Article

L.F. Marsigli (1658-1730): Early Contributions to Marine Science and Hydrography

By Anita McConnell, London, UK

Abstract

During a career as a military engineer working in and around the Danube basin, Marsigli's wide-ranging scientific investigations provided him with a method when in 1706 he settled on the southern coast of France. His maritime studies led him to compose a treatise on the sea bed and its waters, followed by a lengthy section on corals and other lithophytes, which he misguidedly believed to be plants. Published as Histoire physique de la mer (1725), the issue in 1999 of the original text with English translation support the modern view of his priority in describing the physical aspects of this zone and confirm his title as 'Father of Oceanography'.

Résumé

Les investigations scientifiques de grande envergure réalisées par L.F. Marsigli, tout au long de sa carrière d'ingénieur militaire dans le bassin du Danube lui permirent d'acquérir une méthode lorsqu'en 1706 il s'établit sur la côte méridionale de la France. Ses études maritimes le conduisirent à rédiger un traité sur le fond marin et ses eaux, suivi d'une longue section sur les coraux et autres lithophytes, qu'il prenait à tort pour des plantes. La publication du texte original de l'« Histoire physique de la mer » (1725) en 1999, accompagné de la traduction en anglais, confirme la vision moderne de la priorité qu'il accordait à la description des aspects physiques de cette zone et vient conforter son appellation de « Père de l'océanographie ».

Resumen

Durante su carrera de ingeniero militar, trabajando en y alrededor de la cuenca del Danubio, las investigaciones científicas de gran alcance de Marsigli le proporcionaron un método cuando, en 1706, se instaló en la costa meridional de Francia. Sus estudios marítimos le llevaron a redactar un tratado sobre el fondo del mar y sus aguas, seguido de una larga sección sobre los corales y otros litofitos, que confundió con plantas. Publicado como "Histoire physique de la mer" (1725), el ejemplar de 1999 del texto original con la traducción inglesa documentan la visión moderna de su prioridad al describir los aspectos físicos de esta zona y confirmar su título de 'Padre de la Oceanografía'.

Early Education

Figure 1: Marsigli as a young man

Luigi Ferdinando Marsigli was born on 20 July 1658 in Bologna, one of the Papal States, the son of Carlo Marsigli, whose family included several eminent churchmen and diplomats, and his wife Margarita Ercolani (Stoye, 1994). Educated at home up to the age of fifteen, the boy then accompanied his father to Venice and Rome where the botanical garden inspired his lifelong interest in plants and natural history. Back in Bologna, seat of an ancient university, he benefited from the lectures of such luminaries as Marcello Malpighi, anatomist, Lelio Trionfetti, botanist, and Geminiano Montanari, astronomer and mathematician. After training in Rome on mathematics and military arts, he went to Padua, where Montanari and Malpighi were then teaching.

Thus prepared for life, but as a younger son, lacking any obvious career path, Marsigli, now twenty-one, joined a Venetian diplomatic mission to the Ottoman city of Constantinople, with orders to report on the land and its people. He set about his tasks in a methodical manner, making copious notes and writing to his former professors acquainting them of his discoveries. Fortunately for us, Marsigli was an inveterate hoarder of paper, and many volumes of his notes, drawings and letters now repose securely in the University of Bologna (Frati, 1925-28). His interest in the Bosphorus Strait was aroused on hearing from local fishermen and from the British ambassador, Sir John Finch, that the surface current flowing through the narrow channel from the Black Sea towards the Mediterranean was underlain by a current moving in the opposite direction. The possibility of similar contrary undercurrents through the Straits of Gibraltar and elsewhere was being debated in Britain, but neither party was then aware of the other (Deacon, 1997). To investigate further, he devised a simple current meter, consisting of a sounding line bearing spaced white cork discs; from the surface these discs could be seen responding to the force of the respective currents. He took water samples from each, finding that the upper stream was brackish, the lower stream, originating from the Mediterranean, heavier and more saline. This routine, questioning local people, then amplifying their reports with his own experiments, became his standard working method in later years. On his return to Rome he met the exiled Queen Christina of Sweden, a noted patron of science. His letter, conveying the account of the Bosphorus was formally addressed to Christina and she authorised its publication as *Osservazioni intorno al Bosforo Tracio overo Canale di Constantinopli* in 1681 (Marsigli, 1681). This little treatise reached London and the wider educated community the following year.

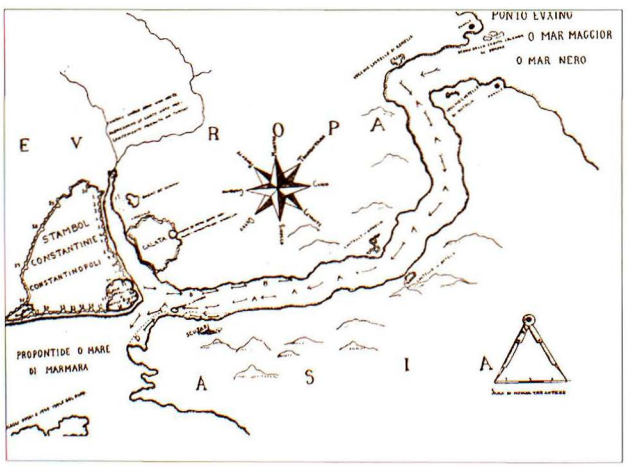

Figure 2: Bosphorus chart, appended to 'Osservazioni ..', 1681

Military Life and Travels

Further travels in central Europe followed until 1682, when, on learning of the Turkish threat to Austria, Marsigli joined the Imperial Army of Emperor Leopold. He was present at the siege of Vienna in 1683, where he was captured and held prisoner in very harsh conditions until ransomed by his

family. Undaunted, he remained in the army, rose to the rank of Colonel and travelled twice to Rome bearing news of Imperial victories. In western Europe interest in the conflict between Ottoman and Christian forces was handicapped by lack of intelligence, but in 1691, while Marsigli was again in Constantinople, a British diplomat, St-George Ashe, proposed him to the Royal Society as someone competent to supply maps of this little-known region, and the Society elected him to fellowship, unaware that many years would pass before Marsigli or his maps would appear in their house. Marsigli, meanwhile, was responsible for the planning and construction of the emperor's fortifications. He regularly crossed the Balkan mountain ranges, and traversed the broad Danubian plain with its many tributaries, locating river crossings suitable for an army with its baggage – no easy task in a land of marsh and fen – regularly visiting the other field commanders, and conveying his maps and reports to Vienna.

Danubian Studies

These migrations afforded afforded him many opportunities to study natural history, which he considered to extend far beyond the land and water, its climate and topography, its fishes, plants and animals, to include Roman antiquities, mines and hot springs, fossils, minerals and metals, and the intangibles of place-name derivations and notes on the plethora of languages spoken across the region. He compiled a vast amount of material on all these aspects of the Danube basin. In his surveys of the rivers, Marsigli had contrived a simple but effective apparatus to measure the velocity of stream-flow in the main river and its tributaries, mooring a boat in the stream and paying out a lightly-weighted line which ran out across a quadrant fastened to the stern of the boat. In still water, the line would run vertically down, moving towards the horizontal as the current velocity increased. The results were tabulated and diagrams showed how the core of maximum velocity swung across the channel as the river meandered, and where eddies and whirlpools formed. By 1698 he was ordering his notes into a suitable Latin text, to be embellished with maps, diagrams, and illustrations. A *Prodromus*, published at Nuremberg in 1701, heralded a lavish production, which was to be dedicated to the Hapsburg emperor.

Figure 3: River current meter, here shown with water-sampler and barometer in a decoration used for several chapter heads in Danubius Pannonico-Mysicus (1726)

Marsigli believed that his god had created an ordered world and that this order had not been destroyed by Noah's flood, as some people claimed. And so in later years, when the opportunity came, he wanted to extend his observations, hoping to find that the stratified rocks visible on land did indeed continue down into the depths of the sea. His chance came sooner perhaps than expected; he was second-in-command at the besieged Alsacian town of Breisach, which to the annoyance of the emperor surrendered precipitately in 1703. The commander was executed and Marsigli was dismissed the service. Disgusted with this punishment he shook the Hapsburg dust from his boots and, welcomed by France, made a whirlwind tour of his Parisian scientific correspondents before heading to the Mediterranean city of Montpellier, in Languedoc, where he arrived in 1706.

Introduction to the Mediterranean Coast

Montpellier confronts a shelving coast; east of the Rhone delta, off the rocky Provençal coast, deep water is close to land. Beachcombing, Marsigli came across shells and fragments of domestic refuse encrusted with a strange growth. For an inveterate collector and note-taker, this was a most interesting find, and he devoted considerable time to this new hobby. He also went out daily with the Italian coral-fishermen, who took their small boats out to the known reefs where bundles of old netting were lowered to entangle the coral and then hauled in on the capstan. When the gear was down, the boat drifted or proceeded slowly under oars, during which time Marsigli was able to sound and take temperature measurements.

Figure 4: Coral fishing boat and its gear. Model in the Museo del Torre Greco, Naples

Marsigli was welcomed to Montpellier's newly-formed 'Société royale', modelled on that of Paris (Carpine-Lancre and McConnell, 1985). He addressed the members on his researches, with water-colour illustrations that included a location chart, a section drawing of the sea bed showing where coral was dredged, and the apparatus used. Precious coral had been prized for centuries as a costly ornament and could be found in most cabinets of curiosity. But it was generally dry and polished, and few people bothered to enquire about its origins. As it was not dived for, no-one had seen it underwater in its natural surroundings. The coral fishermen assured Marsigli that it grew upside down in caves and under rocky ledges, and that it was already hard when it came from the water. Marsigli assumed it to be a mineral concretion, such as he had seen in petrifying springs. This

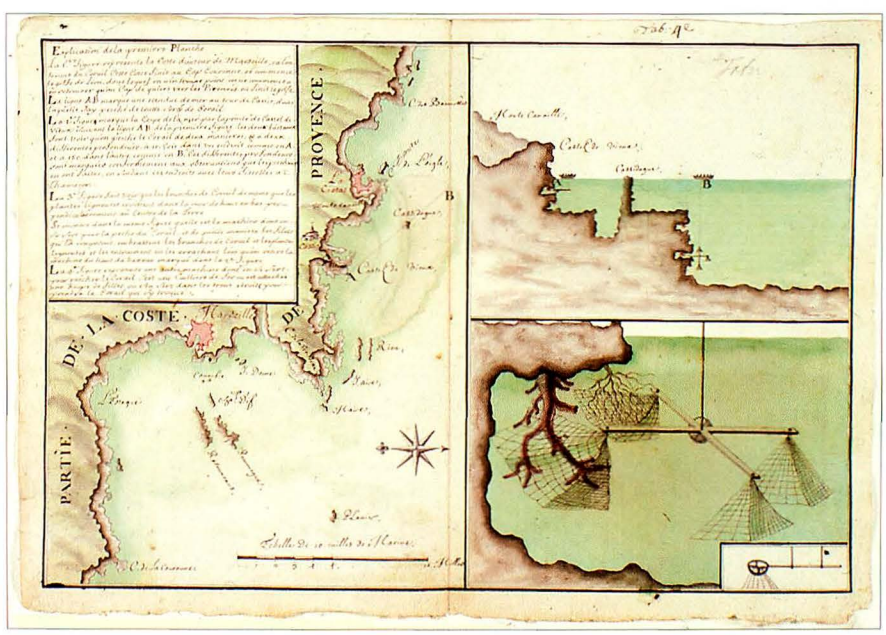

Figure 5: Watercolour, MS Marsigli 89 no.4, of the sort which Marsigli probably showed to the Société royale de Montpellier, to indicate where and how coral grew and was fished. Reproduced by permission of the Ministero per I beni e le attivite culturali

opinion was not universally held in Montpellier and Paris where analyses of coral hinted at a plant or animal origin, but due to his status, Marsigli's view was not publicly contested.

Marsigli then took a house on the shore at Cassis, east of Marseille, installing a laboratory with a furnace where he could analyse his material. The substances under investigation were either calcined - that is, dry heated - or distilled, to break them down into their component fractions, which were identified by adding standard reagents and watching the outcome – usually a colour change, curdling, or frothing. Marsigli refers to his accurate balance, his excellent microscope, and hand lens, but none of these instruments have survived. He started to compose a long letter addressed to the Paris academy (the incomplete draft runs to 65 pages), explaining how limy minerals soon coated sediments and human debris, and eventually formed branched corals. But he was aware that further investigation was needed, and he went out again with the fishermen. The discovery he made in December 1706 completely overturned his earlier opinions.

The Flowers of Coral

At sea one day, he put some coral branches into a bucket of seawater to keep them fresh for subsequent examination ashore. After taking the temperature of the air and the water at the depth from which the coral had been fished, he stored the jar in a cool place. Next morning he was astonished to find the branches covered with little white flowers. He took the branches out of the water – instantly the flowers vanished; he replaced them – the flowers re-emerged. He did this several times over the next eleven days, until the flowers turned yellow and congealed. In his mind Marsigli had already transferred coral to the vegetable kingdom, and he immediately sent his findings to the Académie royale des sciences in Paris, where this letter and its sequel were published in the *Journal des sçavans* (Marsigli, 1707).

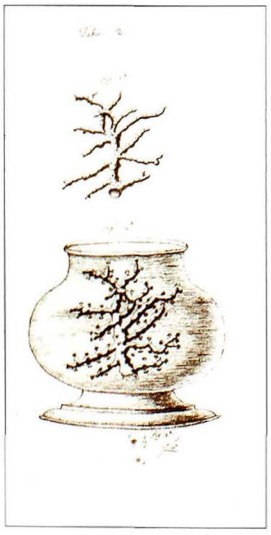

Figure 6: Coral flowering in a glass vessel of seawater. Histoire physique de la mer, Tab. XL .fig.180

Now Marsigli had not explained in his letter that he had been joined on the inspection of the coral by François Bon, president of the Montpellier royal society. Looking through a hand lens, Bon saw the 'flowers' moving, as if they were the legs of some small insect and the way that they retracted when he lifted the branch from the water was also insect-like. He drew Marsigli's attention to this, but the great man's mind was made up, and he did not wish to look again (McConnell, 1990).

He then started on his 'Saggio fisico', or essay, on the sea, which was to have five sections – on the sea bed, on its water, on water movements, on the plants, and on the fishes and other marine life. His exploration of the sea bed , probably sounded with a simple lead-and-line, enabled him to produce a chart of the sea off Provence, showing the locations near the islands where coral was fished, and those near the coast, where he took water samples. For this, he probably contrived a single-valved sampler akin to that used to capture his Bosphorus samples. Whatever its defects, that earlier sampler had recovered fresh water from the upper stream and saline water from below, and probably he found a similar contrast in Provence, where subsurface fresh water emerges offshore. His chart marks the edge of the abyss, beyond which no soundings were possible; in modern terms, a contour outlining the continental shelf, and possibly the first to depict this feature. He also produced profiles showing the nature and topography of the bed. He took water temperature measurements until the day when his thermometer was broken when the coral fishermen were forced to make a hasty escape from Barbary pirates. As the thermometer scale was particular to that instrument, the readings were relative and thus could not have been usefully compared with readings from any other thermometer. No mention is made of any insulation or pressure-protection so his table of temperatures at depth should be treated with circumspection. He tested the specific gravity with his 'areometre', or hydrometer, whose results are given in terms of the ring-weights loaded to bring it to equilibrium. These did not always accord with

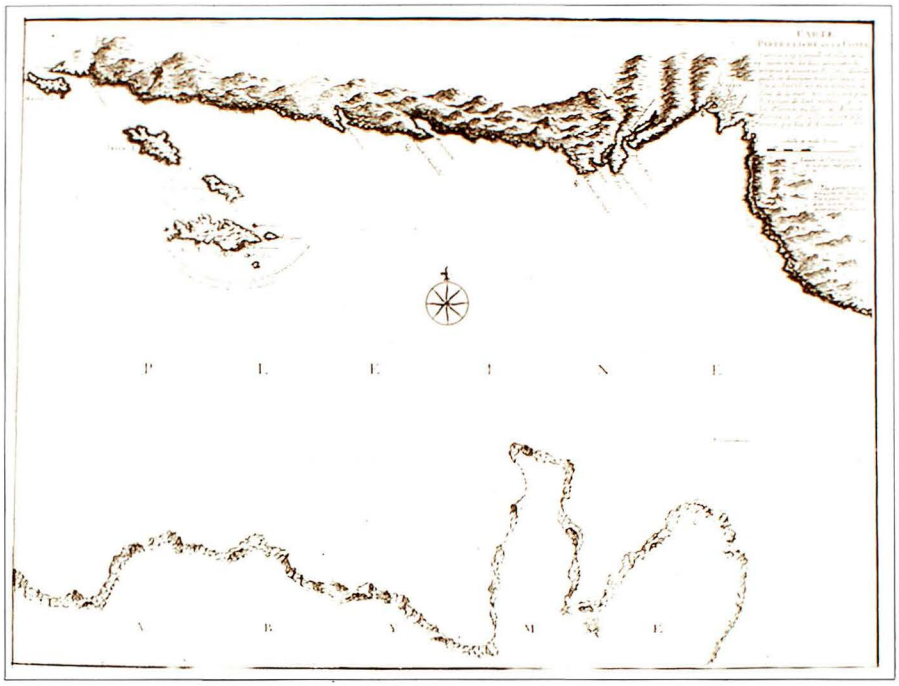

Figure 7: Sea bed chart, Ibid, Pl.II. The little urns, one near Cassis, the other two further west, mark water sampling points; the vertical line locates the profile, Figure 8; the lower horizontal band defines the edge of the 'abyss'

the results given by his hydrostatic balance, in which case Marsigli preferred to trust the hydrometer. He attempted to make artificial sea water, and experimented by cooking various foods in it. He was unable to account for the bitter taste, which he put down to seepage from coal seams outcropping at the sea bed. Movement of the water, in response to tides and currents, he understandably found difficult, for the apparatus which had served him in the waterways of the Danube basin was useless at sea. He set up a tide-pole, abandoning it when he realised that the sea level

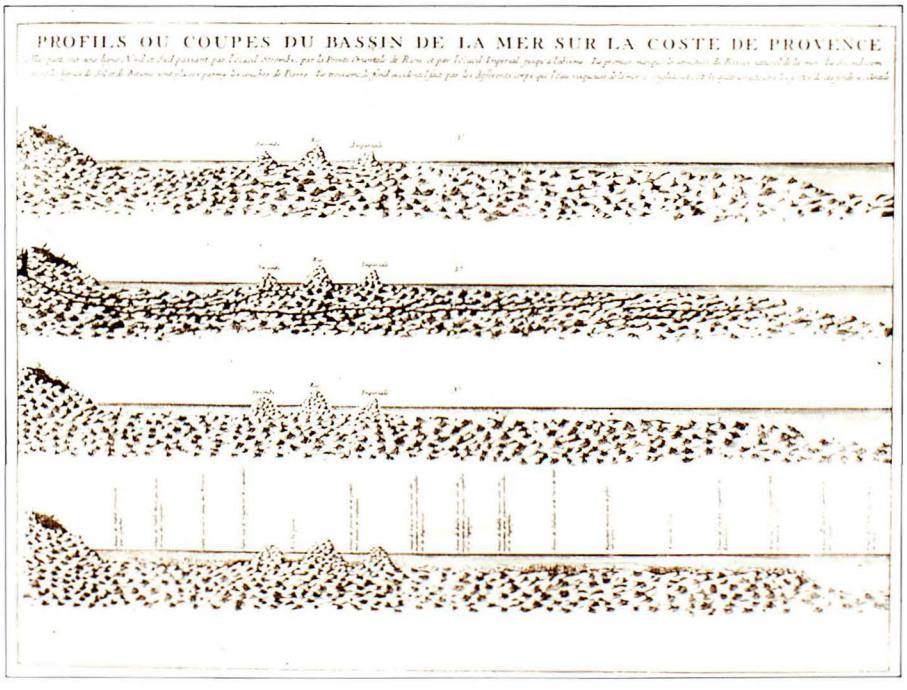

Figure 8: Sea bed profiles, Ibid, Pl. III

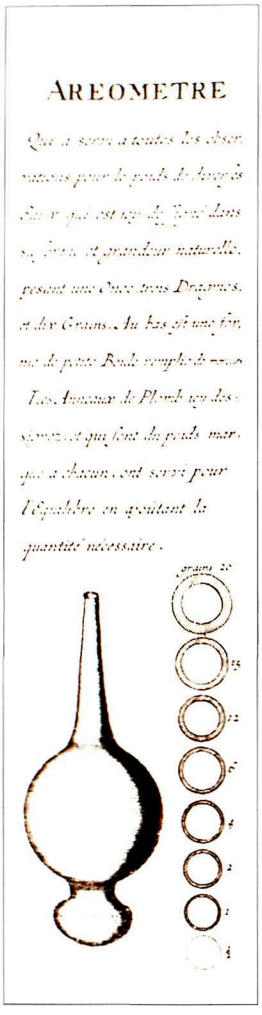

Figure 9: Hydrometer, Ibid, Pl. VII. The vessel is weighted with lead shot; the ring-weights are loaded on the neck until it floats at equilibrium

was influenced more by wind direction than any tidal regime, but he was able to study the form of waves in various weather conditions.

The section on plants, as he termed them, dealt with soft, woody and stony types – sea moss, sponges, sea fans, and assorted lithophytes. Marsigli spent an enormous amount of time examining and describing these strange forms. He sliced the stems along and across, examining each species under magnification, analysing their stems and sap, and tried his hardest to discover what he assumed would be the end product of his flowers, namely, seeds. Political events requiring his presence in Italy interrupted the work, but he was back at Cassis in 1709. He completed the first four sections, and having admitted that one man could never deal with the fifth section on fishes, he despatched the manuscript (in French) in two volumes to Paris, where parts were read at meetings. A synopsis of the work, in Italian, was published in Bologna and Venice in 1711 with the title *Brieve ristretto del saggio fisico intorno alla storia del mare* .... But nothing came of the book itself, beyond a few extracts in the Paris academy's journal.

Meanwhile, in 1709-10 he was involved in negotiations with the Senate and University of Bologna where he wished to reform teaching by endowing a new Institute and Academy, to which he would donate all the works of art, manuscripts and natural history specimens accumulated during his Danubian campaigns. In 1721 he decided to travel to London, where he could meet some of the scientists with whom he had corresponded over so many years. He would then cross to the Low Countries for a lengthy visit to his old acquaintance, the famous Hermann Boerhaave, professor of medicine, botany and chemistry at Leiden (McConnell, 1993).

Voyage to London and Leiden

For the first time Marsigli would see the 'Ocean', distinguished in his terminology from the 'Sea' – namely, the Mediterranean. Packing thermometer, hydrometer and notebook, he embarked at Leghorn in the British ship *Harley*. Plague was raging at Marseille, so the *Harley* sailed direct for the Medway, where the vessel was quarantined. During the voyage Marsigli could do little more than observe to his own satisfaction how the strata matched across the Strait of Gibraltar and along the Channel coast. He took the sea surface temperature daily, while the captain was taking his noon position, and he noted the variation between salinity in the Mediterranean and in that region of the English Channel where the Thames, Rhine and Maas poured in vast quantities of fresh water and sediment. He also observed the waves and endeavoured to judge their heights, captioning his sketch 'Various heights of waves seen in the Ocean during the voyage, except the greatest, named like those we saw in the Mediterranean. We observed not just their heights, but also their lengths, so that anyone may find out how much longer the waves in the Ocean are than those in the Mediterranean. Few ships are aware of how

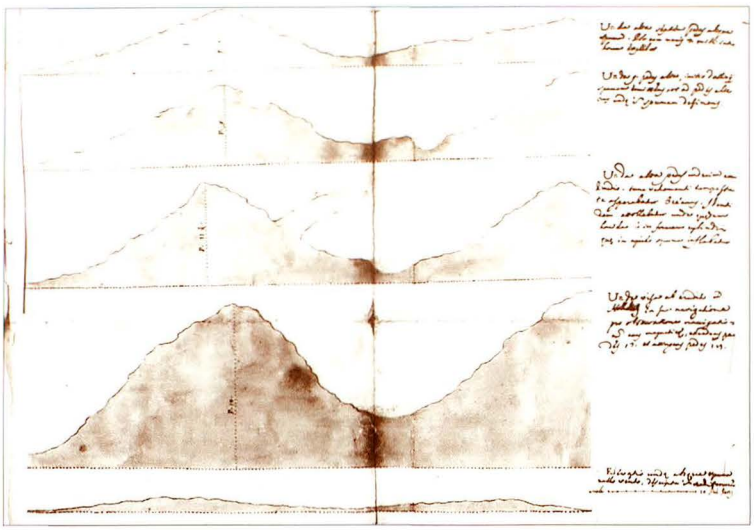

Figure 10: Waves (from the fair copy of MS Marsigli 97). The heights are carefully scaled at 1:10 Paris feet, on an adjacent page Marsigli notes (i) Ocean at its most calm. (ii) Wave two feet high, one affected at its edge a because of the approach of a higher one. (iii) Wave three and a half feet high. Foam borders another approaching wave. (iv) Wave four feet high without foam. The ship makes seven miles an hour through these. (v) Wave nine feet high; foam is sent out from the leading face and foam marks the feet of higher waves. (vi) Wave eleven and a half feet high. In violent storms the ocean then foams. A wave like that at c cylindrical in form and broken into foam at its peak is raised repeatedly. (vii) Wave seen by the learned Dr Halley, in his voyage to observe the magnetic needle at sea, exceeding seventeen feet and reaching eighteen feet. (viii) Height of wave without spray, not seen ...'

true this is for the Ocean, in contrast to the Mediterranean'. In London he met Sir Hans Sloane, John Woodward, Edmond Halley, with whom he discussed the heights of waves, James Sherard (who spoke Italian and whom he had met in Italy), and the aged Isaac Newton, president of the Royal Society, who to Marsigli's surprise could not converse in Latin - however, with the help of an interpreter they exchanged ideas on magnetism. At the Royal Society's house he was at last able to sign the book recording his admittance to membership.

Crossing to Helvoetsluis, Marsigli attended some of Boerhaave's lectures in Leiden before travelling along the Dutch coast, noting how the land had been built up of alternations of sand and peat, and undertaking further marine researches in what was for him an novel environment. He studied the seaweeds - these were unarguably marine plants - and fully intended that the information garnered on his journey from Leghorn and explored in more detail in Holland should supplement his treatise on the sea.

Publication of the Histoire Physique de la Mer

For Boerhaave was eager that his treatise should be published, and in French, which was now replacing Latin for scientific works. Marsigli retrieved his script, a Dutch engraver was commissioned to prepare the illustrations, Boerhaave wrote a foreword in praise of the subject and its author and a group of publishers agreed to undertake the engraving and printing without any money changing hands. A contract was also signed with a different publisher for the Danube study. Marsigli set off back to Italy. His marine treatise came from the press in 1725 as *Histoire physique de la mer*, followed in 1726 by the six double-folio volumes of *Danubius Pannonico-Mysicus*. When copies of the *Histoire* reached Marsigli, he was dismayed to find that the later numbering of the 50 plates had lost synchrony with the numerals keyed in the text, and that various other typographic errors had gone undetected. Further, the publishers changed his title of 'Essai' to 'Histoire', implying a universality which he regretted, not least because there had been no time to incorporate the fruits of his researches outside the Mediterranean. Nevertheless, the book rapidly acquired a readership in many countries, and a few of the 157 copies located in a recent census (Carpine-Lancre, in Dragoni, 1999) have some of the plates hand-tinted, while others have been given manuscript indexes, testifying to their readers' interest.

Marsigli's last watery excursion was on Lake Garda, where he made a somewhat unsatisfactory examination of its bathymetry, its waters and surroundings (Marsigli, 1930). He went back to his house at Cassis but suffered a stroke and was

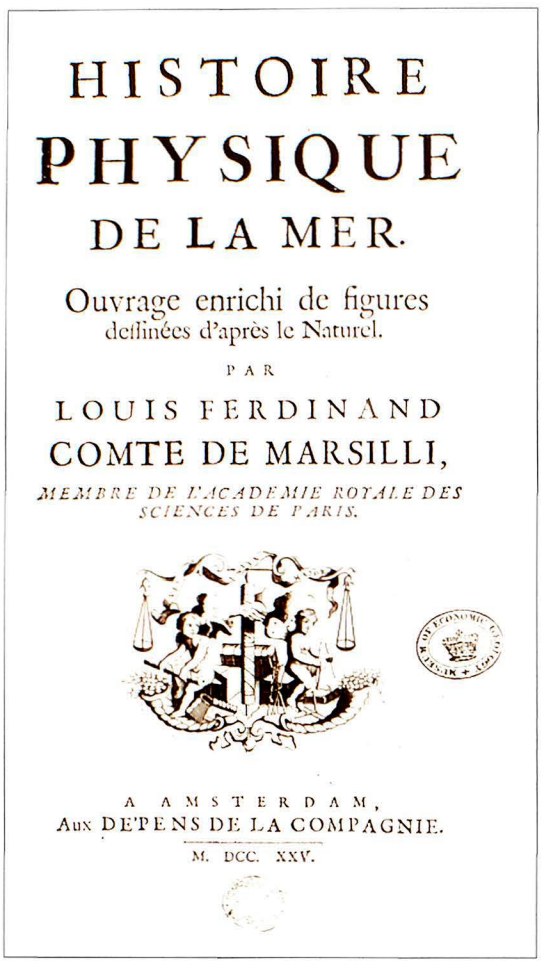
HISTOIRE
PHYSIQUE
DE LA MER.
Ouvrage enrichi de figures
dessinées d'après le Naturel.
PAR
LOUIS FERDINAND
COMTE DE MARSILLI,
MEMBRE DE L'ACADEMIE ROYALE DES SCIENCES DE PARIS.
A AMSTERDAM,
Aux DE'PENS DE LA COMPAGNIE.
M. DCC. XXV.

Figure 11: Histoire physique de la mer, title page

persuaded to return to Bologna. He died there on 30 November 1730, leaving beside his bed two manuscript drafts (one in Italian, one in Latin) and a fair copy in Latin of his journey to London and Holland, in the form of a letter in Latin to Boerhaave, also a manuscript addition to his study of the Bosphorus (which remains unpublished) and a treatise on the Ottoman empire, which was published in 1732.

The delay in publishing the *Histoire* and the *Danubius* and the fact that they were published in reverse order has caused the debt which the *Histoire* owed to the *Danubius* to be overlooked. For it was in the heart of Europe that Marsigli had learnt his geology and natural history techniques. But he had devoted most of the *Histoire* to the so-called plants, and soon after 1725 naturalists had come to accept that sessile marine invertebrates were part of the animal kingdom. Some sections of the book were pillaged for various encyclopaedias; articles on 'Coral' and 'Sea, Basin of the, Fundus Maris' in the several 18th-century editions of Abraham Rees' *Cyclopedia* were widely copied in other encyclopedias. From such sources they were incorporated into texts dealing with the sea and the marine environment until the 19th century. Sir John Murray acknowledged its value in his Introduction to vol. 1 of the *Challenger* Reports (1895), but thereafter Marsigli's reputation, and his book, fell into obscurity, with a concomitant decline in its second-hand price.

In recent years, however, the condemnation of Marsigli for his mistaken ideas about coral has given way to a recognition of his pioneering role in marine research and the value of the first three brief chapters, those dealing with the sea basin, water quality, and water movement. Most early marine investigations were made from ships on passage and their observations had inevitably been random or widely separated, so that it was impossible to check their accuracy; Marsigli, perforce, worked out from shore in a limited area. His charts show a submarine topography clearly related to the adjacent coast, and his values for temperature and salinity, albeit relative rather than absolute, are at least credible. Probably few people today read on to his repetitious fourth section, on what he considered to be the plants. But he himself has been rehabilitated, both as a worthy citizen of Bologna, and as the 'Father of Oceanography'.

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Biography

Since publishing No sea too deep - a history of oceanographical instruments to 1914 (1982), Anita McConnell has enjoyed many happy hours browsing in the vast collection of Marsigli papers in the University Library in Bologna. A curator in London's Science Museum from 1964 to 1987, she now also researches and publishes on the history of London's scientific instruments trade.

E-mail: amac1936@hotmail.com