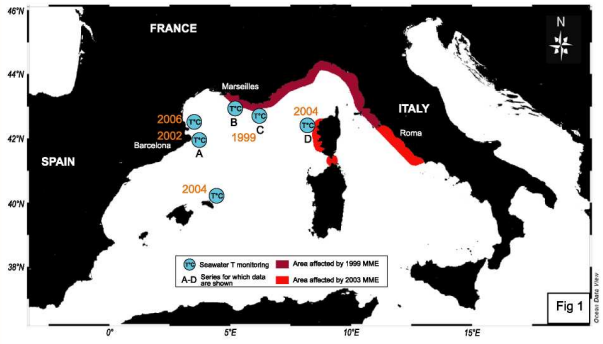
Characterizing regional temperature regimes of NW Mediterranean coastal waters: a step forward to better understand the responses of benthic communities to current climate change

Bensoussan N.[1], Romano JC.[2], Harmelin JG.[1], Garrabou J.[1]

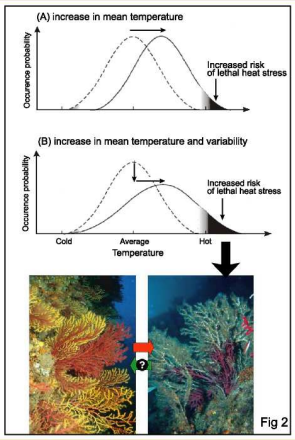
[1]Centre d'océanologie de Marseille, UMR 6540 DIMAR, Station Marine d'Endoume, rue de la Batterie des Lions, F-13007 Marseille,
[2]Université de Corse, UMR 6134 SPE, Laboratoir SPE, Vignola, route des Sanguinaires, F-20000 Ajaccio

Temperature induced mass mortality events (MME), a new source of strong disturbance

Areas affected by the MME and Study sites



In 1999 and 2003 two unprecedented mass mortality events have strongly affected about 30 macro-benthic species in the NW Mediterranean (Fig 1). Anomalous high temperature conditions along the Spanish, French and Italian coasts were evoked as the main triggering factor of the mortality outbreaks. Bearing in mind the warming trend in the NW Mediterranean (Salat and Pascual, 2002) and the likely increasing occurrence of summer heat waves over Europe (Schär et al. 2004), new events may likely occur in the near future raising concern for the conservation of macro-invertebrate communities (Fig 2). In this context, large scale mass mortality events can be considered as a major threat for sublittoral communities.



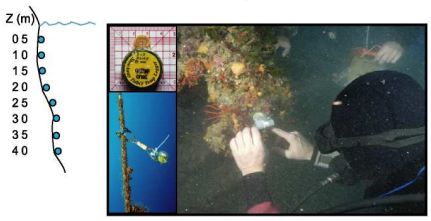
Climate warming is suspected to result in an increase of both mean temperature and variability (IPCC 2001).

What about in Mediterranean coastal waters ?

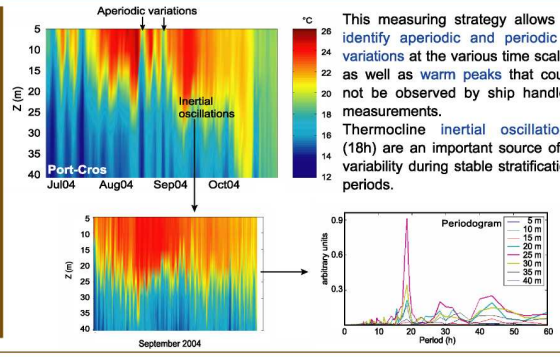
To better understand potential effects and recovery capacities, interdisciplinary studies including long term and high resolution T time series analysis are needed.

Setting up high resolution coastal temperature time series

Sensors implantation

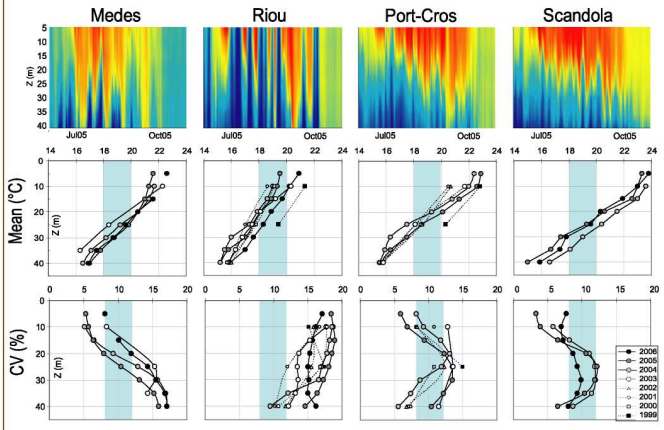


T was recorded hourly by autonomous, permanently operated sensors (Stowaway Tidbits, precision 0.2°C) deployed and recovered annualy or semi annualy by divers in regions suffering different degrees of impact (Fig 1). Since 2004, the sensors were systematicaly set up every 5 m from 5 to 40 m depth among communities, in stations exposed to dominant winds or currents. 4 series are studied here: A - Medes islands (N Spain), B - Riou island (Marseilles, France), C - Port-Cros island (National Park, Var, France) and D - Scandola natural reserve (Galeria, Corsica, France). Data were also collected since 1999 in Riou and Port-cros and since 2002 in Medes at all or some of the fllowing depths: 10, 25 and 40 m.



This measuring strategy allows to identify aperiodic and periodic T variations at the various time scales as well as warm peaks that could not be observed by ship handled measurements.
Thermocline inertial oscillations (18h) are an important source of T variability during stable stratification periods.

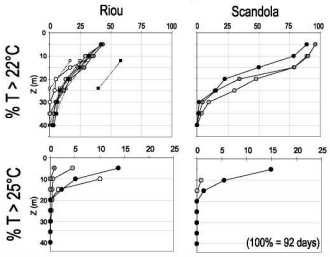
Characterization of regional thermal regime



The 4 regions exhibited contrasted seasonal thermal stratification. N winds caused frequent deepening of the thermocline below 40 m in Medes and frequent coolings (T<16°C) in Riou while warmer conditions with more stable stratification prevailed in Port-Cros and Scandola. Mean T and variance (CV) profiles from July to September exhibited clear cut inter-regional patterns. Differences up to 4°C in mean T were noted in the upper 15 m between Scandola (warmest) and Riou (coldest) while Medes exhibited the warmest conditions below 25-30 m. During the same period, variance (CV) was the highest in Riou in the whole water column while it peaked around the mean thermocline depth (20-30 m) in Port-Cros and Scandola and below 30 m in Medes.

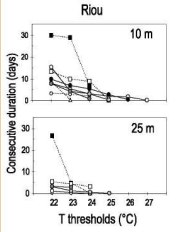
Specific approaches to better characterize temperature anomalies ...

Total duration above significant T thresholds



Given the short interval between measurements, the % of T above thresholds provide a fair estimate of the total duration spent above these T conditions.
From July to September, coldest and warmest regions showed large differences in the occurence of T>22°C in the upper 20 m, but little for T>25°C during summer 2006 heatwave.
Thermal anomalies are also clearly identified.

Consecutive duration approach



1999 T anomaly was characterized by long lasting (30 d) stable warm conditions (22<T<24°C) in the upper 25 m or more.
In contrast, summer 2003 and 2006 heatwaves induced near surface elevated T (>25°C) but during shorter total and much shorter consecutive durations.

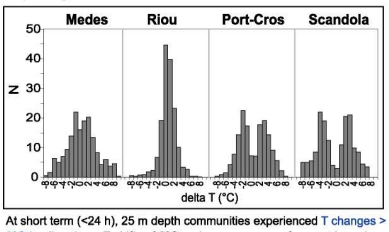
... and variability regime

Depth extension of isotherm 20°C

	2003- 2005 Medes	2004- 2005 Scandola
25 m		
N > 1 day	4 - 11	5 - 11
Duration ± SD	4 ± 2	3 ± 2
N < 1 day	48 - 56	83 - 112
40 m		
N > 1 day	4 - 5	0
Duration ± SD	2 ± .5	
N < 1 day	25 - 63	1 - 14

The frequency of several days and short (<1 d) 20°C isotherm incursions at depth attest of T conditions variability. In Scandola, unlike in Medes, thermocline deepening to 40 m is only transient.

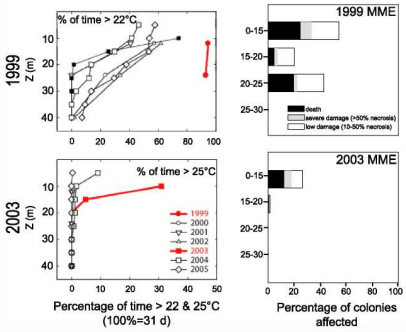
Frequency distribution of short term T variations at 25 m



At short term (<24 h), 25 m depth communities experienced T changes > 8°C in all regions. T shifts of 2°C and more are more frequent in regions exhibiting permanent thermal stratification.

Applications to elucidate potential consequences of climate change

Temperature contexts during MME and relation with mortality rates



In both MME, the mortality impact (here for red coral in Marseilles) decreased along the depth gradient accordingly with the occurence of the temperature anomalies. In 1999, the impact was two-fold greater than in 2003, stressing the importance of the nature of the heat stress. Characterizing magnitude and duration of warm episodes in relation with mortality rates in the regions affected is important to determine realistic thermotolerance experimentation protocoles.

Conclusions and perspectives

Gaining knowledge on the thermal regime of coastal zones is important to forecast potential effects of climate warming on coastal ecosystems. Continuing and extending the acquisition of high resolution T series in the NW Mediterranean will provide:

1- new insights on thermal conditions and warm episodes that have direct consequences on benthic communities
2- relevant information on conditions to which species have adapted
3- data bases to better understand the modalities of current warming of NW Mediterranean coastal waters.

References:
IPCC (2001) Climate change: the scientific basis. Cambridge University Press
Salat J, Pascual J (2002) The oceanographic and meteorological station at L'Estartit (NW Mediterranean). CIESM Workshop Series n°16
Schär C, Vidale PL, Lüthi D, Frei C, Häberli C, Liniger MA, Appenzeller C (2004) The role of increasing temperature variability in European summer heat waves. Nature 427:332-335.

More information at **www.medchange.org** MEDCHANGE