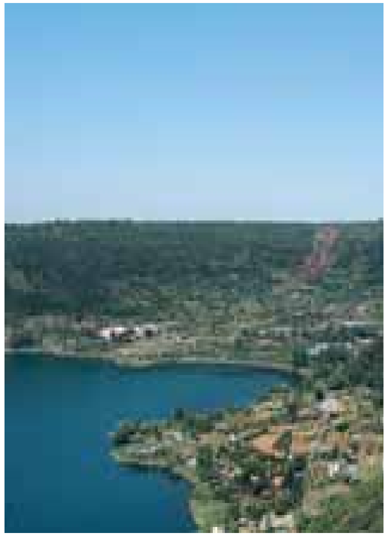
Conservation and management

FABIO STOCH · DARIA VAGAGGINI



Lake Nemi (Latium)

Although volcanic lakes, complex ecosystems which have great natural importance, appear to be calm and tranquil, they may actually conceal a number of problems that are gradually endangering their delicate balance. Society has only recently discovered these environments and has started to exploit them indiscriminately.

Despite the fact that these biotopes have recently come under protective legislation, lakes and their surrounding areas are still managed in ecologically unfriendly ways, and progressive, inevitable alterations to the territory are perpetrated by man with severe consequences for both water quality and ecological integrity. Threats come from several productive sectors, such as construction, agriculture, livestock farming and tourism, all of which have rapidly developed, and have radically changed the original structure of the territory by modifying the shores and polluting the water. Data collected over the years show a gradual worsening in environmental conditions and profound alterations to biological communities, due to chemico-physical stress (e.g., excessive amounts of nutrients and anoxia). We shall now describe the dangers to these environments, hoping that, in the future, volcanic lakes may be safeguarded by strict management policies aimed at respecting them as a unique and irreplaceable Italian heritage.

■ Shore urbanisation

The shores of many large volcanic basins are densely populated (some towns have up to 20,000 inhabitants). In recent years, building has been carried out

Lakes Nemi and Albano (Latium) surrounded by densely populated areas without efficient town-planning schemes to protect the areas surrounding the lakes. Although most lakes are protected in some way (as parks, Sites of Community Interest, Special Protected Areas), illicit building still occurs. Fortunately, most town sewage is collected and does not drain into the lakes, but Lake Albano, for instance, lacks a drainage system surrounding it, and therefore the wastewater of the villages nearby all flows into it, giving rise to unsustainable deterioration of the quality of its water. The same occurs in smaller lakes that are not surrounded by towns but which still collect untreated sewage and wastewater from tourist structures nearby.

When towns do not sprawl around lakes, then shores become large, open stretches of land used for grazing animals or growing crops. If these activities are not monitored, they can severely alter the quality of lacustrine environments. In particular, the indiscriminate use of fertilisers and other agro-chemicals can pollute the ecosystem, as these substances penetrate the watertable or flow directly into the lake waters. As they contain nutrients such as phosphorus and nitrogen, they cause eutrophication, which will be described later in detail. Agro-chemicals containing bio-accumulative active principles are ingested by organisms and, through bio-magnification processes, may affect all levels of the food chain, thus producing considerable modifications to population dynamics.

A particular case is Lake Vico, the surrounding area of which, like that of most

Reduction of sedge meadows along the shores of Lake Nemi (latium)

Italian lakes, changed from traditional agricultural methods to intensive ones in the 1970s. The lake has recently been studied by the University of Tuscia.

In 1954, arable land (extensive agriculture) was estimated to cover 1064 hectares; in 1994, it had fallen to only 177 ha. The land was then transformed into hazelnut orchards, from 414 ha to the present 1235 ha. This transformation introduced large quantities of phosphorus and nitrogen from fertilisers, and pesticides like insecticides (endosulfan, Diazinon, carbaryl, lambda cyhalothrin), herbicides (gluphosinate and glyphosate), and fungicides (iprodione and thiabendazole). The long recharge period of the lake basin prevents these substances from being quickly processed, causing gradual water deterioration in recent years. Agriculture produces extensive pollution which is difficult to monitor because there are no specific sources. The only way of limiting this phenomenon is to adopt eco-compatible agricultural practices, as specified for by the EU, which include an extensive, free lacustrine shore area where vegetation can grow and gradually filter out toxic substances.

Another problem affecting all volcanic lakes is their exploitation for tourist use: summer rental of umbrellas, deck chairs and boats is constantly increasing. In the past decade, the maquis and sedge meadows of many basins, especially the least exploited, have haphazardly been destroyed to create areas for tourist complexes. Cutting riparian vegetation has several consequences for the ecosystem. Firstly, as already mentioned in the chapter on macrophytes, when

Bathing facilities along the shores of Lake Albano

Lowered water level in Lake Albano. In the 1950s, speedboats were used to be at the top of the cement pylons

native vegetation is cut, it is replaced by invasive, opportunist species. From the faunal viewpoint, some fish species have been deprived of their habitats and their populations have fallen. The same may be said of amphibians and reptiles, the breeding grounds of which have constantly declined.

As for agriculture, tourism should urgently become eco-compatible, in order to maintain the natural state of these environments and to avoid radical transformations which, as so often happens in Italy, have negative effects on the ecosystem and on lake economy.

■ Draining

Volcanic lakes are indispensable sources of water for the areas surrounding them. Although they may not be particularly large, their considerable depth provides great volumes of water.

Despite the fact that the waters of some volcanic lakes have been used since Roman times (e.g., Acqua Paola and the Allietino aqueduct, on Lakes Bracciano and Martignano) and some were even reclaimed in ancient times (see p. 22), the problem has dramatically worsened recently. The increased withdrawal of water was certainly favoured by the transformation of traditional agriculture into intensive forms, the higher demand for water, and the exponential increase in the population living in these areas.

The harbour of Lake Bolsena (Latium)

To quote an example, the estimated volume of Lake Bracciano is 5.05 km^2. The activity that takes up most water is certainly agriculture, followed by aqueducts and livestock farming. Just to give an idea of the volume of water drained from this basin, ENEA (the National Alternative Energy Authority) have recently collected data on the quantities required by the various activities in the towns of the area. The total amount was estimayed to be 16,418,728 m^3/year. In particular, 10,938,520 m^3/year are for agriculture (66.6% of the total), 5,330,102 m^3/year are collected by aqueducts to provide water to towns (32.4% of the total), and 150,106 m^3/year are for livestock farming (1% of the total). In addition, 25,000,000 m^3/year (2002 data) were collected by the water authority of Rome to supply the city with water, and by private conduits for other uses, which are impossible to estimate because many draining structures are illicit; according to research on the hydrological balance of these basins, the quantities of unlawfully obtained water are considerable.

The situation is critical, partly because precipitation is insufficient to compensate the total amount of water that evaporates and is drained. As a result, the level of the Lake Bracciano has substantially fallen. The same has happened in most other volcanic lakes surrounded by large, productive towns. Confirmation also comes from Lake Albano: data published in 1998 by the Province of Rome show that the level of the lake was maintained in the period 1960-1980, but then decreased by 160 cm in the period 1980-1996.

The village of Anguillara Sabazia on Lake Bracciano (Latium)

For the following 4 years (1996-2000), WWF data shows that the level fell by another 90 cm.

The same occurred in Lake Nemi, for which the Province of Rome registered equal levels in the period 1960-1993, and a dramatic fall of 190 cm in 1993-1996. An additional loss of 50 cm was reported by the WWF in 1996-2000. The same trend continues to this day, showing that, once again, the delicate balance of these ecosystems can only be maintained by introducing sustainable development measures that keep withdrawal below the capacity of these lakes. Regular monitoring is also required to prevent the minimum level being reached, beyond which the resource is lost.

■ Eutrophication

Eutrophication has several definitions. One of the first, still up-to-date, was given in the 1970s by the Organisation for Economic Cooperation and Development (OECD). Eutrophication is the process whereby water becomes rich in dissolved nutrients that cause typical modifications like increased production of algae and water plants, depletion of fish resources, general degradation of water quality, and other effects that reduce and hinder its use.

Eutrophication, when caused by man, is sometimes called “cultural”, and is a very quick and reversible phenomenon if treated correctly, unlike natural

Water pumping station on Lake Bracciano (Latium)

Greenhouses along the shores of Lake Nemi (Latium)

eutrophication, which requires much longer time-scales and is sometimes irreversible.

As mentioned before, the causes of man-induced eutrophication of lakes include the use of fertilisers for agriculture and water requirements for towns, industry and livestock farming. Wastewater from all these sources then flows into lakes and enrich them with nutrients. Great amounts of these substances cause excessive primary production and algal reproduction.

The small eutrophic basin of Monterosi (Latium)

The abundant phytoplanktonic biomass that develops is greater than the amount herbivores can consume. This excessive production, no longer kept under control by grazing animals, decays, and causes anoxia in the deepest layers of the basin. The micro-organisms which decompose the excessive algal biomass by aerobic processes also use oxygen. However, when oxygen is no longer available, decomposition occurs by anaerobic processes, which release toxic compounds (e.g., H_2S) into the water. When this occurs, algal foam or floating mats form, making the water less transparent. Damage to aquatic life may be direct, with the sudden death of fish, or indirect, whereby the community structure changes slowly, and more tolerant species take over, to the detriment of the more sensitive ones. Obviously, eutrophication compromises other uses that man makes of the water - for example, for drinking or bathing.

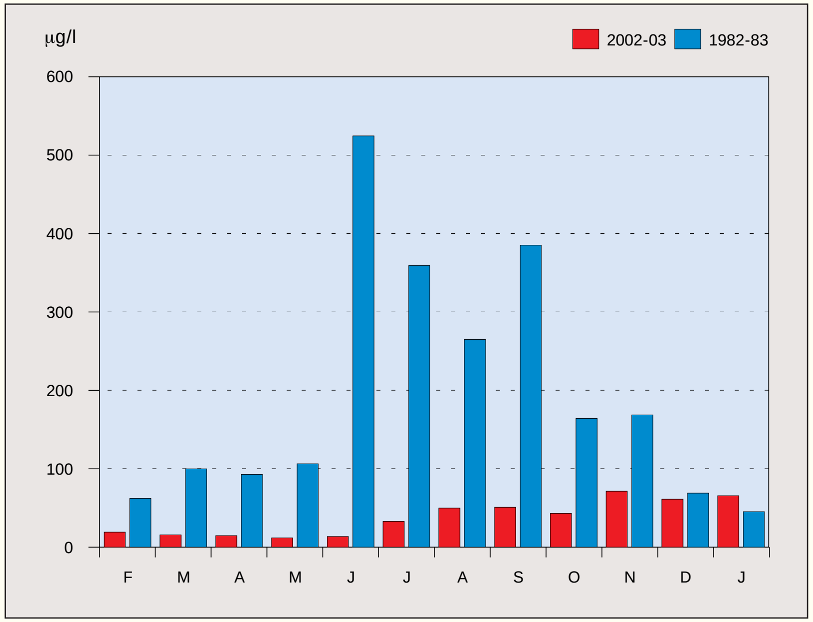
Unfortunately, eutrophication affects most Italian lakes, including volcanic basins. At present, monitoring of nutrients and assessment of biological indicators reveal that the situation is alarming in lakes Vico, Albano and Nemi. In the late 1980s, research on Lake Vico by the University of Rome showed progressive eutrophication of the deep layer of the lake, due to the fertilisers used on hazelnut orchards. The first symptoms of deteriorating environmental quality were reduction of oxygen at the bottom of the lake, gradual colonisation by benthic species more tolerant of stress, and extinction of a pelagic copepod that filtered phytoplankton. As presumably no action has been taken to reduce the excessive amount of nutrients in the water, the lake is likely to be polluted even today, despite its great recovery potential provided by the extensive

The trophic evolution of Lake Nemi

Daria Vagaggini

Set within the volcanic edifice of the Alban Hills, Lake Nemi is 37 m deep, with an area of 1.6 km^2 and a recharge period of about 15 years. Over the past 40 years, the lake has undergone profound trophic modifications, especially as a consequence of human interventions, which have altered the balance of several aspects of the ecosystem.
In the 1960s, the lake was in good condition, and showed diversified biological communities and high oxygenation levels. The situation started to deteriorate in the 1970s, when conduits were built everywhere, draining straight into the lake. Already in the early 1980s, physical, chemical and biological monitoring showed a dramatic decline in environmental quality. Severe deoxygenation was affecting the deep layer of the lake, and nutrients (phosphorus and nitrogen) were highly concentrated and favoured the development of large quantities of algal biomass. All the animal and plant populations lived in the upper layers of the lake, which were therefore no longer transparent.
Within the communities, some species or groups (such as cyanobacteria) clearly dominated over others, and in some seasons bloomed exceptionally. In addition, large numbers of lavarets died, many plankters were affected by fungi and epizoic algae, and the overall benthic populations plummeted.
In the 1990s, the local authorities realised the extent of this dramatic situation, and conveyed all the waters to one collector outside the basin. About 10 years later, the University of Rome carried out analyses showing that the situation had clearly improved, with smaller amounts of nutrients and increased transparency that enabled light to reach the metalimnion. This favoured a change in the composition of algal coenoses, with the development of *Planktothrix*, a typical metalimnic species (see chapter on phytoplankton). At the same time, oxygenation increased, the zooplanktonic and part of the zoobenthic communities became more diversified, and lavaret populations were in better health.
Despite these positive changes, the lake is still classified as eutrophic and, as of today, its balance is very unstable. This is due to the great quantities of fertilisers used on crops surrounding the lake, which are continually leached into the lake water, enriching it with nutrients.
This experience teaches us that it is mandatory to prevent pollution in all lakes by monitoring them periodically, and by adopting efficient management measures. Where conditions are already critical, constant monitoring and prompt intervention are essential for recovery. This can only be achieved if all anthropic pressures influencing aquatic environments are properly checked.

Effects of eutrophication along the shores



Average quantities of dissolved phosphorus in water column in periods 1982-83 and 2002-03 vegetational belt surrounding it (see chapter on macrophytes). Data (2000) on nutrients provided by IRSA for Lake Albano showed concentrations of total phosphorus at 348 µg/l and total nitrogen at 2420 µg/l in the deep layer of the lake. These values indicate severe eutrophication, especially by nitrogen, due to the already-mentioned lack of drainage conduits, which cause excessive amounts of organic matter to accumulate. The deep layer appears to be the most damaged, partly due to many years of meromixis, which in turn causes faunal impoverishment as depth increases (until it disappears completely in the last 50 m). Microbiological analyses revealed the presence of *Clostridium* spores and, in some periods of the year, cyanobacterial blooms (especially *Planktothrix rubescens*). The trophic evolution of Lake Nemi is described in a separate box (see p. 126).

The situation of these three lakes - Vico, Albano and Nemi - is particularly alarming, especially because their condition is progressively deteriorating, to the detriment of their water quality. As already mentioned, although intervention on Lake Nemi improved the situation with regard to 20 years ago, the continual introduction of crop fertilisers make it impossible for the lake to improve its eutrophic condition. As regards Vico and Albano, the local authorities have requested that fertilisers introduced into the waters and, for Lake Albano, also sewage, should be carefully monitored. The same dangers threaten volcanic lakes which are in better condition (like Bolsena and

Farmland along the shores of Lake Nemi (Latium)

Bracciano, the largest), where anthropic pressure must still be reduced and controlled to prevent the deterioration of their water quality. If efficient management policies are not enacted in the near future, entire ecosystems will inevitably be destroyed and become useless.

■ Threats from fishing

Commercial fishing for catching the most palatable species has always taken place in volcanic lakes. However, in recent years, angling has also become very popular and, because it is now extremely well developed from the technological viewpoint and involves large numbers of amateurs, it certainly influences fish populations considerably.

In volcanic lakes, the species most coveted by commercial fishermen, and therefore those which most require conservation and protection measures, are listed in the section describing fishing traps (see pp. 104-105). They include lavaret (an exotic species introduced into central Italy in the early 20th century, which has now naturalised in most basins), common bleak, eel, pike, perch, tench and carp. They are listed in order of preference on the market, which is generally local. The fish are therefore caught and sold in the same area. The type of fish traps used, the declining numbers of fishermen (a few dozen fishing licences for all the volcanic lakes analysed here, generally corresponding to

Hazelnut orchards along the shores of Lake Vico (Latium) entire families devoted to the same activity), and the lack of true fish-collection centres, makes this activity similar to small-scale sea fishing, which is very selective and cannot be quantified.

Generally speaking, where commercial fishing is carried out, there are also supporting fish farms that are promoted and financed by the local institutions in charge of fishery management. They work in collaboration with licensees of exclusive fishery rights (Nemi and Vico), with fishing cooperatives (Bolsena) or with the licensees themselves (Bracciano and Martignano), who provide the local fish farms with reproductive material to replenish the lake (broodstock which is collected in the lake, or spawn which is obtained by inducing broodstock to lay eggs). This is usually sufficient to reconstitute fish stocks, and to maintain the income of fishermen constant without impoverishing the natural source.

One potential danger of this activity is the risk of genetic contamination of fish stocks, particularly when local production does not replenish existing stock. Another risk is that less well selected and perhaps less healthy fish from other areas are introduced.

Another hazard associated with the reproduction period comes from poaching, as large fish like pike gather in numbers near the shores, and may be caught illicitly, with severe damage to the stock of breeders of the same species. As regards angling, we have already mentioned the fact it has become a mass

Carp (*Cyprinus carpio*)

phenomenon in recent years (a few million licensees in Italy). Also, the highly technological equipment and materials used have greatly influenced an activity that is not performed professionally and mainly concentrates on large fish like pike, perch and, among non-predators, carp. Unfortunately, there are no reliable data allowing even approximate assessment of the effects of angling on the condition of fish populations in volcanic lakes.

■ Legislation and protection

Until now, Italian Decree 152/99 and its later modifications and integrations has been the national instrument for protecting and monitoring waters. However, the new Water Framework Directive (2000/60/EC), within a new consolidation act (Decree 152/06) will make considerable changes to the monitoring, management and protection of inland waters in Italy. According to Decree 152/99 and its later modifications, volcanic lakes as “significant bodies of water” have so far been monitored every six months.

The parameters used for their analysis were: transparency of water, hypolimnetic oxygen, chlorophyll and total phosphorus. These values provided 5 categories of ecological quality ranging from 1 to 5 corresponding to excellent, good, average, insufficient and poor quality. According to the Waters Framework Directive, the ecological condition of a lake must be

Lake Martignano (Latium)

Flood events in Lake Albano

Renato Funiciello

Water and volcanoes have always marked the history of Rome, and myths and legends blend in with natural events. In particular, in the sector of the left flank (of the *Sette Colli* - Seven Hills), water has played an important role in moulding the landscape.

All the streams that flowed into the Tiber from the Alban Hills contained silty debris rich in volcanic minerals deriving from the erosion caused by large, sudden floods that had occurred in Lake Albano since the 4th century BC. After the lake flooded during the Roman siege at Vejo (398 BC), in 394 BC, the Romans built an artificial outlet about 1,200 m long, which, since then, has drained the lake from a point about 70 m from the lowest point of the crater rim.

Livy, Plutarch, Dionysius of Halicarnassus, Germanicus and other Greek and Roman writers and historians all reported these catastrophic events.

In the 19th century, geologists and archaeologists uncovered material buried under recent, multiple-layered debris, which can still be observed on the ground, from the margins of the lake as far as the Ciampino plain.

Modern geologists and archaeologists have recently discovered a great amount of palaeo-ethnological, archaeological and geological evidence which all goes towards confirming the data and indications provided by ancient sources.

The most recent evidence is not only found along the flanks of the Alban crater, but also in the plain below, which stretches as far as the main ring-road just outside Rome.

Authors of the 19th century called this plain *Tavolato*, and it was here that the Romans built the last stretches of the long aqueducts reaching the city, and modern engineers built a hippodrome (Capannelle) and an

The artificial outlet built by the Romans in 394 BC to regulate the level of Lake Albano

airport (Ciampino). Both exploited the flat, regular morphology of the Roman countryside.

The main cause of the flood events of Lake Albano is saturation of carbon dioxide in its deepest layers, and convection movement of the water due to lake degassing.

In 1986, similar events occurred in Lake Nyos (Cameroon), which is similar to Lake Albano. Its waters suddenly degassed and exploded, flooding the valleys and plains below. But is carbon dioxide still active as a degassing agent in the Alban Hills? The area between Acque Albule, Capannelle and Ciampino, and that stretching between Solforata di Ardea and Trigoria are still affected by cold thermal degassing like that affecting the best-known active volcanoes in Italy.

Sickler's map (1832), showing the Alban Hills south of Rome

Grey heron (*Ardea cinerea*)

assessed by checking the condition of the phytoplanktonic community, macrophytes, macro-invertebrates and fish, as well as components of hydromorphological and chemico-physical quality. The biological aspect in assessing environmental quality is therefore at the heart of the Waters Framework Directive.

Italian tree frog (*Hyla intermedia*)

Another issue regarding volcanic lakes is the presence of toxic substances (aromatic polycyclic hydrocarbons, agro-chemicals, etc.).

The quality objectives introduced by Decree 152/99 and adopted by Ministerial Decree 367/2003 include the monitoring of these substances and establishment of quality targets, to be achieved by 2008 and 2015, respectively. According to this legislation, “significant bodies of water” are distinguished on the basis of their specific functional use, i.e., freshwater lakes exploited for drinking water, and waters used for bathing.

The law states that, in lakes of the former category, which include Lake Bracciano, the water used for drinking and the type of treatment (chemical, physical, biological) it undergoes must be identified. This process is complemented by a specific decree that establishes the limits of some parameters for drinking water (Decree 31/2001).

Most volcanic lakes can be used for bathing, and their condition is monitored every two months by the competent authorities, according to Presidential Decree 470/1982 and its later modifications, which stipulate 12 chemico-physical and microbiological parameters and their relative conformity thresholds.

The importance of volcanic lakes as an Italian natural heritage is also evident from their protection systems. Except for Nemi and Martignano, they are all Sites of Community Importance, according to the Habitats Directive (92/43/EC). This definition is used for sites that contribute towards maintaining a particular habitat or a species of Community interest (listed in the Annexes) in a “satisfactory conservation state”. These are habitats at risk or typical of a particular biogeographic area, and host endangered, vulnerable, rare or endemic species, which means that sites for their protection must be created.

Volcanic lakes host several species of European interest which require the creation of Sites of Community Importance. Examples are the dragonfly *Cordulegaster trinacriae*, an Italian endemic, and, among fish, spined loach, barbel, south European nase, Italian orange-fin roach, Italian freshwater goby and lagoon goby, the last two being Italian endemics. Amphibians include Italian crested newt, and reptiles like European pond tortoise. Among mammals there is Capaccini's bat, which visits these areas regularly.

In addition, the law stipulates that some species (Annex IV of the Habitats Directive, as included in Annex C of Presidential Decree 357/97 and its modifications) must be rigorously protected, and their capture, captivity or killing, and destruction of or damage to their resting or breeding grounds are all forbidden. Among these are the dragonfly *Cordulegaster trinacriae,* green toad, Italian tree toad, Italian crested newt, European pond tortoise, and all bats.

Annex V of the Habitats Directive also lists some species, including barbel and polecat, the capture of which requires careful monitoring. The Annex also notes shad and lavaret, altough they are alien species in Italy.

The severe problem posed by alien species is covered by Presidential Decree 357/97, included in the Habitats Directive, and particularly in Article 12 of Presidential Decree 120/03 (a modification and integration to the previous one)

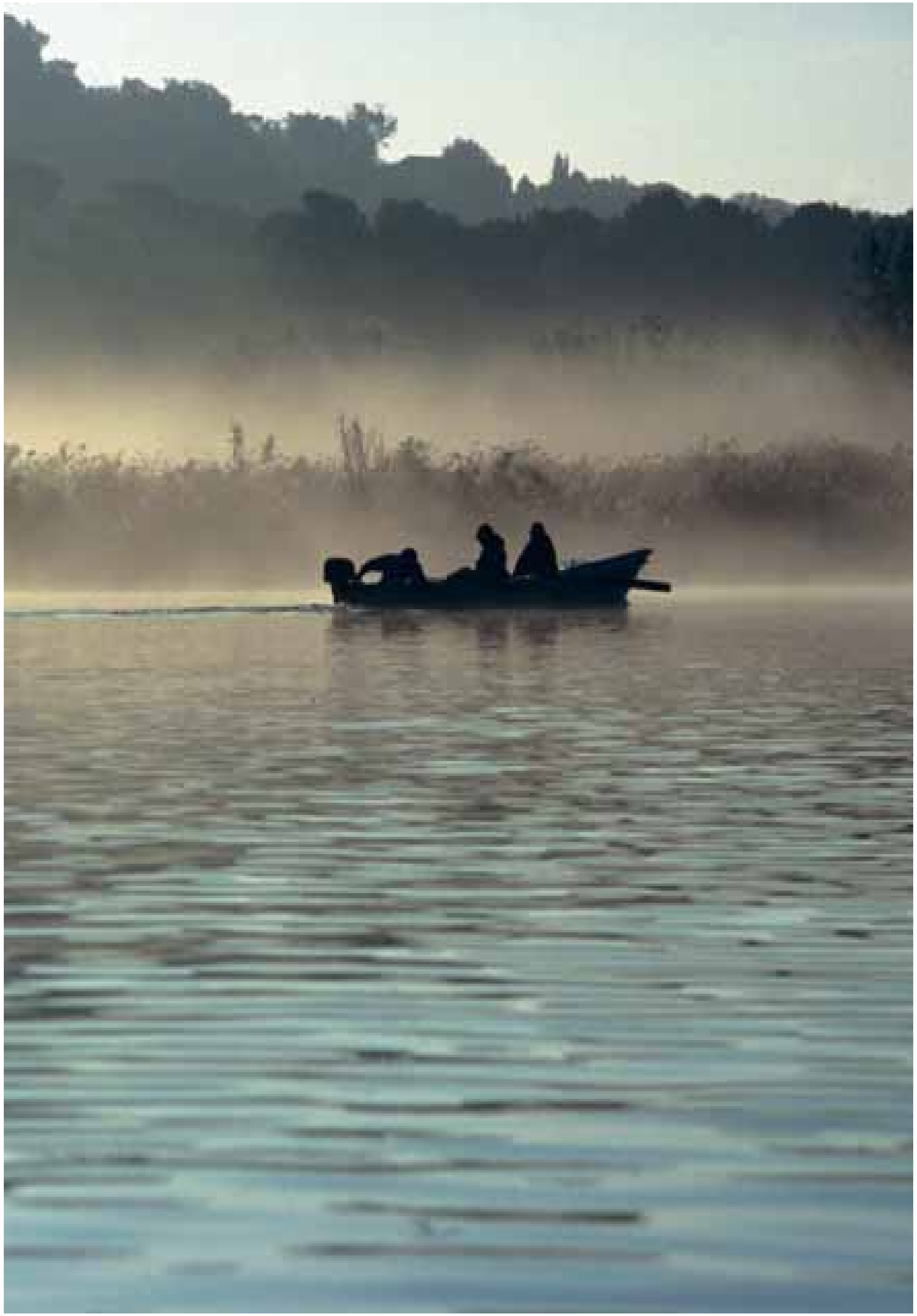
European pond tortoise (*Emys orbicularis*)

which states in sub-section 3 that it is against the law to re-introduce, introduce and restock in nature non-native species and populations. Therefore, the introduction of any and all alien fish species, the numbers of which are exceeding those of native species - with serious damage to lacustrine ecosystems and disturbance of the food chain - and the introduction of other groups (such as crayfish and coypu) are forbidden by law. However, since some species are very palatable, especially lavaret, this prohibition is ignored. Special laws are being devised to monitor the environmental impact of those species that were introduced long ago, have become naturalised, and are now very important for the local economy.

All large volcanic lakes are included in the Birds Directive (79/409/CEE), which was enforced in Italy by Law 157 of February 11 1992, and are classified as Special Protection Areas. These areas are either used for the conservation of endangered bird species or are habitats at risk of excessive change by man. Many bird species that visit volcanic lakes are included in the Annexes to the Birds Directive.

To provide additional protection to these biotopes, regional parks and natural sanctuaries were created (Bracciano-Martignano, Albano-Nemi, Vico) with Law 394 of December 6 1991. They are extremely important, because the protection of large, well-managed areas surrounding lakes should also prevent anthropic pressure and safeguard their natural balance.

Coypu (*Myocastor coypus*)



Suggestions for teaching

MARCO SEMINARA

■ Practical limnology

The silty-sandy shore of Lake Vico (Latium)

- Aims: to study the natural evolution of lakes; lakes as transitional geological phenomena; natural and accelerated anthropogenic eutrophication processes; principles and methods used to assess the trophic condition of a lake; construction of one or more instruments used in limnology.
- Level: middle and high school students (12-18 years).
- Collaboration: a biologist or naturalist specialising in limnology.
- Equipment: relevant literature on eutrophication, its causes and effects; information on the instruments required to carry out limnological sampling (chemico-physical parameters, monitoring plant communities and lake animals); thermometer with pocket, kit for measuring dissolved phosphates and nitrates (used in aquariums), field probes (pH-meter, conductimeter, dissolved oxygen gauge). Material to build one or more limnological instruments (see later). For laboratory analyses, a stereoscopic microscope and, if possible, an optical microscope, test-tubes to examine the material, slides and simple microscopy equipment (slides and cover-slips, needles, tweezers, glycerin). If possible, identification charts for zooplankton.

PRELIMINARY STAGE

1. Introduce the concept of natural lake evolution: eutrophication as a phenomenon associated with human activities and the various uses of the water resource.
2. Make an in-depth study of the factors regulating the process (biogeochemical cycles of nitrogen and phosphorus, light, water movement, recharge periods).

Lake Bracciano (Latium)

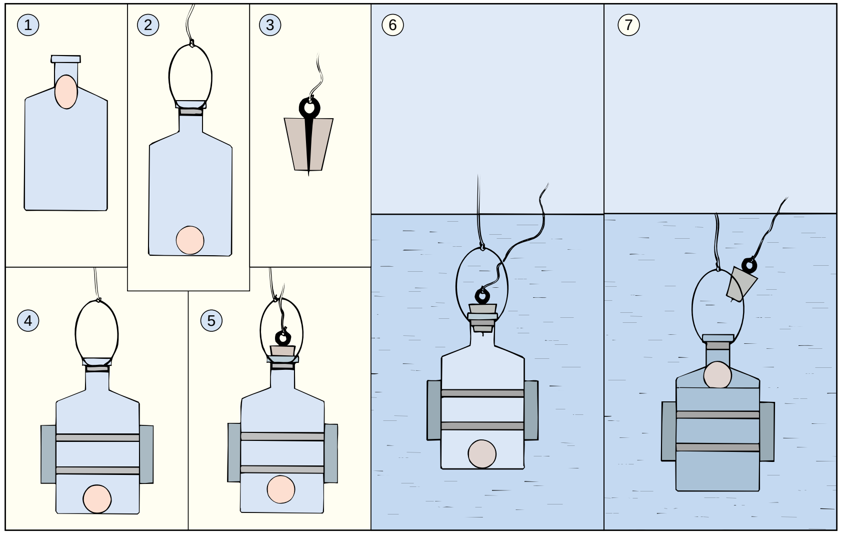
3. Explain the methods of analysis and criteria for evaluating eutrophication.
4. Find a sufficiently deep lake where excursions can be made by boat, to identify some of the parameters associated with the health of the lake, and collect samples of its biological communities.
5. Collect information on the lake, including data on its aquatic communities.
6. Identify which sampling tool would be most suitable to construct, and collect the necessary material.

HOW TO CONSTRUCT A WATER-SAMPLING BOTTLE

Aim: a water-sampling bottle is used to collect water at different depths for physico-chemical and biological analyses, e.g., in summer, above and below the thermocline.

Material required: a glass bottle (2 litres), silicon stopper, eye screw, lines (one, graduated, 4 mm in diameter, and a thinner one), a floating rubber ball slightly larger in diameter than the opening of the bottle, lead sinkers, metal or plastic bands of suitable size, and coated wire. Assemble the material as shown in the drawing below.

1. After heating slightly the rubber ball to soften it, insert it into the bottle.
2. Use a hydraulic metal band to secure a ring of coated wire round the neck of the bottle, and fasten the graduated line to it.



Assemblage and use of a water-sampling bottle (see text for numbers)

3. Screw the eye screw into the silicon stopper and fasten the thin line to it.
4. Attach enough lead sinkers to the bottle to make it sink when empty.
5. “Load” the bottle by stoppering it slightly.
6. Lower the bottle into the water at a depth you can measure with the graduated line, and leave the stopper line free.
7. Pull the stopper line to uncork the bottle allowing it to fill with water.
8. Draw the bottle out of the water slowly. The water in it has been collected at the desired depth.

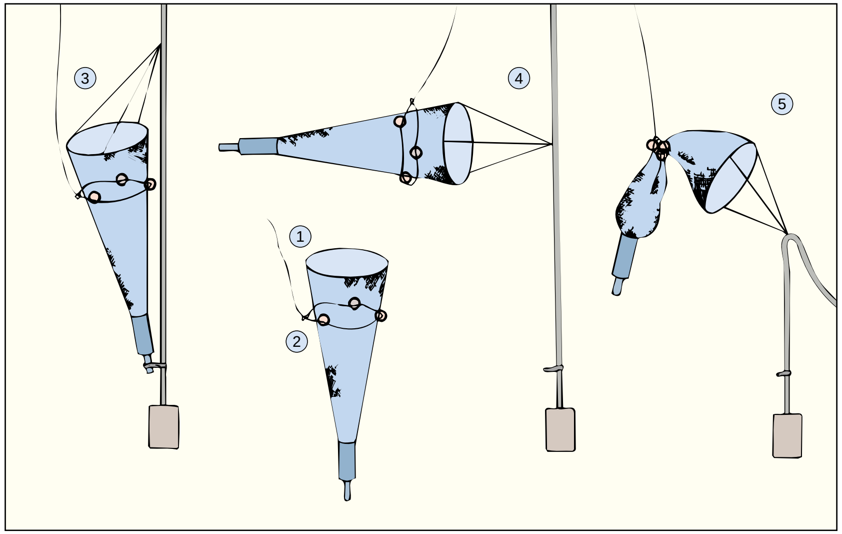
HOW TO CONSTRUCT A PLANKTON NET

Aim: a plankton net is used to collect samples of plankton from varying depths. Sampling depth depends on the maximum depth of the lake and its transparency.

Material required: fine-meshed net, line, three steel key rings, silk sewing thread, a chain 1.5 m long (4 mm in diameter), lead sinkers (1-2 kg), elastic bands.

Assemble the material as in the drawing below.

1. Sew the three key rings around the net at equal distances from each other and at one-third of its length from its opening.
2. Pass one end of the line through the rings to encircle the net completely.
3. “Load” the net (picture 2) and secure its end vertically to the chain with an elastic band, keeping it well stretched.



Construction and use of a plankton net (see text for numbers)

Plankton net

4. Lowering the graduated line slowly, bring the plankton net to the desired depth and pull the line slightly to close the net. Free its end to place it horizontally.
5. Tow the net by the choke line, preventing other plankton from being collected at different depths along the way.
6. Remove the samples from the net, reload it, and repeat the operation at a different depth.

HOW TO CONSTRUCT A SECCHI DISC

Aim: A Secchi disc is used to gauge water transparency.

Material required: a circular metal plate 20 cm in diameter, graduated line, steel key ring.

1. Paint one side of the disc a flat white, and the other black, with waterproof acrylic paint.
2. Make three equidistant holes along the disc circumference and secure three pieces of line.
3. Attach the three ends of the line to the key ring.
4. Fasten one end of the graduated line to the ring.
5. Lower the disc into the water slowly, with the white side facing upwards, until it can no longer be seen, and note the depth.
6. Raise the disc slowly until it can be seen, and note the depth.

Secchi disc

7. This last depth reading is averaged with the reading obtained on lowering, and gives the degree of transparency. The greater the depth reading, the more transparent the water. In certain light conditions, the black side of the disc is used. The operation at point 6 is carried out in the shade, to avoid reflections from sunlight on the white disc.

EXCURSION

1. Plan an excursion to a lake with an expert, preferably in summer (late May-June or September, for schools), when thermic stratification occurs.
2. Take the temperature at varying depths with a thermometer.
3. Collect water from near the bottom and also just below the surface.
4. Measure its transparency with the Secchi disc.
5. Analyse the main parameters of the water collected with the water-sampling bottle, using an analytic kit and/or field probes.
6. Collect plankton samples at varying depths, for later analyses in the laboratory.
7. Fix samples on site in 70% ethyl alcohol. Don't carry out this operation on all samples, but keep a few to analyse some organisms in vivo.

LABORATORY WORK

1. Analyse the plankton samples under a stereoscopic microscope.

A zooplankton sample taken from Lake Martignano (Latium)

2. Analyse the organisms in vivo, to identify rotifers (previously examined in fixed samples).
3. Prepare microscope slides with single animals collected from the fixed sample, soaked in a drop of glycerin.
4. Classify the material collected, distinguishing between rotifers, cladocerans, calanoid and cyclopoid copepods, and further, if classification tables and/or the help of an expert are available.
5. Under the microscope, separate the individuals of each collected sample into sub-samples and, if possible, calculate the numbers of individuals per litre, considering the volume of filtered water.

CONCLUSIONS

1. Analyse the various depths, calculating the percentages of copepods, cladocerans and rotifers, or other easily identified species.
2. Process collected data using graphs of each of the parameters identified (temperature trends, values of main parameters measured at different depths).
3. According to the data collected, define the approximate trophic category of the lake.
4. Write a scientific report, with an introduction (describing the aim of the work and the lake examined), methods used, results obtained (with graphs and charts) and their analysis.

The Isola Bisentina, in the middle of Lake Bolsena (Latium)

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Although this it is one of the first books on limnology, its general descriptions still maintain their value.

Glossary

> Abiotic: characterised by the absence of life.
> Alien: species or population introduced by man and not belonging to local flora or fauna.
> Anaerobic (process): chemical process occurring in the absence of free oxygen.
> Amphigony: sexual reproduction.
> Anoxia: lack of oxygen.
> Caldera: a large depression at the summit of a volcano, many times the diameter of the vent, caused by the violent emanation of large quantities of gases, partial emptying of the magma chamber, and consequent collapse of the central part of the volcano above the vent.
> Carapace: in crustaceans, the calcareous or chitinous case or shield covering the cephalothorax and sometimes the abdomen.
> Chlorophyceae: a class of unicellular or colonial green algae. In lakes, they are the group with the greatest variety of shapes, sizes and ecological requirements.
> Clostridia: anaerobic or microaerophilic saprophytic rod-shaped or spindle-shaped bacteria, some of which carry infectious diseases.
> Coenosis: community of plant species and animals living in an environment.
> Cyanobacteria: prokaryotic colonial bacteria containing photosynthetic pigments; they are usually included among algae due to their ecological role.
> Diatoms: yellowish-brown unicellular or colonial eukaryotic algae whose cells are enclosed in siliceous sheaths called frustules.
> Dinoflagellates: solitary plant-like flagellates that are typically enclosed in a cellulose envelope; as their flagella enable them to swim and they can feed on other organisms (e.g., bacteria), dinoflagellates are classified as both animals and plants.
> Distensive tectonics: movements of the Earth's crust creating normal and transcurrent faults, general increase of the surface where rocks are distribute, and thinning of the Earth's crust.
> Dyke: solidified magma in the fissures of a volcanic edifice. Dykes may be up to several kilometres long and range in thickness between a few centimetres and several dozen metres.
> Endemic: an organism exclusive to a specific area.
> Euphotic (zone): of, relating to, or constituting the upper layers of a body of water in which photosynthesis occurs at a light intensity of about 1% that of the surface.
> Euryhaline: able to tolerate a wide range of salinity.
> Fault: a fracture in the Earth's crust, accompanied by a displacement of one side of the fracture with respect to the other and in a direction parallel to the fracture; transcurrent faults run transversely and the two blocks move horizontally; in normal faults, the two blocks move away from each other; in inverted faults, the two blocks approach each other.
> Glycolysis: the enzymatic breakdown of glucose, glycogen, or other carbohydrate in the cytoplasm to produce energy; an essential stage in cellular respiration.
> Hydrogen ion: the cation H^+ of acids, consisting of one hydrogen atom whose electron has been transferred to the anion of the acid.
> Hydromorphic: of, or relating to, an intrazonal soil characterised by an excess of moisture.
> Ignimbrite: a hard rock formed by pyroclastic flux, i.e., a mixture of gas, liquid and fragmented solid material that may flow along the surface at high speed following explosive eruptions.
> Limiting (nutrient): a nutrient which is present in the environment in lower concentrations than others, limiting the growth of organisms when it is no longer available.
> Limnological: relating to limnology, i.e., that section of aquatic ecology that studies lakes as ecosystems.
> Lithosphere: the outer part of the solid earth composed of rock, essentially like that explored at the surface and believed to be about 50 miles thick; below the lithosphere is the asthenosphere, an earth-circling shell or zone within which the not necessarily molten material is believed to yield more readily to persistent stresses than the rigid crust above.
> Melilite: a silicate of sodium, calcium, aluminium and iron present in effusive volcanic rock.
> Meromixis: a layer of dense, concentrated water undergoing incomplete circulation at the autumn overturn; meromixis may be ectogenetic (an occasional event developing outside), crenogenetic (from springs below the lake that provide its deep layers with water containing dissolved substances), or biogenetic (accumulation in the deep layers of bicarbonates and silicates produced by biochemical decay or bacterial mineralisation).
> Nauplius: a crustacean larva in the first stage after leaving the egg; it usually bears three pairs of appendages and one median eye.
> Optical properties: the physical characteristics describing the behaviour, in terms of quantity and quality, of light.
> Photoreceptor: a receptor and transmitter of light stimuli.
> Palaeolimnology: the science that reconstructs the temporal evolution of lake environments by examining the inorganic remains of animals and plants extracted from samples of lake sediment.
> Petro-chemistry: characteristics associated with the chemical composition of rock.
> Petrographic: of petrography, the description

and systematic classification of rocks, usually based on microscopic study.
> Phylogeny: the history of the evolutionary relationships of animal and plant groups.
> Psammon: minute plants and animals that live in the water filling the interstices of sand adjacent to a body of freshwater.
> Pyroclastic: formed by fragmentation as a result of volcanic or igneous action.
> Rheophile: species preferring or living in flowing water.
> Syenite: a phanerocrystalline intrusive igneous rock composed of dominant alkaline feldspar with or without subordinate plagioclase and without notable quartz or nepheline; it is a variety of granite quarried in ancient times at Syene (now Aswan in Upper Egypt).
> Stenothermal: organisms resisting only slight changes of temperature.
> Synanthropic: ecologically associated with man and his activities.
> Taxocoenoses: the species of a taxonomical group living in a certain environment.
> Taxon (pl. taxa): any species or group of species corresponding to a formal taxonomic category (e.g., class, order, family, genus, etc.).
> Thermal conductivity: the quantity of heat that passes in a unit of time through a unit area of plate whose thickness is one when its opposite faces differ in temperature by 1°C. Heat propagates by conductivity because, in liquids, single molecules can travel considerable distances and collide with other molecules, thus generating an increase in temperature.
> Trophic: relating to the amount of nutrients available in the aquatic environment.

List of species

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