262500 (1000 Ha)
Source: FAOSTAT. Estimated, 2007

Land area: 260450 (1000 Ha)
Source: FAOSTAT. Estimated, 2007

Agricultural area: 164000 (1000 Ha)
Source: FAOSTAT. Official data, 2007

Aquaculture Production Average 2004-2008: 1343 tonnes
Source: FISHSTAT. Official data

Aridity:
Approx. areas of hyperarid regime: 11160 (1000 Ha)
Approx. areas of arid regime: 76860 (1000 Ha)

A typical landscape of an arid region in Nambia.

COURTESY OF B. MAPFUMO

THE GENERAL ENVIRONMENT

There are two major deserts in Southern Africa: the Kalahari Desert (large portions in Botswana) and the Namib Desert (Namibia). In addition, there are large tracts of arid lands that receive less than 250 mm rainfall per annum in countries such as South Africa, Zimbabwe, Angola, Zambia and Mozambique. These areas are also characterised by high temperatures, especially in the summer and thus high water evaporation rates.

The Kalahari Desert is a large arid to semi-arid sandy area with an area extending to 900 000 square kilometres that covers much of Botswana and parts of eastern Namibia. The Kalahari is ranked the fourth largest desert in the world. However, it should be noted that most of the Kalahari is not a true desert, as it forms part of the temperate savannah (Warder, 2010). The rainfall in this desert is barely 75–300 mm per year and summer temperatures are very high. The surrounding Kalahari Basin covers an additional 2 500 000 square kilometres extending further into Botswana, Namibia and South Africa, and encroaching into parts of Angola, Zambia and Zimbabwe (Figure 1).

Very little aquaculture development is recorded in the main desert area, although some momentum has recently been created further westwards in the Omaheke Region of Namibia, where some community-based small-scale fish farms are being promoted by the Namibian Government. This review focuses mainly on aquaculture developments in Namibia, which has recently achieved good progress in developing its aquaculture sector, even in arid lands. Very little information is available on Botswana and South Africa, apart from the large-scale ventures being planned there, and expected to be producing in the next few years[1]. The remaining 12 countries of the region are predominantly tropical to sub-tropical, hence do not have deserts, but contain some patches of arid lands that receive <250 mm rainfall per annum. There is very little information available about aquaculture development in the arid lands of these countries.

In the southwestern part of Africa lies the Namib Desert. This desert occupies an area of ~80 900 km², stretching for about 1 600 km along the Atlantic Ocean coastline. Its east to west width varies from 50–160 km. Though primarily in Namibia, the Namib Desert also extends into the southwest of Angola. Having been arid or semi-arid for at least 55 million years, this desert is considered to be the oldest in the world. It has sporadic, unpredictable rainfall without a clear seasonal pattern, in most cases less than 10 mm annually, and is almost completely barren.

There are a few on-shore mariculture operations located in the Namib Desert area, in the coastal towns of Walvis Bay, Henties Bay, Swakopmund and Luderitz[2]. These produce shellfish such as oysters (*Crassostrea gigas*, *Ostrea edulis*) and abalone (*Haliotis midae*), utilizing pumped water from the Atlantic Ocean. Apart from this, the bulk of mariculture operations in Namibia are in offshore-based systems. Oysters and abalone produced in Namibia are destined for export markets and have been attractive enterprises for the commercial sector. Until now, mariculture operations in Namibia, which are worth about USD10 million per year, have been the driving force behind aquaculture development there. However, the industry has recently suffered a major setback due to harsh environmental conditions experienced in the Atlantic, where sulphur eruptions and algal blooms within the grow-out areas have led to mass mortality of oysters.

There are a few potential sites for aquaculture development, identified by the Government of Namibia and some private investors, that are close to the Namib Desert, in the very arid Erongo Region (Figure 2) in the west of Namibia.

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[1] The author has visited many sites in Namibia and one key site in both Botswana and South Africa. These sites have been highlighted in the review.

[2] Although these few on-shore mariculture farms are located within the Namib Desert area, the fact that they utilize water from the Atlantic Ocean disqualifies them from the scope of this review.

FIGURE 2
The dry and arid features of Erongo Region, Namibia

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Beside the Kalahari and the Namib deserts, there are other vast areas of arid/semi-arid lands in Namibia, South Africa, Angola, Mozambique, Zambia and Zimbabwe. Much of these lands are either irrigated farm lands or are used for livestock ranching, or are completely underutilized due to their state of aridity. Stronger solar radiation, extreme temperatures and higher levels of water evaporation characterize much of these areas. There is little rainfall occurring during the summer periods (November to April). Groundwater, accessed through drilled boreholes, is the main source of water supply, unless the area has a perennial river or reservoir.

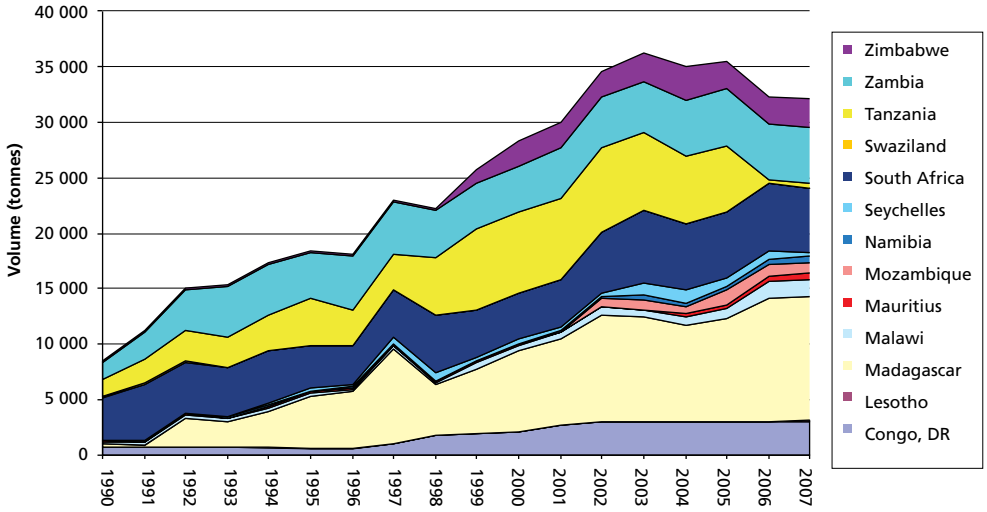
The upper Karoo districts of South Africa, in Eastern Cape Province (dubbed the "place of great thirst"), which receive less than 200 mm of rainfall per year are an example. There is a large-scale freshwater aquaculture project called the Camdeboo Satellite Aquaculture Project (CSAP) that is being established just beyond the small town of Graaf Reinet. This large-scale project aims mainly to utilize borehole groundwater and is starting production in 2011.

In Northern Botswana, near the border with Zimbabwe and just outside the main Kalahari Desert, a multi-million dollar, vertically integrated tilapia project is being planned as part of an integrated large-scale agricultural/aquaculture complex, jointly developed under a private and public partnership scheme between the Government of Botswana (GoB) and a multinational investment company, the TAHAL Group, based in Israel (GoB, 2008). This project, called the Zambezi Integrated Agro-Commercial Development Project, aims to utilize water pumped from the Zambezi River (via a pipeline that stretches for about 50 km). Production is expected to start in 2014. A few small-scale fish farms are also proliferating in this area.

Unlike in other countries such as Egypt, very little is known or recorded about the success of aquaculture in deserts and arid lands so far, since it is an activity that is in its early stages within the region. Aquaculture in Southern Africa dates back to the 1960s and was introduced by governments and donor agencies on a small-scale subsistence basis and for rural development, and was intended to complement agricultural practices mainly for food security reasons. Fish farms were mainly sited in tropical/subtropical lands where water is in abundance; probably none were established in arid lands. Production systems were characterized by small ponds constructed near existing water sources such as rivers, reservoirs, etc., and managed at low cost. Some ponds were even rain-fed during the summer periods.

Species such as tilapia (*Oreochromis* spp.), North African catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio*) were mainly cultured for domestic consumption. Unlike in many Asian countries, small-scale subsistence-oriented aquaculture has been a general failure in Southern Africa. There are new interventions in the pipeline in many countries that aim to change the situation and produce sustained growth in this sector. One example of this is the FAO Special Programme for Aquaculture Development in Africa (SPADA) (FAO, 2008). Such approaches, if implemented well, provide good potential for an accelerated aquaculture development in Africa, as they aim to promote the development of profitable small- and medium-scale aqua-businesses. Large-scale commercial ventures, both freshwater and mariculture, peaked in the late 1990s and

FIGURE 3
Aquaculture production in Southern Africa



Source: FAO, 2009a.

early 2000s. These have been the driving force behind aquaculture production in Southern Africa so far (Figure 3). However, the large-scale commercial investments planned in the desert and arid lands of South Africa, Botswana and Namibia have the potential to outclass those that are in areas with better potential in terms of water supply.

In addition to those activities mentioned above, culture-based fisheries have existed for many years. Water bodies such as dams, reservoirs, natural water-holes, disused mine pits, natural fountain pools, etc., exist in the arid lands of Southern Africa, and can be used for this extensive form of aquaculture. In many countries, culture-based fisheries have provided a large source of fish at minimal cost and, in some cases, have become an important recreational fishing ground. These water bodies are managed to ensure their long term sustainability. In fact, the Ministry of Fisheries and Marine Resources of Namibia has been enhancing fish stocks in many of its state owned water bodies for many years. A number of these dams are located in arid lands.

GEO-HYDROLOGICAL MAPPING

Geo-hydrological patterns can be an important indicator to determine areas with good aquaculture development potential. For instance, while vast areas in Namibia have little water, a geo-hydrological survey has shown that, despite low rainfall, there are pockets of the country with very good groundwater reserves. The underlying rocks are structured to allow good containment of groundwater, which is constantly recharged or replenished by annual rainfall.

In some cases, there are "underground rivers" that stretch for hundreds of miles. One commercial farmer in Pretoria, South Africa, has reported that his efficient borehole, which is capable of producing over 90 m^3 of water per hour, lies within a "crack" of the Okavango underground river line. The mighty Okavango River (one of the largest in Southern Africa) stretches for about 1 600 km from Angola to Botswana via Namibia and through the Kalahari Desert, where it then forms the Okavango delta, northwest of Botswana. The Okavango basin itself stretches for thousands of square kilometres and studies have revealed that massive volumes of water from the river have recharged groundwater reserves in the dry, arid lands of Namibia, Angola, South Africa and Zimbabwe.

Namibian geohydrological maps also provide data on the buried rock structures. As well as indices to estimate the volumes of groundwater potentially available, and the possible annual recharge/replenishment patterns, the rock structures also determine the feasibility of water extraction by boreholes and the drilling depth required for access. Such surveys, supported by additional research information, have aided the Ministry of Fisheries and Marine Resources and other potential aquaculture developers to map potential aquaculture zones based on the availability of water and other associated economic factors. In this context, the author was involved in conducting a feasibility study and research for freshwater aquaculture development in a relatively arid region of Omaheke, located in the eastern part of Namibia, that covers a surface area of about 85 000 km^2.

It is important to note that the quality of the groundwater is generally geothermic and has variable concentrations of salinity, heavy metals and minerals; water quality determination is, therefore, essential during feasibility studies. Fish stock trials are also important to anticipate the potential growth in such water resources. For example, Mozambique tilapia (*Oreochromis mossambicus*), a candidate fish species for most arid regions of Namibia, can tolerate brackish water at salinity levels of up to 40 ppt. Water needs to be tested to ensure it is of good quality and that heavy metals are within threshold limits for optimum fish growth and survival and for food safety reasons. Good water quality is also useful for crop/horticultural irrigation, which may be part of an integrated agriculture-aquaculture practice.

HUMAN RESOURCES

One of the main attractions of accelerating aquaculture development in Southern Africa is the sector's potential to generate employment, thus, contributing to poverty alleviation and food security for millions of poor people. This potential is being taken into consideration at the policy level by governments of the region. However, in reality, employment opportunities in the sector so far are still very limited as the sector is still gradually expanding.

Namibia has one of the most organized aquaculture policy and management structures in Africa. In 2003, a Directorate of Aquaculture was set up within the Ministry of Fisheries and Marine Resources to administer and regulate all aquaculture operations in the country. The directorate has its central administrative functions in the capital, Windhoek, and has regional one-stop information centres where well-trained extension agents, technicians, biologists and other resource persons are based. These are essential human resources for small-scale communities and extension programmes. The Namibian aquaculture sector alone currently has about 76 permanent government employees, with an additional 95 employees as farm attendants at its country-wide cooperative fish farms. Hundreds of self-employed small-scale subsistence oriented fish farmers stand also exist in this country. Larger-scale pipeline projects in arid lands are expected to expand employment in the sector. Spin-off sectors, such as fish feed production, marketing, etc., are also expected to generate additional employment.

There are thousands of unemployed youths in Namibia, and the government earmarked 2010 as the "year for the youths" in terms of development. Various incentives were designed to encourage young people to develop aquaculture in the country, wherever resources permit, either as self-employed or working in cooperatives under government initiated pilot projects. However, such youths require extensive and effective training to obtain the necessary technical skills.

Similarly, the gender sensitive CSAP project in South Africa intends to employ many unemployed youths and women within the areas of Graaf Reinet. Many of these women and youths are currently undergoing a comprehensive skills development programme to enable them to be fish farm attendants, supervisors, etc. (L. de la Harpe, personal communication, 2010).

According to the 2009 Aquaculture Institute of South Africa (AISA) – Aquaculture Benchmarking Survey (AISA, 2009), the South African aquaculture industry employed 1 837 full-time and 355 part-time employees in 2008 (Britz, Lee and Botes, 2009). Employment in aquaculture grew by approximately 80 percent between 2005 and 2008. Significant employment opportunities are also expected once the large-scale aquaculture project in Botswana becomes operational. Currently, less than 100 people are employed in the aquaculture sector in Botswana (FAO, 2007). At the private commercial level, the rate of employment is generally based on the intensity of the operation, the production level and the associated profitability of the operation. Farmers try to avoid high labour costs; generally, the farm owner serves as his own farm manager but may recruit a few farm attendants to assist on a part-time or temporary basis, as and when needed.

FARMING SYSTEMS DISTRIBUTION AND CHARACTERISTICS

Generally, production systems for fish farming projects in desert and arid lands vary based on the water resource type, its availability and the surrounding environments, also taking cognisance of associated investment and construction costs. Intensive, semi-intensive and extensive systems have been identified in the arid lands under review. Some of the identified aquaculture projects in desert and arid lands are listed in Table 1.

TABLE 1
List of selected aquaculture projects in desert and arid lands in Southern Africa

Country	Fish farm/project	Location	Region/ province	Status	Water resource
Namibia	Eco-Fish Farm (Pvt.) Ltd.	Mariental town outskirts, Hardap Dam	Hardap	In operation Private	Hardap dam (from Fish River)
Namibia	Hardap Inland Aquaculture Centre	Mariental town outskirts, Hardap Dam	Hardap	In operation Government initiated project	Hardap dam (from Fish River)
Namibia	Fontetjie Fish Farm Project	Keetmanshoop town outskirts	Karas	In operation Government initiated project	Groundwater (boreholes)
Namibia	Uis Aquaculture Farming (Pvt.) Ltd.	Uis District, disused mine pit, Uis Centre (1)	Erongo	In operation (pilot scale) Private	Disused mine pit groundwater reservoir
Namibia	Uis Youth Project on Aquaculture	Uis District, disused mine pit, Uis Centre (2)	Erongo	Initiation phase Community Youth-JICA-MFMR pilot project	Disused mine pit groundwater reservoir
Namibia	Leonardville Village Aquaculture project	Leonardville town outskirts	Omaheke	Under construction Government initiated pilot project	Groundwater Borehole/fountain
Namibia	Community based water point tanks	Whole of Omaheke Region	Omaheke	In operation/ planning phase Government initiated pilot project	Groundwater/ Borehole
South Africa	Camdeboo Satellite Aquaculture Project	Graaf Reinert	Eastern Cape	Establishment phase Multi-stakeholder	Groundwater/ boreholes
Botswana	Zambezi Integrated Agro-commercial Development Project	Pandamatenga District	Northern Botswana	Planning phase Public/Private Partnership Scheme	Water drawn from the Zambezi through long pipeline
Zimbabwe	Lowveld Cocrodile & Fish Farming Project	Chiredzi District	Masvingo	In pilot phase	Water drawn from sugar cane irrigation dams

Recirculation aquaculture systems – Water conservation is the main aim of using recirculation aquaculture systems (RAS). Many commercially operated ventures that extract underground water or that are in areas of high evaporation rates use this form of highly intensive production system. Fish are reared in concrete or plastic tanks that allow zero water seepage and the water is conserved through recycling and reuse. In some cases, the rearing unit is hosted in a greenhouse to maintain optimum water temperatures, especially when warmwater fish, such as tilapias and catfish are reared. The extreme cold of the winter season can occupy about four months in Southern Africa (from May to August).

In Namibia, this type of culture system has been erected by the Hardap IAC, Ecofish Farm (Pvt.) Ltd. (Figure 4) and the Fontetjie Fish Farm and is also being set up at the Leonardville site. Similarly, the CSAP in South Africa has planned to use RAS on many of its satellite farms for hatchery and grow-out operations. A number of South African fish farms have even developed advanced RAS and aquaponics systems. Nutrient rich effluent water is further utilized for irrigation purposes, thus, comprising integrated aquaculture.

FIGURE 4
A recirculation aquaculture system in action, covered by a greenhouse, Hardap Region, Namibia

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Cage culture – In some cases, the water contained in water bodies (dam, reservoir, disused mine pit, etc.) may be adequate enough to accommodate floating cages for grow-out purposes, providing the water quality is good. A private commercial farmer has established a small-scale floating cage unit within an open disused mine pit in Uis, Erongo Region of Namibia (Figure 5). A hatchery that supplies fingerlings is located a few kilometres away from the cage site. This farmer aims to produce ~5 tonnes of market size fish per month. Namibia, with its rich mineral resources, has many disused mine pits that contain groundwater with the potential for aquaculture development.

FIGURE 5
Floating cages in a small ground water reservoir, Uis, Erongo Region, Namibia

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Earth pond culture – Depending on local available water volumes, soil quality and water seepage rates, fish farms may use open pond, semi-intensive culture systems. The ponds may be plastic lined to prevent water seepage if the soils are highly permeable (like those in sandy deserts). Open pond culture requires large volumes of water as most are flow-through systems.

The Zambezi Integrated Agro-Commercial Development Project being planned in Botswana will extract

water from the Zambezi River and then utilize both open water pond systems and RAS. Another private farm located in Leonardville, Omaheke Region of Namibia, grows tilapia in open pond systems utilizing groundwater from an aquifer (Figure 6). Similarly, the large-scale pilot project in existence in Chiredzi, lower Zimbabwe has large commercial, flow through ponds.

Open tank culture – Semi-intensive/ extensive tank culture has been recorded in Namibia and some parts of South Africa. In such systems a borehole is drilled and a water storage tank (tank volumes vary, but most are ~60 m^3; Figure 7) is erected for livestock and further utilized for small-scale fish rearing. It costs ~USD30 000 to drill a borehole to about 100 m depth. In Namibia, one private farmer in the Omaheke region rears some ornamental fish (koi carp *Cyprinus carpio*) in multi-purpose water storage tanks. In addition, in the same region, the Ministry of Fisheries and Marine Resources of Namibia has begun stocking some of the community based water points with fingerlings from its hatcheries. About 37 small-scale fish farmers in arid lands received fingerlings from the government in 2008.

Stock enhancement practices in small water bodies – Small water bodies located within desert and arid lands can be important resources for farmed fish. Such water bodies derive their water from seasonal rivers, as is the case with the Fish River that feeds the Hardap dam in Namibia. Alternatively, they may be low-lying natural or artificial water reservoirs/pools fed by groundwater through springs or aquifers. The advantages of this form of aquaculture are that costly facilities are not required and management is limited; thus, the fish are produced at lowest possible cost (Rouhani and Britz, 2008). Recreational fishing has been noted within most of these small water bodies (Figure 8).

FIGURE 6
Private farms at Leonardville, Omaheke, growing tilapia in earth ponds utilizing aquifer waters

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FIGURE 7
Private farms at Leonardville, Omaheke, growing tilapia in earth ponds utilizing aquifer waters

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FIGURE 8
Harvesting of a state-owned dam in arid lands, Namibia

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CULTURED SPECIES

In general, aquaculture policy in countries in Southern Africa favours culturing their indigenous species for environmental and biodiversity concerns. There are trepidations that some highly invasive species such as Nile tilapia (*Oreochromis niloticus*) not indigenous to Namibia, South Africa and Botswana, but an attractive candidate for commercial aquaculture, can easily replace endemic tilapia species such as the Mozambique tilapia (*O. mossambicus*), three spotted tilapia (*O. andersonii*), longfin tilapia (*O. macrochir*), blue tilapia (*O. aureus*) and others within the local ecosystems, mainly through hybridization. Nile tilapia is believed to have spread throughout Southern Africa uncontrollably since its introduction about 50 years ago (van der Waal, 2002). Despite these concerns, the Nile tilapia is the most favoured candidate for aquaculture in Southern Africa to date. Indigenous species are however still regarded as important for extensive aquaculture practices, i.e. for stock enhancement. Tilapias have a better market share than carps and catfish in most parts of Southern Africa (van der Waal, 2002).

The national authorities in Botswana, Namibia, and South Africa are highly cautious, and only allow the introduction of alien species after a risk assessment in the area and surrounding ecosystem. However, many potential commercial farmers claim that some of the indigenous species mentioned above are not as economically viable in terms of growth rates, food conversion efficiency, disease resistance and management as Nile tilapia. Hence, many commercial farmers prefer rearing introduced, fast growing hybrids for better returns on investments. In any case, they need to obtain authorization from the relevant authorities.

The indigenous species that are cultured by smallholder farmers in the area under review include Mozambique tilapia (*O. mossambicus*), three spotted tilapia *(O. andersonii*), redbreasted tilapia (*Tilapia rendalli*) and North African catfish (*Clarias gariepinus*). The common carp (*Cyprinus carpio*), which was introduced many years ago, is now well-established within the ecosystems and is a good candidate species because of its positive production characteristics. There are several other indigenous species that are still being investigated for potential freshwater aquaculture, including the giant river prawn (*Macrobrachium rosenbergii*). Apart from molluscs, the production of land-based marine or brackishwater finfish species is still very limited in the arid land areas of Southern Africa (Table 2).

In Namibia, trials have indicated that, with good feed, water quality and management, the hybrid all-male red tilapia (*Oreochromis* spp.) being grown at the

TABLE 2
Cultured species produced at fish farms located in arid lands

Country	Fish farm/project	Species grown
Namibia	Eco-Fish Farm (Pvt) Ltd	Hybrid red tilapia *(Oreochromis* spp.*)* special licence of introduction provided
Namibia	Hardap Inland Aquaculture Centre	Indigenous *(O. mossambicus)*, *C. Carpio*, Yellowfish, mudfish (trials)
Namibia	Fontetjie Fish Farm project	Indigenous *(O. mossambicus)*, *C. Carpio*
Namibia	Uis Aquaculture Farming (Pvt) Ltd	Indigenous *(O. mossambicus)*, *O. andersonii (C. gariepinus)* trials
Namibia	Uis Youth Project	Indigenous *(O. mossambicus)* trials
Namibia	Leonardville Village project	Indigenous *(O. mossambicus)* trials
Namibia	Community based tank farms in Omaheke	Indigenous *(O. mossambicus)*, *(C. gariepinus)* trials
South Africa	Camdeboo Satellite Aquaculture project	Indigenous *(O. mossambicus)*, *(C. gariepinus) (C. Carpio)* trials
Botswana	Zambesi Integrated Agro-commercial Development Project	*Oreochromis* spp.
Zimbabwe	Lowveld Crocodile & Fish Farming Project	*Oreochromis* spp.*, C. Carpio*

Ecofish Farm in Hardap (Figure 9) can grow from fingerling stage (20 g) to market size (700 g) in about eight months, in RAS (F. Naviloski, personal communication, 2010). This is a good result for commercial aquaculture that is oriented to export markets. In comparison, given the same conditions, the indigenous *O. mossambicus* takes a year to grow to 250–400 g, as experienced in Namibia. Both *Clarias gariepinus* and *Cyprinus carpio,* although only cultured in Namibia on a small-scale, have generally performed when grown under favourable conditions.

FIGURE 9
Red tilapia in grow-out production at Ecofish Farm, Hardap, Namibia

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Recently, the culture of ornamental fish including koi carp (*Cyprinus carpio*) is becoming big business in Southern Africa, practised mainly by commercial farmers. In 2008, this industry was worth almost USD1.5 million in South Africa alone and, after trout and abalone, ornamental fish are considered one of the most valuable commercial species groups.

CULTURE PRACTICES

Hatcheries

The Namibian Government has begun setting up hatcheries in regional centres around the country for the production and supply of broodstock, fry and fingerlings to government initiated pilot projects and interested private farmers. These hatcheries mainly produce indigenous species such as Mozambique tilapia (*O. mossambicus*), three spotted tilapia (*O. andersonii*), redbreasted tilapia (*T. rendalli*), North African catfish (*C. gariepinus*), as well as common carp (*C. carpio*). Other species are being investigated prior to the grow-out phase. The hatcheries basically consist of indoor RAS for fry production (Figure 10) and outdoor secondary nursery ponds for fingerling production. If the hatcheries are located outside the main grow-out area, the government has also provided transport and equipment for fingerling distribution. So far, the hatcheries operating within the arid lands of Namibia are:

- Hardap IAC hatchery (supplying fingerlings to the southern and eastern regions).
- Uis Aquaculture Farming (Pvt.) Ltd. hatchery (supplying fingerlings for own cage farm and with potential to supply interested farmers in the area).
- Leonardville hatchery (supplying fingerlings throughout the Omaheke Region, once in operation).

Other hatcheries located in non-arid zones, but also important for broodstock and fingerling production around the country, are:

FIGURE 10
Indoor fish fry production unit, Omahenene/Onavivi, Namibia

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- Omahenene/Onavivi hatchery, in the Omusati region (supplying fingerlings within the northwest regions of Namibia.
- Ongwediva hatchery, in the Oshana region (supplying fingerlings within the northwest regions of Namibia); Kamutjonga Inland Fisheries Institute hatcheries (supplying fingerlings within the northeast regions of Namibia).

The most significant hatchery projects in South Africa and Botswana are:

- CSAP in South Africa, which is setting up its own hatchery on-site for tilapia, catfish and common carp. The hatchery will supply fingerlings to all the satellite farms located in the surrounding areas.
- The Zambezi Integrated Agro-Commercial Development Project in Botswana will also have its own tilapia hatcheries on-site. This project aims at producing 40 000 tonnes of market size fish once in full operation. Usually, private commercial fish farmers also have their own hatcheries. Cooperation between hatchery research projects at Stellenbosch University, Rhodes University and private hatcheries in South Africa have resulted in improved quality of start-up broodstock and fingerlings.

Grow-out farms

In Namibia, grow-out farms in desert and arid lands use farming systems varying from intensive, semi-intensive to extensive. Highly intensive systems such as RAS (in green house) have been set up at Fontetjie, Hardap IAC, Ecofish Farm (Figure 11), the latter having the capacity to produce 360 tonnes of fish per annum. Such RAS are also being established at Leonardville and several other sites under investigation across the country. However, a number of community based, small-scale ponds and on-farm water storage tanks of different sizes are also used as grow-out systems in the arid regions. The Karoo districts of South Africa are very dry; hence, the CSAP intends to use integrated and intensive RAS for grow-out production.

A pilot-scale, intensive cage culture system has been set up at the Uis Aquaculture Farm (Pvt.) Ltd. This floating cage farm aims to produce ~60 tonnes of fish per year. Within the same area, in Uis, a floating cage project for youth development is being established and is expected to produce a minimum of 30 tonnes of fish per year.

Plastic lined ponds are used in mariculture for the rearing of spat oysters and for oyster quarantine purposes onshore, for example in Walvis Bay. This coastal town is in the middle of the highly sandy Namib Desert. The Zambezi Integrated Agro-Commercial Development Project in Botswana will utilize both intensive RAS and open earth ponds on a large-scale for its grow-out production.

FIGURE 11
Super intensive grow-out facility at Hardap IAC, Namibia

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SECTOR PERFORMANCE

Currently, as can be observed from this review, little has been achieved in Southern Africa with regard to aquaculture in deserts and arid lands so far. Most of the operations are still in the pilot-scale phase. However, with the currently great focus on aquaculture by policy makers in the region, the potential looks bright; major developments are expected within the next ten years. Aquaculture development is being prioritized by all countries in Southern Africa.

PRODUCTION

Total freshwater aquaculture production in Namibia in 2009 was less than 100 tonnes, potentially generating an approximate value of USD250 000; in comparison, capture fisheries had a landed volume of about 400 000 tonnes valued at over USD300 million. Namibia's combined fishing sector contributes about 6 percent to GDP. The Namibian Government has already invested well over USD750 000 towards the development of aquaculture. A further investment of USD8 million is planned for the next five years, a recognition that developing aquaculture has multiple potential in terms of employment creation, improved fish supplies, the development of local associated industries (packaging, distribution, feed, etc.) and improved livelihoods for many people, especially in the rural areas (G. Kibria, personal communication, 2010). The results of these investments are not yet known, as almost all initiated community based aquaculture projects (including those in arid lands) are in a pilot-scale phase.

If successful, the large-scale integrated operation in Botswana is expected to generate significant results. Considering the magnitude of its production volume (40 000 tonnes per annum at full operation), this could be a very significant event for Southern Africa (probably one of the world's largest production volume from a single fish farm). Using current regional fish prices, this could be equivalent to an income of ~USD100 million per annum from fish alone. Additional income will be generated from its multi-integrated agricultural projects. Currently, the fisheries (mainly capture fisheries) contribution to GDP in Botswana is around 0.002 percent (Wyk and Strub, 2007).

Aquaculture production in South Africa mainly consists of abalone. Besides the CSAP project mentioned below, not much has been documented regarding aquaculture production in the arid lands of this country.

MARKET

Southern Africa has a strong tradition of consuming fish. Demand for farmed fish products, especially freshwater fish such as tilapias, is generally good. This fact has attracted many investors to consider setting up aquaculture businesses in the region. Wild catches of freshwater fish are undoubtedly dwindling and many people are gradually becoming accustomed to buying farmed fish, although supply is still very limited. The two large-scale commercial ventures (CSAP and the Zambezi Integrated Commercial Project in Botswana) described in this review aim to produce tilapias and catfish for local and regional markets, following regional market feasibility studies. Species such as catfish and carp are becoming increasingly popular in the markets of Namibia, Angola and South Africa.

Since the demand for farmed fish exceeds supply, whatever is produced is sold out immediately after harvest as fresh fish. Markets include sales to individuals at the farm gate or to local restaurants, supermarkets, seafood distribution outlets, etc. Most of the fish are either sold fresh, immediately after harvest or frozen (whole gutted). Consequently, there is little processing or fish storage.

The CSAP project in South Africa intends to grow its fish (tilapia and catfish) to a market size of <100 g and then to process the product through canning (in large cans) for distribution to schools, hospitals and prisons where, according to their marketing feasibility studies, there is huge demand (L. de la Harpe, personal communication, 2010). Fish prices vary according to location and species. The current average regional price for farmed whole gutted tilapia is ~USD2.50/kg. However, the retail prices of whole gutted and frozen tilapia in some supermarket chains in South Africa and Botswana is >USD4.50/kg. This compares favourably with international market prices.

Southern Africa is experiencing a gradual shift from a focus on international markets (European Union, United States of America, etc.) for farmed freshwater fish products towards local and regional markets. This is because costs of production in Africa are much higher than in Asia. Most operations are relatively small scale in terms of

production volumes and, hence, may not compete in terms of economies of scale. Many inputs, such as feed and equipment, have to be imported and, since freight space has become more expensive, this contributes to high production costs.

CONTRIBUTION TO THE ECONOMY

Generally, in all the 15 countries of Southern Africa, the contribution of aquaculture to the economy is relatively negligible as the sector is in its early stages and production is still low.

INSTITUTIONAL FRAMEWORK

In Namibia, the Directorate of Aquaculture has set up regional centres for the management of government initiated pilot projects, as well as the provision of extension services to small-scale fish farmers and the management of culture based fisheries in state-owned water bodies. Some of these centres, for instance, the Hardap Inland Aquaculture Center, Kamutjonga Inland Fisheries Institute (KIFI), Omahenene/ Onavivi, have fingerling producing units and research facilities (Figure 12). The Directorate of Aquaculture is also supported by other directorates within the Ministry, such as the Directorate of Resource Management (responsible for scientific research and advice); the Directorate of Operation and Surveillance (responsible for monitoring, control and surveillance); the Directorate of Policy Planning and Economics (responsible for the coordination of the planning activities of the MFMR, as well as formulating fisheries policies and legislation and undertaking research and advising on socio-economic issues).

In South Africa, aquaculture is regulated by the Department of Agriculture, Forestry and Fisheries (DAFF) at the policy level. Recent political changes in South Africa may lead to institutional reforms in the fisheries and aquaculture sector. Other departments and institutions with close ties to aquaculture development in South Africa include the Department of Water Affairs, the Aquaculture Institute of South Africa (AISA) and the Aquaculture Association for Southern Africa (AASA).

In Botswana, aquaculture is within the remit of the Fisheries Unit of the Department of Wildlife and National Parks (within the Ministry of Environment, Wildlife and Tourism). This unit deals with fisheries technical matters, extension services and aquaculture. The government has recently expressed its intention to develop an aquaculture policy and strategic planning document to pave the way for the future development of the sector.

FIGURE 12
Research facility at Kamutjonga Inland Fisheries Institute, northern Namibia

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GOVERNING REGULATIONS

There is currently no specific legislation for developing aquaculture in desert and arid lands of Southern Africa. However, a legal framework for the development of aquaculture is in place in Namibia (GoN, 2001, 2002, 2004). This legislation ensures that the sector is managed sustainably and has been harmonized with other legislation concerning the environment, biodiversity, inland fisheries management, etc.

In South Africa, the newly formed Department of Agriculture, Forestry and Fisheries is currently developing an accessible and enabling regulatory

framework to guide the development of sustainable aquaculture practices. This development follows a long period during which the sector has been fragmented and regulated by separate government departments, and many requests for a united aquaculture policy and strategy. Towards this goal, two long-term policy documents are being prepared: the National Department of Agriculture draft aquaculture policy and the Marine and Coastal Management draft marine aquaculture policy.

There is no separate fisheries regulation in Botswana, which is probably related to the absence of a national fisheries policy. The only fisheries management legislation that exists is the Fish Protection Act, CAP 38: 05 of 1975, managed under the Department of Wildlife and National Parks strategic plan which is founded on the Wildlife Conservation and National Parks Act of 1992 (GoB, 2009). The basis of this plan is that fish and wildlife resources contribute to the cultural, socio-economic and biological integrity of the nation through:

- creation of economic opportunities;
- diversification of the economic base;
- contribution to biological diversity;
- provision of resources for tourism development; and
- provision of platform for aesthetic, scientific, recreational and educational values.

In general, the current legislative framework for aquaculture in Southern Africa needs to be revisited, updated and harmonized to take into account the developments being initiated in desert and arid lands.

APPLIED RESEARCH, EDUCATION AND TRAINING

In Namibia, aquaculture training has been named as a priority area by the government, which has established training, extension and research facilities across the country. The MFMR begins with pilot projects, followed by research and development, in the whole value chain from fish production through to marketing. The R&D efforts will ensure that each venture is sustainable, through improvements based on lessons learnt. The Department of Fisheries and Aquatic Sciences at the University of Namibia also assists in graduate training and research for fisheries and aquaculture candidates. The Polytechnic of Namibia is planning to introduce aquaculture related courses and has already supported courses in business management, information technology, agricultural management, etc., for those operating or intending to run aqua-businesses.

In addition, fisheries and aquaculture technicians and biologists working within the Directorate are regularly sent abroad to key producer countries such as China, Norway, South Africa, Malawi, etc., to participate in further practical training and attachment courses. Technical experts from Bangladesh, China, Norway, Spain, Viet Nam, Japan, Cuba, the United States of America and many others have also visited Namibia under bilateral relations programmes and have been of great assistance. The principal aim of such relations is to develop a sustainable and effective skills base for small-scale community-based aquaculture extension.

International institutions such as FAO and the WorldFish Center are closely linked with developments in the region and offer regular training and technical advisory services on aquaculture. For instance, FAO is currently offering short-term, custom based training courses on complex subjects such as Risk Assessment in Aquaculture and Aquatic Biosecurity subjects in the region. The WorldFish Center, through its technical centres in Malawi and Zambia, has been instrumental in training, research and development on inland fisheries and small-scale aquaculture.

The intergovernmental organization for Marketing Information and Technical Advisory Services for the Fisheries Industry in Southern Africa (INFOSA) collaborates with MFMR in offering localized and tailor made training courses on aquaculture in Namibia (Figures 13a and 13b). INFOSA has trained over 100 participants in the past three years, including fish farmers from the southern arid areas of Namibia.

FIGURE 13a AND 13b
Participants receiving hands-on training on (a) aquaculture techniques and practices of fish stocking and (b) fish processing at Hardap, Namibia. INFOSA/MFMR course

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The CSAP in South Africa has a comprehensive training programme for youths and women who do not have any background in aquaculture. This programme, commissioned by FAO in July 2010, is integrated with adult basic education, business management and orientation programmes, with follow-up practical mentorship programmes. The training courses are also linked with national training programmes being offered by the AISA and other local institutions. The project is conducting a market research and development model for canned freshwater fish products (probably first of its kind in Southern Africa), and is also seeking funds for R&D in localized fish feed production.

Regional universities such as the Bunda College in Malawi and Stellenbosch and Rhodes universities in South Africa have traditionally been important training and research centres in all areas of aquaculture. Other universities and technical colleges in Southern Africa have begun incorporating aquaculture in their curricula.

Despite all these, the concept of developing aquaculture in desert and arid lands is still relatively novel. Thus, learning from successful operations in the pilot projects in operation today is crucially important. Most farmers, especially in the private sector, are cautious and sceptical about constructing fish rearing facilities in locations where risks, as well as infrastructural costs are potentially high, such as deserts and arid lands. Farmers will wait to see if there are success stories generated by the pilot scale farms.

TRENDS, ISSUES AND DEVELOPMENT

The main constraints and challenges in developing aquaculture in the desert and arid lands of Southern Africa include:

- Lack of well-defined policy, public sector interventions, legal frameworks and institutional capacity for the development of aquaculture in general, especially in countries such as South Africa, Botswana, Angola and Zimbabwe.
- Lack of finance and start-up capital for developing aquaculture. Financial institutions are still reluctant to lend money for aquaculture projects due to the high risk involved. These challenges are slowly being tackled in Southern Africa. In Namibia, for example, the government has to date invested over USD1 million on aquaculture development, with more funds allocated in its annual fiscal budget. The government is also encouraging financial institutions to recognize aquaculture as a potential business and to assist in its expansion.
- Lack of interest by the private sector in investing in aquaculture in desert and arid lands because of the potential risks involved, including the high costs associated

with constructing and managing the production facilities, taking into consideration the returns on investment envisaged. The private sector is the driving force behind aquaculture development in Southern Africa.
- Lack of basic infrastructure such as hatcheries, fish feed factories, etc., and in some cases, lack of basic infrastructure such as roads, electricity, communication, etc., especially in remote areas.
- For large-scale commercial aquaculture ventures, the introduction of fast growing species is needed for cost management and to provide good returns on investments; however, some governments are reluctant to issue licences for introductions unless a risk assessment has been undertaken.
- Scarcity of water resources in some areas which makes it difficult to plan for large-scale expansions as groundwater resource replenishment is based on annual rainfall. Surface water may be insufficient in drought years.
- In some places, the quality of the groundwater is not satisfactory for some freshwater aquaculture species. For example, although species such as the indigenous Mozambique tilapia (*O. mossambicus*) can tolerate higher levels of salinity, their growth rates are compromised as salinity levels increase.
- Fish feed and other raw materials are currently imported and are therefore, expensive and beyond the reach of many small-scale or large-scale fish farmers.
- There is a lack of a biosecurity framework in Southern Africa. Fish disease outbreaks have been recorded recently in Southern Africa where the region is battling with the spread of epizootic ulcerative syndrome (FAO, 2009b).
- Lack of clear-cut marketing feasibility studies on which the private commercial sector can base their business plans prior to project implementation.
- Adequate skills for aquaculture development are still limited, so training and capacity building programmes are important for the development of a vibrant aquaculture sector.

SUCCESS STORIES

One case study is provided in this section of the review.

Camdeboo Satellite Aquaculture Project, South Africa

The CSAP is located in the dry area of Graaf Reinet, in the eastern Cape Province of South Africa. The area receives about 230 mm of rain per year, with most rainfall occurring mainly during the autumn. Average temperatures range from 17 °C in June to about 30 °C in January, with coldest temperatures recorded in July at about 2.5 °C. Although very arid on the surface, the whole area has many livestock farms and the lands have pockets of good groundwater supplies, ready to be further utilized for aquaculture.

The overall goal of CSAP is to link poor, vulnerable, marginalized communities to sustainable livelihood and economic activities, while simultaneously addressing food security. CSAP has initiated a commercially viable fish production venture through the establishment of aquaculture "clusters", each consisting of a central management and support farm and a network of satellite farms, which will benefit from economies of scale through their collaboration. The fish produced will be canned in order to increase shelf-life and sold at an affordable price in order to fill the enormous gap caused by the reduction in the South African annual pilchard quota. This could considerably alleviate poverty through the creation of sustainable self-employment for rural women, youths and the stimulation of pro-poor economic growth, whilst simultaneously producing an affordable, nutritional, food source for low income groups.

Each satellite farm is designed to produce 10 tonnes of fish per month (120 tonnes per annum). This is enough to feed over 15 500 people per annum, based on the national fish consumption rate of 7.7 kg per person per year. Fifty satellite farms are envisaged in the area.

CSAP is currently working on the basic product development, testing three fish species – Mozambique tilapia (*Oreochromis mossambicus*), North African catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio*) – in a range of tomato sauce recipes. CSAP will also conduct a national market acceptance survey that will be the ultimate deciding factor in selecting the species of fish to rear. CSAP believes that the gap in the canned fish market is enormous, but it is imperative for them to develop a marketable product in order to proceed.

The project has received the approval of the DAFF – the national authority overseeing aquaculture development in South Africa. DAFF is assisting CSAP in sourcing funding for research and development to further refine the canned fish product, as well as for the development of a local fish feed based on ingredients that could be grown locally.

The project design phase of CSAP was completed in 2009. Full-scale production is expected to commence in 2011 once funding for developing the rearing infrastructure and the purchase of other raw materials is available. This will involve the construction of RAS facilities at the central farm, as well as satellite farms. The central farm will include a hatchery, which will supply all the required fingerlings to the satellite farms.

WAY FORWARD

There is a huge opportunity for Southern Africa to explore the freshwater and brackish water resources that exist in its vast deserts and arid lands, where there is generally limited competition for land from other developmental activities such as agriculture, town development, etc. However, there is a need for guidance from policy makers through the crafting of harmonized aquaculture policies, legislative frameworks, strategic plans and institutions that are aligned to potential developments in desert and arid land environments. Governments should aim at creating an enabling environment for private sector investments, promoting private sector participation, developing areas specifically designated for aquaculture and providing facilities and other necessary support services.

Role players in aquaculture should promote the new FAO initiated SPADA approach that aims to work with public and private institutions, service providers, non-governmental organizations and the private sector to establish sustainable and responsible aqua-businesses which will in turn increase employment, fish supply and investment opportunities.

There is a need for clustering small-scale farmers for their sustainability. CSAP has highlighted that the cost of operating an individual fish farm is prohibitive. Individual satellite farms can work together and thus, have bulk negotiating power when purchasing equipment, raw materials, feeds, etc. In the case of CSAP, cooperation between individual satellite farms is essential to access an existing canned fish market (where demand drastically exceeds supply) in South Africa. Such a model is worth duplicating across the SADC region.

There is a need to establish effective information exchange platforms and networks on aquaculture development throughout Southern Africa. There are responsible institutions in place, such as the AASA, WorldFish Center, INFOSA and others but these need further strengthening.

Access to finance for aquaculture development is still difficult in Southern Africa. National development banks should be encouraged to bear the risks and to provide venture capital for commercial operations.

Research, training and extension services should always be prioritized at all levels for successful aquaculture production. The concept and systems for growing fish in arid lands can be complex from a layman's perspective. In addition, more participatory action research is needed with various public and private sector stakeholders to appraise the potential role of desert and arid lands in aquaculture (Rouhani and Britz, 2008).

There is a need to set up a centralized database that integrates biophysical and socio-economic information and other parameters of importance for aquaculture development that is specific to desert and arid lands. In cases of super-intensive commercial aquaculture, there is a need to harmonize legislation that permits the introduction and rearing of fast growing species, without endangering ecological systems or environmental balance.

The next step in countries with arid lands where water is scarce and expensive is to show farmers that they could also use the water in which their fish are raised to irrigate their crops. The organic waste produced by the fish makes the water especially useful because it acts as a crop fertilizer. Such integration of aquaculture with crop production is practised in the Negev Desert of Israel, where water recycled from fish ponds irrigates desert plantations of olive, alfalfa and dates (Rothbard and Peretz, 2002). There is a need to build capacity on this subject.

There is a need for information dissemination to demonstrate the opportunities offered by desert and arid lands aquaculture in Africa to potential stakeholders and investors.

The CSAP, which is described above, is still in its pilot scale phase. Once successfully finalized, the project could have a positive effect for the Southern Africa region because of its commercial design model and for the multi-stakeholders approach that it is adopting. The theory of clustering the small-scale fish farms is essential for their sustainability and this idea is believed to have the potential to stimulate successful small-scale aquaculture ventures around the region.

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