Lake Borullus of the Nile Delta: A Short History and an Uncertain Future

Borullus, the most centrally situated of the Nile Delta lakes, probably evolved around the eighth century AD from a preexisting salt marsh by fluvialitic deposition of sand dunes north of the lake and subsidence of the preexisting tidal swamp behind this barrier. It was flooded yearly (September–December) by the Sebennytic branch of the Nile, and evacuated water through an exit, Bughaz. At low river levels, this process reversed and Bughaz functioned as a marine inlet. Because of this switch, its fauna and flora contained a mix of marine, freshwater, and brackish-water species. Around the mid-nineteenth century, damming of the Nile began, culminating with the high Aswan Dam (1964) that brought the yearly flood fully under control. As a result, a steady flow of Nile water, used for irrigated delta agriculture, began to drain to the lake and became a constant evaporator to the Mediterranean. It turned almost fresh, and its fishery, formerly marine and mullet-based, became cichlid–catfish based. However, rice and other new delta crops caused huge amounts of nutrients to wash down the drains, and currently the lake is eutrophied and only resists hypertextification because of the low residence time of its water. Finally, the damming of the Nile terminated the influx to the delta of a yearly sediment layer, but subsidence and coastal erosion continue and are now consuming the sand bar that separates the lake from the sea.

INTRODUCTION

Most lakes are geologically young. The vast majority are of glacial origin and have an age of 10 000–20 000 years. Some, like ox-bow lakes in the lower valley of rivers, are even younger and have a life expectancy of a few centuries to a few millennia. Lake Borullus in the Egyptian Nile Delta is such a case. Its oldest known name, Lake Buto, might be rooted in the Ptolemaic period, and evolved to Lacus Buticus, which became Lacus Baralios (-us) in Hellenistic times. It is the most centrally situated of four shallow, brackish water lakes, together covering about 1100 km², and is more or less representative of all four. Here, we dwell upon its origin, history, and future.

PHYSICAL CHARACTERISTICS OF THE LAKE

Borullus extends along the northern fringe of the Nile Delta. It is centrally situated (Figs. 1 and 2) and second in size only to Lake Manzala. Around the early 1900s, it had a surface area of about 600 km²; by 1974, land reclamation for agriculture in its southern sector had caused it to decline to about 460 km², and this decline continues today. Its long axis, about 65 km long, runs parallel to the adjacent Mediterranean shore; its width is between 6 and 16 km, with the average being 11 km. The lake is extremely shallow, with a depth between 0.4 and 2.0 m. The deepest part is in the western sector, which is also the freshest, while the eastern sector, which contains a 250 m long canal connecting Borullus to the sea (Bughaz), is shallow and saline. This horizontal saline gradient is quite significant: Values as low as 0.4 g L⁻¹ of chloride occurred in the west in the early 1970s, against 14–16 g L⁻¹ in the vicinity of the outlet, especially at low Nile stands and when northerly winds push seawater into the lake. Being so shallow, there is a rather broad ecotone between lake and dryland, most of which is overgrown with Phragmites reeds. There are also several large and countless small islands, and large sectors of the lake are invaded by emergent, floating, and submerged water plants. A canal (Brimbal), connecting Borullus to the Rosetta (Rachid) branch of the Nile, used to supply up to half the water of the lake; after 1964, this amount rapidly declined to 5% because the Rachid branch of the Nile was largely inactivated. This small amount of brackish estuarine water has only a negligible influence on the lake. Agricultural drains have now taken over the function of Brimbal; the drainage network in the eastern part of the lake is a remnant of the former Sebennytic branch of the Nile (next section).

ORIGIN OF THE LAKE

The origin of Borullus is connected with the building of the postglacial Nile Delta (1). Around 20 000 y BP, with the Mediterranean some 120 m below its present level, the river had incised a valley deep below its current surface. After declagation, the sea level rose to about 5 m above the present, and the Mediterranean invaded lower Egypt. Modern delta building could only begin after the sea had stabilized around its present level, some 6000 years ago.

Once initiated, the delta attained its present shape with surprising rapidity. Except for its northern third, it must have looked as it does today shortly after 6000 BP as a result of the Nile depositing on average 20 cm of alluvium per century. The average sediment sheet currently amounts to 10 m, reaching 40 m in places (2). As it expanded into the sea, the northern edge of the delta created a vast marine swamp through which the Nile branches evacuated sediment-loaded water, gradually depositing shoulder areas, seasonally overflowing and depositing fine mud in the swamps, while laying down coarser sand in the sea ahead of the swamps. Inman and Scott (3) estimate the yearly amount of sediment (sand + silt + clay, with the last two categories together forming the mud fraction) reaching lower Egypt before 1964 (early filling of the Aswan high dam) at 160 × 10⁶ – 180 × 10⁶ t y⁻¹, of which about 110 × 10⁶ t was mud, and the rest sand. The sand deposits, after finding their way to the sea, contributed to the building of a dune barrier that began to shield the swamps from the sea. Each of the four lakes maintained an outlet that evacuates excess water during floods.

The Nile branches themselves were unstable and different from today's Damietta and Rosetta branches (4). The centrally located Sebennytic branch, now defunct but still surviving in some canals that drain agricultural irrigation water to the east basin of Borullus, discharged at or near the present outlet of the lake (Fig. 2).

Two additional processes were vital to the creation of the lake: delta subsidence and coastal erosion. With time, the mud layers deposited by the Nile floods became compacted, and the weight of the sediment caused a subsidence of the delta area. This subsidence is far from negligible. Stanley (5) estimates it at 40–50 cm per century; thus even in the absence of the eustatic
sea level rise of the second half of the twentieth century, the net movement of the delta is a sinking one. Coastal erosion is controlled by the wind regime at sea, facing the delta. Predominantly landward winds occur and supply enough wave energy to carry eastward about $3 \times 10^3$ m$^3$ of material (mainly sand) per annum. This amount used to be more than compensated for by the Nile floods that brought in about $40 \times 10^6$ m$^3$ y$^{-1}$ of sediment, and thus the net result was positive, and the delta advanced into the sea. The progression of the delta, with a sinking of the newly created land behind it, is what finally transformed the tidal swamps into four discrete lakes. When exactly Borullus ceased to be a swamp is not known accurately. When Herodotus [cited by Butzer (2)] visited Egypt, he declared the delta uninhabitable, but this statement must have applied to the northern third only because archeological remains dating back to the old and middle kingdoms are found far north along the Sebennytic Nile (2). Probably, the lake did not exist as a separate entity at that time, but as a continuum of salt marshes separated by river arm levees (Fig. 2). Toubar (6) studied two cores from the bottom of Lake Borullus. The longer of the two, 4 m in length, went back to 1500 ± 30 y BP, and suggests that the area at that time was still in the marine mud flat-marsh stage. At 1200 ± 50 y BP, abundant Cardium and Epitomina shells demonstrated that the marine stage had not ended, but a lake had now materialized, shielded from maritime waves by a dune barrier. Yet, Borullus remained under a strong marine influence until the second half of the twentieth century because the Nile floods only lasted from August until November; after that, sea water returned, and the outlet turned into an inlet. This outlet, situated at the far eastern end of the lake, created a horizontal salinity gradient on top of a seasonal one. It is probably not an oversimplification to state that around Bughaz, except at the peak of the Nile flood, salinity was close to seawater, while at the far western end, freshwater conditions prevailed.

These gradients and fluctuations in salinity deeply marked the biology of the lake. To paleolimnologists, such fluctuations occurred at lightning speed, and wind-driven lateral transport and sediment resuspension would make it impossible to trace their signature. In the framework of CASSARINA, a project aimed at comparing a number of Mediterranean lakes, two sediment cores from Borullus, covering the entire twentieth and a fair portion of the nineteenth century, were studied for microfossil remains (7). The arid climate of the area caused problems in determining recent sediment ages (8), and the study of diatom, zooplankton, benthos, and insect remains (9–12) revealed a mix of marine, freshwater, and brackish water biota, as could be expected. However, a trend toward a freshening occurred after ca. 1950, even if it was not a clear-cut change from a saline toward a freshwater environment. Rather, typical marine as well as freshwater biota continued to occur up to the late 1990s, but in changing proportions. These changes clearly related to a human manipulation of the Nile.

**NINETEENTH AND TWENTIETH CENTURIES: THE AGE OF DAMMING**

During an average year, the Nile discharges some $100 \times 10^3$ m$^3$ of water. The bulk flows from the Ethiopian and East African plateaus, and most of it used to be lost to the Mediterranean. It is uncertain whether many pharaoh ever considered hydraulic works other than building irrigation channels; no such initiatives seem to antedate the nineteenth century (13). Under Mohammed Ali, the then Ottoman governor of Egypt embarked on a program of improving irrigated agriculture that included making the delta more productive. In addition to numerous canals, a barrage was built north of Cairo at the point where the Nile divides into the western Rosetta and the Eastern Damietta branch. The dam, improved by the British in
A view from Lake Borullus, showing open water in the foreground, two artisanal fishermen barges, and in the background a wall of *Phragmites* reeds; in front of it, patches of the South American floating macrophyte *Eichhornia crassipes*.

1890, was able to retain water at 4 m above the summer level of the river (13). To some extent, it may have influenced the water supply to the northern delta and Lake Borullus. Later, the Edfina and Zifta barrages, well inside the delta, were added. Because we have no direct scientific information on Lake Borullus dating back to the nineteenth and early twentieth centuries, we may never know what their influence was. Neither Napoleon’s savants nor the Ottomans and British gave much attention to Lake Borullus or the other delta lakes.

The first “limnological” information available is in a paper by Steuer (14), a fisheries expert who visited Egypt in 1933 to work on the fauna of the mouth of the Rosetta branch, yet briefly looked at some delta lakes as well. The only other contemporary source of information available is from Egyptian fisheries statistics. In their early years these give only a rough idea about the type of fish caught in the lake (15).

Dam building, with an aim at increased water retention, accelerated during the twentieth century with the construction of the first Aswan dam in 1902. This dam was raised twice, in 1912 and 1933, increasing the storage capacity of the reservoir, and additional reservoirs were built at Assyut (1902), Zifta (1903), Isna (1909), Nag Hammadi (1930), and Edfina (1951), in addition to the dams on the Blue and White Nile in Sudan. Together they only partly controlled the Nile flow but undoubtedly smoothed out the peaks and sags in the amount of water reaching the delta lakes.

**THE GRADUAL IMPACT OF DAMMING, AND THE DECISIVE INFLUENCE OF THE ASWAN DAM**

Today, countless papers blame the Aswan Dam for incisive changes in the ecology of the Nile, and of Lake Borullus in particular. However, the paleolimnological results cited previously suggest that even the modest-sized dams of the nineteenth century had an influence on the regime of the lake, apparently extending the impact of the Nile flood in time, and nibbling at the amount of seawater that entered Lake Borullus through the Bughaz. By 1950, freshwater biota had decidedly begun to take a more prominent position in the lake’s food web. Marine molluscs, crabs, and shrimp continued to be commercially exploited until their final decline in the 1970s. At the same time, marine-origin fish like sea bass and mullet disappeared or became localized to the Bughaz region.

Full control of the Nile floods was finally achieved with the commissioning of the Aswan high dam, constructed some 6.5 km south of the old dam. The reservoir is capable of storing 1 ½ year’s worth of Nile discharge, and water can in principle be released or retained at will around the year, as needed for agriculture and other purposes. The lake started filling in 1964, and reached a volume of about $115 \times 10^9$ m$^3$ in 1975.

The year 1964 was thus the last one with an unregulated Nile flood, and by 1967, all water reaching the delta area was used for irrigation purposes. Cotton, later rice farming, boomed, and the irrigation water used in the fields south of Borullus was drained toward the lake. The contribution from the Nile via the Brimmel canal rapidly dropped, and the lake, instead of a flood, started receiving a steady inflow of freshwater. Specifically, the peak discharges decreased, while the minimum discharges increased (from 8200 m$^3$ s$^{-1}$ in September and 500 m$^3$ s$^{-1}$ in April before, to 2500 m$^3$ s$^{-1}$ in July and 1300 m$^3$ s$^{-1}$ in January after the damming). As well, these figures show that the timing of the peak shifted. A counterintuitive result was that between 1935 and 1967, the total amount drained was about $2300\text{-}2700 \times 10^9$ m$^3$, which increased in 1970 to about $3200 \times 10^9$ m$^3$ (15, 16), and in 2001 and later, a plateau value of about $4000 \times 10^9$ m$^3$ was reached. Because this total amount is parcelled out more or less evenly across the year (Table 1), the water level in the lake rose to 25–60 cm above the average maximum sea level, Bughaz functioned as a quasi-permanent outlet, and the lake was transformed from a fluctuating brackish environment into a shallow freshwater lake. If, however, Aswan closes down, as may happen for periods of 2–3 weeks in winter, the lake level falls to 20 cm below sea level, massive amounts (of the order of $100 \times 10^9$ m$^3$) of seawater are sucked in, and salinity jumps. In the east, it reaches almost seawater strength, and a marine fauna is locally restored, while the freshwater fauna retreats to the west.

**LIMNOLOGY OF LAKE BORULLUS**

Borullus is shallow and warm. Winter temperatures descend to 11°C, and in summer, temperatures reach 30°C. The lake is thus polymictic and turbid. The former floods that either flooded the lake directly, or via the Brimmel canal, were a source of sediment and nutrients, and so the lake was naturally eutrophic. In line with this, photographs show a lakescape with fragmented open water, huge “walls” of *Phragmites-Typha* along the shores and around the islands, and the aquatic fern *Azolla nilotica* and South American invader *Eichhornia* floating on top, while the water of the lake itself is of a green or greenish-brown color. A total of 65 species of higher plants have been recorded from the lake shores, 89 from the islets, and 10 from the open water. Water birds abound, and the lake has been declared a Ramsar site for migratory and breeding water fowl. Of 112 species and subspecies recorded, 46 are residents and 80 are winter visitors. Many find shelter and a livelihood in the almost 7000 ha of reeds and marshes that surround the open water. These reed beds hold one of the largest populations in the West Palaearctic of little bittern, purple gallinule, and clamorous reed warbler. The only western palaearctic populations of painted snipe and senegal coucal are found here, as well
as two subspecies of bird endemic to Egypt, the lesser short-tailed lark (only known from the Nile Delta) and the Egyptian wagtail (17).

Currently, fishing and fish culturing are important economic activities and provide a livelihood for about 20,000 fishermen and their families (see further).

The evidence given earlier suggests that Borullus had reached its early twentieth century state somewhere around the eighth century AD. What did its biota look like at that time? Available paleolimnological information does not reach back far enough, but in broad terms it is likely that, before Nile damming started, the lake was under strong marine influence for about two-thirds of the year, to be flushed and freshened by the river flood in the remaining third. The canals that served as inlets have remained fresh at all times, the eastern sector around Bughaz was polyhaline, and the large central basin was in a permanent state of flux with regard to salinity.

**FAUNA AND FLORA BEFORE AND AFTER THE ASWAN HIGH DAM**

The main macrophyte fringing the lake, as elsewhere in similar situations, was the reed Phragmites communis, with Ruppia and related taxa as submerged macrophytes, and perhaps Potamogeton pectinatus around the mouth of the drainage canals. The fish fauna, no doubt exploited by the delta people for centuries on a subsistence basis, may have contained all the species that were still extant around 1970: Of 29 species recorded (meanwhile about 40 species have become known), about 12 were marine, 12 freshwater, and the remainder diadromic or of brackish water. Among the saltwater species, not less than five species of mullet are to be noted, but also five freshwater cichlids of African affinities, and the catfish Claria lazera. Marine crab species and mollusks (Cardium edule and about eight others) were so common as to be exploitable (14). For a long time, about 5000–8000 fishermen fished the lake artistically, and yearly landings stagnated at about 4000–6000 t year−1, with mullet the dominant catch (15).

Steuer's data on invertebrates show a mix of marine and freshwater taxa, with plenty of biota tolerant of strong fluctuations in salinity. Thus, he mentioned that marine-origin cirripeds (Balanus improvisus) settled on the stems of Phragmites, side-by-side with the Caspian-origin colonial cnidarian Cordylophora caspia, and that the macrobenthos contained two species of mysids, two polychaetes of the genus Nereis, the serpulid Mercierella enigmaticta, and three amphipods, including the burrowing Corophium volutator. In contrast, he also mentions freshwater organisms like insect larvae of several midge groups (e.g., Cricotopus) and even damselfly larvae. He was well aware that this heterogeneous assemblage was rapidly waxing and waning, and illustrated this with graphs of 4 years of Nile flow (1846–1849).

On phytoplankton, he only cited two diatom species, and his data on zooplankton were sketchy and no exact collecting sites are given. Remarkably, however, he recorded a number of typical freshwater species. Among copepods, there were two Mediterranean species typical of freshwater temporary ponds (Neolevula alluadi and Metadiaptomus sp.), and a Nile endemic (Thermodiaptomus galebi). He also cited the cladocerans Daphnia, Bosmina, and Diaphanosoma beside representatives of some marine groups, unfortunately without indicating whether they all co-occurred or whether the latter were restricted to the Rosetta estuary.

It took until the 1970–1980s before Egyptian ecologists began to show an interest in the delta lakes, and by that time, these had begun changing. The first phytoplankton study on Borullus was the PhD thesis of El-Sherif (18), followed by a second study during a low-flow Nile year (19). More recent evaluations of the phytoplankton include Radwan (20) and Okbah and Hussein (21), and the species inventory expanded from 2 to well over 200. According to these studies, the order of relative abundance between the major algal groups changed little between 1980 and 2003: Diatoms made up about half of the microfloral species richness, followed by Chlorophyceae. Blue-greens (Cyanobacteria) came only in third place, but had increased from 1.7% to 9.5% in 20 years. This order is not fully confirmed by the CASSARINA study (7). Although Borullus emerged from this as the most species-rich lake out of 12, with 43 species found, the order of dominance was Chlorophyceae (12 spp.), followed by Cyanophyceae and diatoms (9 spp. each).

Alarming, Borullus was the only lake high in the blue-green "blooms" species Microcystis aeruginosa, well-known for its toxin production (22) and a signal of advancing eutrophication.

The first study on the zooplankton and benthos following Steuer’s, was Aboul Ezz’s Ph.D. thesis in the early 1980s (23), with a follow-up paper about a decade later (24). The merit of this work is that it produced the first comprehensive list of all major groups of invertebrates, yet it is marred by weak taxonomy. For microcrustaceans, keys to the American region were used, resulting in a large number of identification errors. The checklist for the years 1978, 1979, and 1987–1988, useful as it may be, should therefore be interpreted with care (Dumont and El Shabrawy, in prep.).

Alarming, some facts stand out. Thus, in the late 1970s, a sizeable fraction of species extending from seawater to mesohaline conditions occurred, and this fraction was especially large (about 14 species) in the calanoid and harpacticoid copepods. Only three of these survived in a survey carried out by us in 2001–2005, while about seven species, already present in the 1970s, had maintained themselves, and seven new freshwater species had first appeared. All large freshwater calanoids reported by Steuer had disappeared, as well as the large cladocerans (Daphnia spp.). Such a change in the size spectrum of the zooplankton suggests other changes in the food chain, in particular at the fish level, where zooplanktiuves of freshwater origin had become more prominent. A further difference in the freshwater species that had survived was that their abundance had become about 10 times that in the 1970s. This, in turn, suggests fewer competitors (the larger species that had disappeared), and abundant food (eutrophication). Currently, saltwater intrusions and with them, saline animals, only occur when the Aswan Dam closes. This happens infrequently, and in winter only (the latest events were in early 2004 and 2005).

Ostracoda are normally as trustworthy indicators of salinity as copepods; seven species were reported by Aboul Ezz (24), but all were misidentified North American taxa. In the late 1990s, three extant species were mentioned by Ramdani et al. (10, 11): Cyprideis torosa extends from oligohaline to mesohaline environments; Limnocythere inopinata and Loxocochea elliptica are oligohaline taxa. In sediment deposits, only Cyprideis was found throughout a core spanning at least the twentieth century; the two freshwater species appeared before 1950, possibly shortly after 1900, suggesting a saline crisis around the beginning of the twentieth century, but other fossils (e.g., chydorid cladocerans) and a saltwater foraminiferan, Ammonia becari, contradict or at least do not confirm this. As we saw earlier, saline episodes were common in the past, but even then were too short-lived and local to leave an unambiguous signature in the fossil record because of sediment resuspension and lateral transport, and strong horizontal saline gradients. Two typical freshwater species, the cladocerans and the rotifers, abound in the lake and no doubt were also present in the first half of the century (14). Of rotifers, about 200 species should be expected (25), of which about 50 have now been...
found (24; Dumont and El Shabrawy, in prep.). They include the saline-water tolerant species, Brachionus plicatilis and Hexarthra fennica. Likewise, in a lake like Borullus about 50 species of cladocerans should occur. Currently, only about 15 species have been reliably recorded, but the macrophyte beds, where most of the species richness resides, have hardly been studied. All species recorded are typical freshwater, but during the saline intrusion of 2005, the marine onychopod Podon polyphemoides briefly appeared around Bughaz.

The inventory by Aboul Ezz (24) also contains truly marine animals, in groups ranging from Protista (the foraminiferan Ammonia) to Amphipoda, Cirripedia and Mysidacea already reported by Steuer, and some typical marine animals like Sagitta sp. (Chaetognatha) and Oikopleura dioica (Urochordata), both also recorded by Steuer. These species had disappeared from the lake by the late 1990s (10, 11) and were not seen in our survey of 2001–2003, except during the brief saltwater intrusions.

NEW PROBLEMS: EUTROPHICATION AND EROSION OF THE SEAWARD SAND BAR

The fish landings from the lake evolved in a remarkable way (Fig. 3). Between the 1930s (15) and the mid 1960s, fish landings had fluctuated around 4000–8000 t (corresponding to about 150 kg ha\(^{-1}\)). Following the establishment of the Aswan Dam, there was a drop, especially pronounced in the early 1970s, and lasting until the mid-1980s. After 1980, an exponential increase resulted in a plateau around 1990, and lifted the landings to about 50 000 t y\(^{-1}\) (about 1000 kg ha\(^{-1}\)) (26, 37). The fisheries shifted from mullet-based fish (marine) to tilapia-based fish (freshwater). Yet, the average size of the fish decreased by about 30% across the 1990s. Such a decrease is a sure sign of overfishing; productions of 1000 kg ha\(^{-1}\) are indeed extremely high and not sustainable in the long run (38). However, they may have contributed to keeping the lake from turning hypertrophic by removing nutrients along with fish biomass. A recent development is fish farming, with again four species of tilapia, and with the freshwater catfish Clarias lazera, the most important species.

As agriculture expanded, so did the use of chemical fertilizers and pesticides. Washing out of nutrients was rather modest until the mid-1990s, but had amplified tremendously by the end of the twentieth century (Table 2). The nutrients loaded to the lake (our estimate for 2003 is 14 000 t of nitrogen and 4000 t of phosphorus) are derived from agriculture; their concentration in the drainage canals is even higher than in the lake. Such fertilization holds the danger of shifting the lake ecosystem from a macrophyte-dominated state to one with perennial cyanobacterial blooms, and the question arises why this has not occurred yet. Removal of N and P with the fish harvested certainly contributes, but not in a decisive way. The answer probably lies with the nature of the water balance of the lake: about 97% of all incoming water is drainage, 2% is local precipitation, and 1% groundwater. On the loss side, 16% evaporates and the remaining 84% flows out to the Mediterranean Sea. Furthermore, the drains situated across and east from Bughaz account for half the total input to the lake, and that water chooses the shortest way and almost immediately flows out again [Table 1, values for 2001, from (30)]. Another 31% of the incoming water flows through drains 8 and 9 in the central basin, such that, on average, only 23% enters the lake in the west. As a result, the bulk of the nutrient load is promptly exported.

Even so, in the long run, a blue-green takeover is unavoidable, as suggested by the steady increase of the cyanobacterial fraction (39) and of Microcystis in particular, cited earlier. The question now is whether the lake will exist long enough to see this happen. A final threat indeed weighs on its very existence and was unanticipated at the time Aswan was built, although in hindsight, there were signs of a delta breakdown since the early days of delta damming, some 150 years ago (31, 32). As the Nile transported less and less sediment to the sea, and finally nothing at all, the expansion of the delta changed from positive to negative: Shore erosion instead of shore building began to prevail. This “destructive phase” as it has been called by Stanley and Warne (31, 32) transformed the delta into a subsiding (at a rate of about 0.5 mm y\(^{-1}\)) and eroding coastal plain. The sand bar separating Borullus (and among the other lakes, especially Manzala) has been shrinking in size from about 1000 m in 1919 to 350 m in 1949 and 100 m around 1970 (33, 34). At this rate of 10–20 m y\(^{-1}\), it would be a matter of a decade for sections of the northern shore of Borullus to collapse. However, while the delta as a whole erodes, the situation at a local scale is often complex, as shown by remote sensing studies (35). Thus, the coastal bar of Borullus is subject to erosion for most of the time, but in 1985 accretion, not erosion, occurred. There is also a different situation east and west of Bughaz, with accretion to the west of the outflow, and erosion to the east. And finally, protective works (jetties and
concrete sea walls) locally interfere with natural processes and slow down the erosion of the coastline (30). However, in spite of all these interventions, the lake’s future looks bleak: it is only a matter of time before its life cycle will be terminated by reintegration into the Mediterranean as a coastal bay (36).

References and Notes

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