Processes affecting upwelling and primary productivity of the Messina Straits

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Abstract. The effect of tidal currents on the upwelling in the Messina Straits was investigated during summer 1992, both by continuous survey of tracer parameters with a sailing vessel and by 24-hour surveys at significant hydrological stations. The current field of the Straits was also monitored by a grid of currentmetric chains and periodical surveys using a Doppler current profiler. Deep waters reach the upper layer everywhere in the Ionian basin of the Straits during syzygy, with the exception of the middle zone of the system where the warmer Tyrrhenian surface water flows. The upwelling of nutrients stimulates phytoplanktonic growth and greatly increases the primary productivity. Divergence of deep waters is strongly reduced in quadrature phase, when current velocity is attenuated. The oscillation of the tidal level is mainly responsible for the upwelling at the sill, while the vertical movement induced by longitudinal advection on the lateral areas appears to be correlated with the speed of both southward and northward fluxes.

1. Introduction

The strong tidal currents in the Messina Straits have been well known since ancient times. Indeed, the tidal cycles of the Tyrrhenian and Ionian seas have opposite phases, and currents flooding alternately through the sill reach velocities higher than 6 knots. Various investigations have been carried out since 1925-26 (Vercelli, 1925; Vercelli and Picotti, 1926): on the hydrodynamics by Defant (1940 and 1961), Bossolasco and Dagnino (1957 and 1959), Massi et al. (1979), Brandolini et al. (1980), Tomasin and Tomasino (1983), Mosetti (1988); on physical, chemical and biological aspects by Magazzù and Andreoli (1971), DeDomenico et al. (1976), Magazzù et al. (1981), Genovese et al. (1984), Cortese and DeDomenico (1990); and on water quality conditions by DeDomenico et al. (1980 and 1988). The intensity of energy as well as the

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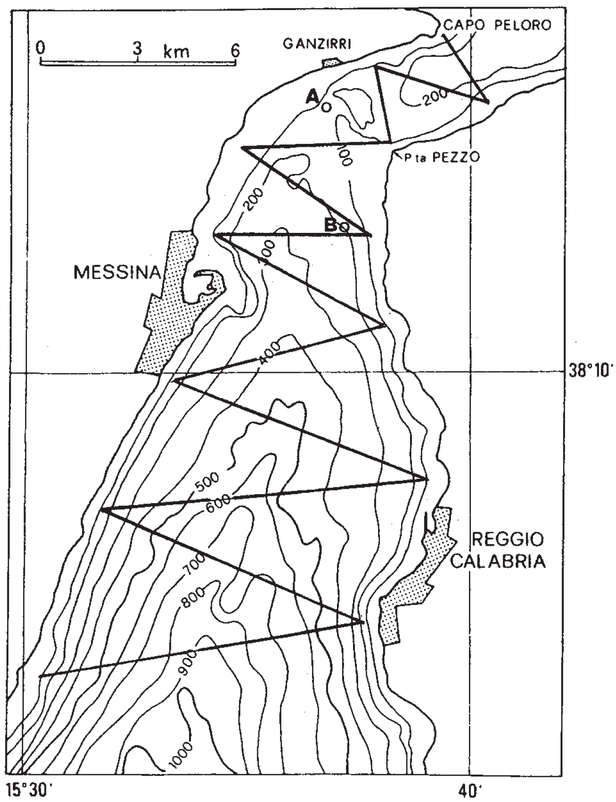


Fig. 1 - Track of the continuous survey. Southward and northward directions were followed at low and high tide respectively. Bathymetry is in meters. Stations A and B refer to Fig. 8.

particular morphological features of the Straits are responsible for the upwelling of intermediate water to the photic layer. Despite the potential ecological and economical impact of this process, available information is not exaustive regarding the extent of the area affected by upwelling, the role of forcing factors and any biostimulation of phytoplanktonic growth by nutrients reaching the photic layer. The presence of an upwelling area characterized by high concentration of nutrients was detected close to the sill by DeDomenico et al. (1988) and confirmed by Cortese and DeDomenico (1990). However a deep understanding of the process is not attainable chiefly because the greater part of previous surveys were carried out only at the central axis of the Straits. Furthermore, the behaviour in both time and space of the main forcing factor (i.e., tide) was rarely accounted for in planning upwelling studies.

2. Methodology

Both the techniques of continuous survey of suitable tracers from a sailing vessel and 24-

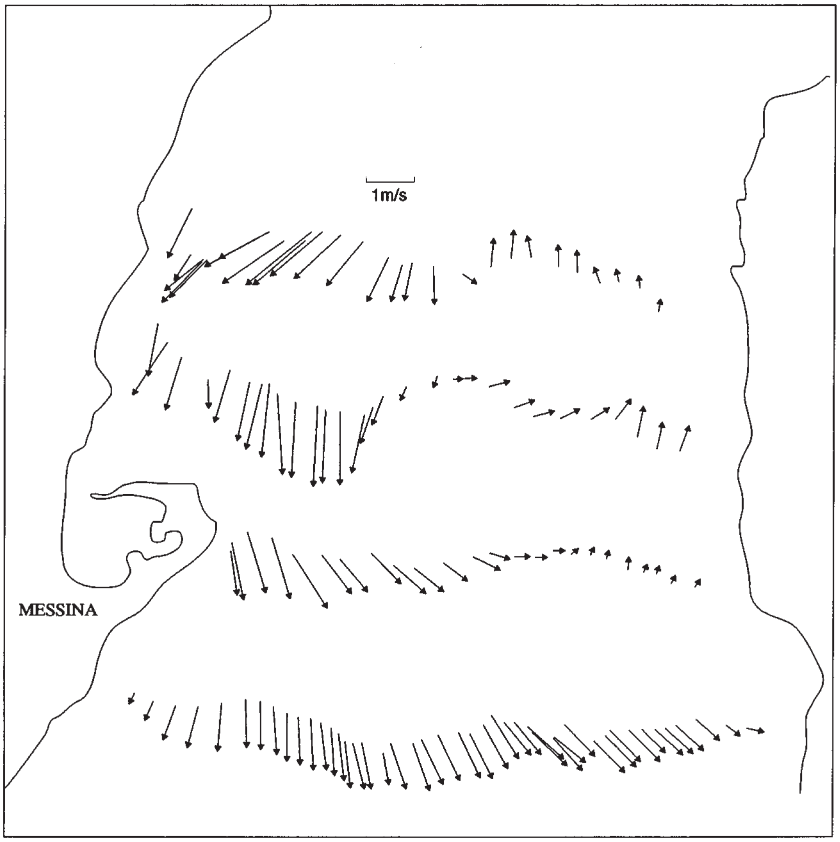


Fig. 2 - An example of the current field at a depth of 8 m found during the low tide phase using an acoustic profiler.

hour surveys at significant stations were used to investigate the upwelling processes. Each continuous survey was performed over about 3 hours around the peaks of maximum and minimum tidal level, in order to seize the quasi-stationary situations following the dynamic phases of growing and ebbing tide, respectively (see Fig. 1).

On the other hand, according to Mosetti (1988), the amphidromic node lies approximately at the sill. Therefore the phase distribution varies sharply in this area where cotidal lines intersect, as indicated by the detected current field (see the example of Fig. 2). Nervertheless, the tidal phase is distributed more homogeneously in the southern areas of the Straits (Defant, 1961). A multiparametric ME-ECO probe was used for the continuous determination of salinity, temperature, dissolved oxygen, pH, turbidity and "in vivo" fluorescence on seawater pumped on board from selected depths. Nitrate was measured automatically by Whereby's method with a SYSTEA-INTEGRAL analyzer. Primary productivity was determined discontinuously on samples collected from the same water line after "on deck" incubation, under controlled light and temperature conditions, using a BECKMAN mod. 1801 liquid detector. An IDROMAR CTDO probe was used for vertical profiles at fixed stations. Analytical data were elaborated and plotted

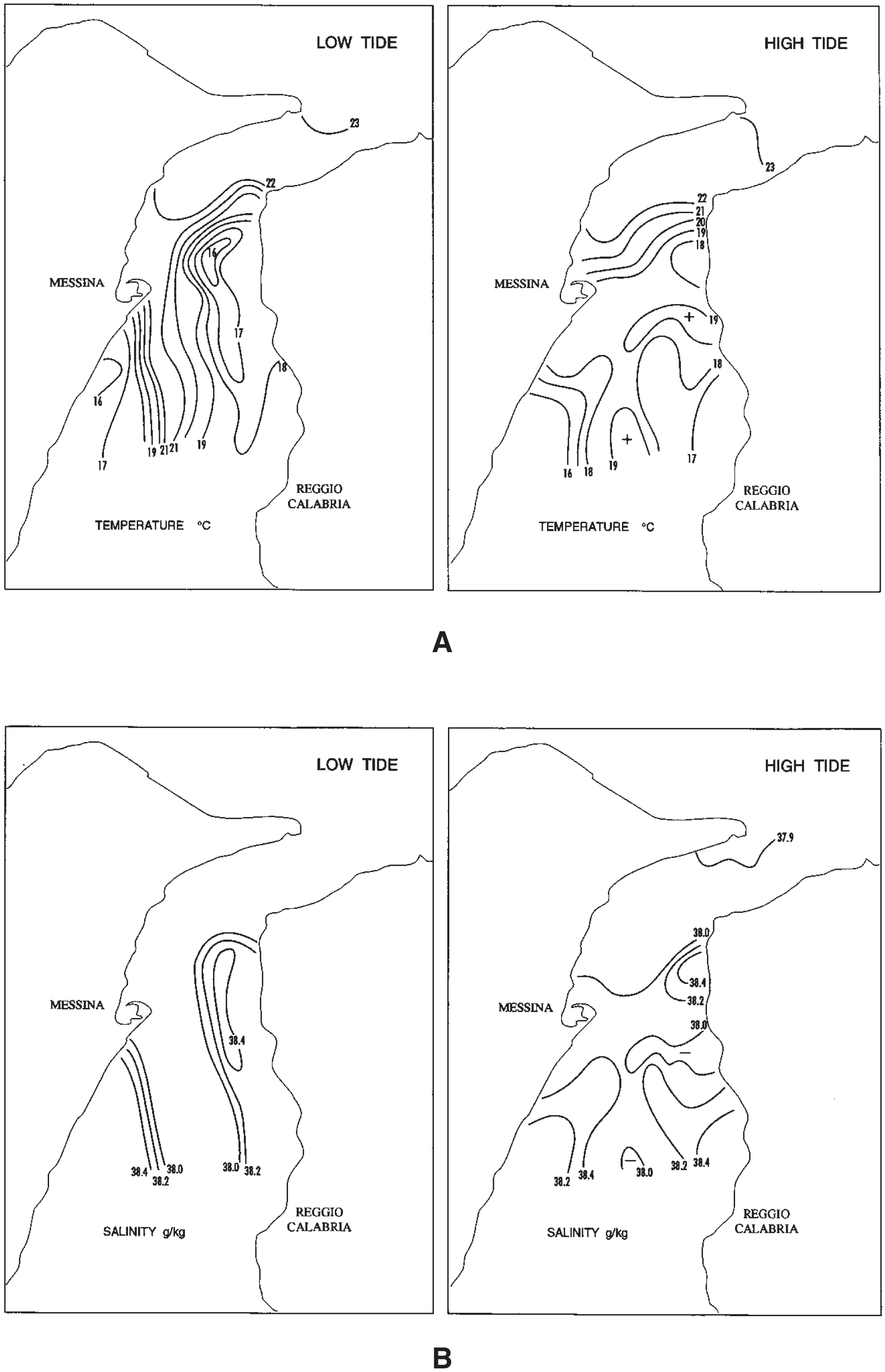
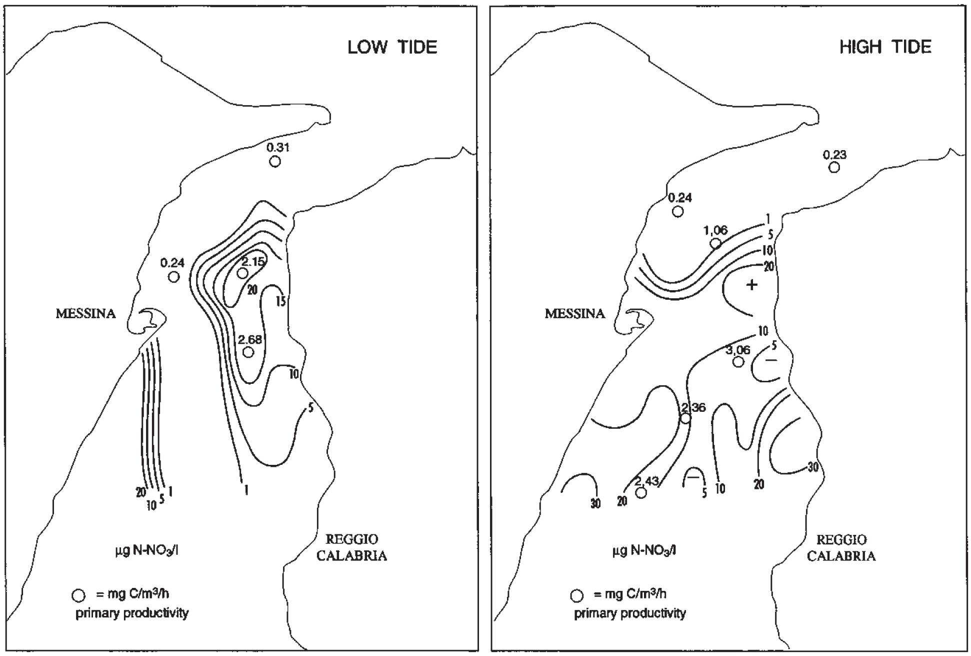


Fig. 3 - Effect of diurnal variability of syzygial tide on the surface distribution of temperature (A), salinity (B), nitrate and primary productivity (C) and fluorescence (D) - (July 17, 1992).



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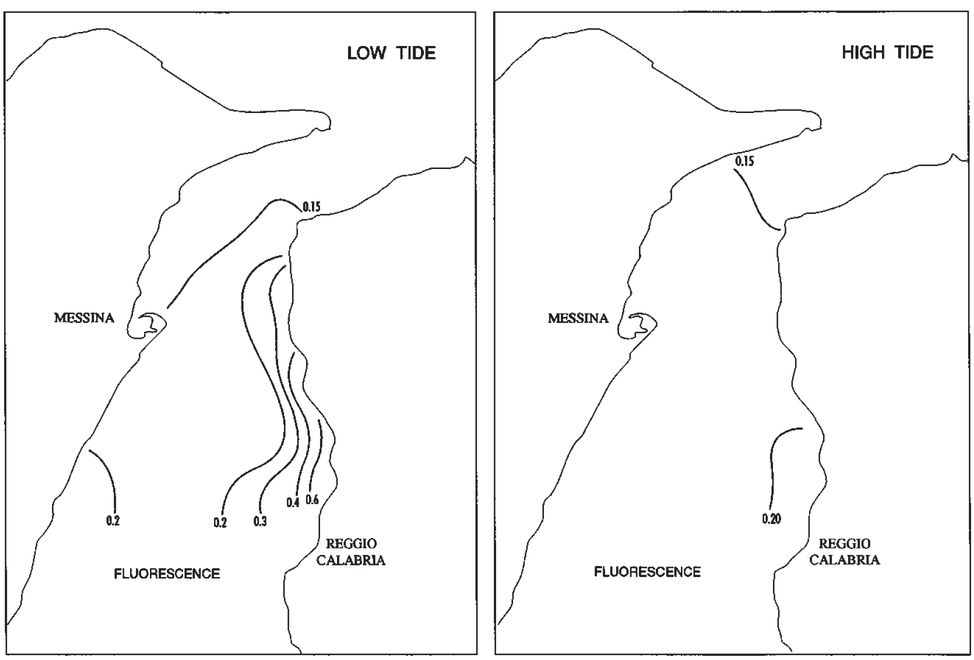

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Fig. 3 - Continued.

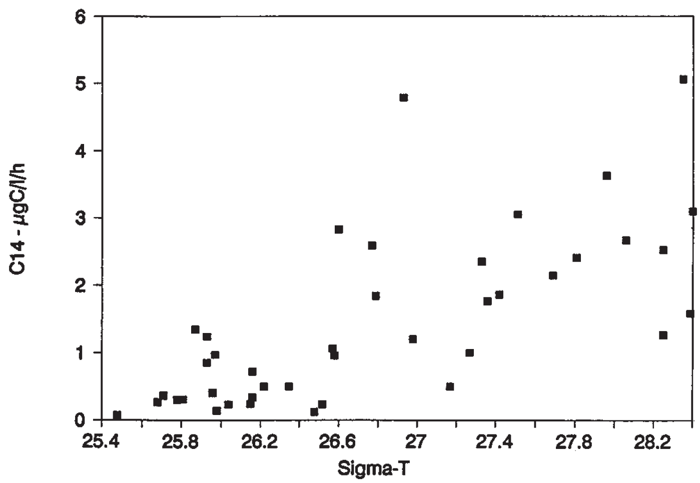

Fig. 4 - Correlation between water density and primary productivity found from July 15 to 18.

on line, together with the associated Loran coordinates. The results obtained are being used for the calibration of simulation models. This paper refers to some of the phenomenological aspects.

The surveys were performed in July and September 1992.

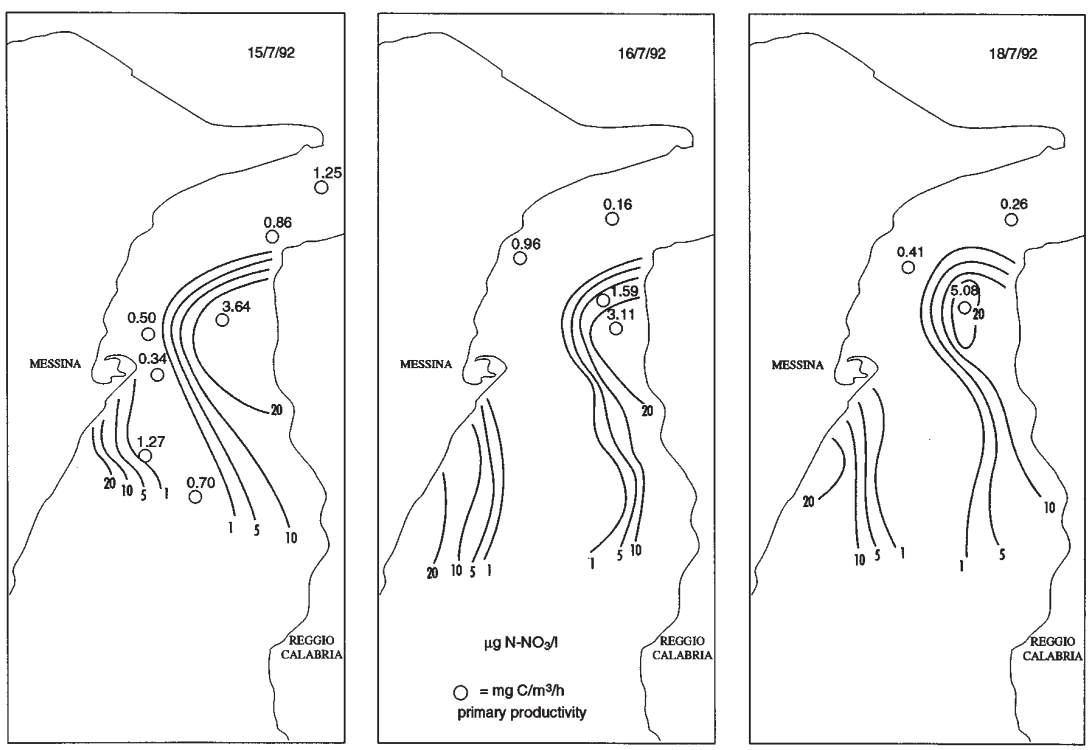

Fig. 5 - Sequence of nitrate and primary productivity distributions found in the low tide phase from July 15 to 18.

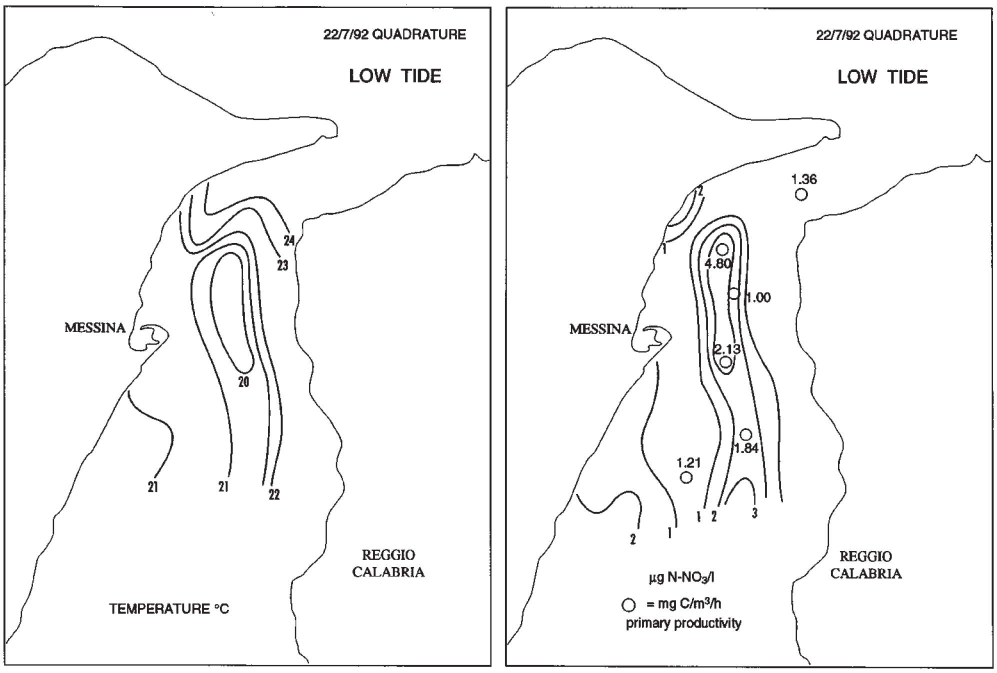

Fig. 6 - Example of surface distribution of temperature, nitrate and primary productivity in quadrature, low tide.

3. Results and discussion

The most significant results obtained are reported and discussed hereinafter.

An example of the surface distribution of temperature, salinity, nitrate, primary productivity and fluorescence during a phase of syzygy is reported in Fig. 3 (July 1992). The whole southern area of the Messina Straits is characterized by upwelling. The warmer, nutrient-poor Tyrrhenian water flows like a surface river, and its centerline trajectory passes along the middle area of the system during the ebb phase. The Tyrrhenian water flows back 6 hours later, during the successive high tide phase. Isotherms move northward and a wider area of colder and nutrient-rich Ionian water of intermediate origin becomes evident.

A good correlation was found among the surveyed parameters. An increase of primary productivity about ten times higher compared to Tyrrhenian waters was also found in the upwelling areas. Fig. 4 shows the correlation between primary productivity and density surveyed from July 15 to 18. The observed deviations are explainable by the different residence times of upwelled waters in the euphotic layer at the moment of sampling. In any case the correlation is statistically valid and stimulation of the planktonic growth is likely to contribute considerably to the abundance of fish in the area. Very similar results found on different days near syzygy confirm the described behaviour (see Fig. 5).

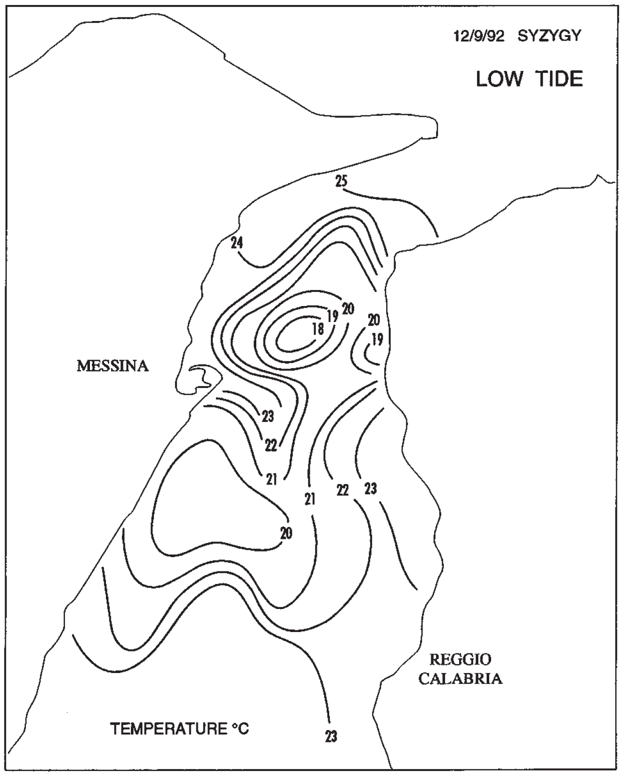

Fig. 7 - Temperature distribution in September 1992 during a low syzygial tide.

Fig. 6 shows the effect of the transition from syzygy to quadrature. In quadrature the lowering of the tidal current velocity reduces the upwelling strongly. A small fraction of deep water is still present at the surface along the centre of the Straits. The average primary productivity is not however reduced, probably due to the longer renewal time of the system.

Fig. 7 summarizes the situation found in September (syzygy). The general pattern does not exibit very significant variations, although higher temperatures were found probably as a consequence of thermocline sinking. The NE-blowing wind (Grecale) is likely to be responsible for the disappearance of the south-eastern upwelling area. Two stations indicated in Fig. 1 were submitted to a 24-hour survey with a 2-hour frequency in syzygy (see Fig. 8). According to Cortese and DeDomenico (1990), rising of deep waters occurs every 12 hours, in concomitance with high tide phases, at station A lying on the sill, where upwelling is strictly connected with the tide level fluctuation. On the contrary, upwelling seems to occur every 6 hours at station B when the northward and southward maximum current velocities are reached.

Therefore, depending on the considered area and tidal phase, the vertical movement of water masses can be either the response to the tide level oscillation or a dynamic effect, i.e., the vertical circulation induced by the horizontal advection. A similar effect to Bernulli's aspiration of deep waters through straits is suggested also by Kinder and Bryden (1990).

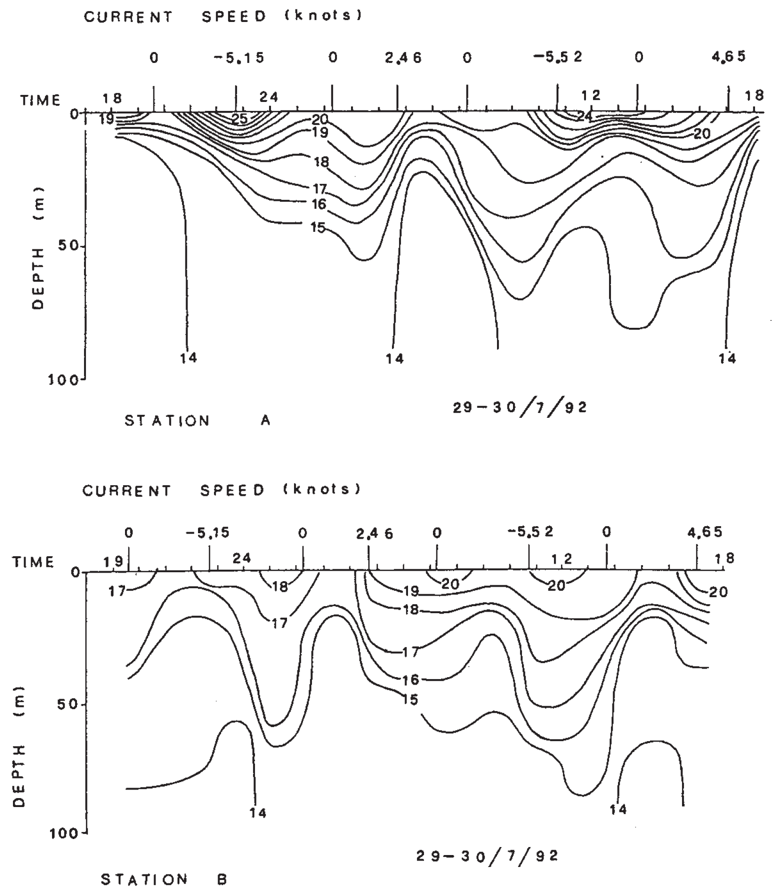

Fig. 8 - 24-hour behaviour of temperature at two stations surveyed with a frequency of 2 hours at syzygy (July 1992). Reference to Fig. 1.

4. Conclusions

The particular features of the Messina Straits, namely the steep bathymetry, the funnel-shaped geometry of the coasts and the diachroneus tidal cycle of the adjacent seas induce very interesting oceanographic conditions. In particular, the whole area south of Capo Peloro is affected by an intense upwelling.

Mixing between surface Tyrrhenian waters and Ionian intermediate waters gives rise to a great increase in the primary productivity. The exchange of water masses and energy through the sill depends strictly on the tidal cycle, and in turn behaves as a predominat factor forcing upwelling processes.

A deterministic study aimed at a quantitative hindcasting and forecasting of the complex phenomenology of the Straits should be based on a systematic long-term monitoring of the processes individuated.

The use of complementary techniques such as continuous survey of chemical and biological indicators from a sailing vessel, remote sensors and moored buoys (also equipped with miniaturized chemical analyzers) is advisable owing to the wide variability of the system. The future monitoring of the Straits should also take into consideration further forcing factors, such as for instance wind, depth and shape of the picnocline and seasonal cycles.

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