# İSTANBUL BOĞAZI'NDA MARSİLİ'NİN AKINTI ÖLÇÜMLERI

# MARSILI'S CURRENT MEASUREMENTS IN THE BOSPHORUS

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**ÖZET:** 17. yüzyılda doğadaki yoğunluk akımlarıyla ilgili doğrudan gözlemler yapan, bu gözlemleri deneysel ve kuramsal temelde doğrulayan bilimci ve diplomat Luigi Ferdinando Marsili, karmaşık deniz sistemlerinin en önde gelen bir örneği olan Türk Boğazlar Sistemi'ndeki değişim akıntılarının dinamiğini ilk kez bilimsel bir anlayışla ortaya koymuştur. Marsili'nin zamanından bugüne değin bu kavramlar boğazlar dinamiğinin ve deniz-bilimin temelini oluştururlar.

**ABSTRACT:** Luigi Ferdinando Marsili, scientist and diplomat of the 17th century, making direct observations in nature, verifying these measurements with experiments and a theoretical basis for density driven currents, provided the first scientific understanding of the dynamics of the exchange currents through the Turkish Straits System, a foremost example of complex marine systems. The leading concepts from Marsili's time still form the basis of the present understanding of strait dynamics and the foundation of ocean science.

### First Scientific Measurements in the Bosphorus

Unlike the confused attempts of his time to explain natural phenomena, Luigi Ferdinando Marsili proposed an innovative hypothesis stating that 'the sea could be measured', following the Galilean tradition (Pinardi, 2009). Direct field observation was for him the real instrument of knowledge (Francheshelli and Marabini, 2006).

His voyage from Venice to Constantinople in 1679 gave young Marsili the chance to determine density (weight) of sea-water samples collected at the surface and at depth along the sea route, and then within the Bosphorus Strait. His measurements showed water near the Black Sea to be much lighter than the Mediterranean water, and his measurements in the Bosphorus showed the surface water of Black Sea origin to be significantly lighter than the water samples from the undercurrent, which had weight consistent with the Mediterranean water (Gill, 1982; Pinardi, 2009). Based on these initial observations, Marsili reached a good understanding of the pattern of circulation of the Strait of Bosphorus and successfully constructed the first theoretical explanation of its hydrodynamics.

Although Marsili's explanation of Strait exchange flows was recognized as early as 1684 by the greater world, it fell into obscurity in the centuries ahead, until rediscovered in the 19th and 20th centuries. Despite the reputation he enjoyed during his time and later, Marsili's scientific work was almost forgotten as a result of some idealistic bias in the following centuries. Although he also had great contributions to earth science, his geotectonic ideas were largely ignored or mentioned perfunctorily in historical reviews such as by Şengör (2003) and others (Vai and Caldwell, 2006).

It has been said that Marsili's personal encounter with the Bosphorus, the relatively small channel of a strait where waters from two great basins with the highest contrast of properties in the world, accessible for measurements played a central role in his discoveries, which would not have been possible otherwise (Soffientino and Pilson, 2005). While British scientists had long-lasting concern over Gibraltar currents, they were not able to come up with an understanding of the exchange currents until the 19th century, for lack of reliable measurements. Despite the urge for new information in the 1860's on straits, Captain Spratt (1811-1889) found no evidence of undercurrents in the Bosphorus and Dardanelles and insisted that the fast surface currents ran over static water below. If there was any Mediterranean water underlying the Black Sea water, it was due to occasional incursions caused by wind pulses (Mills, 2009). Some of these myths and orthodox views fed by the absence of new evidence, survived until the 20th century, despite Marsili's ingenious discoveries in the 17th century.

Marsili had heard about the existence of an undercurrent from local fishermen (Marsili, 1681; Deacon, 1971), who already had experienced the reversal of currents at depth with their nets submerged into it. About a century earlier, Peter Giglio (Gilles, 1561) had referred to "Anaplus Bospori" of Dionysius of Byzantium from the second century AD (Gungerich, 1958), mentioning reversed currents at depth. Gilles intuition based description, supported by local stories accumulated over the ages, was close to the modern view, although his attempted speculations did not provide a physical explanation. The underflow was also referred to in the sixth century note of Procopius of Ceasarea (Gill, 1982; Deacon, 1982; Korfmann and Neumann, 1993), and possibly known since ancient ages.

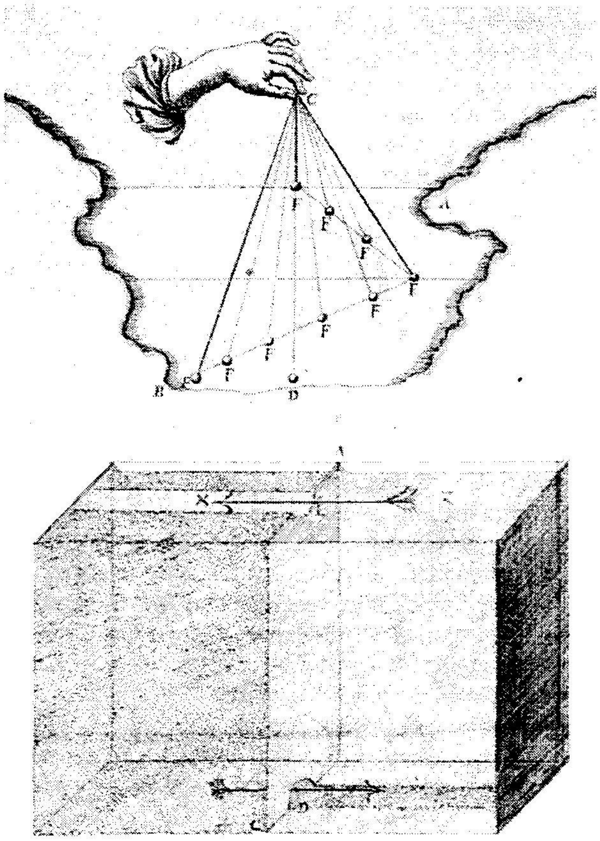

**Fig. 1.** (a) Measurement of currents by visual observation of the drift of markers on a rope, (b) Marsili's experimental setup for observing density driven currents.

Marsili thus went forward for direct experimental verification of the current reversal by visually observing the relative horizontal displacements of white markers on a rope lowered into the water (Fig. 1a). He found the depth of reversal of the currents to be between 8 and 12 'arşın' or 'kulaç', the Turkish length units of the time.

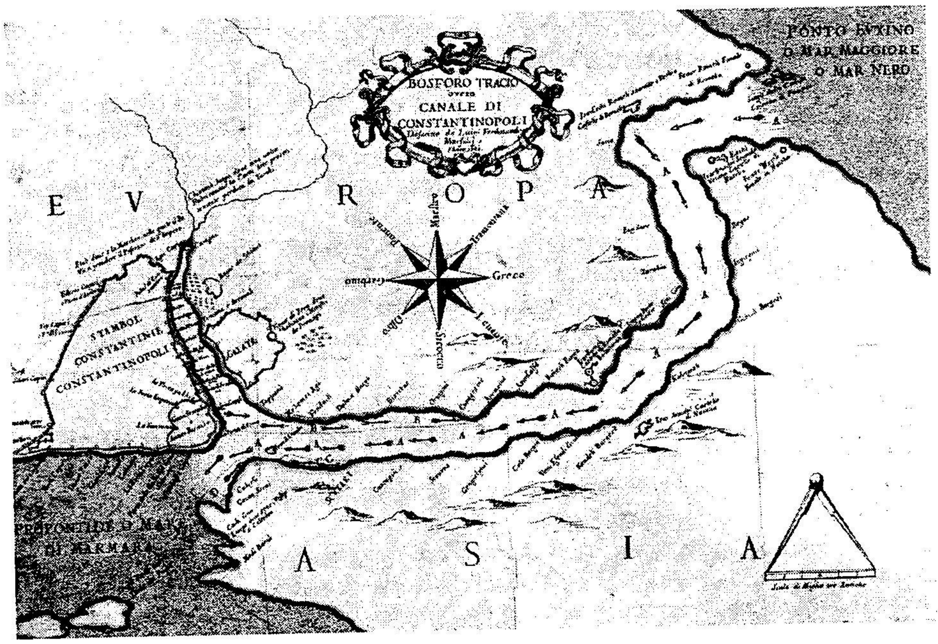


**Fig. 2.** Bosphorus currents as depicted by Marsili. Note the 'A' letter indicating the surface flow of Black Sea waters to the Marmara Sea, while B and C indicate reversals near the coastlines.

Marsili finally devised a laboratory'fluid dynamics' experiment upon return to Italy from İstanbul - a total novelty of his day (Fig. 1b), which highlighted the density difference between waters of the adjacent seas to be responsible in generating currents of opposite directions at different depth levels. Filling two sides of a partition placed in a tank respectively with water taken from the undercurrent and the dyed water of the Black Sea, Marsili observed currents flowing in opposite directions through holes opened in the top and bottom of the partition plate. Referring to his failed earlier attempt to measure sea level difference between the Black Sea and the Mediterranean with a mercury barometer, Marsili also observed and hypothesized that the exchange currents in the laboratory experiment did not need a water level difference between the two partitions, and thus was a direct result of the different density of water in the divisions (Gill, 1982),

Marsili constructed the first current-meter (Frazier, 1974) of his day, a wooden instrument with six paddles on an axle, and measured currents by counting its turns against time measured with the swings of a pendulum (Soffientino and Pilson, 2005, 2009). The maximum currents he measured were about 1 m/s, of the same order as modern measurements, which indicate extreme currents of up to 2-3 m/s in the southern Bosphorus. He then used his measurements for a realistic depiction of surface currents in the Bosphorus (Fig. 2). The reversal of currents near Beşiktaş, on the western (European) side near the southern end of the Strait (current B, which Marsili incorrectly attributed to freshwater discharge effects) as opposed to the southward flowing main current (A) is a well-known feature today. He also showed reversed currents (C and D) on the eastern (Asian) side, but these can not be verified today because of extensive harbor breakwaters built in the area since then.

The arguments therein incurred by Marsili, especially about the existence of a complex vertical structure of currents in the Strait of Bosphorus was the subject of lively debate in the next decade both in books and in geographic publications.

The first mention of the work of Marsili in 1684 was in a paper on currents of the Adriatic Sea by Geminiano Montanari (1633-1687), Marsili's former master, mathematician and astronomer of Modena, professor at Universities of Bologna and Padua, and animator at the didactic Accademia della Traccia (Cavazza, 1990, 1995). A positive assessment of the work of Marsili appearing in Leipzig, (Actorum Eruditorum Academy, 1692) presented a detailed summary on the surface circulation, surface current measurements, seasonal sea level variations, tidal range in the Bosphorus, and gave Marsili's reasoning on the role of density differences on driving the counter-flowing lower current. His book reached the Royal Society of London in 1684; yet the significance of Marsili's work remained largely unnoticed until the 19th century (Deacon, 1997, 2001).

Soon enough, harsh criticism of the scientific work of Marsili appeared. Some observers (Benetti, 1688) claimed that Bosphorus was no different from a big river that carried water and sediments out from the Black Sea. The same year, a Dutch author (Dapper, 1688) stirred opposition by claiming that Marsili had no right of boasting about the discovery of the lower current of the Bosphorus, since it was known by Turkish fishermen and revealed by Gilles nearly a century and a half earlier.

It is not known whether Marsili responded directly and publicly to Dapper, but it seems that he did not, busy as he was in the ongoing military campaigns in the Hungarian plains at the time. Only later, in the second decade of the eighteenth century when he prepared a new edition of the comments about the Thracian Bosphorus, he noted as part of his partly handwritten autograph (Marsili, undated) that Dapper had no right to accuse him of plagiarism, as he had acknowledged the poor fishermen of the Bosphorus with gratitude and praise, and had shown, quite unaware of Gilles, that the current system originated from density (weight) distribution, based on measurements. In this short reply, Marsili did not at all attempt to subvert the chronology proposed by Dapper, but rather emphasized the senselessness of the comparison between opportune discovery of an existing natural curiosity already described by Gilles and the identification of the cause of the current reversal including its demonstration by laboratory experiment. Marsili believed he belonged to the 'aliquos neotericos' school, i.e. a later term for second generation followers of Galileo, rather than the old Greek / Latin tradition of geographers / adventurers.

The importance of Marsili's conceptual scheme, quite different from the old compilers of Isolario, did not escape the attention of Queen Christina of Sweden, who suggested Marsili to put less emphasis on his interesting studies of political, military and civilian lives of the Ottoman Empire, and instead to focus exclusively on natural observations and to build a complete model to carry out laboratory experiments on the circulation in the Strait, with Cristina financing the publication of results, as Marsili recalls in his autobiography (Lovarini, 1930).

It seems that the need to update archaic ideas from the work of Gilles, produced an effect of alienation (Ginzburg, 1994), demonstrating the inability of the dominant culture to give recognition to the work of Marsili, for example, indicated by errors of interpretation in the Leipzig summary of his work (Actorum Eruditorum Academy, 1692).

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