Global effects of moon phase on nocturnal acoustic scattering layers

Perdana K. Prihartato¹, Xabier Irigoien¹, Marc G. Genton¹, Stein Kaartvedt¹,²,*

¹King Abdullah University of Science and Technology, Red Sea Research Center, Thuwal 23955-6900, Saudi Arabia
²Present address: Department of Biosciences, University of Oslo, PO Box 1066, 0316 Blindern, Oslo, Norway

ABSTRACT: The impact of moon phase on the global nocturnal vertical distribution of acoustic scattering layers (SLs) in the upper 200 m was studied during the Malaspina expedition that circumnavigated the world. We assessed the nocturnal weighted mean depths and the vertical extension of the SL (the range between the upper 25th percentile and lower 75th percentile of the backscatter) and used a generalized additive model to reveal the relationship between the nocturnal vertical distribution of the SL and moon phase, as well as other environmental factors. Moon phase significantly affected the SL distribution on a global scale, in contrast to other factors such as dissolved oxygen, temperature and fluorescence, which each correlated with nocturnal SL distribution during the large geographic coverage. Full moon caused a deepening effect on the nocturnal SL. Contrary to expectations, the shallowest distribution was not observed during the darkest nights (new moon) and there was no difference in vertical distribution between new moon and intermediate moon phases. We conclude that the trend of deepening SL during approximately full moon (bright nights) is a global phenomenon related to anti-predator behavior.

KEY WORDS: Moon phase · Diel vertical migration · Acoustics · Predator avoidance

INTRODUCTION


The anti-predation window theory suggests that planktivorous fish exploit periods with limited light intensities to forage on food-enriched surface layers, while avoiding visually searching piscivorous fish (Clark & Levy 1988, Rosland & Giske 1994, Scheuerell & Schindler 2003). As the light intensity decreases at night, foraging ability of piscivorous fish is hampered by reduced reaction distance and extended searching time (Aksnes & Utne 1997, Staby et al. 2013). Other organisms may forage in the upper water column while the predation risks are reduced (Iwasa 1982, Clark & Levy 1988, Dypvik & Kaartvedt 2013, Staby et al. 2013), although nights may also become too dark for foraging for planktivores detecting their prey by sight (Giske & Aksnes 1992).

Mesopelagic acoustic scattering layers (SLs) comprising organisms carrying out diel vertical migration (DVM) are ubiquitous in the oceans (Marshall 1951, Barham 1966, Gjøsaeter & Kawaguchi 1980, Irigoien et al. 2014). Light intensity has been established as a cue for mesopelagic animals to perform DVM (Kampa & Boden 1954, Roe 1984, Frank & Widder 1997). Mesopelagic fish may follow fixed thresholds of light intensity called isolumes (Baliño & Aksnes...
creases in zooplankton standing stock were ex-
be initiated by the rate of change in the light in-
Staby & Aksnes 2011). Migrations may also possibly 
1993), or be associated with ranges of light intensities 
Childress & Seibel 1998). 

In such cases, recurrent monthly declines and in-
slightly migrating mesopelagic fish migrated all the way to the surface, and low mortality of zooplankton on moonlit nights, when mesopelagic fish were assumed to avoid the 
環境 

and population struc-
ture among zooplankton have been related to the 
state of the moon (Hernández-León et al. 2001, 2010). 
ring taxonomic and ontogenetic composition of the 
mesopelagic krill (Ringelberg 1995).

Monthly patterns in mortality and population struc-
ture among zooplankton have been related to the 
state of the moon (Hernández-León et al. 2001, 2010). 

When mesopelagic fish were assumed to avoid the 
upper layers where zooplankton reside, minimizing 
their own predation risk (Hernández-León et al. 
2001, 2010). Moonlight is hypothesized to have 
global effects on dielily migrating mesopelagic fish 
(Hernández-León 2008), yet no large-scale, global 
study has been carried out to date.

During the Malaspina expedition analyses were 
made of how nocturnal SLs in different environmental 
settings behave in the different light regimes fol-
lowing varying lunar cycles. Klevjer et al. (2016) 
analyzed the DVM patterns along the cruise track and 
showed that dielily migrating mesopelagic organisms 
contribute considerably to the nocturnal backscatter 
in upper waters. This concurs with other studies (e.g. 
Escobar-Flores et al. 2013). Irigoien et al. (2014) con-
cluded that the majority of the mesopelagic backscat-
ter recorded during the Malaspina expedition origi-
nated from fish. This assumption is in accordance 
with many other studies of mesopelagic SLs (e.g. 
Kloser et al. 2009, Olivar et al. 2012), although other 
taxa will also contribute to the backscatter (e.g. 
Barham 1966). Here we use the acoustic data from 
the Malaspina expedition to analyze whether the 
moon phase has a global effect on nocturnal vertical 
distributions and thereby DVM. We hypothesize that 
in this large-scale exercise, global effects of moon 
phase (interpreted in terms of moonlight) will over-
ride other potential significant factors known to be 
important for the vertical distribution and DVM of 
mesopelagic fish (and other taxa). This includes vary-
taxonomic and ontogenetic composition of the 
SLs (Linkowski 1996), cloud cover (Boden & Kampa 
1967, Balian & Aksnes 1993), distribution of food 
(Shreeve et al. 2009, Dypvik et al. 2012), presence of 
predators (Kaartvedt et al. 2012), water clarity 
(Kaartvedt et al. 1996, Widder & Frank 2001, Franke & 
Widder 2002), temperature (Wurtsbaugh & Never-
man 1988, Giske & Aksnes 1992) and oxygen level 
(Torres et al. 1979, Childress & Seibel 1998).

We aimed to address 3 hypotheses: (1) moonlight 
effect on the distribution of nocturnal SLs in upper 
waters is a worldwide phenomenon; (2) moonlight 
during the brightest phase (full moon) hampers 
migrations to upper layers due to increased danger of 
predation, so that dielily migrating organisms deepen 
their nocturnal distribution; and (3) the shallowest 
distribution occurs during the darkest nights (new 
moon).

MATERIALS AND METHODS

Data were collected during the Malaspina expedi-
ton on board R/V ‘Hespérides’ (www.expedicion 
malaspina.es) that circumnavigated the world in 
tropical and subtropical waters from 14 December 
2010 to 15 July 2011. Acoustic records that encom-
passed nearly 8 lunar cycles and covered more than 
32000 miles of ship track were recorded (Fig. 1). A 
Simrad EK60 echo sounder operating at 38 kHz was 
used to collect the data. The taxonomic composition 
of the organisms responsible for the backscatter 
along the path of this circumnavigation voyage is not 
known. However, organisms with air inclusions 
make stronger echoes, and organisms smaller than 
the acoustic wavelength of ~3.9 cm at 38 kHz will 
normally be relatively weak acoustic  targets at this 
frequency (MacLennan & Simmonds 1992), so 
Irigoien et al. (2014) concluded that most of the 
backscatter was made up of fish. Swimbladder reso-
nance may increase acoustic backscatter from small 
mesopelagic fish and other organisms with air bub-
bles, yet resonance effects at 38 kHz seem to be most 
prevalent at day depth (Kloser et al. 2009). Regard-
less, we do not believe this is an important factor in 
the comparison on vertical distributions relative to 
moon phase in the upper 200 m at night.

The acoustic data were cleaned of noise in several 
steps. Prior to import into the large scale surveying 
system (LSSS) software (Korneliussen et al. 2009) for 
post-processing, the data were subjected to a series 
of filters to remove bad data, as outlined in Irigoien 
et al. (2014). Thereafter, a moving average sliding 
window was applied to smooth the data. Finally, 
additional visual examination of echograms was per-
fomed to ensure that bubbles and bottom effects did 
not affect the echoes. This procedure was performed 
using the LSSS software. Noise was particularly 
prominent in the nocturnal data due to periodic inter-
ference from the ship’s navigation system at night 
and such obviously corrupted data were deleted from 
the analyses. The procedures outlined above left 106
nights of cleaned data usable for the acoustic analyses out of a total of 206 d sailing time. For exporting purposes, data were integrated at 2 min per 2 m depth for the upper 200 m water column, apart from the upper 15 m (the acoustic dead zone and near field). This depth range was selected as it basically encompasses the nocturnal distribution of the dielly migrating mesopelagic organisms (Klevjer et al. 2016). The extracted nautical area scattering coefficient $S_A$ (m$^2$ nmi$^{-2}$) was used as an estimate of acoustic biomass (Knudsen 1990).

In this study, only nocturnal acoustic data were used, here defined as data from 2 h after sunset until 2 h before sunrise at local time. Information on the sunrise and sunset along with the moon phase (percentage illuminated phase of the moon) was obtained from http://aa.usno.navy.mil/data/. Night length according to these criteria roughly varied between 6 and 8 h throughout the cruise.

SL density center estimated as weighted mean depth (WMD) was calculated for each night, $t$, hence WMD($t$) is a value of $S_A$ at each integrated depth multiplied by depth index, $d_i$, and divided by the total $S_A$ for the respective date, where $i$ refers to the depth layer corresponding to the $d_i$:

$$WMD(t) = \frac{\sum_i S_A(t, i) d_i}{\sum_i S_A(t, i)}$$  \hspace{1cm} (1)

We categorized moon phase into 4 different groups: C1 (moon phase 0–25%; 47 d), C2 (moon phase 25.1–50%; 21 d), C3 (moon phase 50.1–75%; 13 d) and C4 (moon phase 75.1–100%; 27 d). Analysis of variance (ANOVA) with Tukey’s post hoc test was applied to WMD averaged across each moon phase in order to reveal which of the categories distributed more deeply or shallowly.

Moon phase was also analyzed as a variable per night, assessing the WMD and the vertical extension of the SL. The daily vertical extension of the SL was calculated by estimating the daily upper limit at the 25th percentile (P25) and the lower limit at the 75th percentile (P75) of $S_A$. Each of these characteristics of SL depth (P25, WMD and P75) were tested against daily means of environmental parameters for the upper 200 m using generalized additive model (GAM) regressions (Hastie & Tibshirani 1990, Swartzman 1997). GAM is a non-parametric method with the ability to analyze the relationship between response and predictor variables without limiting the form of the relationships. Specifically, we fit a GAM model as follows:

$$WMD(t) = f_1[WMD(t−1)] + f_2[temperature(t)] + f_3[dissolved oxygen(t)] + f_4[fluorescence(t)] + f_5[turbidity(t)] + f_6[salinity(t)] + f_7[moon phase(t)] + e(t)$$

where $f_1, ..., f_7$ are nonparametric functions, WMD ($t−1$) is used to account for temporal autocorrelation
and \( e(t) \) is an independent and identically distributed normal error term with mean zero and constant variance. We fitted the same GAM model to P25 and P75.

We used the mgcv package (version 1.7-28) of the R program (Wood 2006) with cubic smoothing spline functions (Hastie & Tibshirani 1990). In order to better visualize the GAM result, we multiplied the depth index by \(-1\) so that the effects on the SL visualized shallowing trends as positive and deepening trends as negative.

Environmental parameters were measured daily (data from 92 d used in this study) using a CTD for temperature and salinity (Catalá et al. 2015), the instrument package also being equipped with turbidimeter, oxygen sensor and fluorometer. For 3 of the 92 d, high turbidity values were considered as outliers, and for the analyses these were substituted with averages based on the previous and subsequent measurements. CTD stations were mainly from daytime, whereas the acoustic data were from night, but space–time lags between measurements are negligible on the large spatial scales presented here. Data were imported into MATLAB for visualization. A global coverage of water clarity was also presented in the form of downwelling attenuation coefficient irradiance at 490 nm \( (K_{490}) \) retrieved from the Aqua MODIS using monthly averages and 4 km spatial resolution (http://oceancolor.gsfc.nasa.gov).

**RESULTS**

**Water properties**

Sea surface temperatures varied from 18.1 to 29.3°C throughout the voyage. The depth of the thermocline ranged from ~20 to 140 m, with temperatures at ~20°C often delineating the mixed layer depth. Surface salinity varied between 33.4 and 37.6, with high salinity detected at the edge of the Gulf of Panama (mid-June to July). In general, turbidity values were below 0.1 NTU (nephelometer turbidity units), with values for the upper 200 m being 0.031 ± 0.008 (mean ± SD). This was also shown by the surface \( K_{490} \) of the Aqua MODIS satellite over 6 mo.
period of the cruise, with an average $K_{490}$ at near surface of $0.15 \text{ m}^{-1} \pm 0.64$ (Fig. 1). Fluorescence values for the upper 200 m were $0.075 \pm 0.049$ relative units. Fluorescence generally peaked between depths of 25 and $-90$ m. The maximum recorded value was 3.55 (Fig. 2). There was a distinct oxygen minimum zone ($<1 \text{ ml} \text{ l}^{-1} \text{ O}_2$) near 50 to 200 m in the eastern Pacific Ocean (May to June; Fig. 2).

**Acoustic analyses and GAM model of SL and environmental factors**

The WMD of the nocturnal SL for the upper 200 m varied from the shallowest at $\sim31$ m to the deepest at $\sim130$ m. The average nocturnal WMD for the whole cruise was 74.7 m, with 95% CI at 43.8 to 108.6 m (Figs. 3 & 4).
Moon phase had significant effects on the WMD \( (p < 0.0001) \), the P25 \( (p < 0.0001) \) and the P75 \( (p = 0.046) \) (Table 1). In general, a deeper distribution of the SL (negative effect) occurred when the values were 0.75 to 1 (full moon) (Fig. 5). The acoustic results from the 4 moon phase categories suggested that the deepest occurred at C4 (Fig. 6), although for the 4 periods \( (C_1, C_2, C_3, C_4) \) the mean depths were not significantly different from each other (ANOVA with post hoc Tukey). Most of the backscatter was confined to ~40 to 80 m during the dark periods \( (C_1, C_2 \text{ and } C_3) \), whereas during brighter nights \( (C_4) \), SLs were dispersed more deeply at ~40 to 140 m (Fig. 6).

The distribution of the SL also was significantly related to environmental factors other than the moon phases (Table 1). Temperature significantly affected WMD and P75 (Table 1), becoming deeper in warmer waters (Fig. 5). The GAM model expected the SL depths to be shallower with integrated dissolved oxygen values of less than ~3 ml l\(^{-1}\) (Fig. 5). The nocturnal SLs also shallowed with increasing fluorescence. This was particularly evident for the lower part of the SL, with P75 moving ~50 m toward the surface with increasing values (Fig. 5). The distribution of WMD and P25 was significantly related to turbidity (Table 1), yet there was no consistent association with depth along the cruise track (Fig. 5). Correspondingly, it appeared

<table>
<thead>
<tr>
<th>SL parameters</th>
<th>Environmental factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moon phase</td>
</tr>
<tr>
<td>P25</td>
<td>8.525 ( (&lt;0.0001) )</td>
</tr>
<tr>
<td>WMD</td>
<td>6.723 ( (&lt;0.0001) )</td>
</tr>
<tr>
<td>P75</td>
<td>4.049 (0.046)</td>
</tr>
</tbody>
</table>

Table 1. Results of generalized additive model (GAM) regression for the effect of environmental factors on the scattering layer (SL) parameters. Values are degrees of freedom with p-values in parentheses. P25: 25th percentile; WMD: weighted mean depth; P75: 75th percentile. **Bold**: significantly different at p < 0.05

Fig. 5. Generalized additive model (GAM) showing the effect on the statistics representing the vertical distribution of the SL (P25, WMD and P75). Difference lag 1 refers to the effect of the respective parameters in the GAM model if lagged by day. The y-axis represents the effect of the spline functions on the statistics (m). Shaded gray areas indicate 95% CI. Note that the y-axis scale differs for P75. Tick marks on the x-axis refer to observed data points.
that salinity did not have any consistent effect on the SL (Fig. 5), even though significant relations appeared in the analyses (Table 1, Fig. 5).

The residuals from GAM fits to the SL (P25, WMD and P75) were analyzed in Fig. 7. Plots of scaled Pearson residuals (first column) did not reveal any abnormal patterns. Normal quantile-quantile plots of the residuals (second column) suggest that the assumption of normality is reasonable. Plots of the residuals’ autocorrelation functions with 95% confi-
DISCUSSION

Here we present the first study of the effect of moon phase on the distribution of nocturnal SL in the tropical and subtropical ocean worldwide, documenting consistent effects on the habitat choice of the vertical migrants. We could not identify the species constituting the SL, since no trawling was carried out during the cruise. However, the backscatter was likely mainly caused by dielly migrating mesopelagic fish (cf. Irigoien et al. 2014). This concurs with a multitude of studies from throughout the world’s oceans concluding that mesopelagic SLs at 38 kHz echo are dominated by mesopelagic fish, as follows: Arabian Sea (Gjøsæter 1984, Kinzer et al. 1993), Red Sea (Dalpadado & Gjøsæter 1987, Klevjer et al. 2012, Dypvik & Kaartvedt 2013), Japan Sea (Sweatt & Forward 1985), Hawaiian waters (Clarke 1978), Northeastern Atlantic Ocean (Roe 1984), Tasman Sea (Kloser et al. 2009) and the Mediterranean Sea (Olivar et al. 2012), although the relative contribution to nocturnal backscatter in upper layers remains to be established.

The GAM showed that moon phase significantly affected the nocturnal SL (P25, WMD and P75), particularly in causing a deeper distribution when moon phase was above 0.75 (Fig. 5). The pattern was consistent throughout the voyage, even though the data were collected on a large geographic scale, encompassing regions characterized by different environmental conditions, which each independently correlated to some extent with the vertical distribution. Also consistent along the cruise track was the similarity of the vertical distribution in the darker, yet still variable periods, with respect to moonlight ($C_1$, $C_2$ and $C_3$; Fig. 6). Similar results appear from a long-term acoustic study in the northern Arabian Sea, where Wang et al. (2014) found what they call a critical light intensity at ~65% of full moonlight, above which dielly migrating mesopelagic SLs stayed deeper. Therefore, a step function, and not a linear relation, between vertical distribution and moonlight is suggested in both cases. This deviates from studies suggesting the shallowest distribution occurs during the new moon (Hernández-León 2008, Benoit-Bird et al. 2009a).

A relatively deep nocturnal distribution during full moon is most likely explained in terms of predator avoidance. This explanation is in accordance with several previous studies addressing different taxa in various pelagic environments (Gliwicz 1986, Luecke & Wurtsbaugh 1993, Tarling et al. 1999). Hernández-León et al. (2001) concluded that oceanic mesozooplankton biomass and abundance peaked at full moon, as planktivorous mesopelagic fish then avoided the upper layers at night to reduce vulnerability to piscivores, thereby alleviating predation pressure on the plankton. Benoit-Bird et al. (2009b) concluded that a predator–prey relationship between dolphins and mesopelagic fish in Hawaiian waters was synchronized to the lunar cycle, with dolphins diving deeper to forage on the mesopelagic fish during full moon in contrast to shallow foraging depth during new moon. Similar behavior was also observed for other mesopelagic fish predators, when during full moon they had to search for mesopelagic fish more deeply than during other lunar phases; for example, cod (Giske et al. 1990), octopus (Villanueva 1993) and seabirds (Connan et al. 2007).

While a deeper nocturnal distribution during full moon was in accordance with our initial hypothesis, we did not find the shallowest distribution during the darkest night at new moon, as we had initially expected. Examples of another, seemingly counter-intuitive, response to moonlight are the Myctophidae Hygophum macrochir and Hygophum taaningi, which apparently ceased their migration during new moon and rather stayed at 400 m depth (Linkowski 1996).

We suggest that limited moonlight would provide sufficient light to forage on zooplankton-enriched surface layer at night, with sufficiently reduced mortality risk during most phases of the moon. Such trade-offs between visual foraging and predator avoidance would be in accordance with the anti-predator window theory (Clark & Levy 1988, Rosland & Giske 1994, Scheuerell & Schindler 2003). The presence of shallow anti-predation windows for mesopelagic fish foraging in upper layers has mostly been related to short periods of intermediate light at dusk and dawn (Staby et al. 2013), but also to less dark summer nights at high latitudes (Kaartvedt et al. 1998, Prihartato et al. 2015). These studies have focused on the more shallow-living components of the mesopelagic fauna (the pearlside Maurolicus muelleri). The deeper-living myctophids that prevail among mesopelagic fish in the world’s ocean (Catul et al. 2011) have more dark-adapted vision (cf. Warrant & Locket 2004), with other trade-offs between foraging and predator avoidance. Clear oligotrophic oceanic waters likely provide appropriate anti-predation windows throughout the night for dark-
adapted fishes (cf. Dypvik & Kaartvedt 2013), possibly enhancing nocturnal foraging opportunities compared to more productive regions. Note, however, that although we here assume that most of the backscatter is related to dielly migrating fish, the distributions of other organisms also relate to nocturnal light. For example, results from nights with lunar eclipse suggest that krill may immediately respond to sudden changes in the light level (Tarling et al. 1999). The trade-off between foraging and predator avoidance would be different for organisms not searching for prey by sight (most invertebrate predators), as only vulnerability to visual predators, and not own foraging success, would increase during full moon.

Reduced nocturnal light related to overcast nights versus clear nights may affect the relationship, as mesopelagic fish are known to move to shallower depths with the presence of clouds in daytime (Baliño & Aksnes 1993). We have not analyzed weather data along the cruise track, yet overcast versus clear nights would likely have the effect of including noise in the data set. Benoit-Bird et al. (2009a) found that lunar phase per se actually accounted for more of the variability in migration of a SL at the shelf than variation in nocturnal surface irradiance. They suggested that moonlight might be a cue for an endogenous lunar rhythm in the process of diel migration rather than a direct cause.

Among other environmental factors, reduced dissolved oxygen correlated with a shallower distribution. Oxygen plays a vital role for the habitat selection of migrating animals, particularly in regions with oxygen minimum zones (oxygen values <1.4 ml l\(^{-1}\)) (Childress & Seibel 1998). Regions of hypoxic waters, particularly in the marked oxygen minimum zones of the eastern tropical Pacific (Gilly et al. 2013), will affect the vertical extension of DVM (Longhurst 1967, Stramma et al. 2008, Bianchi et al. 2013). This clearly relates to daytime depth, but may cascade into nocturnal distributions as well, and Irigoien et al. (2014) recorded shallower nocturnal distributions in regions of hypoxic waters than elsewhere.

Fluorescence values may be used as a proxy for productivity. There was limited variation in the depth of the fluorescence maximum throughout the survey (Fig. 2), with mean values at 67.7 ± 11.82 m, while absolute fluorescence values varied considerably. In particular, the deeper part of the SL was consistently related to fluorescence values, suggesting some causative relation to the shallower distribution of the mesopelagic fish in regions with high fluorescence. Increased fluorescence values in the surface may reflect increased food abundance for zooplankton, in turn causing the migrating mesopelagic fish to stay near surface. Increased fluorescence will also cause increased shading, affecting the nocturnal light conditions. We cannot distinguish between these 2 possibilities.

Previous studies on mesopelagic fish document shallower daytime distribution with increasing turbidity, ascribed to shading (Kaartvedt et al. 1996, Widder & Frank 2001, Frank & Widder 2002). While the GAM analyses gave significant relations between the SL and turbidity, no such consistent trend appeared in our data.

The nocturnal SL during the cruise was confined to depths above the thermocline except for approximately full moon (bright nights). The deeper part of the SL (WMD and P75) became significantly deeper with increasing temperature. Temperature is known to play a role in nocturnal habitat selection for dielly migrating fish (Wurtsbaugh & Neverman 1988), and nocturnal habitat selection to speed up metabolism in warmer waters has also been suggested for mesopelagic fish (Giske & Aksnes 1992). However, we cannot conclude whether the correlation with temperature and the SL in our data relates to the temperature per se, or rather reflects another water mass signature. One possibility is the effect of of warm and clearer oligotrophic water masses.

In conclusion, regardless of the many factors that can affect the nocturnal vertical distribution of dielly migrating organisms, the full moon caused a deepening effect on the nocturnal SL worldwide. The relation to moonlight was not linear, but rather appeared to be a step function, with predator avoidance during full moon as the main effect.

**Acknowledgements.** This research was supported by the Malaspina 2010 Expedition project, funded by the Spanish Ministry of Economy and Competitiveness (Consolider-Ingenio 2010, CSD2008-00077) and co-funded by AZTI-Tecnalia. The research was equally supported by the baseline funding of S.K. provided by King Abdullah University of Science and Technology (KAUST). We thank Udane Martinez for setting the acoustics onboard and all those who contributed to the success of the Malaspina 2010 Expedition.

**LITERATURE CITED**


Baliño BM, Aksnes DL (1993) Winter distribution and migration of the sound scattering layers, zooplankton and
micronekton in Masfjorden, western Norway. Mar Ecol Prog Ser 102:35–50


Korneliussen RJ, Hegelund Y, Eliassen IK, Johansen GO


Editorial responsibility: Stylianos Somarakis, Heraklion, Greece

Submitted: December 3, 2014; Accepted: January 14, 2016

Proofs received from author(s): February 11, 2016