Xjenza

JOURNAL OF THE MALTA CHAMBER OF SCIENTISTS

Volume 2 No 1 June 1997

Contents

Xjenza

Official Journal of the Malta Chamber of Scientists

Editorial Address
Xjenza,
c/o University of Malta
Medical School,
Guardamangia
Malta.

Tel: (+356) 25951882
Fax: (+356) 235638

Cover Picture: Deployment of ICTD probe for profiles of sea temperature and salinity.
Picture by: Aldo Drago

editorial

Preparedness and Response to Accidental Marine Pollution 4

research articles

Hydrographic Measurements in the North Western Coastal Areas of Malta 6
Aldo F. Drago

Evaluation of Environmental Impact of Yacht Marina Development in Malta 15
Victor Axiak

The Impact of Aquaculture on the Water Quality of Maltese Waters 21
Christopher Rizzo and Alain Le Breton

Geochemistry of the *Soll* Facies of theLower Globigerina Limestone Formation, Malta 27
Alfred J.Vella, S. Testa and C. Zammit

Preliminary Investigation on Radon Levels in Local Dwellings 34
Ian Mifsud, Andrew Amato Gauci, Lucienne Licari and Michael Sammut

current research profile

Edward A. Mallia D.Phil(Oxon) 39

book reviews

The Non-Marine Molluscs of the Maltese Islands 41

Introduction of Alien Species of Flora & Fauna: Proceedings of Seminar held at Qawra, Malta 41

The Faber Book of Science 42

instructions for authors 43

Malta Chamber *of* Scientists

P.O. Box 45,
Valletta B.P.O.,
Valletta, Malta.

Printers: Printcare, Valletta.

Editorial

Preparedness and Response to Accidental Marine Pollution

Most of the time, merchant vessels go about their work in a benign sort of way carrying cargo from place to place, out of everybody's sight with occasional sightings in a port or at the sea's horizons. Only when a shipping accident occurs and is brought to our TV.screens do we probably note the existence of the shipping industry. It is the graphic images of large quantities of spilled oil, damaged beaches, mangroves, blackened foreshores, oiled marine birds and mammals which leave their mark and linger in our memory. Undoubtedly, at the time of the event, these images provoke strong reactions with worries of lasting damage to the environment and human welfare.

The 23rd Business and Scientific Meeting of the Malta Chamber of Scientists held on 19 June focused on the topic of "Preparedness and Response to Accidental Marine Pollution". Four speakers were invited to express their views on the subject: The Hon. Dr. G. Vella, Deputy Prime Minister, Minister of Foreign Affairs and the Environment and Leader of the House of Representatives; Mr. J.C. Sainlos, Director, IMO/UNEP Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC); Professor V. Axiak from the Department of Biology and Professor A. Vella from the Department of Chemistry, University of Malta.

"Accidental marine pollution" arises from low probability-high consequence maritime related events. This is because shipping casualties are not an everyday occurrence and therefore of low probability but of high consequence because the effects from the relatively large volumes spilled can be quite damaging. Much has been done at the international, governmental and industrial level to prevent accidental marine pollution through the introduction of tighter preventative measures such as environment protective ship design (e.g. the double bottom in oil tankers), more efficient cargo handling and better trained and qualified personnel serving on vessels. However, despite these regulatory measures, accidents continue to occur as shown by the Exxon Valdez in 1989 which lost 37,000 tonnes of crude oil in Prince William Sound, Alaska, and the more recent accident of the Sea Empress which lost 72,000 tonnes of crude oil and 360 tonnes of heavy fuel oil off the Welsh coast in 1996. It follows, therefore, that the protection of the marine environment from such events should be integrated in the overall environmental policy of a country with a coastline.

The risk of accidental marine pollution is very much related to the area itself. In the Mediterranean, some 23% of the world's seaborne oil transits this sea. This consists of oil exported from the Middle East via the Suez Canal and the Sumed pipeline at Sidi Kerir, Egypt, together with substantial exports from Libya and Algeria en route to Spain, France and Italy. In future, it is anticipated that oil throughput will increase from the Black Sea through the Bosphorus and from certain Turkish ports on the Mediterranean side as new oil reserves are discovered and pipelines built in the newly-formed ex-Soviet Union States. Although this traffic might not be of economic value to the Mediterranean ports, from the point of view of accident potential, it cannot be ignored. In addition, the Mediterranean suffers from a high density of merchant traffic other than oil tankers which, like oil tankers, either do not enter any one port but transit the sea in an East-West direction and vice-versa or are directed to the 300 or so odd ports scattered along the coastline. Overall, it can be said that the Mediterranean is an area of high risk with the bottlenecks of the Straits of Gibraltar, Boniface, Messina, the Suez Canal, the Dardanelles and the restricted waters of Southern Greece at an even higher risk.

Evidence of this risk is highlighted by some accidents: the oil tanker *Patmos* (1985) which spilled 700 tonnes of oil, off the coast of Messina following collision with another tanker which was in ballast; the oil tanker *Haven* (1991) which caught fire and suffered a series of explosions off Genoa and subsequently broke into three parts spilling 10,000 tonnes of fresh and partially burnt oil in the process; the oil tanker *Iliad* (1993) which spilled 300 tonnes of light crude oil following its grounding after leaving the port of Pylos.

When a spill occurs, irrespective of its size, there are a number of other mitigating factors that will determine the impact of the spill and influence the scale of the response. Although the system will vary from country to country, it is essential to have in place a national system to deal with such events. The purpose of a national system is to maintain an organisational framework capable of optimising the country's resources to support the response effort. All this requires pre-planning which will pay dividends in times of crisis. A national contingency plan for preparedness for and response to marine spills will describe the system. The plan should, as a minimum, contain:

- the organisational relationship of various entities involved (public, parastatal, private) and a clear definition of the responsibilities of the participating organisations;
- the lead agency responsible for providing the response (at sea, on shore, in port etc.);

- the arrangements of communications for mobilizing resources;
- an inventory of strategically positioned spill equipment and programmes for its use in the protection of pre-defined sensitive areas such as ecologically important habitats, water intakes for desalination plants or power stations;
- a comprehensive national training programme for response personnel including the periodic organisation of exercises to test the plan.

Undoubtedly, a country's response capability may be overwhelmed regardless of the resources available. In 1975, the United Nations Environment Programme (UNEP) in co-operation with other specialized U.N. agencies launched a programme for the Mediterranean and invited coastal states to adopt a comprehensive action plan for the protection of the Mediterranean sea. This paved the way for the adoption of an international treaty for the protection of the Mediterranean sea against all types of pollution, in 1976 in Barcelona, which entered into force in 1978. This treaty has been ratified by all coastal states, including Malta, and by the European Union. Known as the Barcelona Convention for short, it is a framework Convention that leaves specific commitments to be taken up under separate technical Protocols, which in turn are themselves full-scale international treaties. One such Protocol deals with "Co-operation in Combating Pollution of the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency".

The rationale behind this particular Protocol is that coastal states will pool forces to combat massive accidental pollution and assist one another in such catastrophic events. Importantly, the Protocol was never conceived as a "substitute for" a national response capability but rather as a "supplement to ". Also in 1976, the Mediterranean coastal states agreed to establish a centre to help with their commitments under the Protocol which, at the invitation of the Government of Malta, is hosted in Malta. This centre, known at the "IMO/UNEP - Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)", is administered by the International Maritime Organisation (IMO) which is the specialized U.N. agency dealing with safety in shipping and protection of the marine environment from ship related activities. The centre operates on the basis of decisions by the Contracting Parties to the Barcelona Convention. In layman's terms, this means that the mandate and activities of the Centre are decided by the coastal states and the E.U. Funding is ensured by the same Parties through a common kitty known as the Mediterranean Trust Fund.

The role of REMPEC is to reinforce the response capability of the Mediterranean coastal states by: 1) disseminating information and technical advice; 2) organizing training programmes at the regional and national level; 3) assisting in the preparation of contingency plans including sub-regional operational agreements; 4) facilitating and co-ordinating mutual assistance in cases of emergency.

In Malta, efforts continue to be undertaken to build the capacity to deal with accidental marine pollution. Oil combating equipment has been purchased under a project financed by the E.U. and this is being augmented by civil protection equipment to be bought under the bilateral agreement between Italy and Malta. In addition, equipment belonging to the private sector is also available. Towage and salvage capacities exist. A governmental unit - the Pollution Control Co-ordinating Unit has been set up some time ago. Local media have reported that inter-agency exercises based on likely scenarios have been carried out. Malta is also a Contracting Party to the Protocol in Cases of Emergency for the Mediterranean. All this augurs well. However, one point that emerged from the June meeting of the Malta Chamber of Scientists was the lack of a national plan which might infer a disjointed response effort with critical time lost in the initial stages of a major pollution accident.

There is no doubt that a tested national contingency plan supported by administrative arrangements in the form of a legal act which will define and dispatch duties and responsibilities for each component of the envisaged system to deal with such major events will go a long way. A hidden value when developing a plan of this type is that organisations are brought together, contacts established, views exchanged and competencies recognized.

Malta relies heavily on the sea. In the case of a marine casualty involving major pollution affecting our shores, we will have more on our hands apart from the complex task of salvaging the vessel - a lot more.

Stefan Micallef
IMO/UNEP Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)

This was an invited editorial. It reflects the views of the author and not necessarily those of the United Nations, its specialised agencies or the Malta Chamber of Scientists.

Research Article

Hydrographic Measurements in the North Western Coastal Area of Malta

Aldo F. Drago
Malta Council for Science and Technology, Valletta, Malta.

Summary. *The first synoptic CTD data set obtained during summer 1992 in the coastal waters of the Maltese Islands is presented. The nature of the summer water structure in the upper 50m depth reveals a strong water column stratification with significant horizontal gradients in both temperature (T) and salinity (S). A diurnal vertical oscillation of the thermocline is confirmed by comparison with subsurface temperature time series recorded at an open sea station in the area of study. The T,S profiles are characterised by very sharp salinity reversals at the subsurface layer where a stepwise micro-structure is developed.*

Keywords: CTD, coastal, double diffusion, salinity, salt fingering, temperature, micro-structure

Physical oceanographic data in the nearshore and coastal waters of the Maltese Islands is generally lacking. Before 1991, the only published measurements (Havard, 1978) are those carried out in the framework of the IOC/UNEP (Intergovernmental Oceanographic Commission/United Nations Environment Programme) co-ordinated pilot project MED-VI. Within this project several mechanical bathythermograph (BT) measurements were made between April-July 1976. The abrupt interruption of this work in 1980 resulted in the loss of these unarchived and unprocessed data.

Later, data from this work together with BT, XBT (expendable bathythermo-graphs) and hydrographic data extracted from data banks were reviewed in the paper presented at the CERP (Coastal Environment Research Project) Workshop in 1991, (Drago, 1991). Although these data include only few hydrographic stations in the close vicinity of the Maltese Islands, it can be inferred that the nearshore summer water column structure is dominated by a solar heated upper water mixed layer, averaging 20m in depth. Sustained sea surface evaporation rates increase the salinity which reaches maximum values of S=38.0 to the south of Malta. The high surface temperatures between 20-26°C formed a well stratified surface layer above the cooler and relatively fresher Modified Atlantic Water (MAW). In the underlying layer, the water mass has a characteristic temperature of 15°C and a salinity of S=38.4, which indicates the influence of the modified Levantine Intermediate Water (LIW). The winter mixing processes result in the homogenization of the water column up to depths in excess of 100m, and with temperatures on average 0.5°C higher to the south of Malta.

The CTD data set

The first physical oceanographic campaign in the Maltese coastal waters was carried out as part of the CERP programme, during August 1992. This two-week long survey aimed to obtain valuable information on the circulation and water column structure in the North Western coastal area of Malta, comprising Mellieha Bay and St. Paul's Bay. The data were acquired from the 20-foot boat *Sabrina* by means of a profiling ICTD (Conductivity-Temperature-Depth) probe from Falmouth Scientific Inc. (FSI). The ICTD carried both a platinum thermometer and a fast thermometer which enabled very precise determination of sea water temperatures at the rate of 25 scans per second down to a depth of about 50m. The ICTD was calibrated at FSI three months before the survey. The location of the 26 CTD stations shown in Fig. 1 covers an area of approximately 12 square nautical miles. The CTD casts were made over a period of 3 successive days (16-19 August 1992).

A 1200Khz RD Instruments shipborne Acoustic Doppler Current Profiler (ADCP) was also utilised for vertical profiles of water currents at 1m depth bins up to a depth of 30m and at 30 second intervals along selected transects. In addition, a subsurface current meter mooring was deployed at a location approximately mid-way between Dahlet-ix-Xilep on the Mellieha Bay western headland, and the White Bank to the northeast. This location is situated between the CTD stations 11, 13 and 14. Two RCM4 Aanderaa current meters were used at 23m and 6m from the seabed respectively, and in a total water depth of 35m.

Processing of CTD data

The pre-processing of the station raw data files consisted in the detection and auto-correction of salinity spikes according to prescribed allowed levels of fluctuation. After converting pressure data into engineering units, pressure averages of the unscaled temperature and conductivity values at pressure intervals of 2 decibars were then calculated. In this process a correction was applied to eliminate the effect of time lags between the temperature and conductivity sensors. An exponential recursive filter was used by means of the following algorithm:

$$C(t)=C(t-dt)\exp[-dt*\tau_c/\tau_f] + C_{raw}(t)\,(1 - \exp[-dt*\tau_c/\tau_f]$$

$P(t)=P(t-dt)\exp[-dt*\tau_c/\tau_f] + P_{raw}(t)\,(1 - \exp[-dt*\tau_c/\tau_f]$

where C(t), P(t)=lagged Conductivity/Pressure value at time t
$C_{raw}(t)$, $P_{raw}(t)$=raw Conductivity/Pressure value at time t
dt=CTD sampling interval in seconds;
τ_c, τ_f=time constants of conductivity cell/fast thermistor.

The fast thermistor temperature was then added to the Pt thermometer temperature to give the summed temperature T(t) as follows:

$F(t)=F(t-dt)\exp[-dt*\tau_f/\tau_{pt}] + F_{raw}(t)(1 - \exp[-dt*\tau_f/\tau_{pt}])$
$F'(t)=Fraw(t) - F(t)$
$T(t)=Tpt(t) + F'(t)$

where $F_{raw}(t)$=raw thermistor temperature at time t;
$T_{pt}(t)$=raw Pt thermometer temperature;
τ_{pt}=time constant of platinum thermometer.

In the pressure averaging process, values in air were flagged and ignored; the lowering rate dP/dt was calculated in order to detect pressure reversals. At such reversals the last previously good data value was substituted in order to keep the time sequence in the averaging.

The pressure averaged temperature and conductivity values were finally converted into engineering units. In this process, values of conductivity were adjusted for cell distortions by temperature and pressure. The location in time of the temperature and conductivity averages may not necessarily coincide with the centre of the pressure interval; in order to ensure a uniform pressure series, temperature/salinity gradients with pressure were thus used to calculate interpolated values in synchronisation with the central pressure.

Salinity was computed from the averaged P, T and C values using the PSS-78 algorithm. The pressure averaged values were also used to calculate other parameters treated in the study. A special Fortran code was developed in order to prepare files of the studied parameters at selected depths. Horizontal contour plots were made by means of SURFER, a PC product by Golden Software Inc.

Water column structure
The T/S profiles in Fig. 2 show the summer stratified structure of the water column that characterises the study area. A surface thermally heated and more saline mixed layer extends to an average thickness of 16m. This surface layer is separated from the underlying Modified Atlantic Water by a very sharp halocline that overlies some remarkable salinity reversals at depths between 15-30m. These reversals occur at depths coinciding with a monotonic temperature and density profile. The composite T-S diagram (Fig. 3) confirms an extensive range of mixing between the surface mixed layer with average values of T=27.5°C, S=37.74 and the underlying water mass of MAW origin characterised by T=16°C, S=37.45.

The water column in the bays is homogeneous due to the intense surface heating. The profiles in Fig. 4 show the temperature and density horizontal structure in St.Paul's Bay. The water body in this bay is greatly dominated by the salinity with a consistent along-axis gradient of the order of 0.025 Km^{-1}. This is an indication that the water in the bay has a relatively long retention time while at the same time it is undergoing vertical mixing.

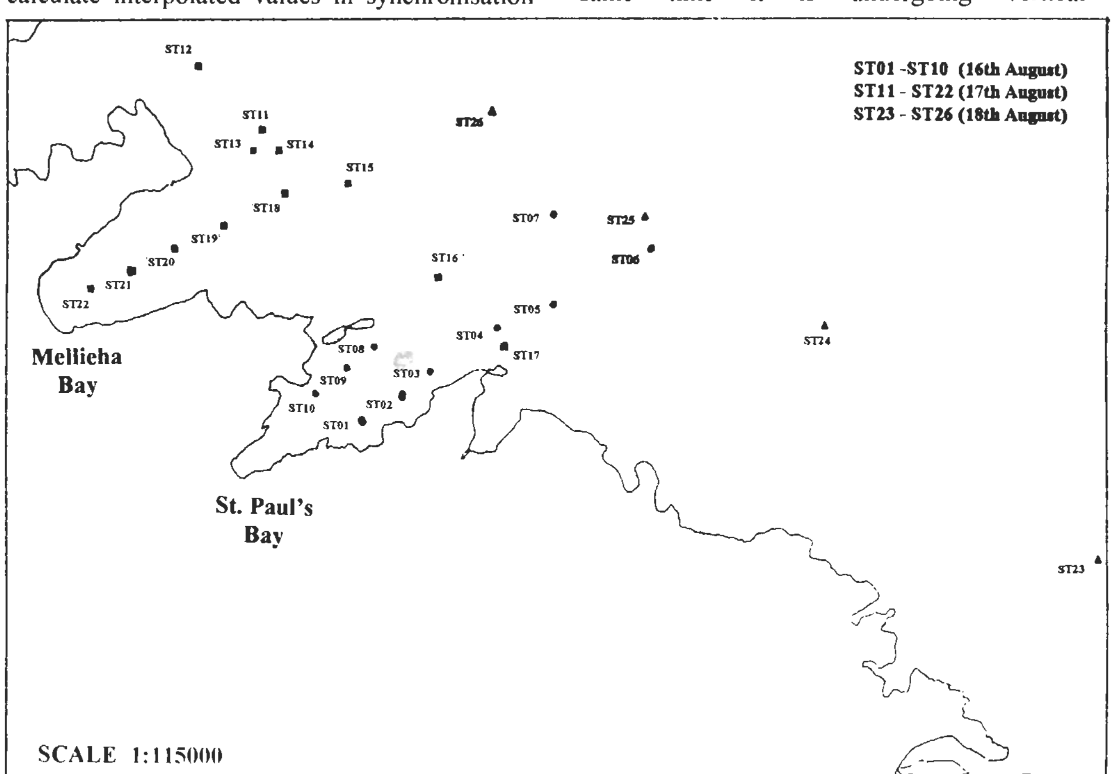


Figure 1. CTD stations in the NW coastal waters of Malta.

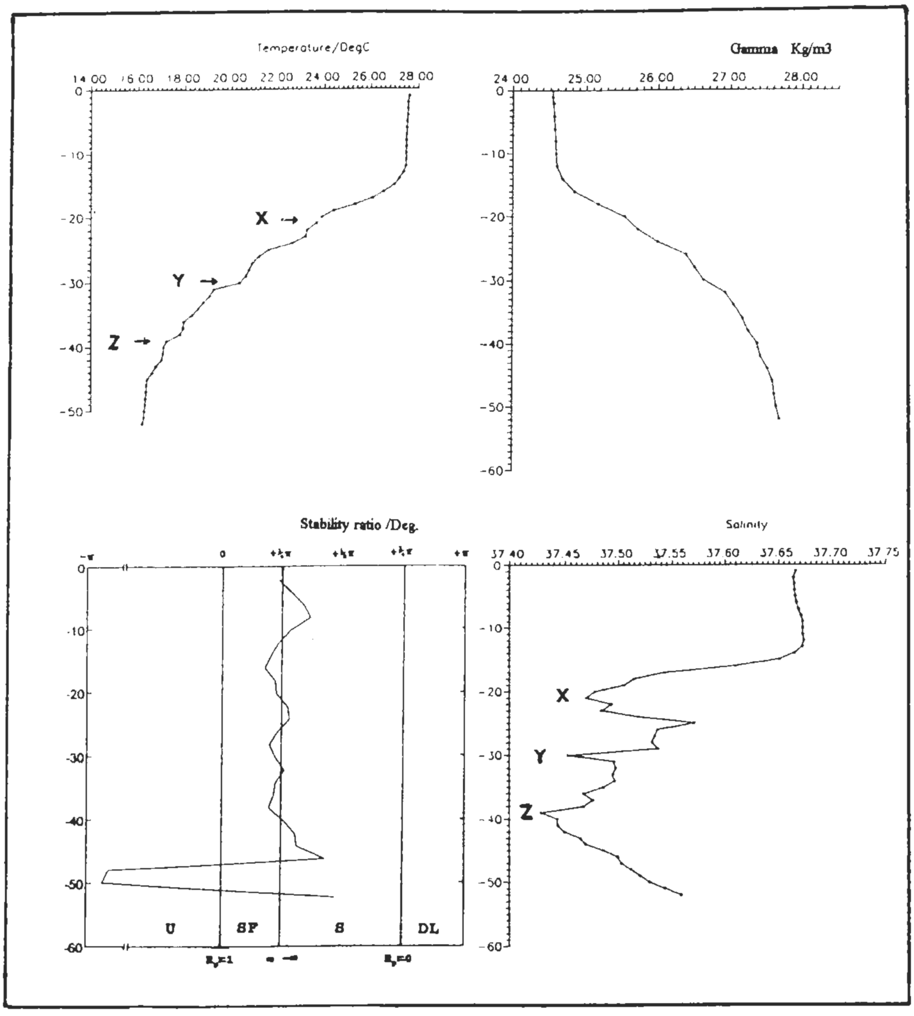


Figure 2. Temperature, salinity, density and stability angle profiles at station 25 (Position 35° 58.93'N 14° 27.21'E Depth 55m).

The CTD data and the temperature data time series, recorded by the thermistor probes of the two current meters, reveal an oscillation of the thermocline. The position of the current meters, with respect to the thermocline (Fig. 7), indicates that the vertical movement of the thermocline is followed very precisely from the recorded temperature variations. The upward movement of the thermocline results in a decrease of the temperature at the upper current meter when it becomes immersed in the thermocline and is exposed to cold water. Moreover, when the thermocline is moving downwards the temperature at the lower current meter increases as it is exposed to warm water carried from the water layers above it. These temperature fluctuations occurred for a few days in the second half of August and reached average values of 8°C. By early September, the mixed layer engulfed completely the upper current meter and the temperature variations disappeared. The CTD casts at nearby stations carried out on the 17th of August, show that the average temperature gradient along the thermocline is 0.5°Cm^{-1}. The magnitude of the vertical oscillation of the thermocline was thus quantified to be of the order of 4m.

STATION NUMBER	MIXED LAYER THICKNESS	TIME OF CAST (GMT)	DAY
4	16	07H40	
5	19	08H06	
6	19	08H55	AUG 16
7	16	09H40	
8	16	10H40	
11	10	06H14	
12	9	06H37	
13	9	07H08	
14	9	07H50	
15	11	08H25	
16	10	08H42	AUG 17
17	12	09H08	
18	10	09H50	
19	11	10H10	
20	11	10H30	
21	13	10H42	
23	15	06H27	
24	15	07H14	AUG 18
25	13	07H48	
26	11	08H25	

Table 1: Variation of thermocline depth.

On the basis of the vertical extent of the mixed layer (Table 1), these CTD casts carried out in the open sea area can be grouped into three sets, that coincide with the respective days of measurement. Considering that these CTD data sets were collected over a short period during each day, this grouping can be related to the phasing of the thermocline oscillation. The variation in the thickness

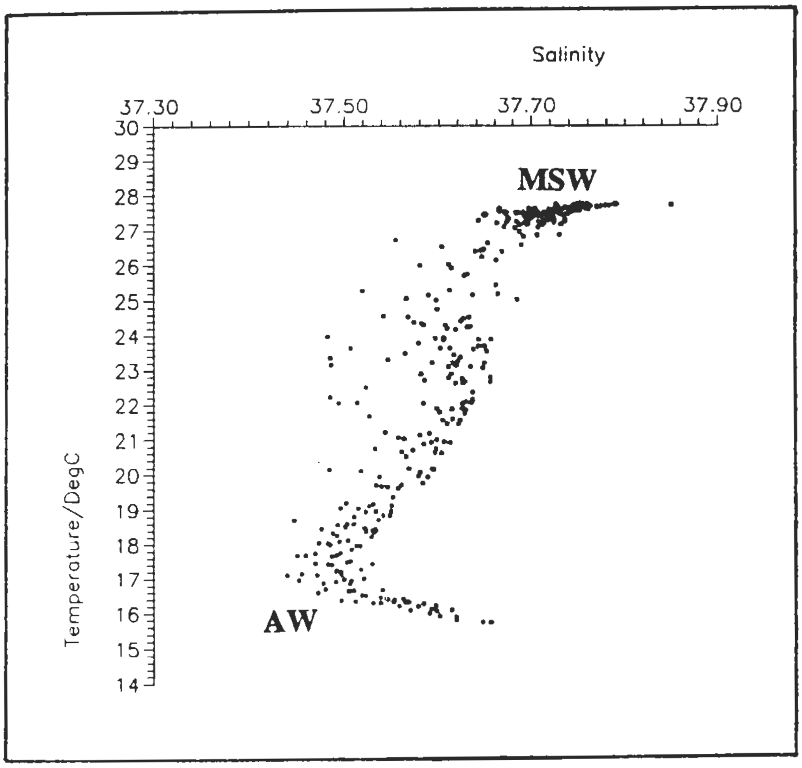


Figure 3. Composite T-S Diagram (16-19 August 1992).

of the mixed layer (Fig. 6), observed during different days by the CTD casts ST06 and ST25 agrees with the phase of the temperature time series recorded at the nearby current meter station.

Fig. 5 shows the contours of temperature, salinity and density at three depths, in the mixed layer (8m), on the pycnocline (20m) and below (30m) respectively. A positive salinity gradient exists towards the coast, and a negative gradient for temperature. The latter parameter is dominant on the water density. The disposition of the temperature and density isolines in the mixed layer suggests an anticyclonic residual flow around the White Bank. An opposite return flow outside Mellieha Bay proceeds further downcoast towards southeast. The horizontal distribution of temperature below the surface mixed layer is affected by the vertical movement of the thermocline. This may be aliased into fictitious horizontal gradients. The reversal of the thermocline gradients in the deeper layer with respect to those in the mixed layer may be artificial, especially in the areas closer to the shore.

Salinity gradient reversals

At the bottom of the sharp halocline, salinity gradient reversals are observed. This salinity neutrally buoyant tongue is associated with step-like fine structure in temperature and density and is present in the whole area outside the bays. It is exemplified by the CTD plots at ST25 at the eastern extremity of the area of study (Fig. 2), and at ST14 (Fig. 8) close to the current meter station. Reviewing older data, collected in 1976, a striking sequence of steps and layers is also noted in the summer bathythermograph profiles to the north of the Grand Harbour and in the southern Comino Channel. This phenomenon appears to exist in the whole northern coastal area of the Islands. The small scale structure of the thermohaline fluctuations consists of successive 'layers' of nearly uniform density that are separated by thin interfaces or 'sheets' where the gradients are large. This type of microstructure in the water column has been observed in much of the central waters of the world's oceans and especially in the Mediterranean Outflow by Tait and Howe (1968), Howe and Tait (1970), Magnell (1970) and more recently by Washburn and Kase (1986). In the Tyrrhenian Sea, the deepest recorded stepped structure was found at depths below 600 dbars and down to 2800 dbars (Zodiatis and Gasparini, 1996). Fine thermohaline formation associated to lens formation in the SE Ionian Sea, at a depth of 400 dbars, has also been reported by Zodiatis (1992). The occurrence of this type of T, S structure in coastal shallow areas has been recently reported in the Arabian Gulf by Sultan and Elghribi (1996). The fine structure in the coastal waters of the Maltese Islands is considered to result from the convergence of cool and less saline MAW with the warm and saline surface coastal water. This gives rise to situations where variations of one property alone determines the density and the interfaces that are unstable to double-diffusive processes.

A controlling parameter in the fluxes of heat and salt between two well-mixed layers is the density ratio R_p, defined as:

$$R_p = aT_z/bS_z$$

where T_z and S_z are the vertical in situ temperature and salinity gradients, a is the coefficient of thermal expansion (a>>0), and b is the coefficient of haline contraction. Following the laboratory experiments by Schmitt (1979), McDougall and Taylor (1984) have found a rapid

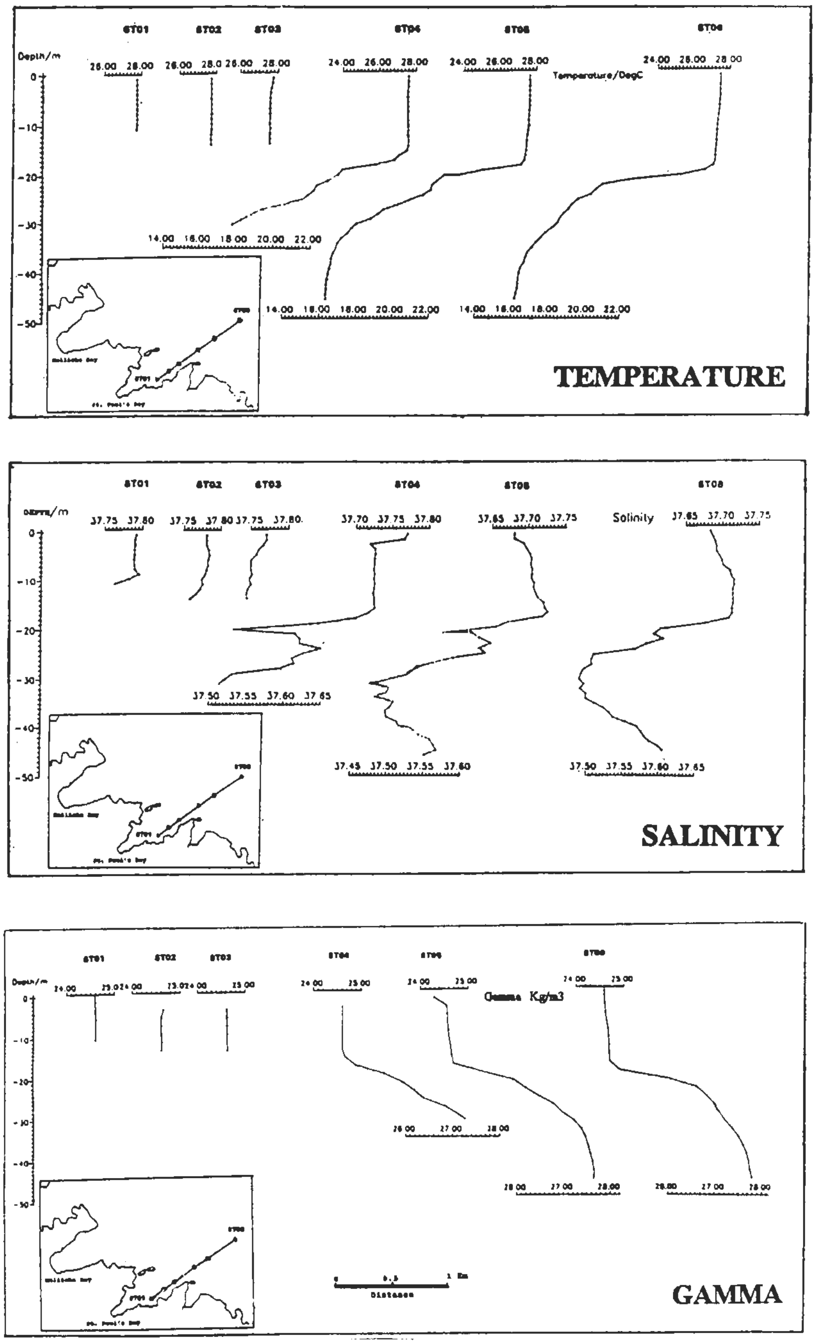


Figure 4. Composite T, S, gamma profiles along St. Paul's Bay.

increase in salt flux between two layers as R_p decreases to 1.2. Following Washburn and Kase (1986), the stability properties of the local stratification in the water column are studied by the stability ratio T_u instead of directly from R_p. T_u is defined as:

$$T_u = Tan^{-1}[(R_p - 1)/(R_p + 1)]$$

so that it removes some ambiguities in R_p plots, and replaces the infinite scale of R_p by a finite one running from +180° to -180°. Taking the z-axis as positive downward, the stabilizing contributions to vertical density gradients are $aT_z << 0$ and $bS_z >> 0$. The vertical distribution of T_u allows portions of the profile to be grouped into four stability regimes: S denotes a stable region of the profile, U a region with density inversions (resulting from instrument errors or potentially due to overturning), SF a region that is diffusively unstable to salt fingering, and DL a region that is unstable to double diffusive layering. The profiles of the stability angle (Fig. 2c and Fig. 8c) at two representative CTD stations, show that diffusive layering regions are excluded at all depths.

The section of the water column underneath the mixed layer is found to consist of alternate layers of relative stability, which coincide with the 'layers' of moderate temperature gradient. These are separated by 'sheets' of potential salt fingering activity and which coincide with the higher gradients of the temperature profile. Close to the thermocline, the temperature step across 'sheets' is of the order of 2°C. At the deeper parts of the water column it decreases to 1°C. The vertical position of these 'sheets' coincides with impressive precision to the salinity minima such as at A and B for ST14, and X,Y and Z for ST25. Brunt-Vaisala frequencies along

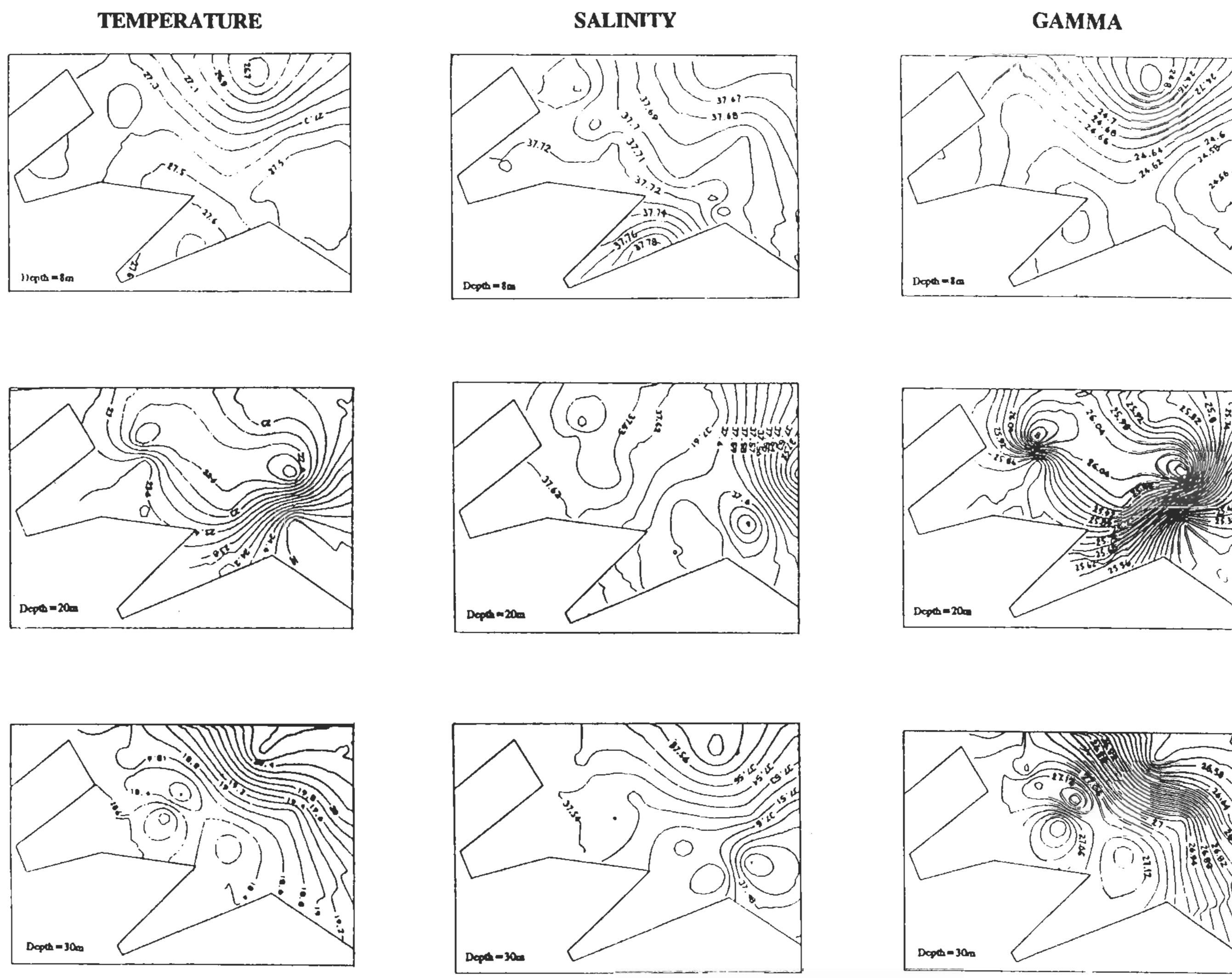


Figure 5. Level plots of Temperature, Salinity and Density at three depths.

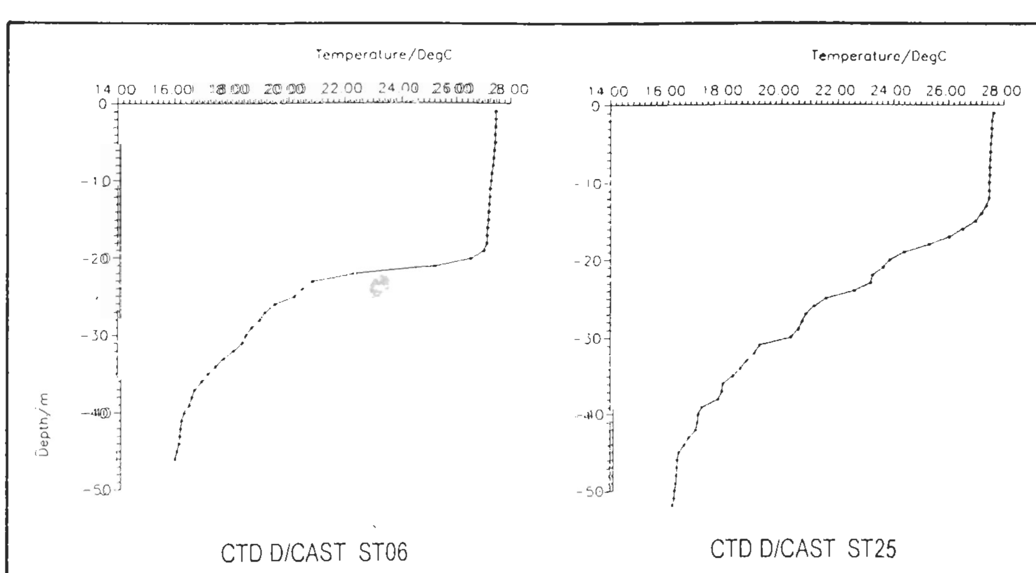


Figure 6. Comparison of temperature plots ST06 and ST25.

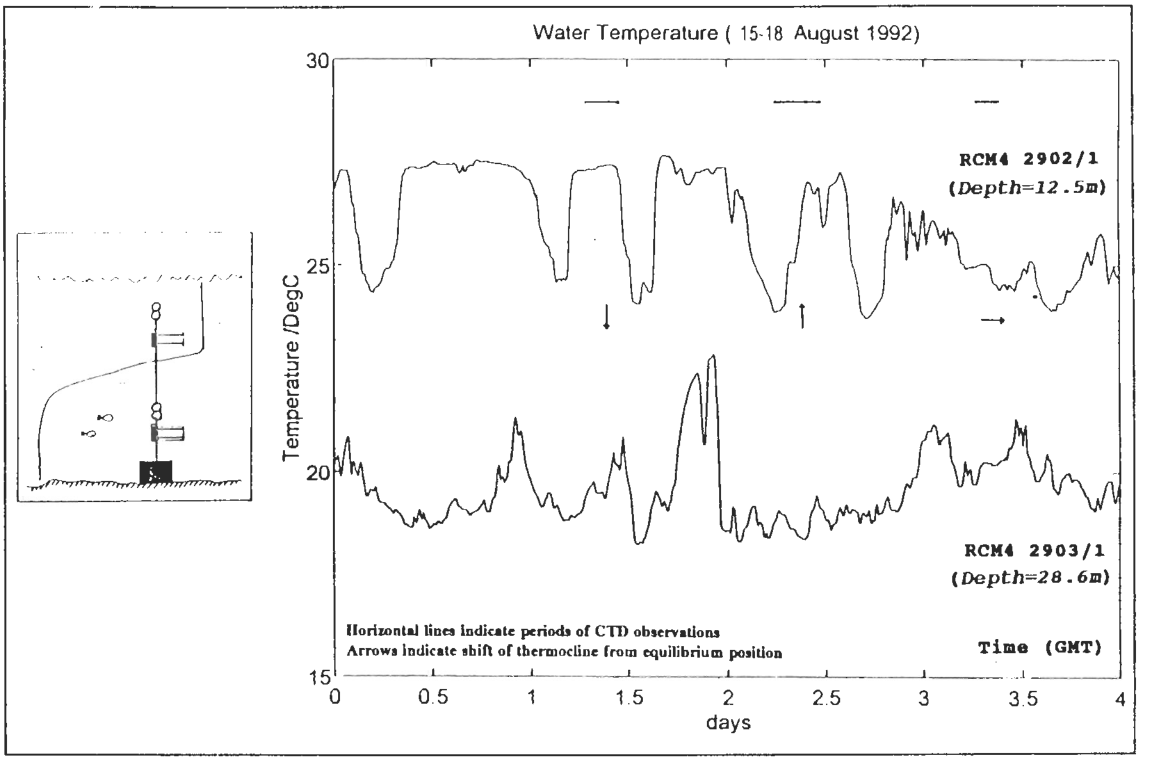


Figure 7. Temperature time series at two depths measured at Ahrax Station

'sheets' reach values close to 30 c/hr, which is two to three times higher than in the neighbouring 'layers'. The examination of the S and T profiles reveals the coincidence of the local minima of salinity and temperature at these points.

The multiple salinity inversions and the associated irregular T-S relationship suggest that in addition to vertical salt fingering, intrusive activity sustained by the strong horizontal salinity and temperature gradients could also be a responsible agent. The intrusive nature of these inversions is further supported by their stable nature and by the associated closed contours of temperature and salinity. Further in-situ CTD measurements can quantify the extent to which these fine-scale inversions are transient phenomena, and confirm their relation to tongues of interleaving water.

Conclusion

The horizontal and vertical distribution of sea water parameters such as temperature and salinity provide information about water movement in the sea. The seasonal and annual variability can be examined by regular in-situ hydrographic observations. Knowledge on the T-S fields are furthermore essential for assimilation in hydrodynamical numerical models.

This kind of baseline data is unfortunately lacking for the coastal areas of the Maltese Islands. A set of CTD casts obtained during a research study in a small area on the NW coast of Malta, comprising two embayments, has provided the first near-synoptic hydrographic data set. The results obtained from this study have revealed some aspects of the coastal oceanographic regime in the region of the islands.

The Maltese Islands constitute an obstacle to the main vein of Atlantic water moving across the Sicilian Channel towards the Eastern Mediterranean, and wake-like streaks have been observed to trail towards the east behind the westernmost tip of Gozo, following well-defined swerving paths downcoast, capturing surface garbage and debris along their way. This area of the Mediterranean is very prolific in mesoscale phenomena that give rise to a system of intertwining frontal structures which pervade the offshore areas around the islands. These phenomena have been also synthesised by satellite views notably from the Coastal Zone Colour Scanner (CSCZ) and the Along Track Scanning Radiometer on ERS-1. The phenomenology of the T-S field in the coastal seas of the Maltese Islands needs a dense grid of hydrographic stations in both time and space in order to be studied properly.

The coastal water in the area of study is dominated by the effect of both salinity and temperature. The salinity shows a consistent horizontal gradient especially beyond the entrance of the embayments. The along-axis salinity gradients and homogeneity in temperature of the embayment waters during this period of the year indicates that the retention time is relatively long and that vertical mixing processes are in action. The SSE main Atlantic Water flow close to the islands is greatly influenced by bottom topography. The White Bank to the North of Mellieha Bay is a source of negative vorticity which results in a reversal of the residual flow closer to the coast and at the entrance of the embayments. The vortex circulation in the top homogeneous layer outside Mellieha Bay is reinforced by the coastal configuration and the seabed topography. This inhibits flushing of the inner bay waters with the open sea.

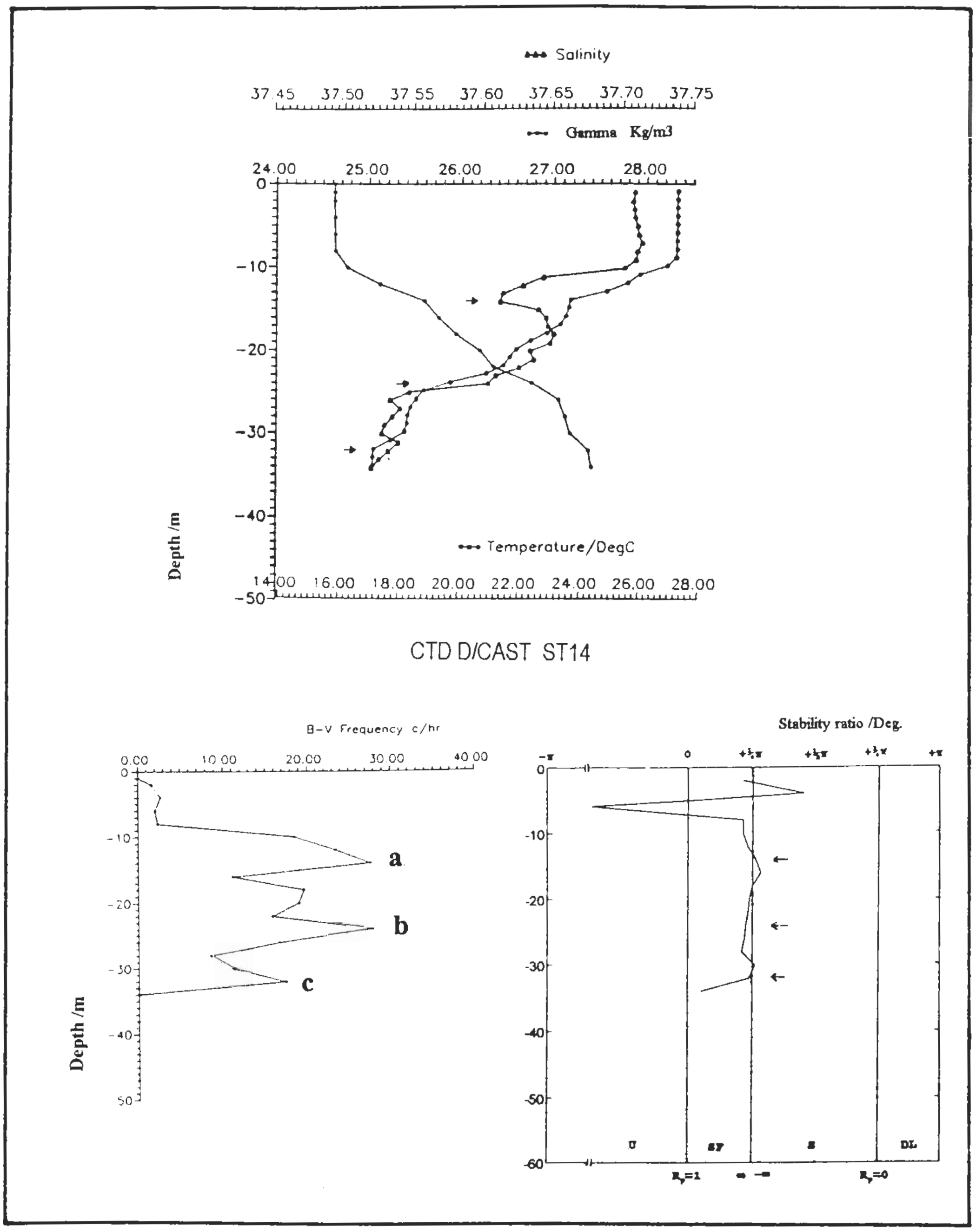


Figure 8. Temperature, Salinity and Density anomaly profiles, Brunt-Vaisala Frequency and Stability Angle close to Ahrax Stattion (35° 59.48'N 14° 23.50'E, 17 August, 1992).

A fine thermohaline structure exists in the summer thermocline layer with vertical scales of a few meters. It is notable that these T,S inversions are very similar to those observed by Armi and Zenk (1984) and Washburn and Kase (1986) in the regions around the salt lenses of the Mediterranean Water outflow into the Atlantic, at depths of 1400 decibars.

These hydrographic measurements were not originally intended to investigate microstructure. Future studies shall focus on the identification of the mechanisms generating the observed fine structure steppiness.

Acknowledgments

This work was jointly financed by the Marine Resources Network of the Malta Council for Science and Technology, and by the Euro-Med Centre on Insular Coastal Dynamics. Helpful discussions and comments on the data analysis have been enjoyed with Dr. Paolo Scarazzato from the Osservatorio Geofisico Sperimentale, Trieste, Italy, and Dr. George Zodiatis from the Laboratory of Physical Oceanography, Department of Fisheries, Centre of Marine Research, Cyprus.

I am also grateful to Dr. Simon Boxall from the Department of Oceanography, Southampton Oceanography Centre, UK, for supervising the preparations of the marine survey, and to Dr. Rhu Nash and Dr. Paul Forster for their support during the field measurements. I would also like to thank Mr. Anton Micallef for logistic support and Dr. Alan Fougere of Falmouth Scientific Inc., MA for lending me his personal CTD probe.

References

Armi L and Zenk W (1984) Large lenses of of highly saline Mediterranean Water. *Journal of Physical Oceanography*, **14**, 1560-1576.

Drago AF (1991) Physical Oceanography in the Coastal Waters of the Maltese Islands, Malta CERP Workshop, October 1991, *MRN Technical Report Series*, No. **1**, pp 24.

Gregg MC (1975) Microstructure and intrusions in the California Current. *Journal of Physical Oceanography*, **5**, 253-278.

Havard DA (1978) The Study of the Problems of the coastal Transport of Pollutants in Maltese Coastal Waters. *4th Journees Etudes Pollutions* 555-557 Antalya, C.I.E.S.M.

Howe MR and Tait RI (1970) Further observations of thermohaline stratification in the deep ocean. *Deep Sea Research*, **17**, 963-972.

Magnell B (1976) Salt fingers observed in the Mediterranean Outflow region (34°N 11°W) using a towed sensor. *Journal of Physical Oceanography*, **6** 523-551.

McDougall TJ and Taylor JR (1984) Flux measurements across a finger interface at low values of the stability ratio. *Journal of Marine Research*, **42**, 1-14.

Schmitt RW (1979) The growth rate of super-critical salt fingers. *Deep Sea Research*, **26**, 23-40.

Schmitt RW (1981) Form of the temperature-salinity relationship in the Central Water; evidence for double-diffusive mixing. *Journal of Physical Oceanography*, **11**, 1015-1026.

Sultan SAR and Elghribi NM (1996) Temperature inversion in the Arabian Gulf and the Gulf of Oman. *Continental Shelf Research*, **16**,1521-1544.

Tait RI and Howe MR (1968) Some observations of thermohaline stratification in the deep ocean. *Deep Sea Res*earch, **15**, 275-280.

Washburn L and Kase RH (1987) Double diffusion and the distribution of the density ratio in the Mediterranean waterfront southeast of the Azores. *Journal of Physical Oceanography*, **17**, 12-25.

Zodiatis G (1992) Lens formation in the SE Ionian Sea and double diffusion. *Annales Geophysicae*, **10**, 935-942.

Zodiatis G and Gasparini GP (1996) Thermohaline staircase formation in the Tyrrhenian Sea. *Deep Sea Research*, **43**, 655-678.

Research Article

Evaluation of Environmental Impact of Yacht Marina Development in Malta

Victor Axiak
Marine Ecotoxicology Laboratory, Department of Biology, University of Malta, Msida, Malta.

Summary. *The past few decades have witnessed a rapid development of yachting activities and of marinas in Malta. This trend is expected to persist, with new marinas being included in the latest development projects at Spinola and at Manoel Island. Limited coastal resources and other factors have led, however, to significant concern being expressed about the associated environmental implications of such trends. The potential risks of marine contamination resulting from both the construction phase and the operation of such marinas are identified. A brief review of the risk management strategy being used for a new marina which is presently being developed, is then given. Subsequently the available data on the quality of coastal waters is used to assess the significance of such risks for the marinas in Marsamxett Harbour. On the basis of the experience of the past few years, a national strategy for marina development and management is proposed.*

Keywords: Yacht marinas, marine contamination, risk assessment

In view of its position at the crossroads of the Mediterranean, Malta's economic and social development has always been directly and indirectly influenced by maritime transport. The maritime sector is in fact responsible for approximately 95% of Malta's trade with other countries, with the islands' ports currently handling 2.6 million tonnes of cargo annually. This excludes the trans-shipment activities of the more recent port at Marsaxlokk. As a seafaring people, many Maltese have a close relationship with the sea and a significant percentage own small water craft for pleasure or to earn a living. Most of the bays and creeks in Malta act as convenience or mooring harbours throughout the year.

Over the past two decades, Malta has witnessed a dramatic increase in yacht marina development coinciding with a parallel increase in the tourist industry and improvement in the local standard of living. In one local main harbour, Marsamxett, the number of available berths have increased by more than 100% over a period of 10 years. The Msida marina within Marsamxett now consists of no less than 870 berths and represents the main yachting centre in Malta. Figure 1 shows the various locations of the main harbours and marinas as well as of those areas which are exposed to heavy boating activities during most of the year.

The national Structure Plan for Malta (Ministry for Development of Infrastructure, 1990) states that 'favourable consideration will be given to suitable development proposals that contribute towards the creation of an integrated and comprehensive network of various types of safe havens for yachts around the coasts ...to attract cruise and flotilla sailing, marine sports, and marine plus culture high yield tourism markets'.

Since 1990, a number of proposals for new marinas have been made, each ranging from 100 to 1500 new berthing capacities. The proposed sites for such new marinas included Salina Bay, Xatt l-Ahmar (Gozo), Spinola, Manoel Island, Xlendi (Gozo), Kalkara and others. It is evident that while most of these proposals have not in fact been successful (mostly due to environmental considerations), one should still expect a continuation in the present trend of expansion of berthing capacities in existing marinas and possibly of new marinas. Presently, a new marina is being constructed on the Spinola headland with an expected berthing capacity of up to 150 berths. Furthermore, the Manoel Island and Marsamxett area is expected to act as the principal focus of such new marina development. The latest proposed development project for Manoel Island and Tigne', include a new marina at Lazzaretto Creek with 340 new berths.

While the economic benefits of yachting development are self evident, environmental considerations are bound to limit such development to ensure sustainablility.

Malta has one of the highest population densities in the world (approx. 1300 persons km^{-2}) which is periodically increased significantly by seasonal tourism. Coastal geology and topography are such as to produce natural deep-water harbours and a series of inlets and bays on a limited stretch of coastline, leaving much of the southwestern areas of mainland Malta and most of Gozo as rugged and inaccessible coast. These factors led to intense coastal development over a limited coastline causing rapid loss of natural habitats and other associated environmental problems. Intense boating and port activities (including one of the largest ship-repairing yards in the Mediterranean) as well as marina developments may present a number of marine contamination risks. In the present paper, attention will be focused on these risks resulting principally (though not exclusively) from marina developments. Wherever possible, such risks will be assessed on the basis of

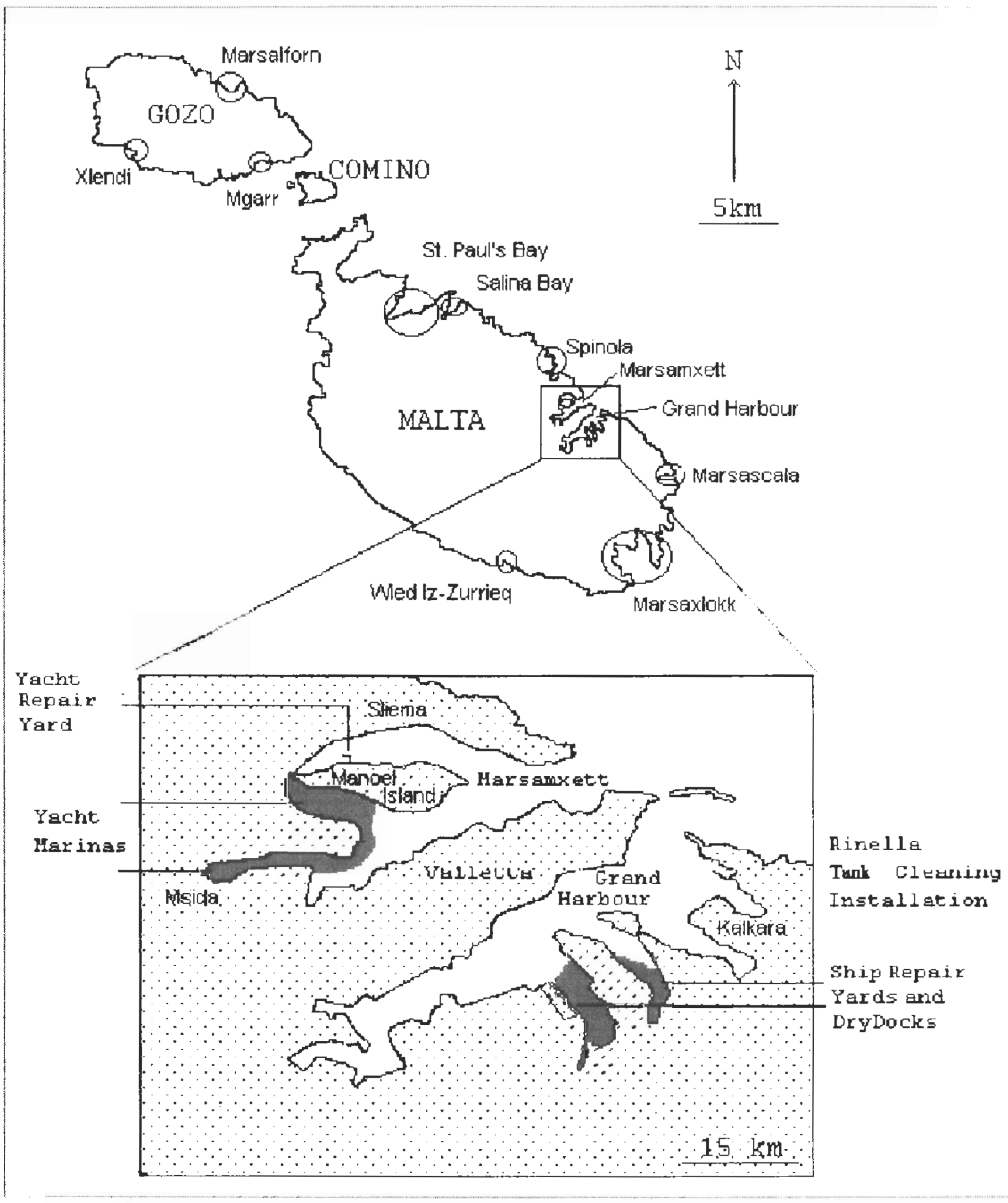


Figure 1. The Maltese Islands and locations of major ports, marinas and areas generally exposed to heavy boating and berthing activities.

presently available data. Finally specific recommendations will be made for a national strategy for marina development and management in Malta.

Environmental risk during the construction phase of marinas

During the construction phase of a marina, extensive coastline alteration and marine works may lead to loss of ecologically important habitats, including rockpools and littoral seagrass meadows. The resultant release of suspended matter in the water column as well as of resuspension of contaminants from sediments during dredging may lead to a general deterioration of water quality. *Posidonia* (and other sea grass) meadows are particularly vulnerable to reduced water visibility and benthic habitat disturbances. The construction of breakwaters and marina piers may lead to changes in the prevalent water hydrodynamics with wide-ranging effects on sediment transport, shore erosion and transport of potential contaminants.

To-date, most of the marina developments in Malta have been limited to Marsamxett harbour which was already heavily urbanised, and as such the environmental risks related to construction as identified above have not been significant. Nonetheless, there is evidence to suggest that heavy dredging activities within Lazzaretto Creek during the early 1990s led to significant increases in dissolved nitrates and phosphates over large areas within Marsamxett and moderate eutrophic conditions were evident (Axiak et al, 1992).

Any new marina developments in more pristine coastlines (as proposed on various occasions during the past few years) such as on the northern coastline of Malta and along most of the island of Gozo may be expected to result in more significant and pronounced environmental impacts.

Awareness of the potential environmental risks resulting from major coastal engineering works associated with new marina development, has led the planning authorities to formulate an extensive marine environmental monitoring programme for the new marina being presently constructed at Spinola. This monitoring programme was initiated in June 1996. To date, four water monitoring surveys, as well as three sediment and *Posidonia* monitoring surveys were carried out, together with a benthic survey of the vegetation communities along the Spinola headland (Axiak et al, 1996; Axiak et al, submitted to PA, 1997).

Demolition of the old Hilton Hotel started in August 1996, while rock cutting and transport using barges started in September 1996. No marine dredging works have been as yet undertaken. This means that most of the data collected so far may be considered to be baseline data which essentially characterize the relevant environmental parameters before that phase of project which is associated with the highest environmental risks. Baseline levels have now been established for a number of relevant parameters including dissolved nutrients, primary productivity (Chlorophyll *a* content), water transparency (in terms of beam attenuation coefficients and Secchi depths), surface and sub-surface currents, microbiological indicators, as well as petroleum hydrocarbons and organotins in superficial sediments in the area likely to be affected. Furthermore an extensive benthic survey has been carried out to identify the biological resources of the area mostly at risk from the proposed development. The geographical extent of *Posidonia* meadows as well as the state of health of such meadows have been now established using certain bioparameters including shoot density, adult leaf length, leaf density and epiphytic growths on leaves.

On the basis of such baseline information, and on the basis of environmental quality objectives being proposed for this monitoring programme, a number of environmental quality standards and threshold limits have been submitted to the Planning Authority for most water and sediment parameters being measured.

The proposed general environmental quality objective set for the area will be to maintain the existing environmental quality so as to protect bathers, aquatic life and the general water quality required for tourism and recreation (including aesthetic and visual properties of surface waters).

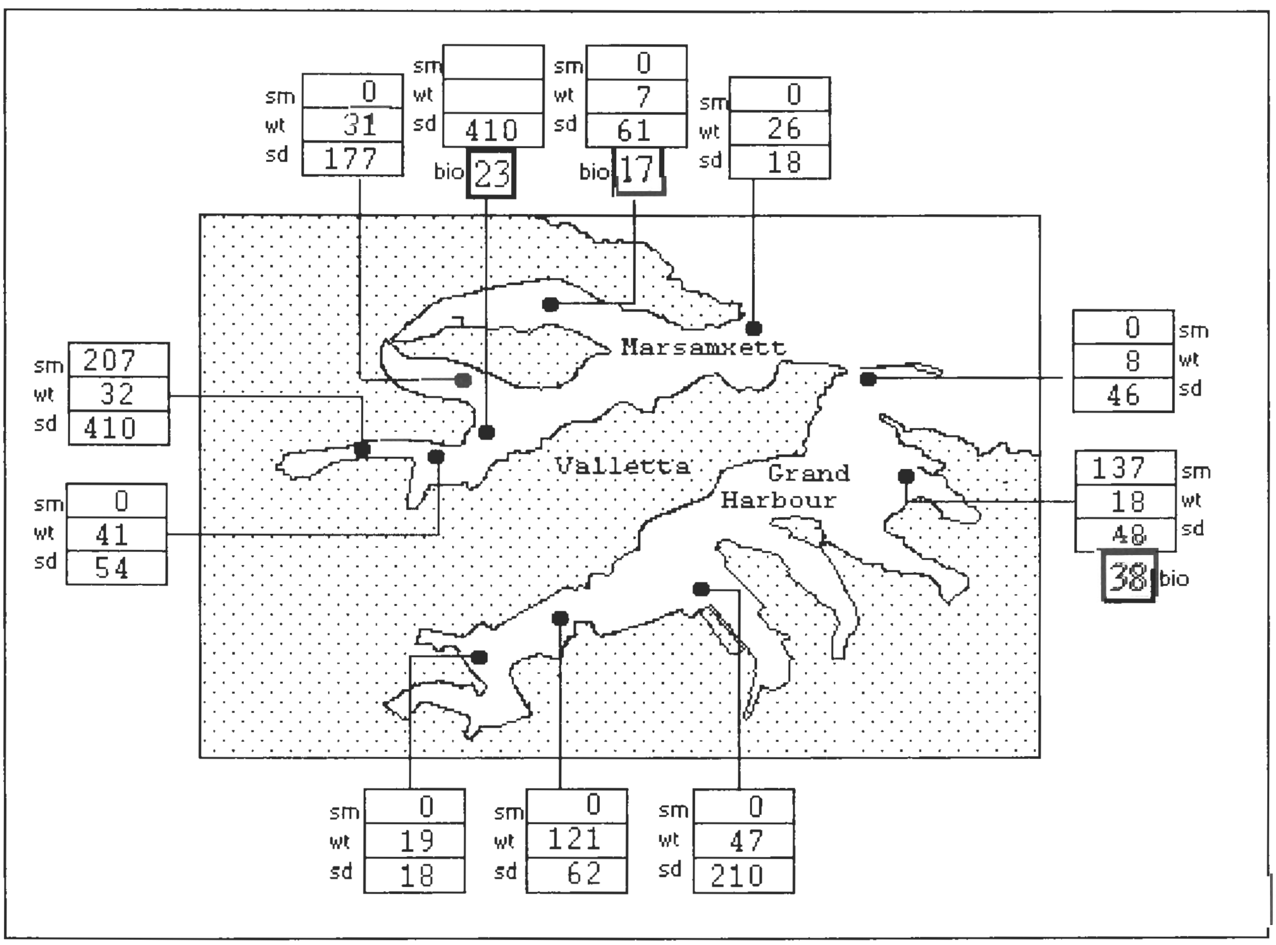


Figure 2. Environmental levels of TBT during the period Summer 1993 to Spring 1994. sm: levels in surface microlayer (ng Sn/l); wt: levels in water columns at 1m depth (ng Sn/l); sd: levels in sediments (ng Sn/gDW); bio: levels in *Hexaplex trunculus* (ng Sn/gDW). Values expressed as a mean of 3 readings.

With reference to *Posidonia* meadows, the environmental quality objective will be to prevent any degradation of such meadows, beyond the state as assessed prior to the commencement of the project.

Future monitoring will be for surveillance purposes with the aim of detecting any environmental damage and of bringing into effect the appropriate mitigating measures at the earliest possible stage. Compliance with the set environmental standards and thresholds as applied under certain specific conditions will ensure a satisfactory control of environmental risks associated with the construction phase of this marina. It may be pointed out that this marina development was the first major coastal development project in Malta to be submitted to a rigorous environmental risk management which incorporates comprehensive environmental monitoring and subsequent surveillance. It is hoped that other similar coastal projects (including future marina developments within Marsamxett) will be submitted to similar environmental risk management.

Environmental risk during the operation of marinas
During the operation of marinas, release of antifouling agents and petroleum hydrocarbons from boats (and boat yards), the generation of liquid and solid wastes, and the reduced water circulation, may lead to rapid deterioration in environmental quality not only within the marina basin proper but also in the surrounding areas. The evaluation of significance of such risks as identified above will depend on the availability of environmental data which is unfortunately very limited. The following account will review such data with the aim of establishing the real significance of such risks.

TBT antifouling agent
There is evidence to suggest that the present marinas in Malta are (together with ship-repair yards) the major sources of coastal contamination by the antifouling agent tributyltin (TBT). This is possibly one of the most toxic substances which is intentionally discharged into the marine environment. No legislation currently exists in Malta to limit the use of TBT-based paints on boats. An extensive chemical monitoring programme for butyltins in surface microlayers, water column and superficial sediments in local marinas and in their vicinity have been carried out recently (Axiak et al, 1995; Vella et al, in preparation,) and a synopsis of results is presented in Fig. 2. Levels of TBT in the sediments, and the water column within the marinas were found to be high and comparable to those near the drydocks. Such levels were found to vary with time presumably depending on the time of year when boats are repainted annually. The highest levels of TBT within the surface microlayers were detected within the marinas. Such levels are generally higher than those which would be expected to exert a significant environmental impact (generally 20 ng TBT/l or less). Levels of butyltins were also monitored in marine organisms collected from Marsamxett and Grand Harbour. In the case of the neogastropod, *Hexaplex trunculus* (Axiak et al, 1995), most of the TBT was found concentrated in the digestive gland/gonad complex.

The likely biological impact of such elevated levels of TBT in Maltese coastal waters has been recently reviewed by Axiak et al (in preparation). Various laboratory investigations have shown that at such levels of TBT, several sublethal responses may be evident including significant reductions in MFO enzyme system activities of fish, digestive cell atrophy in the oyster, *Ostrea edulis*, and induction of imposex in the marine snail, *Hexaplex trunculus*. The latter two biological responses are evident below the 20 ngTBT/l level.

TBT is known to cause imposex, which is the imposition of male sexual characteristics in female neogastropods. This effect may be quantified in terms of a Relative Penis Size Index (RPS) as defined by Gibbs et al (1987). Fig. 3 presents RPS indices for various populations of this species along the Maltese coastline.

All populations of *H. trunculus* were drastically affected by imposex within Marsamxett. Moreover, this effect was evident along most of the coastal areas of the Maltese Archipelago, indicating that TBT may exert a negative biological impact on localities which are several kilometres away from suspected sources of TBT pollution (Axiak et al, 1995). Recent field data however indicate that very low background levels of imposex in some populations of this species may occur even when unexposed to boating activities.

Moreover, the presence of TBT within the two harbours and possibly elsewhere, may interfere with the potential use of MFO induction in fish as a biomonitoring tool for other pollutants. The implications of these results on the future development of biomonitoring of pollution within the Mediterranean are self-evident.

Petroleum hydrocarbons
Studies undertaken from 1987 to 1993 indicate that the levels of petroleum hydrocarbons (such as diesel, fuels and oil products) in superficial sediments from several coastal areas show an upward trend (Axiak et al, 1993). Such levels of petroleum hydrocarbons may be expressed as micrograms per dry weight gram of sediment (Chrysene Equivalents). For the Mediterranean, levels which exceed 10 ug/g dry weight of sediment are usually considered as indicative of significant pollution by oil. Over the period 1987-1993, mean levels of petroleum hydrocarbons in superficial sediments collected from Pieta and Msida creeks increased from 7 and 16 to 43 and 48 ug/g dry weight, respectively. This represents an almost five-fold increase in oil pollution load in these areas, over this period. Operational and accidental spillages of diesel, fuels and oil products from boats are evidently responsible for this. During such period there was a rapid development of the Msida marina with an increase in berthing capacities and construction of a breakwater at the mouth of Msida Creek.

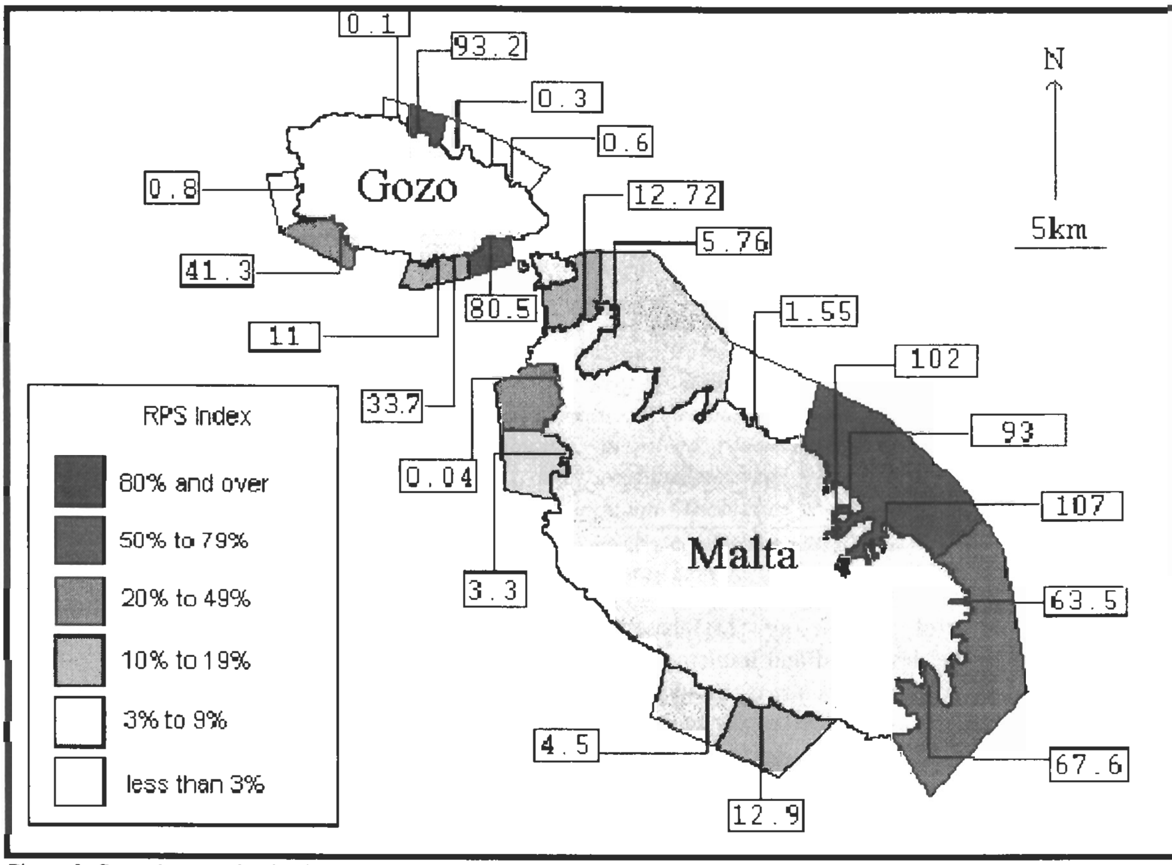


Figure 3. Coastal contamination by TBT as indicated by the intensity of imposex bioindicator in *Murex trunculus* (expressed in terms of the Relative Penis Size Index, RPS).

These data indicate that though the coastal waters of Malta have not yet been exposed to any massive oil pollution incident, chronic low-level pollution by oil and petroleum products from boats and yachts is becoming increasingly significant. There is an urgent need to improve practices within the marinas so as to minimize such risks of oil pollution which may present a hazard both to the environment as well as to the safety of the boats themselves.

Other contaminants

Mismanagement of liquid and solid wastes within a marina may lead to increased coastal contamination by sewage, elevated nutrient levels and in cases exposed to reduced water circulation, the resultant risks of eutrophication become significant. Evidence of moderate eutrophic conditions associated with various parts of Marsamxett and especially within Msida marina is available (Axiak et al, 1992). Landsat satellite TM data of coastal water quality within Marsamxett during 1995 have confirmed such data (Axiak and Geraci, 1995).

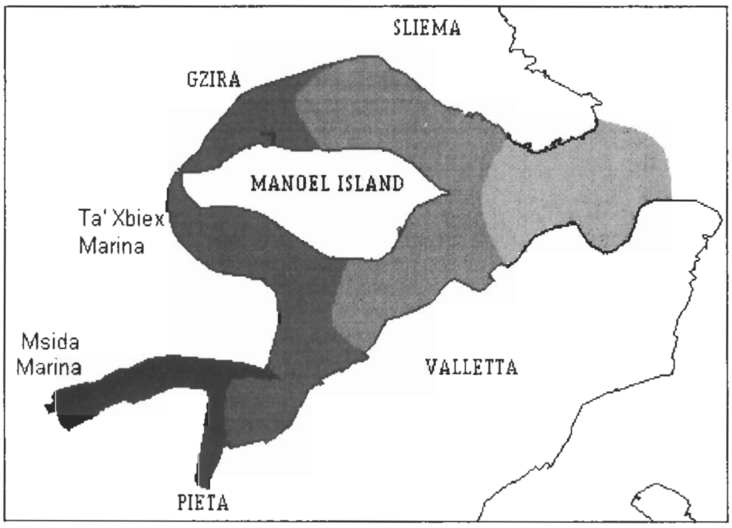
These available data confirm that elevated levels of nutrients, chlorophyll *a* and high water turbidity, which are usually indicative of eutrophic conditions are evident within the Msida marina and in the vicinity. This is illustrated in Fig. 4.

Conclusions and Recommendations

The above account has identified the trend in yachting activities and development of marinas in Malta and the associated risks of marine contamination associated with such development both during the construction phase and during their operation. Any further marina developments in Malta should be designed so as to fully control and mitigate against such risks.

A national strategy for marina development and management should be formulated and implemented as soon as possible. This should be carried out within the existing administrative frameworks and should be the result of close collaboration between the various management partners involved, including the Department for Environmental Protection, the Planning Authority and the Malta Maritime Authority. Such a strategy should identify priorities and desired objectives. It should be based on a comprehensive assessment of the present environmental problems related to the existing marinas. Such information may then be utilized to identify potential localities for new marina development, and to set an upper limit to the number of yacht marinas, as well as to the maximum berthing densities to be accommodated. Present data suggest that it would be undesirable to extend marina development well beyond the immediate vicinity of Sliema, Marsamxett and Grand Harbour.

Guidelines should be formulated to regulate marine works during the construction of coastal structures associated with marinas, as well as to ensure proper design (such as the prevention of surface run-off from jetties and piers of any spilt diesels and oil into the sea). Furthermore any new marina projects will need to be submitted to a rigorous environmental risk management which should include compliance and surveillance monitoring. An example of such an approach has been given above, with respect to the new marina at Spinola.



	Water turbidity in Secchi depths (m)	Nitrates (μg-at N/l)
	7	less than 15
	5 to 6.5	16 to 19
	4	generally 19 to 20
	3.5 or less	generally above 20

Figure 4. Eutrophication in Marxamxett Harbour related to marinas as monitored by water turbidity (measures by Secchi depths in m) and nitrate levels, during 1989-1991.

Legislation on the control of use of TBT-based antifouling paints should be developed and implemented as soon as possible. Moreover regulations should be developed to regulate liquid and solid waste management within marinas as well as to control normal boating practices within such basins.

Future marina development and operation in Malta which would be conforming with sustainable coastal development as well as with environmental protection would only be possible within the context of such a national strategy for marina development and management.

References

Axiak V, Bajada M, Dimech J, Grima G, Gauci V, Muscat J and Pisani S (1992) Eutrophication monitoring in Malta (Central Mediterranean). *CIESM Rapport Committee Inernational Mer Mediterranee*, **33**, 166.

Axiak V, Gauci J, Grech P and Vella C (1993) Recent trends in coastal pollution by petroleum hydrocarbons in Malta (Central Mediterranean). *Clean Seas 93 Conference (Malta) Proceedings.*

Axiak V, Vella AJ, Micallef D, Chircop P and Mintoff B (1995) Imposex in *Hexaplex trunculus* (Gastropoda: Muricidae): first results from biomonitoring of tributyltin contamination in the Mediterranean. *Marine Biology,* **121**, 685-691.

Axiak V and Geraci AL (1995) Monitoring of Environmental Quality of Maltese Coastal Waters using Remote Sensing. A Feasibility Study Malta Council for Science and Technology 50pp.

Axiak V, Vella A, Agius D, Bonnici P, Cassar G, Cassone R, Chircop P, Micallef D, Mintoff B and Sammut M *Evaluation of Levels and Environmental Impact of TBT In Malta* (in preparation).

Axiak V, Vella A, Borg JA, Micallef SA and Lanfranco E (1996) *Hilton Redevelopment Project: Marine Environmental Monitoring Programme First Report* May-June 1996 Malta University Services 47pp.

Axiak V, Vella A, Borg JA, Micallef SA and Lanfranco E *Hilton Redevelopment Project: Marine Environmental Monitoring Programme First Report May 1996 - January 1997.* Draft Version presented to PA on the 4th March 1997 Malta University Services (in preparation).

Gibbs PE, Bryan GW, Pascoe PL and Burt GR (1987) The use of the dog-whelk, *Nucella lapillus*, as an indicator of tributyltin (TBT) contamination. *Journal of the Marine Biology Association UK,* **67**, 507-523.

Ministry for Development of Infrastructure (Planning Services Division) (1990) *Structure Plan for the Maltese Islands Draft Written Statement and Key Diagram* 125pp.

Vella AJ, Mintoff B, Axiak V, Agius D and Cassone R *Butyltin compounds in seawater, surface microlayer and sediments in Malta* (in preparation).

Research Article

The Impact of Aquaculture on the Water Quality of Maltese Waters

Christopher Rizzo and Alain Le Breton
National Aquaculture Centre, Fort St. Lucian, Marsaxlokk, Malta.

Summary. *The impact of marine fish farming on the water quality of Maltese Waters was monitored monthly over a period of one year. Water samples were collected at different depths in the water column from several stations distributed around six fish farming sites. Physical and chemical parameters were measured: temperature, pH, dissolved oxygen (DO), salinity, turbidity, unionised ammonia, dissolved reactive phosphorous (DRP), nitrate-nitrogen, chlorophyll a. The bacterial flora, faecal coliforms and faecal streptococci, were also investigated. Results show that the impact of local aquaculture on the water column is minimal. Anomalies observed near the offshore cages were in most cases also observed at control sites. Other factors such as climatic conditions, sewage outflows and possible underwater freshwater outlets play a key role in the fluctuation of several of these parameters.*

Keywords: aquaculture, pollution, bacteriology, nitrate, nutrient, phytoplankton

Environmental pollution, whatever its origin, is a major problem encountered by authorities in different countries. Industrial activities are continuously contributing to such pollution and therefore authorities are much involved in ensuring that pressures on the environment remain within sustainable limits that permit natural adjustment. The Mediterranean, being a relatively enclosed sea, is subjected to a high risk of pollution. Thus, continuous monitoring of potential sources of pollution is of prime importance to prevent irreversible damage to the marine environment. With the recent increase of the aquaculture industry in the Mediterranean and around the Maltese Islands, concern has grown over its possible adverse effects on the marine environment. Ackefors and Enell (1990) have observed that the contribution of other industries to the degradation of the environment is much higher than that of fish farming. The extent of impact induced by these latter activities is related to several factors such as the size of the farms in terms of annual production and their location. The evaluation of this effect on the environment is required by the licensing authorities to estimate potential adverse effects that new lease proposals may generate. Environmental impact assessment and monitoring has been done for several years in various countries, even though very few equivalent studies have been reported from the Mediterranean.

The intensive culture of fish in offshore cages leads to the generation of particulate and soluble wastes. The effect of the particulate waste namely, fish faeces and uneaten feed that sinks to the bottom, is currently being studied at the National Aquaculture Centre. A small part of these wastes may be recycled by mineralisation and resuspension processes (Agius and Jaccarini, 1989). These recycled nutrients are difficult to quantify (Wallin and Hakanson, 1991), but are of considerable importance when considering the possible nutrient enrichment effects from a fish farm (Cassar, 1994). The availability of these nutrients is, however, dependant on environmental conditions and may explain the short-lived high nitrate-nitrogen levels (Agius and Jaccarini, 1989). The soluble wastes which are of interest in this review consist mainly of fish excreta (soluble ammonium and urea) and dissolved nitrogen and phosphorous compounds from feeds as they sink to the bottom. The proportion of ammonia is variable, but is usually 80% of fish excreta (Gowen and McLusky, 1988). Soluble nitrogen and phosphorous compounds are an important source of nutrients for phytoplankton. Thus, where phytoplankton is limited by lack of nutrients, an increase in nitrogen and phosphorous levels (hypernutrification) will result in an increased primary production in the water column which in extreme cases may result in O_2 depletion (eutrophication). Eutrophication may also result in an increased turbidity of the water column. Ammonia is also of prime importance. Under alkaline conditions the unionised form is highly toxic to fish, causing branchial hyperplasia. Previous studies have shown ammonia levels in local waters to be below 0.1ppm (De Giovanni, 1991) which is below the level toxic to fish.

The location of fish farming operations plays a major role in the extent of impact on the water column. Wastes produced by marine cage farms undergo a better dispersal when the farm is situated in an exposed site with an efficient water exchange. Except for very enclosed sites, the water exchange at local sites is sufficient to prevent the build-up of phytoplankton and nutrients (Cassar, 1994).

Locally, no long term studies have been performed to measure and quantify the effect of the aquaculture industry on the marine environment. The objective of this study was to determine the extent of the impact on the water quality by local fish farming activities, and to provide background information for future studies.

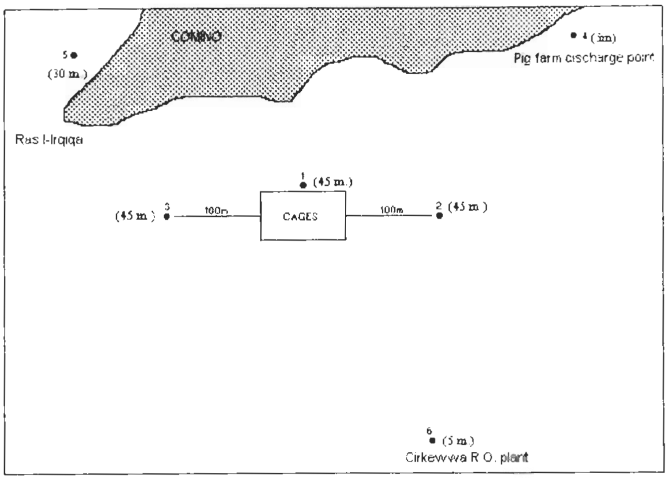


Fig. 1a - Site A

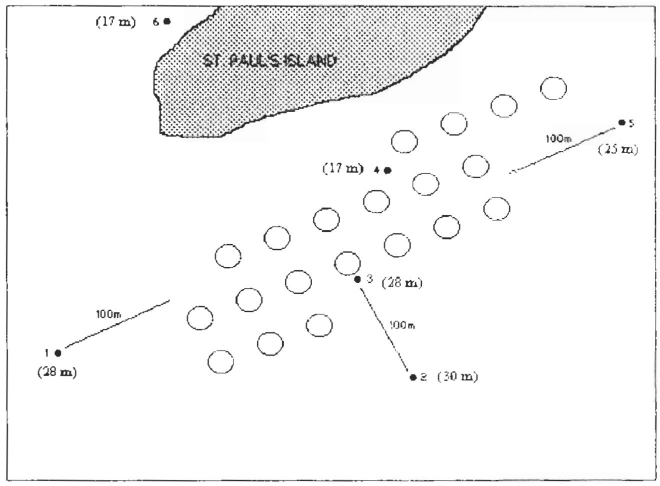
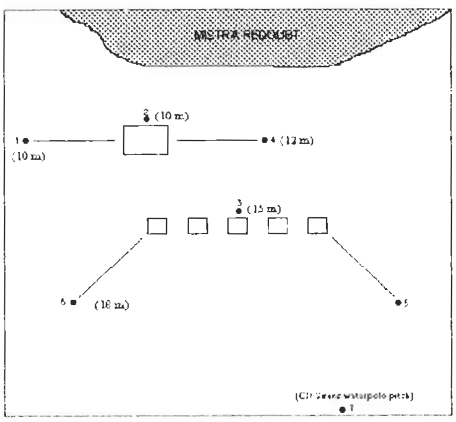


Fig. 1b - Site B



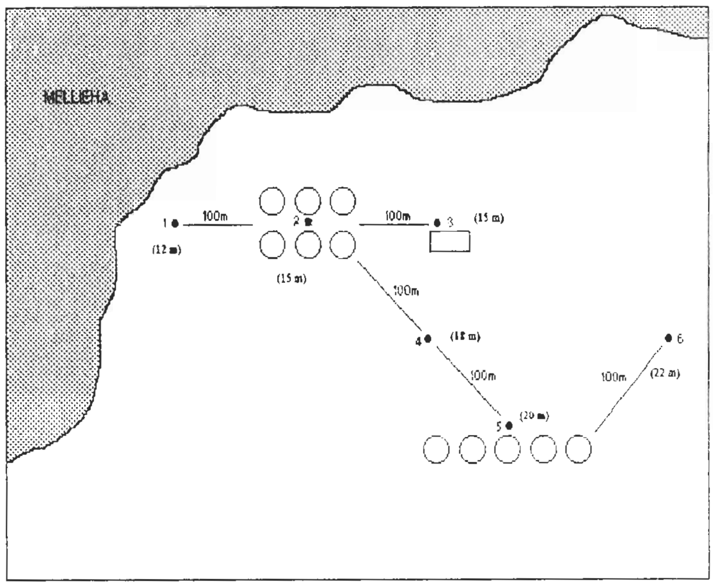
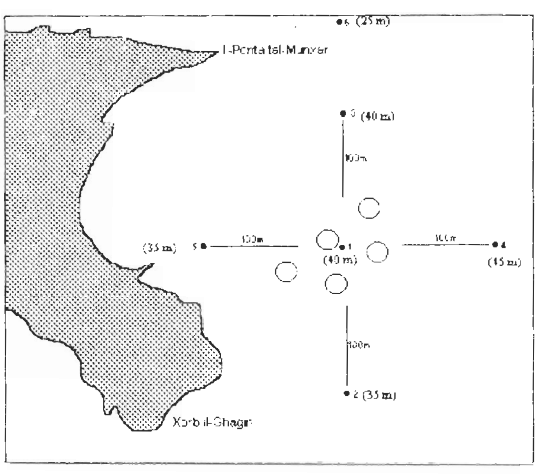


Fig. 1c - Site C

Fig. 1d - Site D

Fig. 1e - Site E

Fig. 1f - Site F



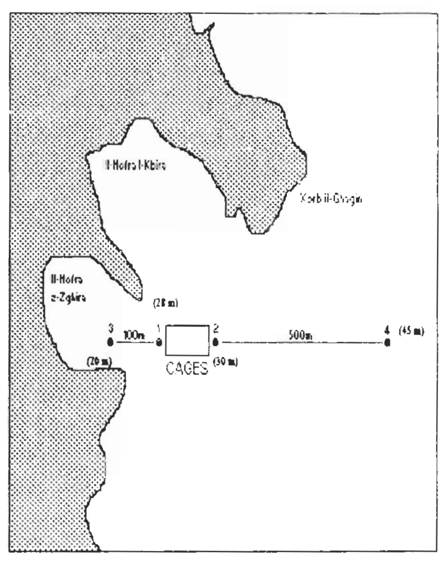


Figure 1. Fish farming sites monitored for their impact on water quality. The location of the samples spots and the control points are represented with the respective water depths.

Materials and Methods

Sample sites and sampling spots description

Water samples were collected monthly from thirty-five sampling stations distributed around six local on-growing units. At each site, sampling spots were chosen either in the vicinity of the cages or at one hundred metres outside the rearing units. The control points were situated in an independent zone or in an area where a potential source of water contamination was present, which can affect the site, was identified. The locations of all the sampling spots with the correspondent water depths are presented in Figures 1a, 1b, 1c, 1d, 1e, 1f.

Currents were not monitored. One site (Figure 1a) is particularly affected by strong east or west currents which are in the axe of the units. Surface and deeper currents can eventually be observed simultaneously with an opposite direction.

Main characteristics of the rearing facilities and management

The production units followed during this survey are each of a volume 3000-4500m^3, equipped with Dunlop or Bridgetone type cages. In site A, the unit is composed of two groups of five cages, while in site B and D the unit is composed of 19 and 9 cages respectively. The site C is equipped with a group of 4 small Dunlop cages and a group of Jetflot cages. Four Farm Ocean cages, each of a capacity of 3500m^3, constitute the site E. The biomass in the cages fluctuates from 10kg.m^{-3} to a maximum of 30kg.m^{-3} in some cages of market size fish.

In 1996, 1550 tonnes of fish were produced. More than 90% of which were sea bream *Sparus aurata,* the rest being sea bass *Dicentrarchus labrax*. Two different type of feed, steam-pressed or extruded, are distributed and the total amount of food employed this year was approximately 4000 tonnes. The steam pressed feed has an average composition of 48% protein, 12% lipid, 10% ash, 8% moisture and 2% fibre. The extruded feed contain 46% protein, 16% to 22% lipid 10% ash, 8% moisture and 2% fibre. The percentage of carbohydrate is calculated by substraction. The size of the pellets distributed depends on the size and the age of the fish and range from 1.0mm to 6mm.

Sampling procedures

Water samples for chemical analysis were collected at three different depths (1m, 10m, 20m) in the water column by means of a 3-litre capacity Van Dorn water sampler. They were transported to the laboratory in plastic containers which were disinfected and rinsed with sterile deionised water. Samples were analysed immediately. If the analysis had to be delayed, they were deep-frozen in a domestic type freezer at -20°C.

Bacteriology samples were collected and transported in sterile containers held in iced coolers. They were processed on arrival at the laboratory.

Physical and chemical parameters

Physical parameters were measured in the field at the time of sampling. Water temperatures were recorded at three different depths (1m, 10m and 20m) using a digital thermometer. The pH and DO content were measured using a portable Oxyguard Handy pH meter and an Oxyguard Handy Mark I oxygen meter respectively. The salinity was measured at the surface only, using a portable Atago S/Mill refractometer, whilst the turbidity was evaluated by lowering a Secchi disc vertically into the water column.

Chemical and bacteriological analysis methods

The determinations of nitrate-nitrogen, DRP and Chlorophyll *a*, were carried out using standard procedures (Strickland and Parsons, 1972). Unionised ammonia levels were measured using the standard method described by Stirling (1985). Bacteriological analysis, determination of faecal coliforms and faecal streptococci were carried out using the reference method for water bacteriology (Anonymous, 1975).

Results

Temperature shows seasonal variation with an average minimum of 15.7°C in January and an average maximum of 26.9°C in August. No evident differences were observed throughout the year between the control sites and the samples taken from the vicinity of the cages (Figure 2).

No seasonal variation in surface salinities at the six different sampling areas was noticed. Average surface salinities at the six sites range from 35.4 to 38.5 ppt which is within known norms for local waters. Furthermore, no obvious differences are observed in surface salinities at the different sampling areas. Figure 2 shows a comparison of the annual variation of surface salinities at control sites and at the cage areas.

No particular seasonal variation was seen in pH values, even though there was a slight gradual decrease during summer. pH values varied from 6.48 in July to 8.49 in December. Figure 2 shows no difference between pH values recorded at control sites and in the vicinity of the cages. No correlation was observed with increasing depth.

Seasonal variation in DO levels was observed (Figure 2). The average dissolved oxygen values ranged from 5.64 to 8.34mgL^{-1}. No obvious difference was observed between the control site and the cage area even though occasionally average DO levels near the cages were found to be slightly lower. No readings were taken during the month of August. The turbidity is related to climatic conditions with average values ranging from a minimum of 6m in autumn and winter to a maximum of 27m in August. No particular differences were observed between Secchi depths at control sites and those in the vicinity of the cages.

Unionised ammonia levels were generally very low at all sampling areas, and in the majority of cases were

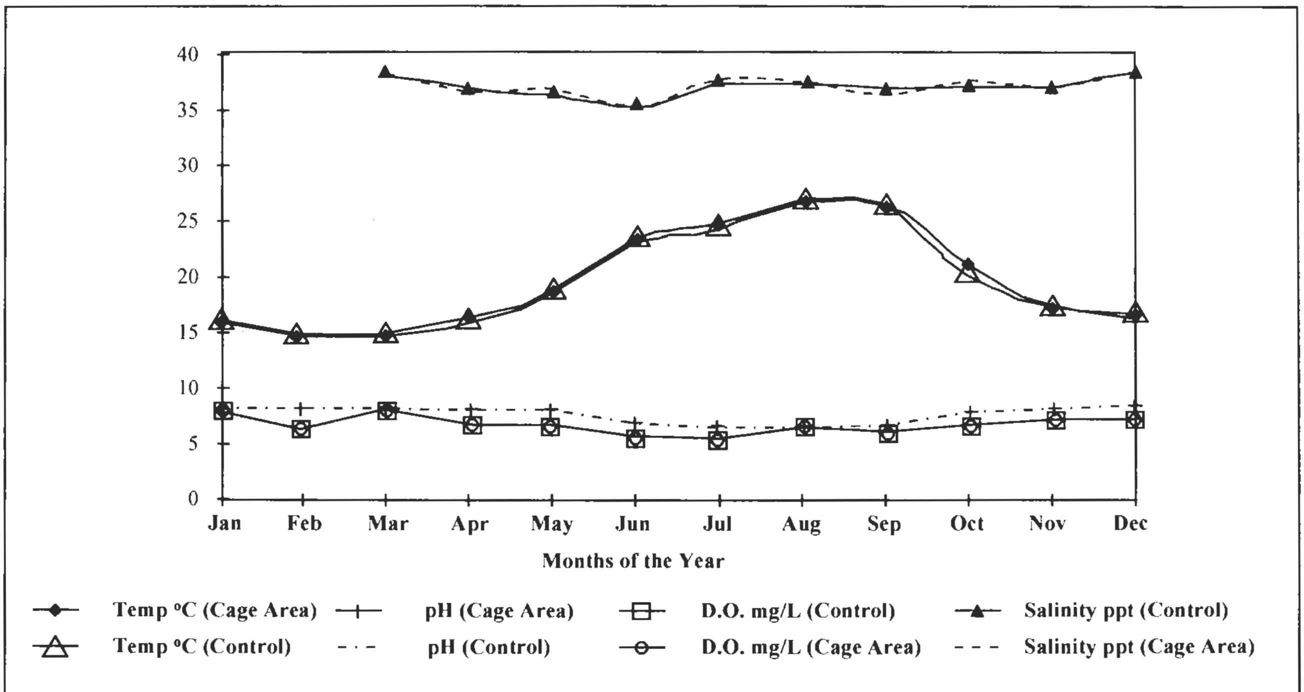


Figure 2. Average annual variation of temperature, D.O. content, pH and salinity in 1996.

never detected by the method employed. When unionised ammonia was detected, levels were found to lie between 0.001mg/L and 0.094mg/L. No particular differences were observed between control sites and samples from the vicinity of the cages.

Figure 3 shows the annual variation of nutrient levels and phytoplankton biomass during 1996. DRP levels were found to be rather constant even though a slight increase was observed during July. No difference in DRP levels between the control sites and the cage units at all sampling areas were noticed. Average DRP levels recorded ranged between 0.03 and 0.31mg/L. No correlation was observed between DRP levels and increase in depth. Nitrate-nitrogen levels fluctuate frequently throughout the year and were always higher than DRP levels. The average nitrate-nitrogen levels recorded over this one year period ranged between a minimum of 0.23 and a maximum of 4.98mg/L. No relationship was observed with increasing depth. Figure 3 shows a marked difference in nitrate-nitrogen levels between the control sites and the cage areas during April and December. Chlorophyll *a* levels fluctuate moderately within known norms (0.06 to 0.97mgm^{-3}). No difference was observed between the control sites and the cage areas. No correlation with increasing depth was seen.

Faecal coliforms were detected occasionally at very low levels and are not clearly seen in Figure 4. Faecal *Streptococci* were continuously detected, with greater amounts recorded during spring and summer.

Discussion

Water temperatures were observed to fluctuate seasonally with higher temperatures being recorded during the summer months. Higher temperatures are known to reduce the solubility of gases (Roberts, 1989), which explains the reduction in DO levels observed during the summer period both in the vicinity of the fish farms and at the control sites. This effect coupled with the enhanced oxygen consumption of the cultured fish makes DO levels a critical factor for ongrowing activities during this period. Even though in summer a drop in DO levels is recorded inside the cages themselves, there was no significant impact on the surrounding water. This is indicative of efficient water exchange around the cage units and that the drop in DO levels in the surrounding waters cannot be attributed to fish farming activities.

In the majority of cases a temperature gradient was observed with increasing depth (thermocline). During the winter months when there is sufficient mixing of the water due to wave action and underwater currents, this temperature gradient was found to be approximately 0.8°C. In summer, this temperature gradient is much larger (-3°C) as a result of less efficient mixing due to the favourable climatic conditions. Rainwater and terrestrial run-off do not significantly influence the surface salinity which was more or less constant throughout the year at the sites studied. This is obviously aided by the fact that all fish farms are situated in relatively open sites.

Levels of unionised ammonia were in the majority of cases below the detection limit of the method employed. When detected, no significant difference was recorded between the control sites and the cage units. This further supports the results showing adequate water exchange and minimal impact of fish farming activities on the marine environment.

The turbidity is greatly dependant on climatic conditions. Lower Secchi depths were observed during the winter months. During this period, the transparency of the water is reduced by terrestrial run-off following heavy rainfall, agitation of the sediments due to strong underwater currents and wave action. The results have shown that the

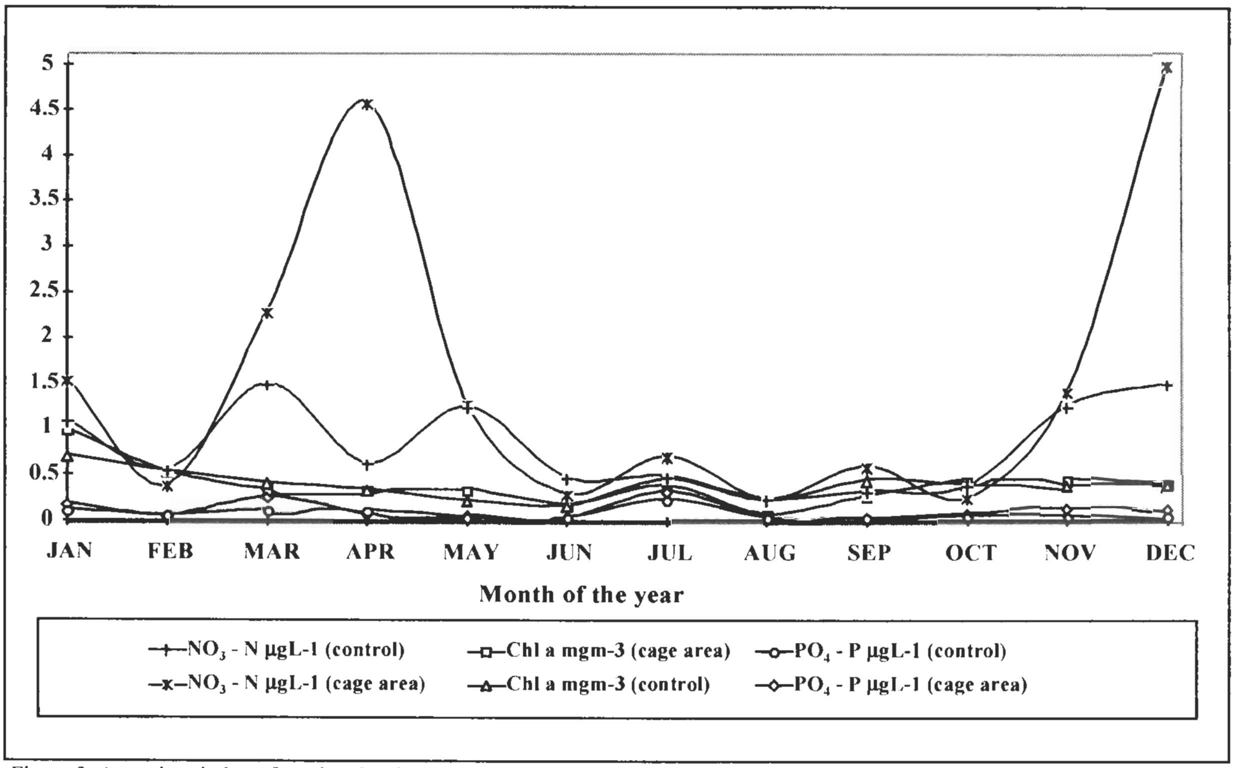


Figure 3. Annual variation of nutrient levels (NO_3 and PO_4) and phytoplankton biomass (Chl, chlorophyll) in 1996.

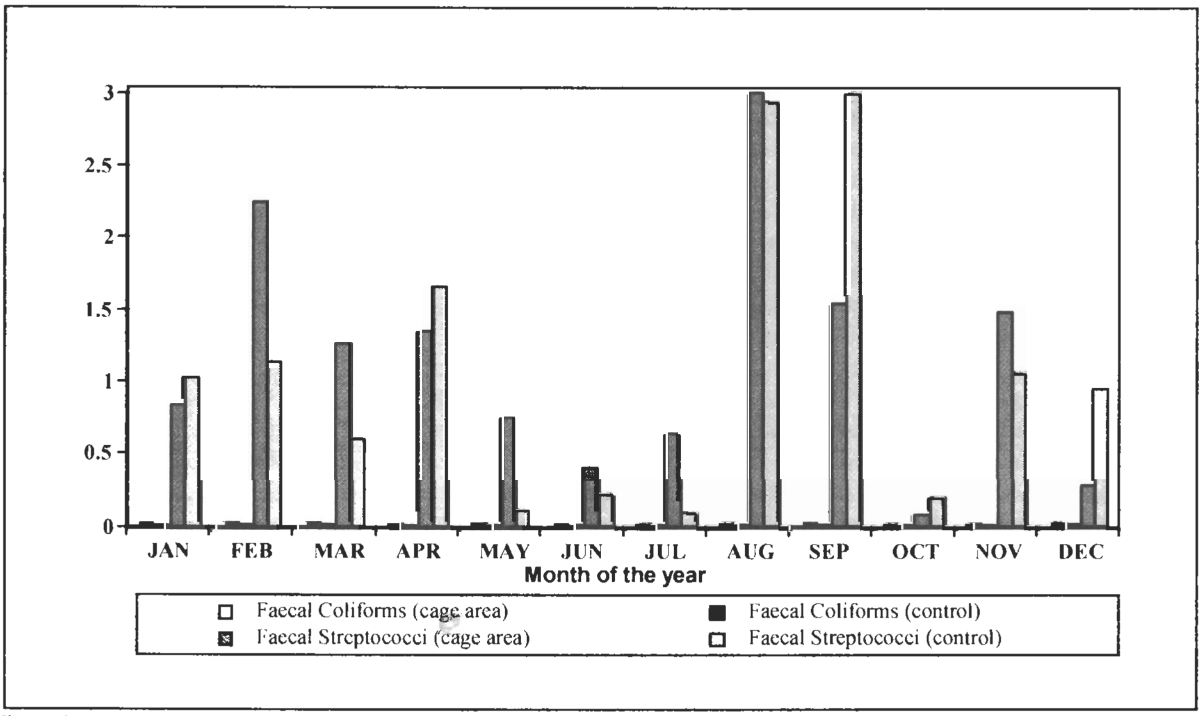


Figure 4. Average variation of faecal bacteria in 1996.

input of nutrients from fish farming activities are minimal. The latter, when combined with inputs of nitrogen and phosphorous compounds from terrestrial run-off and resuspension processes, never reach levels that may cause hypernutrification. This explains why no lower Secchi depths linked to an increase in phytoplankton biomass were recorded. The results of DO obtained during the winter confirm this observation. Therefore the low Secchi depths recorded during the winter months cannot be attributed to fish farming activities but to climatic conditions. In this study, no differences in Secchi depths were observed between control sites and cage areas during this study.

The main impact of fish farming activities on the environment is due to nutrient levels generated from fish feeds and fish excreta. An increase in the feeding regime and fish metabolism during the summer period might be correlated with higher levels of nitrate-nitrogen and DRP. Previously, results have shown that fluctuations in these nutrient levels are more influenced by climatic conditions rather than by aquaculture activities. DRP levels fluctuate slightly throughout the year showing a limited increase during the months of March, July and November. The increase during March and November may be explained by a substantial terrestrial run-off following heavy precipitation and resuspension from sediments as a result of strong underwater currents and wave action. The anomaly observed in July, may also be explained by resuspension processes as adverse weather conditions and strong wave action were recorded that month. Resuspension processes are known to contribute to increasing DRP levels in the water column, as 30 % of particulate-bound phosphorous which is in a readily soluble form, is lost rapidly to the water column (Cassar, 1994). No particular difference was observed between DRP levels at control sites and those recorded in the vicinity of the cages. Nitrate-nitrogen levels were always found to be higher than DRP levels. This fact is concordant with results obtained by Agius and Jaccarini (1989). This may be explained by differences in their solubilties. Nitrates are very soluble and liable to go into solution whereas phosphates are less soluble and on agitation of the sediments may only exist temporarily in a finely suspended state before resettling on the seabed. Several factors, such as terrestrial run-off from agricultural land and resuspension processes, influence nitrate-nitrogen levels in sea water. The sampling points closer to the coast are more subject to these factors. This can explain the two major increases observed in April and December and the differences noticed between some control points and the cage area. The fact that these differences are short-lived is an indication of an efficient water exchange at the sites studied. Other small nitrate-nitrogen fluctuations recorded during the year can be linked to the intermittent discharge of sewage (which releases large amounts of nutrients) and underwater freshwater outflows. The possibility of freshwater outflows from the lower water table of Malta contributing to nutrient levels must not be overlooked. Although several such outflows have been located below sea-level in various coastal areas, their contribution to nutrient availability remains to be investigated (Agius and Jaccarini, 1989). From this survey, it seems that the nutrient levels in the water column are mainly induced by different factors independent of fish farming activities. However, these nutrients released from the various sources do not seem to have any effect on the phytoplankton biomass. No evident increase in chlorophyll *a* levels were observed throughout the year. Moreover, no obvious difference in chlorophyll *a* levels was seen between the control sites and the samples taken from the vicinity of the cages, indicating further that there is no effect on the surrounding water column by the fish farms.

Conclusion

The release of nutrients from the ongrowing units is not disputed, since the intensive culture of fish in offshore cages is bound to generate soluble wastes which are released into the environment. This study has shown that the quantity of wastes released into the environment from fish farming operations is very limited and localised. Climatic conditions, sewage effluent and underwater freshwater outlets seem to play a much larger role in the fluctuation of certain parameters. Moreover, the water exchange at the different sites studied is sufficient to disperse these soluble wastes and hinder their accumulation thus preventing eutrophication and the impact it may have on the marine environment.

A previous short term study (Cassar, 1994) has shown that the effects of the fish farm cages on the benthos is more evident and that the increased organic input to the sediment directly below the cages, results in a degradation of benthic communities. Thus it is probably more appropriate to study the effect of local fish farming activities by investigating the extent of damaged caused to the underlying sediments and benthic communities. Such a study is in progress.

References

Ackefors H and Enell M (1990) Discharge of nutrients from Swedish Fish Farming to Adjacent Sea Areas *Ambio* Feb 1990.

Agius C and Jaccarini V (1989) A survey of nitrate and phosphate levels of inshore marine waters from Malta (Central Mediterranean). *Centro* **1** (4), 1-7.

Anonymous (1975) *Standard methods for the examination of water and wastewater* 14th edition Washington D. C. American Public Health Association, 1193 pp.

Cassar M (1994) *Environmental Impact of a Marine Cage Fish Farm.* Unpublished M.Sc. thesis, University of Malta.

De Giovanni MS, (1991) *The effects of fish farming on water quality at Mistra Bay.* Unpublished B.Sc. thesis, University of Malta.

Roberts JR (1989). *Fish Pathology* 2nd edition. Bailliere Tindall 467 pp.

Stirling HP (ed) (1985). *Chemical and Biological Methods of Water Analysis for Aquaculturists* I.O.A., University of Stirling 119 pp.

Strickland JDH and Parsons TR (1972). *A practical handbook of seawater analysis* Bulletin No. 167, 2nd edition. Ottawa. Fisheries Research Board of Canada 310 pp.

Whole ED Armstrong FAJ and Richards FA (1967). Determination of nitrate in sea water by cadmium-copper reduction to nitrite. *Journal of Marine Biology Association* U.K., **47**, 23-31.

Research Article

Geochemistry of the *Soll* Facies of the Lower Globigerina Limestone Formation, Malta.

Alfred J. Vella, Simon Testa and Christopher Zammit
Department of Chemistry, University of Malta, Msida, Malta.

Summary. *Rock from the "soll" seams of the Lower Globigerina Limestone Formation is distinguishable from "franka" because of its characteristic honeycomb weathering. However, when freshly quarried, "soll" limestone, an inferior building material, is not so readily recognizable. This study was aimed at characterizing "soll" on the basis of its inorganic geochemistry. It is shown that "soll" has a significantly higher silicon content than normal "franka". The silica content of "soll", which is a measure of its clay content, is typically less than 5%. Therefore, the traditional belief that "soll" is a limestone which is rich in clay is untenable. The silicon content may be useful in differentiating "soll" limestone from "franka". Besides that in silicon, other elemental anomalies are found associated with the "soll" facies of the Lower Globigerina and also with "soll ahdar", a stratigraphically related grey-green variety.*

Keywords: Globigerina, limestone, geochemistry, silica, weathering, Malta

The sedimentary rock outcrops of the Maltese Islands are largely composed of limestones and marls deposited in layer cake succession during the Tertiary. The stratigraphic pile is extensively faulted. Listed in order of deposition, the geologic formations are: Lower Coralline Limestone, Globigerina Limestone, Blue Clay, Greensand and Upper Coralline Limestone (Spratt, 1843; Murray, 1890). The Globigerina Limestone Formation is exposed over large areas of central and southern Malta and of Gozo and shows marked variations in thickness, ranging from about 20m to 210m. The formation consists of yellow to pale grey, fine-grained biomicritic limestones, composed almost wholly of the calcitic tests of globigerinid planktonic foraminiferans.

Lithologically and palaeontologically, the formation is divided into Lower, Middle and Upper Members, with a conspicuous phosphatic conglomerate (or "nodule") bed marking the base of each member (Rizzo, 1932; Pedley et al, 1978; Zammit Maempel, 1977). The Upper Member of the Globigerina Limestone displays three major layers: an upper and lower layer consisting of brown-weathering freestone, separated by a seam of blue-grey marls. The stone from the Upper Globigerina weathers very badly and is not considered suitable for masonry work. The Middle Member (Maltese name: *il-qarghija; il-bajjad)* consists mainly of white to pale grey marly limestones with numerous nodules. The lower section of this member contains local layers of chert. Generally, this stone is not useful for building purposes. The Lower Member (Maltese name: *franka*) is composed of massive bedded, pale yellow limestone which, generally, weathers well on exposure. Marine macrofossils may be locally abundant and well preserved, usually as brown-coloured internal moulds. This division of the Globigerina Limestone provides most of the stone employed in the building industry in Malta and represents an important and unique mineral resource. The size of this resource is practically unknown.

The building quality of stone from a given quarry is generally dependent on the stratigraphic level from which the stone is derived. Typically, going from top to bottom, a layer of fractured stone (Maltese: *qxur*) is encountered just beneath the topsoil. The first seam of good quality building stone, or *franka*, which may be several metres thick, generally underlies this fractured rock. Eventually, a layer of limestone, known in Maltese as *gebla tas-soll*, is found. This layer can vary in thickness from about 0.3m to 1.5m or more, depending on the locality. Other discrete *soll* seams may be encountered further down the quarry face. Eventually, the *franka* is permanently replaced by badly-weathering limestone. At this stage, the quarry is usually abandoned. *Soll* limestone is not appropriate for building purposes, since it weathers badly on exposure. A study of the mechanical and physical properties of Globigerina Limestone (Cachia, 1985) has shown that *soll* limestone is less porous and more dense than *franka*. Also, in the dry state, *soll* limestone is mechanically stronger although it becomes much weaker when wet. *Soll* limestone is considered suitable for use only in foundation work.

Soll outcrops exposed at old quarry faces are fairly easy to recognize by their cavitational weathering which produces conspicuous and characteristic honeycomb erosional features. These outcrops frequently occur as horizontal beds with fairly well-defined boundaries with the normal *franka*. A survey of the geological literature reveals that the *soll* seams of the Lower Globigerina have typically been recognized from their peculiar weathering style. Thus Pedley et al (1978), refer to the presence of characteristic honeycomb weathering in Lower Globigerina and they ascribe them to syndepositional trace fossils. It is notable that the descriptive term *soll*, unlike the term *franka*, has not been employed in the literature in order to characterize this limestone facies. "*Soll*" seems to be a term strictly used by masons and quarrymen, and presumably refers to any Malta limestone which weathers by cavitation and flaking. Thus, it probably would also be used by the trade to describe limestone derived from the Middle Globigerina which also weathers badly and which Rizzo (1932) described as being only useful for "foundations and inside thick masonry". In his work, Rizzo never uses the descriptor *soll* either for the facies as it occurs in the Lower Globigerina or for any other rock unit of similar physical properties belonging to the Globigerina Formation.

The inferior qualities of *soll* limestone as a construction material have been traditionally ascribed to a high clay content in this rock. However, no published data exists which supports this belief. Rather, the lithological similarity between *soll* and *franka* limestone, as perceived by visual examination, has probably served to prevent the recognition of the *soll* as a distinct facies in the Lower Globigerina.

The present study was aimed at determining whether *soll* limestone is significantly different from normal *franka* on the basis of its inorganic geochemistry. Apart from the obvious geological interest in establishing such a difference, there is another, possibly more practical, objective which the study addressed. As yet, there exists no conclusive test, either chemical or physical, which can be used to identify whether a sample of globigerina limestone is of the *soll* or normal *franka* type. Freshly-cut stone slabs, small hand specimens or drill cuttings of *soll* limestone are difficult to distinguish from *franka* by visual inspection, even though experienced, local quarrymen claim to be able to distinguish between stone slabs by drenching them with water and observing the sheen produced at the wet stone surface.

Being able to distinguish objectively between *soll* and *franka* is clearly important in technical and legal cases of litigation over the nature of a given construction material. It is also very important to be able to distinguish between these two types of stone when the samples are in the form of cuttings from exploratory drilling aimed at assessing the size of the mineral reserve of Globigerina limestone.

In the first phase of this preliminary study, samples of Lower Globigerina limestone representing both *soll* and *franka* were taken from a site in a quarry which possessed clearly visible *soll* horizons. The rocks were quantitatively analyzed for the six elements calcium, magnesium, carbonate carbon, chlorine, phosphorus and silicon. In the second phase of the study, another set of samples representing both limestone types were analyzed for aluminium and iron, in addition to silicon. A number of these samples were taken from the same quarry as before but other limestones were also analyzed which, although deriving from the Lower Globigerina, included a type of "*soll*" that was different in having a unique depositional style and a grey-green colour.

Materials and Methods

Sampling Sites

The state-owned Tar-Robba quarry at Mqabba was selected for sampling. Figure 1 shows the site plan of the quarry. The quarry is still active, rock cutting taking place in the north eastern sector. Samples were taken from the western and north eastern faces of the quarry. Rock from the western face was last quarried several decades ago and the rock face here is clearly indented with marks made by tools which were in use at the time. In this area of the quarry, two exposed *soll* seams are easily distinguished by their typical honeycomb weathering. The quarrying in the north eastern sector revealed that the lower *soll* seam, of which only about 50 cm were exposed at the western face of the quarry, had already reached a thickness of 30m and presumably continued further down to an unknown extent.

During the first phase of the study, ten samples were collected from a column of rock located in the western quarry face. The column was about 500cm high and included the two *soll* zones. These *soll* zones were separated by a vertical distance of about 260cm. Five samples were taken from the *soll* seams and another five were taken from the *franka*, as shown in Table 1. For the second phase of the study, seventeen limestone samples were analyzed (Table 2). Seven of these were obtained from the same site as employed in the first phase, three from the upper *soll* seam, and four from the contiguous *franka*. A further six samples were collected from the north eastern face of Tar-Robba quarry, three from the lower *soll* zone and three others from the *franka* above.

Sample Descriptor	Height above footpath (cm)	Rock Type
W1S	25	*soll*
W2S	50	*soll*
W3	100	*franka*
W4	150	*franka*
W5	200	*franka*
W6	250	*franka*
W7S	300	*soll*
W8S	350	*soll*
W9S	400	*soll*
W10	450	*franka*

Table 1. Samples taken during the first phase of the study.

The authors based the classification of these latter six samples on advice from quarry personnel because at this particular quarry face, the *soll* seams, being freshly cut, were not yet marked by weathering. The other four limestone samples were obtained from a road cut in Msida next to the Birkirkara Road bridge. The limestone exposed in this area is considered as completely unsuitable for building purposes. At this site, two sedimentary facies could be distinguished: massively

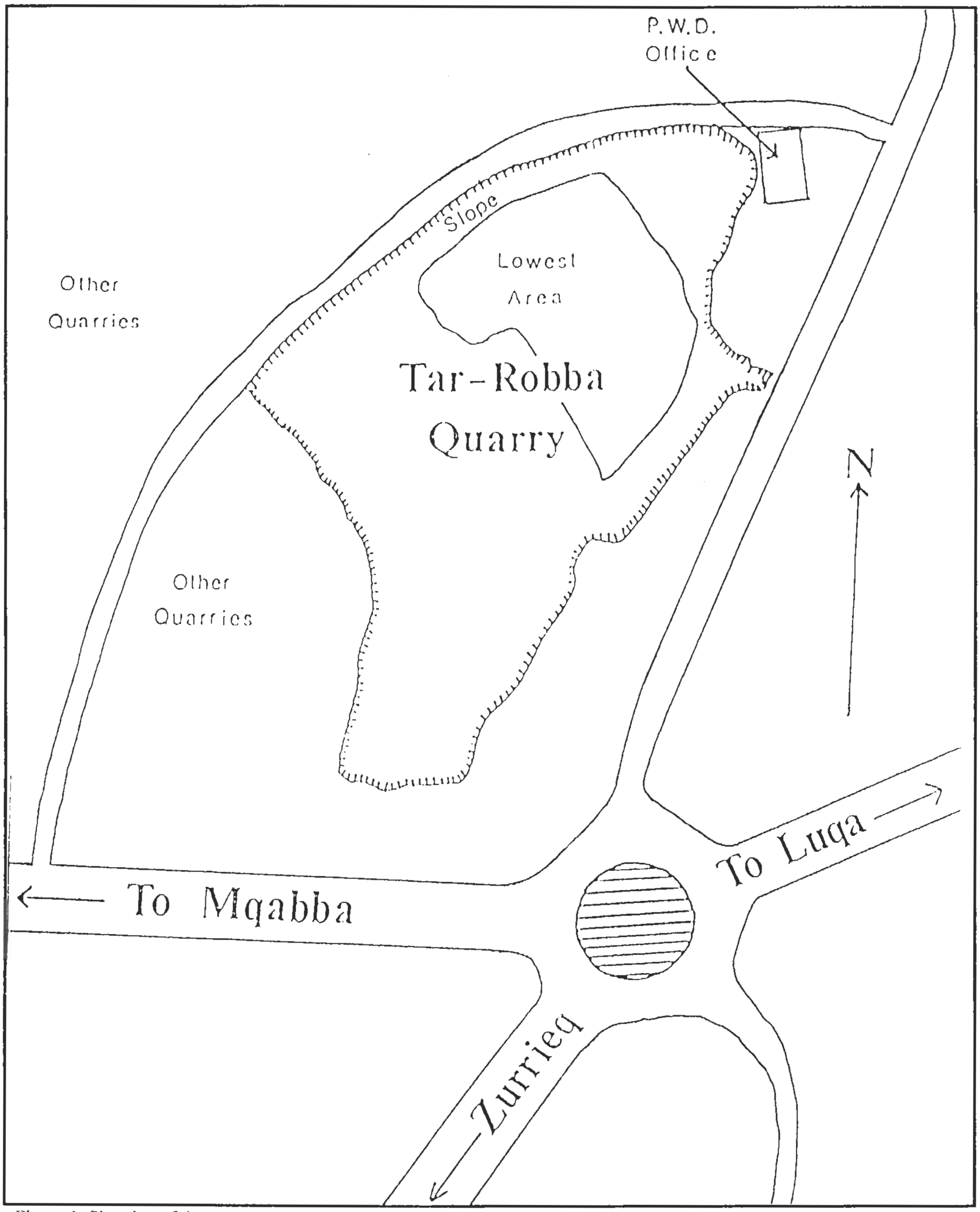


Figure 1. Site plan of the state owned Tar-Robba quarry at Mqabba.

bedded, yellow to white, limestone similar to the fresh *soll* exposed at Tar-Robba and a greyish-green facies occurring as discrete lenticular deposits, about 1m wide on their long axis by 0.5m. The dark coloured lenses were embedded in the yellow-white limestone as local occurrences. Two rock samples were analyzed from each of these two facies. Quarrymen do not probably regard this grey-green limestone as *soll* since it is so obviously different in colour from stone that has been traditionally called so. We propose to refer to this particular facies of the Lower Globigerina Limestone as *soll ahdar* (green *soll*) in view of its colour and its stratigraphic position within the *soll* zone.

Sampling Protocol

Sampling was performed by removing a layer of rock, about 2cm thick and about $40cm^2$ in area, from the surface of the outcrop. This material was discarded and about 100g of rock cuttings were collected from the exposed area. This procedure was adopted in order to avoid sampling rock surfaces which may have been affected by environmental factors. The rock cuttings were placed in labelled polythene bags, pending analysis.

Analytical Techniques

Deionized water was used as solvent and analytical grade reagents were employed without further purification. A Varian Model AA1275 atomic absorption spectrophotometer was employed for calcium and magnesium determination. Double beam spectrophotometry was performed with a Shimadzu/Bausch and Lomb Spectronic 210UV model.

Sample	Height above footpath	Provenance
		Mqabba
W11	100 cm	Western face
W12	200 cm	Western face
W13	250 cm	Western face
W14S	300 cm	Western face
W15S	350 cm	Western face
W16S	400 cm	Western face
W17	450 cm	Western face
	Relative height	
E1S	0 m	Eastern Face
E2S	1 m	Eastern Face
E3S	15 m	Eastern Face
E4	30 m	Eastern Face
E5	32 m	Eastern Face
E6S	35 m	Eastern Face
		Msida
M1SA	0 cm	grey green facies
M2SA	75 cm	grey green facies
M3S	125 cm	yellow facies, proximate to green facies
M4S	200 cm	yellow facies

Table 2. Samples taken during the second phase of the study.

Single beam spectrophotometry was performed using a Milton Roy Spectronic 20. Calcium and magnesium were determined by a method based on atomic absorption spectrophotometry. Phosphorus was determined by the molybdenum blue photometric method using ascorbic acid as reducing agent (Jeffery and Hutchinson, 1981). The carbon dioxide content was found by determining the loss in weight on treating the rock with perchloric acid (Cumming and Kay, 1956). Chlorine was determined gravimetrically.

Two methods were employed for the determination of silicon. In the first phase of the study, a technique based on the absorbance of the silicomolybdate chromophore was employed (Jeffery and Hutchinson, 1981). In the second phase, silicon was determined gravimetrically by volatilization as the tetrafluoride. Total iron and aluminium were determined spectrophotometrically after suitable oxidation and complexation with 8-hydroxy-7-iodo-5-quinolinesulphonic acid (ferron) (Cumming and Kay, 1956).

Results and Discussion

The results obtained in the first phase of this investigation are collected in Figure 2. The data is presented in terms of the mass percentage of the element in the oxide form, except for chlorine.

These results show that both *franka* and *soll* Lower Globigerina limestones consist primarily of calcium carbonate. Statistical correlation tests (*e.g.* the Spearman rho) performed on the carbonate and calcium values show that these values correlate well at the 95% confidence limit. This abundance of calcium carbonate in Lower Globigerina limestone is to be expected from a rock which is, petrologically, a foraminiferal biomicrite. Moreover, previous analyses of Lower Globigerina limestones for calcium carbonate concur with our results (e.g. Lehmann, 1980).

In order to assess whether the individual elemental contents obtained for the limestone in the *soll* horizons were significantly different from corresponding values for *franka*, the statistical, non-parametric, Mann Whitney U test was applied to the values obtained. The results of such an assessment show that at the 95% confidence limits, *soll* limestone has a statistically significant higher content of silicon (Figure 2). The calcium, magnesium, carbon, chlorine and phosphorus content of both types of limestone are not significantly different (Figures 2 and 4)

Furthermore, it can be shown that the mean mass ratio of magnesium to calcium for *soll* and *franka* are, respectively, 0.089 and 0.113 and that such ratios for the different limestone types are significantly different at the 95% confidence limit.

Silicon, in sedimentary rocks, may be present as the dioxide in one or more of its various geologic forms, *e.g.* silica, quartz, chert etc. The element may also occur in aluminosilicates, which in sedimentary materials, are frequently, although not uniquely, represented by the clay minerals. Both these two types of silicon-containing minerals have been reported in Maltese globigerina limestones (e.g. Murray, 1890; Formaggio, 1972). However, there are no reports on the relative abundance of such silicates in the *soll* and *franka* facies of the Lower Globigerina Formation.

The foregoing results suggested further investigations into the possibility that the silicon anomaly of the *soll* facies would correlate with other anomalies in the limestone. It was argued that if the higher silicon content in *soll* was primarily due to the presence of clay aluminosilicates, then the silicon anomaly would correlate with an aluminium anomaly, and possibly also with one in iron. This led to the second phase of the study. The results obtained are shown in Figure 3. From the silicon mass fractions, it is again obvious that higher silicon contents are associated with the *soll* limestones.

This conclusion is confirmed when the experimental results are statistically analysed. The mean percentage silica of *soll* found in Tar-Robba is 2.94 %. Comparision of this value with that obtained previously (4.38 %) suggests that the gravimetric technique tends to underrate the silica content. In fact, the individual *soll* and the *franka* values displayed in Figure 3 are consistently lower than the corresponding values shown in Figure 2. This is an important consideration to be borne in mind.

The limestone samples from the Msida site are even richer in silicon than those from Tar-Robba. The values

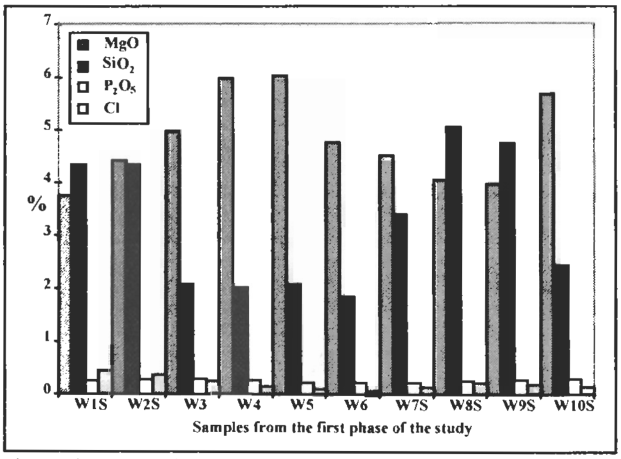


Figure 2. Magnesium, silicon, phosphorus and chloride level in samples from the first phase of the study.

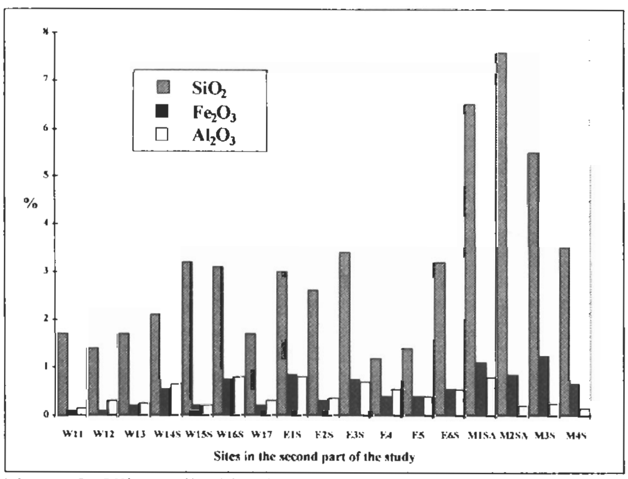


Figure 3 Silicon dioxide, iron(III) oxide and aluminium oxide content in samples from sites of the second phase of the study.

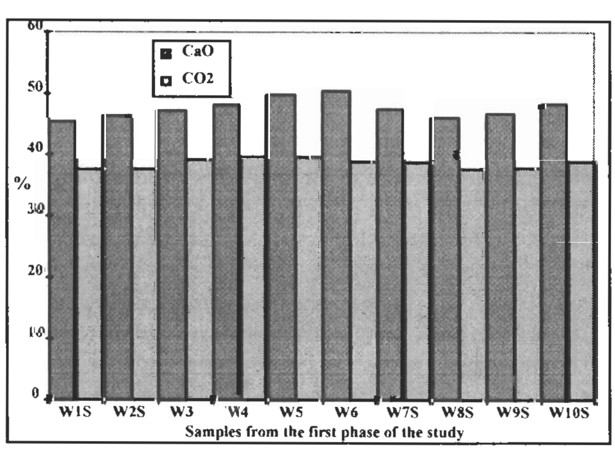


Figure 4. Calcium and carbonate content in samples from the first phase of the study.

show that the grey-green *soll* facies is richest in silica while the Msida yellow *soll* has a similar content to that of Tar-Robba. It is notable that sample M3S, which derives from a region which is stratigraphically intermediate between green *soll* and the usual yellow variety has an intermediate silica content.

Comparision of the aluminium content of the various types of limestones does not reveal any clear-cut anomaly associated with *soll* (Figure 3). Thus, for example, except for M1SA, all the other Msida *soll* samples, while exhibiting pronounced silicon levels, have aluminium contents typical of normal Tar-Robba *franka*. When the aluminium content of all samples are statistically analyzed by the Mann-Whitney U test, no anomaly associated with *soll* emerges, although if the analysis is performed on the Tar-Robba subset, the *soll* seems to have significantly more aluminium. However, even for these limestones, the aluminium oxide content is not statistically correlated to the silicon dioxide content on the basis of the Spearman rho and the Kendall tau tests.

These observations suggest that the main silicon minerals which are responsible for the higher content of the element in Tar-Robba and Msida *soll* facies are probably not aluminosilicates but silicon dioxide phases, possibly including amorphous silica and cryptocrystalline quartz.

The total iron content (Figure 3) of the global set of samples is statistically higher for the *soll* limestones according to the Mann Whitney test. The same conclusion holds true if the Tar-Robba samples are considered on their own. Also, the iron(III) oxide and the silicon dioxide anomalies are statistically correlated with 95% confidence when the samples are considered globally but with just under 90% confidence when the Tar-Robba limestones are considered on their own. Moreover, for the Tar-Robba limestones, the aluminium oxide and the iron(III) oxide contents are also correlated. In the Msida samples, there are no correlations between any pair of elements.

If the contents of silicon dioxide, aluminium oxide and iron(III) oxide are plotted on a three-dimensional scatter plot (Figure 5), we find that the *franka* samples define a compact group in a distinct region of the plot. The *soll ahdar* samples plot away from this *franka* pole while the yellow *soll* samples form a rather diffuse group in the intermediate region of the scattergram, closer to the *franka* than the *soll ahdar* region. From Figure 5, one concludes that sample M3S, stratigraphically proximate to but outside the green limestone lens in the Msida outcrop is closer in lithology to *soll ahdar* than to the yellow variety, in spite of its colour.

Conclusions

We conclude that the differentiation of the *soll* facies from the *franka* of the Lower Globigerina Limestone Formation, as represented at Tar-Robba outcrop, does have an inorganic geochemical basis. *Soll* limestone has a notably higher content of silicon and a less marked but significantly higher content of total iron and aluminium than *franka*.

The higher silicon content of *soll* is probably largely due to the presence of silica cement and cryptocrystalline quartz in these rocks although the correlated iron and silicon anomalies could suggest a more abundant presence of glauconite-derived limonite or other authigenic ferruginous minerals. Only a detailed petrographic analysis of this limestone facies could help decide this point.

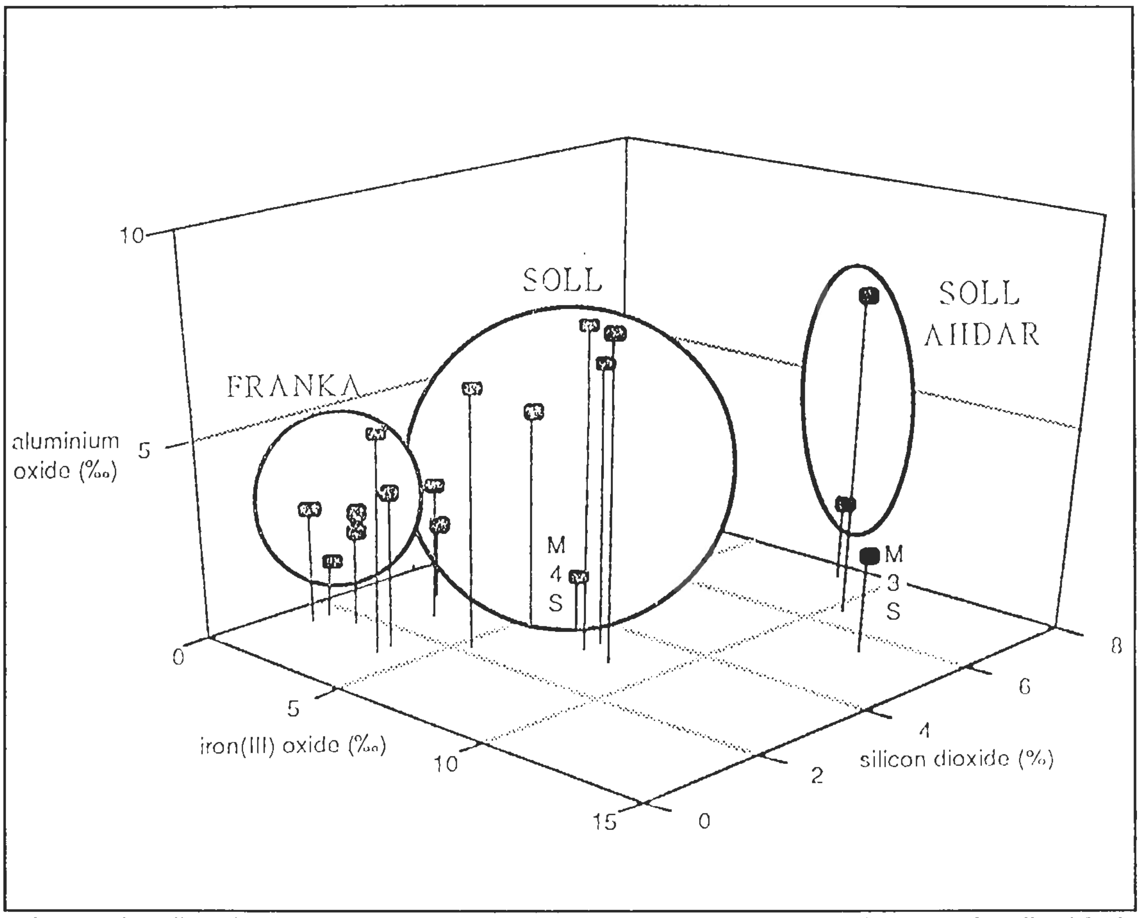


Figure 5. Three-dimensional scatter plot of silicon dioxide, aluminium oxide and iron(III) oxide content for soll and franka samples

To our knowledge this is the first published report on the silicon content of *soll* limestone. In spite of the total lack of experimental information about *soll*, the stone has always been regarded as one containing a high percentage of clay (e.g. Aquilina, 1987). Indeed, although this work does show that there is more silicon in *gebla tas-soll* than in *franka*, the description of the stone as one containing a high percentage of clay is clearly inappropriate in view of the fact that its silica content is less than 5-10%. Petrologically, *soll* is better described as a fairly clean biomicritic limestone and certainly not as a marl.

It does not seem likely that the difference in abundance of siliceous minerals between *soll* and *franka* is large enough to account for the exceptional manner in which *soll* limestone weathers when exposed to the atmosphere. The much reduced resistance to weathering of *soll* probably results from textural differences in the rock caused by a changed depositional environment of the Lower Globigerina sediments brought about by some alteration in the biological activity at the sediment-water interface. This could have been due to increased bioturbation resulting from, perhaps, a reduction in the height of the water column due to a minor regressive shift of the shoreline.

The discrete lenticular occurrences of grey-green limestone found embedded in the yellow coloured *soll* of the Msida outcrop have been shown to be richer in silicon and iron minerals than the surrounding bedrock of *soll*. Our proposal that this grey-green facies be considered as *soll ahdar* seems justified in that the term attempts to take into consideration both the similarities with the normal yellow variety of the rock but also emphasises the facies-difference. There is clearly no difficulty at all in distinguishing *soll ahdar* limestone from the *franka* of the Lower Globigerina.

Finally, although a silicon anomaly has been established for the *soll* at two of its outcrops, one cannot extrapolate confidently this conclusion to all *soll* occurrences of the Maltese Islands. Clearly, a much larger geochemical survey needs to be undertaken. In our view, such a survey would provide basic information which would be required for an eventual proper assessment of the resource potential of the Lower Globigerina.

Note

This paper is dedicated to the memory of Mr Christopher Zammit who has since lost his life in a traffic accident.

References

Aquilina J (1987) *Maltese-English Dictionary*, Vol 1. Midsea Books Ltd, Malta.

Cachia J (1985) *The mechanical and physical properties of the Globigerina Limestone as used in local masonry construction*. University of Malta A. & C.E. Dissertation (Unpublished).

Cumming AC and Kay SA (1956) *Quantitative chemical* *analysis*, 10th Ed. Oliver and Boyd, Edinburgh.

Formaggio G (1972) *Studio petrografico delle serie tipo di Malta.* Sottotesi Laurea Facolta della Scienza Materiale Fisica e Naturale, Universita di Firenze (Unpublished).

Jeffery P and Hutchison D (1981) *Chemical methods of rock analysis*. 3rd Ed, Pergamon Press, Oxford.

Lehmann J (1980) *Hal-Saflieni, Paola: Study of three historic temples with a view to establish a programme for its conservation. (Malta)* National Museum of Archaeology/UNESCO.

Murray J (1890) The Maltese Islands with special reference to their geological structure. *Scottish Geographical Magazine (Edinburgh)*, **6**, 325 - 341.

Pedley H, House M and Waugh B (1978) The Geology of the Pelagian Block: the Maltese Islands. In: *The Western Mediterranean* (The ocean basins and margins). (Eds Nairn A, Kanes W, and Stehli F) Vol 4B, pp 417-433, Plenum Press, New York.

Rizzo C (1932) *Report on the geology of the Maltese Islands, including chapters on possible ground-water tables and prospecting for mineral-oil and natural gas.* Government Printing Office, Malta.

Spratt T (1943) *On the geology of the Maltese Islands.* Proceedings of the Geological Society (London), **4**, 225 - 232.

Zammit Maempel G (1977) *An outline of Maltese Geology.* Progress Press, Malta, 44pp.

Malta Book Fair

The Malta Chamber of Scientists shall be taking part in the 13th Malta Book Fair by presenting its official publication, *Xjenza*. This fair is organised by the Libraries and Archives Division of the Ministry of Education and National Culture that will be held at the Naxxar Fair Grounds from Thursday 20th to Sunday 23 November 1997.

The Book Fair will be open to the public as follows:

Thursday 20 November
9.00a.m.-2.00p.m. / 4.00p.m.-8.00p.m.

Friday 21 November
9.00a.m.-2.00p.m. / 4.00p.m.-8.00p.m.

Saturday 22 November
10.00a.m.-2.00p.m. / 4.00p.m.-10.00p.m.

Sunday 23 November
10.00a.m.-1.00p.m. / 3.00p.m.-8.00p.m.

Activities that are going to be held during the book fair days include:

- Story telling
- Science workshops
- Reading areas
- Internet corner
- School exhibits
- Exhibit depicting 100 years of children's books
- Launching of the year 1998 "Year of Reading" by the Hon. Minister of Education and National Culture.

Research Article

Preliminary Investigation on Radon Levels in Local Dwellings

Ian Mifsud,[1] Andrew J Amato-Gauci,[1] Lucianne Licari,[1] Michael Sammut.[2]
1 ***Department of Public Health, 15 Merchants Str., Valletta, Malta.***
2 ***Department of Pathology, University of Malta Medical School, Guardamangia, Malta.***

Summary *Ionising radiation due to radon has been measured in local dwellings. The results indicate that radon levels are dependent on various factors including floor location, type of underlying geological formation and ventilation. Short term measurements were carried out in this survey. The measured values were within the safety limits recommended by WHO. The use of etched-track detectors has been recommended in order to assess the overall annual exposure.*

Keywords: natural radioactivity, radon, local dwellings

Natural radiation is the principal source of exposure to ionising radiation by the general public. The most important contributing factor to this form of radiation in European dwellings has been identified as radon and its radioactive decay products (NRPB, 1993).

Organisation	Action level - Existing Dwellings	Action level - Future Dwellings
US - EPA	150	150
WHO	200	200
EU	400	200
ICRP	200 - 600	---

Table 1. Recommended intervention levels for radon gas in dwellings (Bq m^{-3})(US - EPA: United States Environmental Protection Agency; WHO: World Health Organisation; EU: European Union; ICRP: International Commission on Radiation Protection).

Radon is a product of the radioactive decay process of uranium and thorium. There are three natural isotopes: radon-219, -220 and -222. Under normal circumstances radon-219 and radon-220 have a limited contribution to human exposure in indoor environments. This study restricts itself to radon-222 exposure.

Lung cancer cases have been attributed to radon's alpha emitting properties. However, there is still considerable scientific controversy over the relationship between radon levels and the risk of lung cancer (Bowie and Bowie, 1991; ICRP,1994; Pershagan et al, 1994). Much of the data gathered to assess the risk from indoor radon has been derived indirectly from studies of underground miners, experimental animal studies and cellular studies. Results of a meta-analysis of eight epidemiological surveys indicate that the risk from indoor radon can be predicted from miners (Lubin and Boice, 1997). Until extensive case-control studies are completed, data from miners remain the best source available.

Some health authorities have stated that the indirect evidence linking low levels of radon exposure to lung cancer is insufficient to warrant a remedial action level of 200 Bq m^{-3} (annual average) accepted by various governments (Bowie and Bowie, 1991).

Estimates given in Table 2 indicate the lifetime risk of lung cancer potentially induced by radon (Bowie and Bowie, 1991). Such estimates suggest that where people are exposed to radon, smokers are more likely to be at risk of lung cancer than non-smokers, with a synergic effect being observed. The numerical estimates of this synergism are still uncertain (IARC, 1988).

Radon level in Bq m^{-3}	Smokers	Non-smokers
20	10 in 1000	1 in 1000
100	50 in 1000	5 in 1000
200	100 in 1000	10 in 1000
400	200 in 1000	20 in 1000

Table 2. Estimated lifetime risk of lung cancer potentially induced by radon.

Materials and methods

A pilot survey to determine the magnitude of radon levels in confined air spaces was carried out between June 1994 and November 1995. Measurements were carried out in 68 localities throughout Malta and Gozo. Sites were chosen from a list of selected acquaintances through the Health Protection Branch (Department of Public Health). Other than this, no particular bias was used in the selection of sites.

Air sampling was carried out by continuous method using 'alpha guard' - a portable electronic radon monitor. The variable measuring cycle period was set at 10 minutes for the duration of a 24 hour measuring period. At this short cycle setting, diurnal variation in radon levels was logged.

During the survey, besides location, the following parameters were also noted (1) ventilation (good or poor -

arbitrary scale based on the number and size of windows, doors and ventilators); (2) site (basement, ground floor, first floor or higher); and (3) underlying bedrock (based on geological maps - Globigerina or Coralline limestone; no attempt was made to further subdivide bedrock into the various strata).

Results

Radon measurements were expressed as time weighted averages (over 24 hour periods) in Bequerels per cubic metre (Bq m^{-3}). The arithmetic mean value for all sites was 55 Bq m^{-3}. The corresponding median value was 37.5 Bq m^{-3}. The lowest mean value was 10 Bq m^{-3} and the highest value was 199 Bq m^{-3}. The computed geometric mean was 40 Bq m^{-3} with a corresponding geometric standard deviation of 2.3.

Comparison of mean levels are shown in Tables 3, 4, and 5 (all values expressed in Bq m^{-3}).

Underlying bedrock	Coral. (Malta)	Coral. (Gozo)	Glob. (Malta)	Glob. (Gozo)
Mean* ± SEM	2.97 ± 0.21	3.88 ± 0.29	3.75 ± 0.12	4.31 ± 0.21
Geomean	19.49	48.42	42.52	74.44
95% confidence interval	13 - 30	27 - 87	33 - 54	49 -113
Number of readings	13	6	41	8

Table 3. Variation in radon levels according to bedrock * values refer to logarithmic transformed data (Coral: Coralline limestone; Glob: Globigerina limestone).

Floor level	Basement	Ground	First/ higher floors
Mean ± SEM	4.64 ± 0.25	3.63 ± 0.12	3.20 ± 0.22
Geomean	103.54	37.71	24.53
95% confidence interval	63 - 171	30 - 48	16 - 38
Number of readings	4	42	6

Table 4. Variation in radon levels according to floor location.

Significant differences ($p < 0.05$) were observed between measurements carried out on Coralline formations in Malta and other types of bedrock in Malta and Gozo.

Significant differences ($p < 0.05$) were observed between measurements taken in basements compared to measurements taken on other floors. No significant difference was observed when comparing ground floor readings to first/higher floor readings.

No significant difference was observed in rooms with poor ventilation when compared to others with good ventilation.

Ventilation	Poor	Good
Mean ± SEM	3.87 ± 0.19	3.56 ± 0.11
Geomean	47.94	35.16
95% confidence interval	33 - 70	28 - 44
Number of readings	26	42

Table 5. Variation in radon levels according to degree of ventilation.

Discussion

Radon levels appear to depend on local geology as well as floor location. (The degree of ventilation was rated on an arbitrary scale. This may have led to discrepancies in the classification of rooms according to the degree of ventilation.) Measurements based on rate of air exchange would have been a better indicator than arbitrary assessments. However, ventilation does influence radon levels. Figure 1 shows the variation of radon in an office located on the third floor of the Medical School building in G'Mangia. Continuous measurements were taken over a seven day period. Lower radon levels were observed during office hours than after office hours when doors and windows were kept shut, resulting in lower rates of air-exchange. During weekends a further increase in radon levels was observed since windows and doors were kept closed for longer periods of time compared to working days, resulting in a further accumulation of radon.

Figure 2 shows readings carried out throughout the two islands (all measurements in Gozo were carried out on the ground floor). No specific factor was identified as responsible for the higher levels recorded in Gozo. Seasonal variations may be a contributing factor but other factors, such as the characteristics of local geology, may also be important.

During this survey, radon levels approximated a log-normal distribution. This is consistent with findings in surveys carried out in other European countries (EC, 1995). This characteristic can be used to estimate the percentage of housing stock above pre-determined threshold levels (NRPB, 1990).

Radon measurements showed diurnal variations. Although no data analysis was carried out on parameters related to diurnal changes (eg temperature, pressure), maximum radon levels were generally recorded during the early hours of the day. (Night time is normally associated with a decrease in human activity, thus lower rates of air exchange may occur during the night.) Other factors such as changes in atmospheric pressure may also have an effect on the diurnal variation of radon.

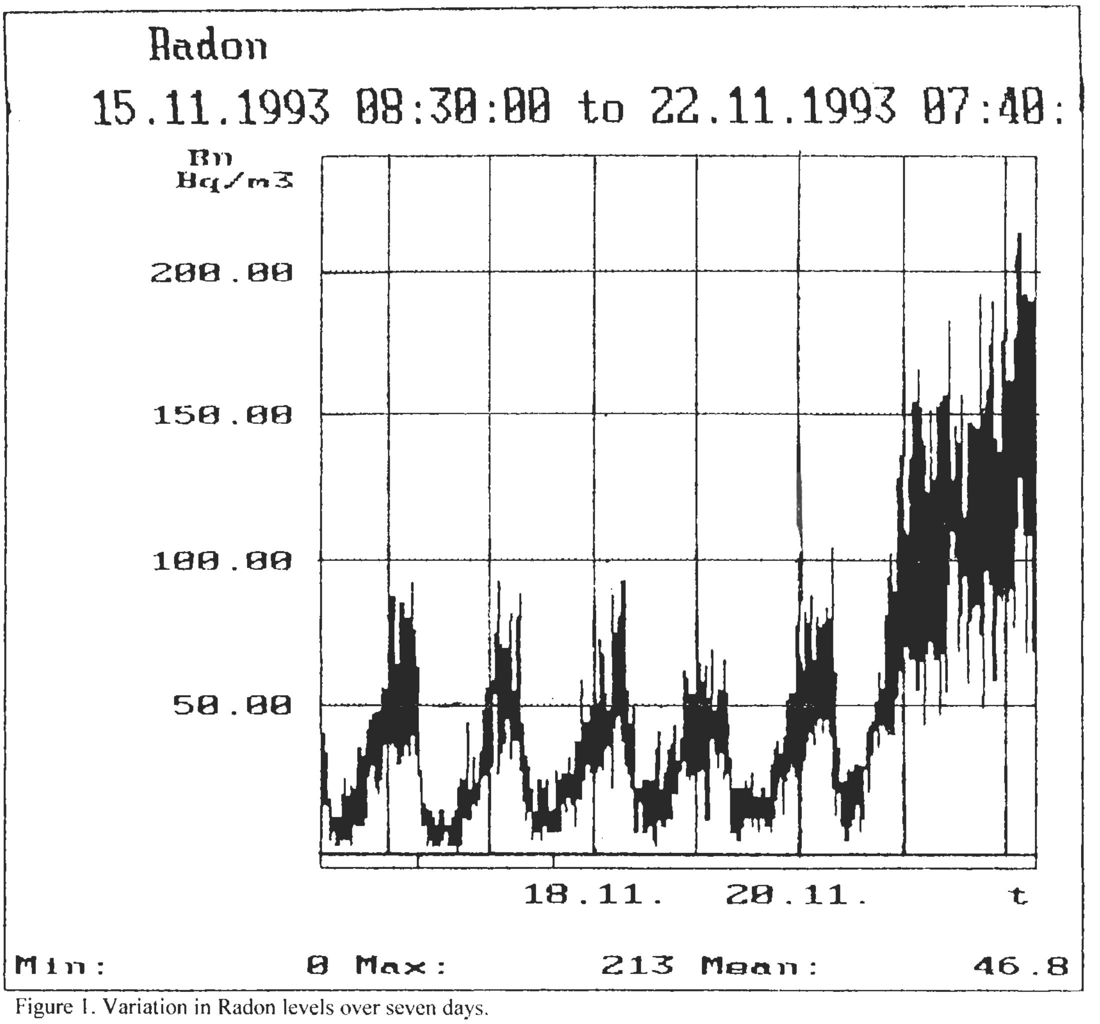


Figure 1. Variation in Radon levels over seven days.

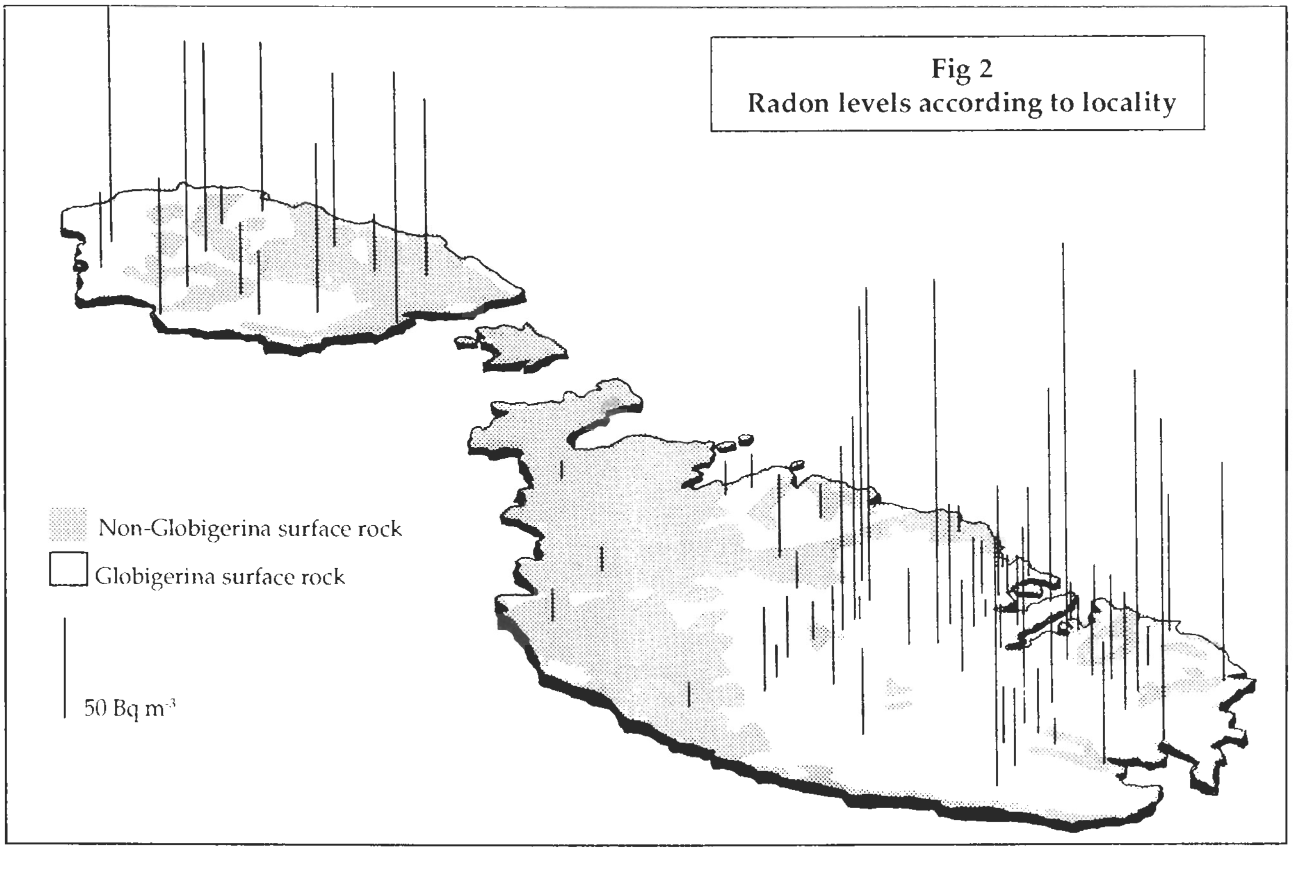


Fig 2
Radon levels according to locality

Country (population size in millions)	Number of houses sampled	Period and duration of exposure	Sample characteristics	Radon conc $[Bqm^{-3}]$ Geom. Aver.Mean		Geom Std. Dev.
Belgium (10.0)	300	1984-1990 3 months to 1 year	selected acquaintances	48	37	1.9
Czechoslovakia (15.6)	1200	1982 grab sampling	----	140	---	---
Denmark (5.2)	496	1985-1986 6 months	random	47	29	2.2
Finland (5.0)	3074	1990-1991 1 year	random	123	84	2.1
France (56.9)	1548	1982-1991 3 months	biased	85	52	2.3
Germany (77.4)	1500	1991-1993 1 year	random	50	40	---
Greece (10.2)	571	1987-1994 6 months	selected acquaintances	92	68	2.9
Hungary (10.6)	122	1985-1987 -2.5 years	---	56	---	---
Ireland (3.5)	1259	1985-1989 6 months	random	60	34	2.5
Italy (56.8)	4800	1989-1993 1 year	stratified random	77	---	---
Luxembourg (0.4)	2500	1991	---	---	65	---
Norway (4.2)	7525	1987-1989 6 months	random	60	32	---
Portugal (10.3)	4200	1989-1990 1-3 months	volunteers in a selected group	81	37	---
Spain (39.0)	2000	1988-1989 grab sampling	random	86	41-43	2.6 - 3.7
Sweden (8.4)	1360	1991-1992 3 months	random	108	56	---
Switzerland (6.6)	1540	1982-1990 3 months	biased (not stratified)	80	---	---
UK (57.0)	2093	1986-1987 1 year	random	20.5	15	2.2
Malta (0.4)	68	1994-1995 24 hour	selected acquaintances	55	40	2.3

Table 6. Summary of radon surveys in European dwellings.

The range of average radon levels measured in European dwellings varies greatly, from about 7 Bq m^{-3} to 140 Bq m^{-3} (Christodoulides and Christofides, 1994; EC, 1995). Table 6 gives values for indoor radon concentrations in various European countries (EC, 1995).

Conclusion

It is difficult to predict with certainty the concentration of radon inside dwellings. Local geological characteristics, housing design, construction material as well as the social behaviour of individuals living inside the dwelling influence radon concentrations. Seasonal changes have a profound affect on radon concentrations (NRPB, 1992). This aspect of seasonal variation could not be evaluated by short-term sampling techniques, as was undertaken in this study. Short term measurements are particularly useful for screening purposes and in assessing the diurnal variations in the concentration of radon. This study was carried out using a sample based on selected acquaintances. This may introduce a bias. Thus, further studies need to be carried out on a random sample representative of the housing stock. Furthermore, such studies need to be directed at taking extended measurements in rooms where people spend a considerable time. These measurements give better estimates than short-term radon measurements. In particular, one-year measurements are the most appropriate, except for cases in which dwellings are not inhabited for a long period of the year. Long term integrated measurements can be conveniently carried out using etched-track detectors. Such detectors are inexpensive, reliable and easy to use. The main disadvantage being that they do not give a measurement in the field and must be sent to a laboratory for processing.

Acknowledgments

The authors would like to acknowledge the assistance of Mr J Cilia, Manager Health Inspector, in providing listings of dwellings in which monitoring could be undertaken. The field work carried out by health inspectors - Mr M Vella Harber, Mr S Sammut, Mr S Farrugia and Mr J Borg is also acknowledged. The authors also wish to thank Prof. A Buhagiar for his advice on the statistical aspect of this work.

References

Bowie C and Bowie SH (1991) Radon and health - a review. *Lancet*, **337**, 409-13.

Christodoulides G and Christofides S (1994) Airborne radon 222 concentration in Cypriot houses. *Science of the Total Environment*, **144**, 255-260.

European Commission (1995) *European collaborative action 'Indoor air quality and its impact on man' - Radon in air*. Luxembourg, Office for Offical Publications of the European Communities.

International Agency for Research on Cancer (1988) IARC *Monographs on the evaluation of carcinogenic risks in humans - Man-made mineral fibres and radon*. Vol 43, Lyon, IARC.

International Commission on Radiation Protection (1994) *Protection against radon-222 at home and at work*. Oxford, Pergamon Press. Cited in World Health Organisation (1995) *Concern for Europe's Tomorrow - health and the environment in the WHO European Region*. Stuttgart, Wissenschaftliche Verlagsgesellschaft.

Lubin JH and Boice JD Jr (1997) Lung cancer risk from residential radon: meta-analysis of eight epidemiological studies. *Journal of the National Cancer Institute*, **89**, 49-57.

National Radiological Protection Board (1990). *Radon affected areas: Cornwall and Devon*. Doc. No. Vol 1. No.4.

National Radiological Protection Board (1992) *Radon affected areas: Derbyshire, Northamptonshire and Somerset*. Doc No. Vol 3. No.4.

National Radiological Protection Board (1993) *Radiation atlas. Natural sources of ionising radiation in Europe*. Luxembourg, Office for Official Publications of the European Communities. Cited in World Health Organisation (1995) *Concern for Europe's Tomorrow - health and the environment in the WHO European Region*. Stuttgart, Wissenschaftliche Verlagsgesellschaft.

Pershagen G, Akerblom G, Axelson O, Clavensjo B, Damber L, Desai G, Enflo A, Lagarde F, Mellander H, Svartengren M and Swedjemark GA (1994) Residential radon exposure and lung cancer in Sweden. *The New England Journal of Medicine*, **330**, 159-164.

Current Research Profile

Edward A. Mallia D.Phil.(Oxon)
Department of Physics, University of Malta, Msida, Malta.

In the late 1950's the University of Malta was still the preserve of "professional" degrees: Medicine, Law, Theology Architecture. Bachelor degrees were mere staging posts on the way to lofty heights. By expressing a preference for technical drawing over dissection of frogs, I had unwittingly joined the Architecture stream, even if my main interests were physics and mathematics.

So when the opportunity to study abroad arose through a Rhodes Scholarship, I had no regrets in ditching Architecture, in the teeth of the most strenuous opposition of the then-Dean.

At the time university physics - a subject in the arthritic grip of the medics - was of such a level as to rule out any chance of moving into postgraduate work after a first degree here. So, at Oxford I had to read physics at first degree (B.A.) level for two years before embarking on a third year designed to lead to a B.Sc. This latter was a post-graduate degree, in fact the Oxford "probationary" D.Phil at the time.

My doctoral work was in Astrophysics and specifically in solar astrophysics (Thesis title: Photoelectric Solar Spectroscopy). At the time Oxford astrophysics was engaged in producing a refined working model of the solar photosphere - the lowest lying visible layers of the solar atmosphere - in order to establish a standard set of element abundances in the sun. Such an abundance set was required as a template for studies of nucleogenesis in those generations of stars between Big Bang and the sun's birth. The nuclear physical processes of element creation from hydrogen and helium had been set out in the classic review article of Burbidge, Burbidge, Fowler and Hoyle in Rev. Mod. Phys. 29 547 (1957).

Part of my contribution to the Departmental programme consisted in the setting up of a large grating spectrometer designed to yield observations limited only by photon noise. Large, state-of-the-art replica gratings were tested on the Fizeau interferometer at the National Physical Laboratory at Teddington. Concurrently, I was writing a computer code for deriving element abundances from observations of absorption lines in the photospheric spectrum. Things came together in the third summer with a series of high quality observations of atomic and molecular absorption lines in the photospheric spectrum. Most of the thesis material was published in three papers, one of which was of joint authorship with my supervisor Professor D.E. Blackwell.

I spent the two years following the completion of my doctorate running a high altitude solar station Oxford had established in the Swiss Alps (Zermatt). The telescope and spectrometer were among the first examples of computer-controlled instruments, with automated data collection and reduction. A second version of the combined telescope -spectrometer was designed to take spectra from sunspots, with small contamination of light from the much brighter surrounding photosphere. In such a situation one needs to keep a sunspot image (some 4-5 mm across) steady on the spectrometer entrance aperture against movements caused by (terrestrial) atmospheric irregularities. This was achieved by projecting an image of the spot on to the tip of a pyramid and balancing the output from four photomultipliers looking at the faces. Error signals were sent to a secondary mirror in the vertical telescope. The mirror was magnetically floated and had significant response up to 100Hz - more than enough to cope with the atmospheric image oscillations which have a peak amplitude at around 10Hz. There was a final filter of unwanted photospheric light. The total intensity in the 1000 samples making up one spectrum scan was determined. If found higher than a pre-set value the sample was rejected. Under good conditions, integration times of a few minutes produced the best sun spot spectra available at the time (1970). The major weakness of the instrument was its inability to determine polarisation directions in sunspots, where magnetic fields of 0.3 - 0.4T are routinely present.

A long series of papers on photospheric and sunspot spectra resulted from this work. Molecular species identified in sunspots included hydrides like SiH, MgH and CaH, oxides like TiO and even a first detection of H_2O. Because of the C:O balance on the sun carbon species like CN, CH and C2 could be observed more easily in the photosphere despite the higher temperatures. Lower sunspot temperatures favour the formation of CO, the most stable carbon diatomic molecule.

By the time of my return to Oxford, both the Department and the U.K., astrophysics community had set in motion a significant investment in instrumentation /facilities for stellar astrophysics. As a result I gradually shifted over to stellar work, a tendency which was reinforced by my appointment as Radcliffe Travelling Fellow at Balliol College in 1974. The main thrust of investigations involved observation of spectra of the oldest existing stars in the Galaxy. Lone exemplars of such stars can be identified by, among other properties, orbits which carry them far outside the plane of the Galaxy. But the most obvious old star groups are the globular clusters: spherical agglomerations of stars with 10^6-10^7 members.

Although most old stars are well over a hundred times fainter than the faintest star visible (not from these islands!) to the naked eye, by the late 1970's telescopes and associated detectors (GaAs photomultipliers, image intensifiers, CCDs) had developed sufficiently to allow the collection of high quality spectra of faint sources. Of course, such observations could not be carried out from the U.K. So the planned programme involved travel to distant parts, starting with an obligatory sojourn at the Radcliffe Observatory in Pretoria, South Africa. There followed a series of visits to observatories in the US (Texas, California) and Chile, interspersed with excursions to Tenerife and Australia. The basis for these visits was an allocation of telescope time between fixed dates. There was no insurance against one's allocation being blotted out by bad weather: a rather nerve-wracking way of doing science, this.

The results from this work carried out in collaboration with Bernard Pagel of the Royal Greenwich Observatory were published in a number of papers in the U.K. Monthly Notices of the Royal Astronomical Society and the European Journal Astronomy and Astrophysics. Perhaps the most important result to emerge was the discovery that the brightest stars in globular clusters were suffering significant mass loss. This led to modifications in their computed evolutionary tracks and therefore in age estimates for globular clusters.

In 1983, I returned to Malta from the U.K., for the next seven years working as physics teacher, Deputy Headmaster and then Headmaster of the Sacred Heart Convent School. In July 1990, I joined the Physics Department of the University of Malta.

Aside from the normal teaching duties, my current 'research' interests centre on alternative energy devices, and specifically on electric and other non-polluting means of transport. Together with members of Engineering departments we are running an electric car in order to establish a baseline for local operation. At the same time we are looking into possibilities of using photovoltaics to supply energy for transport both directly by charging batteries and indirectly through electrolytic production of hydrogen. Some work on use of hydrogen in internal combustion engines has been done, but this application is intended to be a major field of action in the near future.

The Editorial Board would like to thank the Companies who have helped to make the publication of the journal possible:

Book Reviews

The Non-Marine Molluscs Of The Maltese Islands.

Monografie XV, Museo Regionale di Scienze Naturali - Torino. F. Giusti, G. Manganelli & P.J. Schembri. Torino, 1995, 607pp.

Land and freshwater snails, slugs and bivalves travel relatively short distances and remain in close association with their habitat throughout their lives. Those with shells leave them when they die as testimony of their having lived in that particular location. Survival of fossil shells provides clues to the nature of habitats extant at the time and how the changes occurred over the millennia. The biology of these relatively sedentary animals is, therefore, fascinating not only to biologists and malacologists but also to palaeobiologists.

The three authors of this book have strong interests in all these aspects. They have successfully accomplished the task of bringing together all the data relevant to the land mollusc fauna of Malta. It is the first time that an animal or plant group from our Islands has received such a thorough appraisal.

The book begins with an introduction to the physical geography of the Islands. This chapter is full of information applicable to biology beyond malacology. It is also well referenced. I found the section on vegetation all too brief and little more than a list of the dominant species in the various habitats and plant communities. No information (presumably because of lack of data) is given which may help to associate various plant communities with different snail populations and species composition.

The third chapter is an overview of the work done on the non-marine (non-molluscan) fauna of Malta. I am not sure what relevance this topic has to molluscs but the chapter is full of interest and well written. It highlights the deficiencies and therefore the urgency for more studies before the relentless destruction of natural habitats continues.

Palaeogeography dominates the section on biogeography with little data on the present day situation again presumably for lack of studies.

The section on general organisation and morphology is not easy. It is written for the specialist already familiar with the terminology. Students in the early years at university should cope. Although the style is simple and lucid, a non-expert needs to refer to other texts. This problem would have been avoided had there been more diagrams and a glossary. However, structures important for the identification of the species, for example, the radula and the genitalia, are well illustrated. I found the key for the identification of species relatively easy to follow although some characters require experience for correct interpretation. Some words are unexplained, for example, "trochiform" and "pilaster". This may be a stumbling block for amateurs. The authors have not written this book for amateurs but they express the wish in the forward that the book be useful to this (larger) group of individuals.

In my opinion, the main body of the book, which deals with the catalogue of species, is a real gem. It is comprehensive. All acronyms are explained. Excellent black and white photographs illustrate all the species and in many cases these are supplemented with high quality diagrams of dissections of the reproductive system. Also, for each species, the authors deal with palaeontology, distribution, status and conservation.

This is a superb book of high scientific and publishing quality. It will not be superseded for many years to come. It is a must for the professional malacologist as well as the amateur but should a mere enthusiast look through it I doubt whether he or she would fail to find much of interest and of use. The wealth of information contained in the introductory chapters will be useful to biologists working in other disciplines of Maltese terrestrial fauna. At almost LM30, this book is not cheap but it is worth every cent.

Martin J Ebejer
Associate Editor
Xjenza

Introduction of Alien Species of Flora & Fauna Proceedings of Seminar held at Qawra, Malta

A.E. Baldacchino and A. Pizzuto, (Eds.) Environment Protection Department, Malta. 1996, 77pp.

This booklet gives an accurate and complete summary of the proceedings of the seminar. There are seven chapters corresponding to each of the lectures which were delivered by specialists in their respective field. The scope was wide and the speakers, likewise, had very varied backgrounds. They included botanists, biologists, a legal expert, a veterinary surgeon, a horticulturist and a representative of the authorities whose unenviable task and responsibility it is to formulate policies. However, the main purpose of this seminar was to air the major issues and problems, which can be caused by the introduction into Malta of a non-native type of plant or animal.

Many who attended had a vested interest in the proceedings. Consequently, at times, objectivity was lost during the lively discussions, which were recorded and are reproduced, without modification, at the end of the booklet.

The contributions from the speakers were of a high standard but, in my opinion, two stood out as being the most informative, illuminating and pertinent. Philip Tortell defined his terminology and the concepts before giving an excellent review of New Zealand's approach to the problem of importation (accidental or intentional) of alien species. He discussed in detail the enormous economic, ecological and administrative implications. Patrick Schembri and Edwin Lanfranco, in turn, gave a most informative and objective assessment of the imported species in Malta, interspersed with occasional snippets of historical interest.

The booklet needs to be read carefully and comprehensively rather than "dipped into from time to time". This is because of the complex economic, biological and administrative problems created by alien species. The booklet provides food for thought and, perhaps, even some guidance to persons involved locally in biology, ecology, natural history, teaching of life sciences, agriculture, horticulture and the pet trade.

The Editors deserve to be congratulated for an excellent technical production of this booklet and for their comprehensive and faithful recording of the proceedings. Copies are available for the price of LM1.50 from the Environment Protection Department, Floriana.

Martin J Ebejer
Associate Editor
Xjenza

The Faber Book of Science

edited by John Carey.
ISBN: 0-571-17901-0.
Paperback edition first published 1996, 528pp.

If you wish to re-kindle your jaded spirit during the long hot summer months this book is for you. Professor John Carey's anthology is second to none and what is more by one whose first love is English. Carey is the current Merton Professor of English at Oxford University whilst also being a distinguished critic, reviewer and broadcaster, and the author of several books. At first glance, however, it would appear that someone with this sort of background would be inappropriate to relate the excitement of, for example, those hectic months in Edison's laboratory that culminate in the invention of electric light. Do not be fooled by first impressions as Carey's anthology has been carefully researched, in that each piece has been painstakingly selected to engender a feeling of the development of what we know as modern science today. In addition, his preparatory notes at the beginning and sometimes in the middle of a number of pieces provide a clear insight into the period of writing.

The book is arranged in chronological order from da Vinci to the Language of Genes. You will have gathered that Carey has clearly decided to include works from da Vinci onwards and not those of Aristotle (Eureka!), alchemy and astrology, considered to be history and science fiction that would require a book of their own. Consequently, good science writing from da Vinci onwards was the first requirement and secondly, and more importantly, the writing must be of the "mind-stretching" and "explanatory" type with the best usually having a mixture of both.

Carey, however, has a bias for the explanatory and argues that they best provide a "feeling of enlightenment" and divides them into three genres, namely, those that correctly interpret a piece of evidence, problem solving and clarification of a scientific concept. His three favourites to exemplify these are by Galileo, who correctly deduced that the moon's surface was rough not smooth, Darwin's solution to the problem of how a species of plant spread to barren islands in the open ocean and finally, Haldane's exposition "On Being the Right Size" demonstrating the use of simple arithmetic to dispel the idea that the 60-foot-high Giants Pope in Pilgrim's Progress could not have existed as they would have broken their thighs every time they put a foot forward.

I certainly do not live up to Carey's excellent writing style in trying to transmit to you the excitement and fun that I had when I read and re-read a number of passages from this anthology. My favourites however, just might give some inkling into the various scientists and their craft that are covered by this collection. The following titles to the passages contained therein should make some amends: Chains and Rings: Kekule's Dream, The Devil's Chaplain, Socialism and Bacteria, God and Molecules, Inventing Electric Light, The Secret of the Mosquito's Stomach, Drawing the Nerves, Black Holes, Fractals Chaos and Strange Attractors, The Plan of Living Things.

This short list is taken from a hundred or so insertions that make up this anthology, which to my mind is 500 pages to the good. It importantly includes where the original articles first appeared. This anthology should provide, for anyone with an interest in science, the chance to understand and enjoy what science is really all about.

Richard Muscat
Associate Editor
Xjenza

Xjenza
Instructions for Authors

Xjenza will consider for publication papers in the following categories:

- Original research reports
- Short reports
- Reviews
- Commentaries

SHORT REPORTS should be of no more than 1,500 words and 2 tables or figures. Please contact one of the editors to discuss the suitability of topics for REVIEW up to 7,500 words, COMMENTARY - up to 2,500 words, or other material falling outside the usual categories.

Submission of Manuscripts
Manuscripts should be sent to the Editor.

Prof. Angela Xuereb,
Department of Pathology,
University of Malta Medical School,
G'Mangia..

Tel: (+356) 2595 1882
Fax:(+356) 235638

Please submit 4 copies, typewritten, double spaced with wide margins, keep a copy yourself. After an article has been accepted for publication, the final version should be provided in machine readable form with hard copy exactly the same as the data on disk. Please use IBM compatible disks preferably Word (ver. 2.0 or higher) format or Rich Text Format (RTF). Authors are requested to submit together with the manuscript, the names and addresses of two referees, preferably from overseas.

Conflict of Interest
Authors are expected to disclose any commercial or other associations that might pose a conflict of interest in connection with the submitted article. All funding sources supporting the work, and institutional or corporate affiliations of the authors, should be acknowledged on the title page.

Articles are considered for publication on the understanding that neither the article nor its essential substance has been or will be published elsewhere before appearing *in Xjenza.*

Permissions
Materials copied from other sources must be accompanied by a written statement from both author and publisher giving permission to *Xjenza* for reproduction. Obtain permission in writing from at least one author of papers still in press, of unpublished data, and of personal communications. It is the author's responsibility to ensure that permissions are obtained.

Arrangement of Manuscripts
Preface each paper with a suitable **title,** the author(s) name(s), and the full address of the institution in which the work was carried out (please identify the author for proofs - giving telephone and fax numbers - for correspondence and reprint requests), an **abstract** of no more than 200 words, and up to 8 **keywords.** Research reports should give an appropriate **introduction,** a single **methods** section (with the methodology of all experiments reports), **results,** and **discussion.** Either British or American spellings are acceptable, but please be consistent. Authors should express **measurements** in SI units, although they may include older conventional units in parentheses if they wish. Except for units of measurement, **abbreviations** should be spelled out on first use, and should be standard. **Drug names** should be generic, although authors may add brand names in parentheses if they wish.

Illustrations should be lightly numbered on the back in pencil, with orientation and your name. **We** prefer glossy photographs or professionally prepared line drawings; any lettering and symbols *must* be large enough to stand reduction in size - publication could be delayed if lettering or symbols are too small. For halftones send unmounted glossy photographs with explanatory legends on a separate sheet of paper. Please send one set of photographs and attach a set of photocopies to each copy of the manuscript. One colour illustration can be included free of charge. Please contact the publishers for an estimate of the cost for extra colour illustrations

Tables should bear Roman numerals and be typed on separate sheets of paper. Each table requires a title, but no legend; identify footnotes by superscripts [1],[2],[3], etc.

References follow the Harvard system. In the text give the author(s) name and, in parentheses, the date of the paper/book being cited. Differentiate between papers by the same author in the same year by a, b, c etc., immediately after the date. Where there are three or more authors use et al. in the text and a, b, c to resolve ambiguities. All works cited must be listed at the end of the paper, ordered alphabetically by first author's name. For each first author, list single author works, next joint authored works in **alphabetical** order, last multi-authored works in **chronological** order. Each reference should give the names and initials of each author, the year of publication, the title of the paper, the name of the journal or book in full, the volume or edition, the first and last page, and, for books, the publisher and town of publication. For example:

Scerri CA, Abela W, Galdies R, Pizzuto M, Grech JL and Felice AE (1993) The β^+ IVS, I-nt No. 6(T->C) Thalassaemia in heterozygotes with an associated Hb Valletta or Hb S Heterozygosity and homozygotes from Malta. *British Journal of Haematology,* **83,** 669-671.

Felice AE (1992) Molecular Epidemiolgy of Haemoglobin, and the Molecular biology of Normal and Abnormal Globin gene expression. In: *Collected Papers* (Eds R Ellul-Micallef and S Fiorini), pp. 357-391. University Press, Malta.

David Rawn J (1989) *Biochemistry.* Neil Patterson Publishers, North Carolina

Muscat R, Papp M and Willner P (1992a) Antidepressant-like effects of dopamine agonists in an animal model of depression. *Biological Psychiatry,* **31,** 937-946.

Proofs, Reprints and Copyright
Authors will normally be sent page proofs by fax where available. Such corrections as are necessary should be listed in the form of a table, with the location of the correction in the left hand column and the correction required in the right hand column. This table should be faxed to the editors within three days of proof receipt. Alterations, other than essential corrections to the text of the paper, should not be made at this stage; the cost of such alterations may be passed on to the author.

A form for ordering reprints will be supplied with the proofs and should be returned direct to the Publisher. Manuscripts are accepted for publication on the understanding that exclusive copyright is assigned to the Publishers. However, this does not limit the freedom of the author(s) to use material in the papers in any other published works.

ETHICAL POLICY

Studies using human subjects should include a statement within the manuscript that subjects provided informed consent for their participation and that the study was approved by a local ethics committee.

Studies using animal subjects must conform to internationally accepted standards of animal welfare, and authors should include an appropriate statement to that effect, either within the manuscript or in their covering letter. Every effort should be made to minimize the number of animals used.

The editors will welcome the submission of work in any area of science. However, studies that subject animals to pain or stress require special consideration and three principles will be used to judge the ethics of such work. First, experiments of this kind will be required to reach a higher threshold of scientific quality in order to be publishable. Second, the utility of the study will be assessed, in terms of the balance between the distress inflicted and the likelihood of benefit. Third, it must be demonstrated that the objectives of the experiment could not have been achieved by the use of less stressful procedures; the fact that a particular procedure has been used in previously published work will not in itself suffice. The editors believe that scientists apply strict ethical criteria to their work, and will have no difficulty in meeting these requirements.

Published by
Malta Chamber of Scientists
P.O. Box 45,
Valetta B.P.O.,
Valletta, Malta
Tel: (+356) 3290 2774
Fax:(+356) 343535

Ice-cold pleasure
for warm nights
ICE
BEER
LÖWENBRÄU

Caution!

Fasten your seatbelt before takeoff

Test drive a Laser Computer today and feel the difference. We have harnessed the power of Intel's newest Pentium MMX processors to deliver awesome performance at an incredible price. Whether you are surfing the Internet, researching your latest project or playing the latest game, your Laser Computer will fly through the task.

Laser's manufacturing facility carries full ISO 9002 Certification and all our computers are bristling with the latest technology. Standard features like SDRAM, high capacity Fast ATA-3 hard disk, and a high performance graphics accelerator ensure top performance. To deliver the ultimate multimedia experience, we only use the World's renowned Creative Labs CDROM's and Sound Blaster wavetable sound cards.

Quick delivery and our prompt efficient service are our hallmarks. Visit our showroom today and test drive a Laser Computer. You will be pleasantly surprised!

LASER
computer

OFFICE: First International Ltd., Multi-Tech Centre, Regional Road (off Valley Road), Msida Telephone: 483819
SHOWROOM: 880 St. Joseph High Road, Hamrun Telephone: 235606