Aquaculture experiences in the Negev Desert in Israel

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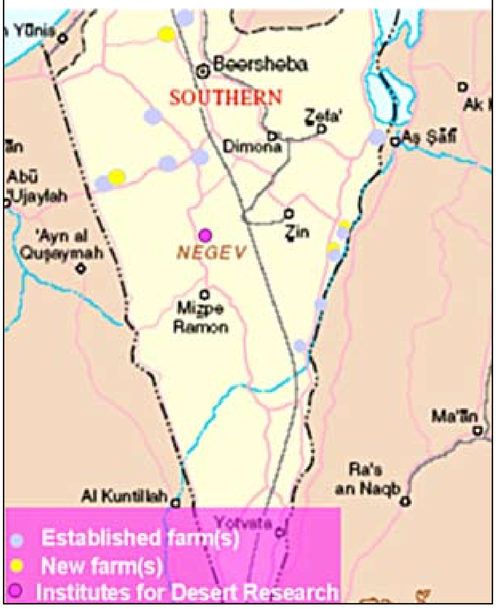
INTRODUCTION

As mentioned in the overview on desert aquaculture in Israel, two-thirds (about 13 000 km^2) of the country is covered by the Negev and the Arava desert regions. Annual rainfall varies between 60–100 mm (and less), and the desert regions are inhabited by just 2–3 percent of the country's population.

For nearly three decades, Israeli research at the Bengis Center for Desert Aquaculture (Albert Katz Department of Dryland Biotechnologies, Institutes for Desert Research of Ben-Gurion University of the Negev in Beer-Sheva, Israel) has shown that the accessible, low-cost, subsurface, brackish geothermal water found in the desert with its moderate salinity (3–7 ppt), mineral composition, constant warmth (at 39–41 °C), purity, and availability regardless of weather conditions is highly suitable for aquaculture (Applebaum, 1995; Appelbaum and Yogev, 1997; Applebaum, 1998; and Appelbaum *et. al.*, 2008). This so-called desert water has been successfully used for the irrigation of agricultural crops in the Negev Desert, easing the pressure on Israel's scarce freshwater resources. Since the late 1980s, aquaculture has also been introduced into the Israeli desert using this desert water. Through the entire Negev and Arava region, in which air and water temperatures are kept constant throughout the year, yields have been up to 35 times higher than those of fish grown in subtropics in conventional outdoor ponds, and have been achieved in half the growing cycle (Rothbard and Peretz, 2002). Currently, 15 commercial fish farms are operating in the Negev Desert producing edible and ornamental fish and crustaceans. All edible fish are produced and sold on the domestic market while most of the ornamental fish produced are exported (Figure 1).

FIGURE 1
Aquaculture farms in the Israeli Negev Desert



Species of edible fish currently being cultured in the Negev Desert, highland district, are the following: barramundi (*Lates calcarifer*); red drum (*Sciaenops ocellatus*); European seabass (*Dicentrarchus labrax*); North African catfish (*Clarias gariepinus*); and Nile tilapia (*Oreochromis niloticus*).

COMMERCIAL AQUACULTURE FARMS IN THE NEGEV HIGHLANDS DISTRICT

Kadesh Barnea Farm is the pioneer fish farm in the Ramat Negev (highland) district. In 1998, this farm started growing European eel (*Anguilla anguilla*) primarily because fresh eels could easily be exported to the European market due to Israel's geographical proximity to Europe and its position as an associate member of the European Union, and secondly due to Israel's favourable climatic conditions for raising eels. However, for cost related reasons, eel cultivation was subsequently discontinued. The farm's current facilities include ten plastic-covered fish ponds receiving brackish (4.5 ppt = 1400 mg chloride/l) geothermal (~40 °C) water from a 700 m deep local well. During the summer months, a minimum of 10–15 percent of the total volume of the ponds is renewed. During the winter months, an additional 5–10 percent of brackish water is added to maintain higher water temperatures. The temperature in the rearing ponds reaches 30 °C in the summer. The farm utilizes ca. 75 000 m^3 of water annually. Nile tilapia (*Oreochromis nilotichus*), red tilapia (*Oreochromis mossambicus* × *Oreochromis niloticus*), North African catfish (*Clarias gariepinus*), barramundi (*Lates calcarifer*), striped bass (*Morone saxatilis* × *M. chrysops*) and gilthead seabream (*Sparus aurata*) were raised. While the tilapia fingerlings were produced at the farm, fingerlings of the other species were purchased from other producers. At present, the farm is undergoing a restructuring of its facilities with the aim of producing barramundi and gilthead seabream as primary fish and tilapia and North African catfish as secondary fish.

Revivim Catfish Farm is the pioneer catfish producer which, in 1991, began raising the North African catfish (*Clarias gariepinus*) using desert water. In 1995, a semi-commercial system consisting of 14 cement ponds (8 m^3 each) was built within a greenhouse. The water in the ponds is refreshed at a rate of 10 percent of the daily system volume. The potential annual production in this system is about 70 tonnes, i.e. fish density can reach 125 kg/m^3. Fingerlings, at an initial weight of about 5 g, can reach 800–900 g within 180 days, i.e. a daily growth rate of 2 percent. As a major producer of North African catfish, this farm has recently completed a new, highly modern, closed water recirculation system for its super-intensive catfish production with the aim of exceeding 100 tonnes per year at a harvest stocking density of nearly 300 kg/m^3 of water. Catfish fingerlings were initially purchased from another producer, but the farm currently produces its own fingerlings.

Mashaabei Sadeh Farm started fish farming in 1992. A water reservoir (3 hectares) containing 70 000 m^3 was built together with a number of covered 250 m^2 rearing ponds. Water from the fish ponds is pumped to the water reservoir for biological treatment and returned cleaned to the fish ponds. The daily renewal rate of water varies between 10–30 percent of the total water volume, depending on the season. Fish receive recycled brackish geothermal water, which is used in the final stages for irrigating jojoba, olives, and melons. Initially, Nile tilapia (*Oreochromis niloticus*) and barramundi (*Lates calcarifer*) were raised. In 1997, the farm started raising the white leg shrimp (*Litopenaeus vannamei*) on a semi-commercial basis. Starting in 1998, only shrimp were raised, aiming at an expected yield of 4 kg/m^3 of fresh shrimp exports to Europe with two crops annually. Shrimp production on the farm was ongoing for about two to three years, but was discontinued because of a decline in retail prices on the European market caused by imports from China.

At present, this farm is producing barramundi (*Lates calcarifer*), the farm's most successful product, as well as European seabass (*Dicentrarchus labrax*), red drum (*Sciaenops ocellatus*), and Nile tilapia (*Oreochromis niloticus*). Fingerlings of these species are purchased from a fingerling producer. Currently, this farm is planning to expand its facilities and significantly increase its present annual production to about 200 tonnes.

Re'em Farm, established in 1992, is the largest fish culture system based on recirculating water technology in the country and in the Middle East (Figures 2, 3 and 4).

It has 15 cement ponds of 600 m^3 each and ten cement ponds of 1 500 m^3 each. Water flows from the fish ponds into a biological filter (300 × 10 × 1.5 m) and back into the rearing ponds. The volume of the entire system is 30 000 m^3. Geothermal-brackish water (4 ppt at 36–38 °C) from an adjoining well – equal to 5–10 percent of the entire system volume – enters the system daily.

Barramundi (*Lates calcarifer*), striped bass (*Morone saxatilis* × *M. chrysops*), European seabass (*Dicentrarchus labrax*), red drum (*Sciaenops ocellatus*), Nile tilapia (*Oreochromis niloticus*), and common carp (*Cyprinus carpio*) have been raised on the farm. The average density of fish is about 25 kg/m^3. The farm requires 1–1.5 m^3 of water for the production of 1 kg of fish. Fish production reached a high of 400 tonnes in 2004. In addition to fish culture, Re'em Farm supplies 120 hectares of olive trees with effluents from the fish rearing ponds for irrigation. Olive trees need water throughout the year (with the demand in winter being 10 m^3/h/day and in the summer 70–100 m^3/h/day). At present, the farm is undergoing structural changes.

FIGURE 2
Re'em Fish Farm, a typical desert fish farm

FIGURE 3
Raceways with aerators in a greenhouse of the Re'em Fish Farm

FIGURE 4
High density red tilapia cultured in a raceway in the Re'em Fish Farm

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Matan Farm was established in 2000 with the aim of rearing and exporting fresh white leg shrimp to the European market. This was based on a study showing shrimp growth of 0.5 g/week at densities >100 individuals/m^3 and with a 70 percent survival rate. Evidently, white-leg shrimp can be successfully raised in the desert water (Appelbaum *et al*., 2002). One major advantage of raising shrimp in inland brackish water and isolated from the sea is that the shrimp are not exposed to marine viruses that cause heavy or total losses. However, due to a significant drop in the price of shrimp in the European market, this farm changed its production from shrimp to finfish.

Erez Thermoplastic Products located in Erez farm is specialized in manufacturing PVC sheets for covering greenhouses and bottoms of fish ponds to conserve energy, to reduce water loss in the pond and to maintain higher water temperatures. Colours are applied to the sheets to make them photoselective and to prevent the penetration of red and blue light rays that promote the growth of green algae. Both sides of the sheet are varnished for easy cleaning of dust and water residues. Under desert conditions, these sheets last for more than three years.

EFFICIENT USE OF DESERT WATER

It is both feasible and economically viable to combine aquaculture and agriculture into so-called integrated farming systems by using desert water for agricultural irrigation and commercial production of fish.

In practice, this means that the effluent from fish ponds, rich with organic waste produced by the cultured species, is used for field and orchard irrigation, making a more rational use of desert water, reducing the use of fertilizers, and creating a chain of users. Israeli fish farms in the southern arid regions have successfully combined aquaculture and agriculture into integrated farming systems that exploit the abundant subsurface saline water. These applied farming technologies in the desert also improve water use and conservation minimizing the waste of this limited and valuable resource.

ORNAMENTAL FISH PRODUCTION IN THE ISRAELI DESERT

The culture of ornamental fish has gained enormous importance worldwide over the past few decades, and interest appears to be continuously growing, making it a potentially profitable business opportunity. Indeed, the market for ornamental freshwater and marine species is an important component of international trade currently worth more than USD10 billion annually. In Israel, raising ornamental and tropical fish for export began more than three decades ago, and continuously high demand is driving its recent expansion. Today, Israel boasts about 20 tropical fish farms, most of which are located in the desert. Farm size is typically between 0.1–0.3 hectares, with each farm operating in separate greenhouses isolated from the others with no common water system. The major ornamental fish species cultured commercially in the desert farms in Israel include guppy (*Poecilia reticulata*); platyfish (*Xiphophorus maculatus*); green swordtail (*Xiphophorus helleri*); freshwater angelfish (*Pterophyllum scalare*); and armoured catfish (*Corydoras* spp.).

DESALINATION OF DESERT WATER

Seawater desalination has been one of the major steps taken to alleviate the problems associated with the country's severe shortage of fresh water. Present (and future) desalination of inland brackish water (i.e. desert water) results in the accumulation of brine that, unlike seawater, cannot be redirected to its source. To reduce its continuously growing volume, accumulated brine from desalinating inland brackish water is deposited into evaporation ponds. These evaporation ponds can be used not only for growing fish and other aquatic species, but also for the reproduction of those marine species that grow well in the lower salinity of desert water but will only reproduce at higher salinities resembling seawater or at brine concentration.

The desalination plant in the Ramat Negev district near the Israel-Egypt border (Figure 5) produces 4 million m^3 of freshwater annually while, at the same time, producing thousands of m^3 of brine as a by-product.

Preliminary studies by Appelbaum and Arockia Raj (2008) have shown the suitability of brine from the desalination plant in the Ramat Negev district for growing several of the edible species previously mentioned.

FIGURE 5
Brackish water desalination plant in the Ramat Negev district

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THE WAY FORWARD

To expand its aquaculture activities and to remain competitive in the lucrative global export market, it has become necessary for Israel to increase the use of available marginal water, i.e. existing brackish geothermal desert water and desalinated sea and brackish water. Expansion of aquaculture in the Negev Desert of Israel, adapting and developing technologies for intensive fish culture and agriculture, with an emphasis on integrated operations, is a matter of necessity.

The hydrologists estimate that billions of cubic metres of water are stored underground, which can be exploited during hundreds of years, supplying demand of the growing population and agricultural development (Rothbard and Peretz, 2002).

Thus, the intensive utilization of the treasure of brackish geothermal water resources in the Israeli desert for integrated agriculture/aquaculture advances the continued expansion of Israel's aquaculture industry and facilitates the significant reduction in the use of Israel's scarce freshwater resources. Desert aquaculture is not a technological revolution; rather, it is an innovative approach that differs from conventional fish farming. Arid or desert lands with subsurface water resources have huge potential for developing and sustaining aquaculture and agricultural farming. Research findings continue to show that the possibility of using inland brackish water for farming aquatic species is a promising and realistic alternative to many of the more traditional operations. Further development of Israeli aquaculture will have to go hand-in-hand with the expansion of the existing domestic desert aquaculture. Technologies applied in desert and arid lands must strive to minimize their negative effects on the unspoiled desert environment and should maximize the preservation of the land in addition to facilitating efficient use of water. Ideally, this can be achieved by integrating aquaculture with agriculture, thereby conserving water through the expansion of the chain of users utilizing the same water (Kotzen and Appelbaum, 2010). The steadily growing consumer market for high quality aquaculture products and the vast amounts of unpolluted brackish geothermal water accessible beneath the Israeli desert suggest that the production of thousands of tonnes of fish and other aquatic organisms in the national desert and arid lands is a realistic opportunity. The development and expansion of Israeli aquaculture in the Negev Desert, associated with and guided by local applied research, should be of great importance to Israeli farmers and policy-makers alike.

CONCLUSIONS

Studies and trials have shown that growth rate, metabolic rate, feed intake, feed conversion, and survival in fish are influenced largely by the salinity of the water in which the organism is cultivated (osmoregulation). Israel's brackish desert and arid lands water has proven to be highly suitable for aquaculture because:

- Desert water provides an osmoregulatory advantage to fish and is detrimental to fish parasites.
- Fish can adapt well to desert aquatic conditions and can respond with good growth and survival.
- Desert water is free of pollutants, and therefore, is suitable and beneficial for producing high-quality aquaculture products.
- New technologies are under development to allow intensified use of desert water while preserving the environment.
- It is expected that, following the continued development of aquaculture in the desert, fish processing and transportation facilities will be established in the desert facilitating shipment to domestic and foreign markets.

This paper describes many reasons to pursue the development of desert aquaculture. The possibilities of desert aquaculture and its generated activities together with initial investment, should generate enough interest to be viewed as a viable business for many local farmers in remote areas. Israel's experience in the practical development of its desert is one example of the sustainable use of arid land and can contribute to the development of arid lands in other countries in such a way that their valuable resources can be utilized while having minimal impact on their environments and natural resources.

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