

## Patterns of scuba diver behaviour to assess environmental impact on marine benthic communities: a suitable tool for management of recreational diving on Benidorm island (Western Mediterranean sea)

S. V. Jiménez Gutiérrez† G. Martín González‡ and J. Tena Medialdea‡

† Instituto de Ecología Litoral. El Campello, Alicante. 03560, España. s.jimenez@ecologialitoral.com

‡ Instituto de Investigación en Medio Ambiente y Ciencia Marina. Universidad Católica de Valencia, Valencia.

46001, España. german.martin@ucv.es; josetena@ucv.es



Instituto de Investigación en Medio Ambiente y Ciencia Marina.



Universidad Católica de Valencia

JIMENEZ-GUTIÉRREZ, S.; MARTÍN GONZÁLEZ, G. and TENA MEDIALDEA, J. 2009. Patterns of scuba diver behaviour to assess environmental impact on marine benthic communities: a suitable tool for management of recreational diving on Benidorm island (Western Mediterranean sea). *Nereis. Estudios y propuestas científico técnicas*, 2, 19-28.

### ABSTRACT

Few studies have analyzed the SCUBA divers' behaviour in the Mediterranean Sea and none of them involved marine unprotected areas. Generally speaking the damage done by individuals is quite low, but the, accumulative effects of these disturbances can cause significant localised destruction of benthic marine organisms. The present study was carried out during the year 2005 on a diving site called La Llosa, on Benidorm Island (Alicante: Western Mediterranean Sea) with more than 7,000 dives per year. Two hundred and seventeen (217) divers were monitored randomly. Each subject was observed underwater for 10 minutes (Rouphael & Inglis, 2001). Samples were randomly collected during the high diving season (June-October). Divers were not aware of this surveillance so as not to interfere with their normal patterns of behaviour. The results showed that 95% of divers came into physical contact with benthic substrata during the 10-min observation period. Fin contact rates were significantly different depending on the diving certification level (Man-Whitney test,  $p < 0.003$ ) detecting the greatest number of contacts within higher diving certification levels (Bonferroni correction). Divers using an underwater light device came into contact with the substratum significantly more frequently than non-light users ( $\chi^2$ ,  $p < 0.022$ ). However, contact rate did not show significant variance across divers using a camera and those who did not ( $p < 0.366$ ). No difference was found between contact rates of divers who were given a briefing and those who were not. Environmental briefing before diving had no effect on the divers' hand contact rates ( $\chi^2$ ,  $p < 0.194$ ), which shows a low marine environmental sensitivity level of divers. We concluded that the decrease in scuba divers contact rate would take place given an improvement of environmental awareness, specially among professional divers.

**KEYWORDS:** Scuba diving, Impact, Management, Benthic environment, Divers behaviour.

### RESUMEN

Pocos estudios han analizado el comportamiento de los buceadores en el mar Mediterráneo y ninguno se ha centrado en las áreas marinas protegidas. El daño hecho por los buceadores suele ser bajo, pero los efectos acumulados, pueden ser importantes, aunque localizados. Este estudio se llevó a cabo durante el 2005 en una zona de buceo llamada La Llosa, cerca de Benidorm (Alicante, Mediterráneo occidental), con más de 7.000 inmersiones al año. La muestra aleatoria de buceadores llegó al tamaño 217. Se observó a cada buceador durante 10 minutos (Rouphael & Inglis, 2001), en la temporada alta (junio-octubre), de manera que los buceadores no supieran que eran vigilados, para no interferir en su comportamiento habitual. Los resultados mostraron que el 95% de los buceadores entran en contacto físico con los sustratos bentónicos durante el periodo de observación de 10 min. Las tasas de contacto fueron significativamente diferentes en función del nivel de certificación de buceo (Man-Whitney,  $p < 0,003$ ) detectándose mayor número de contactos en los niveles más altos de certificación de buceo (corrección de Bonferroni). Los buzos que utilizan linterna tuvieron un mayor número de contactos con el sustrato que los que no la usaron ( $\chi^2$ ,  $p < 0,022$ ). Pero, no hubo diferencias significativas, entre los que llevaron cámara y no la llevaron ( $p < 0.366$ ). Tampoco las hubo entre los buzos a los que se dio una conferencia previa a la inmersión y a los que no. La conferencia previa sobre medio ambiente no tuvo efecto sobre el número de contactos con las manos ( $\chi^2$ ,  $p < 0,194$ ), lo que demuestra un bajo nivel de sensibilidad de los buceadores ante el medio ambiente marino. Se concluye que la disminución de la tasa de contacto de los buceadores se podría conseguir mejorando su conciencia medioambiental, especialmente la de los buceadores profesionales.

**PALABRAS CLAVE:** Buceo, Impacto medioambiental, Gestión, Medio ambiente bentónico, Comportamiento de los buceadores.



## INTRODUCTION

Scuba diving is one of the tourist activities with the greatest growth over the last few years (Davis and Tisdell, 1995). The world-wide growth of this type of underwater tourism could contribute to the alteration of marine communities (Hawkins and Roberts, 1992) on some occasions and on certain diving sites where a high concentration of diving takes place. In recent years, numerous studies have been carried out. These studies have analyzed the SCUBA divers' behaviour and its impact on different parts of the world such as the region of the Caribbean Sea (HAWKINS *et al.* 1997, 2005; TRATALOS and AUSTIN, 2001; BARKER and ROBERTS, 2004; UYARRA and CÔTE, 2007), Australia (ROUPHAEL and INGLIS, 1997, 2001) or the Red Sea (JAMESON *et al.* 1999; ZAKAI and CHADWICK-FURMAN, 2002). The studies that have been carried out in the area of the Spanish Mediterranean concerning this subject are limited, and they have always been in protected areas (SALA *et al.* 1996; GARRABOU *et al.* 1998; ESTEBAN *et al.*, 1999; LLORET *et al.* 2006). In spite of the growing economic importance given to the diving activity in many areas, the works published, which have analyzed the socio-economic aspects related to this activity in the Spanish Mediterranean sea, are even fewer (MUNDET and RIBERA, 2001; TRIVIÑO *et al.*, 2006) and until now, there is no study analyzing divers' behaviour during immersion.

The impacts caused due to recreational diving practice can cause important environmental alterations in highly frequented places. The damage caused by a sole individual might be of low importance. However, it is the cumulative effect of these disturbances that could lead to localized destruction of sensitive marine organisms. (GARRABOU *et al.* 1998; HAWKINS *et al.*, 1999). Specifically, the benthic species with rigid structures are some of the species that could be affected because of the repetitive contact with the different parts of the diver's body as well as with their diving equipment. In this way, bryozoans, gorgonians and coralligenous formations in general, have been generally selected for these studies carried out in the Spanish Mediterranean sea. They have been used as indicators of the impact caused by divers at the bottom of the sea and other actions derived from this activity, for example, the anchoring of boats (SALA *et al.*, 1996; FRANCOUR and KOUKOURAS, 2000). However, more research would be needed to determine the rate from which irreversible damages on organisms are caused, and once the damage is done estimate their recovery time (MILAZZO *et al.*, 2002).

The normal impacts caused by divers can be direct (fracture of rigid elements, accumulation of air bubbles and the physical impact of these bubbles on caves, loosening of sessile organisms, extraction of organisms, abrasive wearing away in bottleneck areas with an excess of circulation, sediment resuspension, feeding) or indirect (anchoring of boats, waste disposal and/or waste of petrol). Many of these impacts could be avoided in an effective way by means of improving the diving techniques and specially improving the control of buoyancy (MEDIO *et al.*, 1997), by the installation of dive mooring buoys, and, above all, by increasing the environmental awareness of those implied in these underwater activities, from divers, and companies including related organizations (such as tourism and diving agencies).

By consulting the companies that operate in the research area, we have verified search, that awareness concerning the environment

is not a primary objective in the courses that aim to train or teach divers. This issue only takes a small percentage of the teaching time. Thus, the knowledge of the underwater media and environmental awareness is usually low. Divers are not aware, in most cases, of the damage they may cause when they carry out their immersions. In some studies, the lack of experience of divers has been related to a higher number of physical contacts with the benthic medium (ROBERTS and HARRIOT, 1994). Other studies consider that the best option to reduce the level of impacts in the development of such underwater activities is the participation of a dive-leader (BARKER and ROBERTS, 2004) or the undertaking of briefings with previous environmental contents prior to immersion (MEDIO *et al.*, 1997).

Load capacity is a concept of growing importance for the management of diving areas. According to Philips (1992), the load capacity is defined as the level of utilization that a natural resource can withstand without reaching an unacceptable level in the deterioration of such resource, thus prohibiting its use. In other works, this definition has been completed by emphasizing the importance of the size and shape of the diving area, the level of fragility of the benthic biotopes present, the type of activity to be carried out (SALM, 1986), the perception by divers of the saturation level of the place, and even taking into account economic aspects (DAVIS and TISDELL, 1996). Works such as those carried out by DIXON *et al.* (1993), Scura and van't Hof (1993) y HAWKINS *et al.* (1999). In the coral reef of Donaire in the Caribbean, it was estimated that 5.000 immersions per year and per place would be the critical figure from which deterioration could then be caused. Although it is important to indicate that this calculation was carried out in tropical underwater marine environments. Estimations for Mediterranean sea relief bottoms do not exist and they are the ones present in this study.

As mentioned above, there are works that which have studied the impact of diving on benthic organisms in Spanish Mediterranean waters. But the absence of studies analyzing the behaviour patterns of divers is confirmed. In the case that such behaviour implied an important deterioration of the environment, a first step to reduce such deterioration would be that of improving the divers' inappropriate behaviour.

In general, those diving sites located in unprotected marine areas are used by companies and those with an idea for exploitation in the short term. The immediate benefits take precedence over the sustained maintenance of the activity, which is concentrated in certain seasons of the year and at specified times of the day. Something that often occurs is that an excessively frequented diving site reduces the quality of the perception of the divers' immersions. This limits the divers' satisfaction level. In this way, the probability of repetition is decreased for the user; for that reason, the excess of immersions has negative repercussions on companies that carry out their activity on such a diving site. In order to make use of a diving site in a sustainable way, the excess of immersions should be avoided in this area. This would increase the quality of the immersion and the probability that the user will repeat the activity. We must remember that the most important criterion for a diver to choose a place to dive is the quality of the immersion (Dixon and Sherman, 1990).

All this would be of benefit for the environmental and the economic aspects in the long run as well as for the diving companies and those who practice this activity. For this reason, it is really important to carry out some studies in those unprotected

places or to limit the activity in order to know the environmental status of the site as well as the influence of the activity regarding the preservation of such a place. All this would allow the adoption of corrective measures, to which it is essential to count on the participation and support from diving professionals and companies.

By means of this work, we try to detect the usual behavioural patterns of divers who practice the activity in the diving area of "La Llosa" (Benidorm). This is a place without any kind of restriction of activity at the time of carrying out the present study, and the elaboration of proposals to the minimization of the possible impacts which could be caused by this behaviour. Divers' behaviour studies can provide important information about the effects of this activity in highly frequented dive sites in addition to serving as a tool for the decision making to the Serra Gelada marine protected area managers.

## METHODS

### Study Area

The present study was carried out during year 2005 on a diving site called La Llosa, near Benidorm Island (Alicante, Spain, Western Mediterranean Sea) with more than 7.000 dives per year (TRIVIÑO *et al.*, 2006). This is around a rocky seamount located at about 300 m away from the southern part of Benidorm island. The depth at the most superficial part is 6 m and its south face descends abruptly reaching 30 m in depth. Based on the nomenclature used by Meinez *et al.* (1983), the biocenosis of the upper infralittoral rock in a calm sea is best represented in the most superficial part of the relief bottom, showing primarily facies of species of algae *Dyctiota* spp., *Dilophus* spp., *Padina pavonica*. Its homogeni-

ty stands out on the northern face with a gentler slope; this kind of community extends itself between 6 m and 20 m in depth. On the vertical walls of the south face as well as in the areas protected from the light and from the hidrodinamism, the most representative algae species are *Udotea petiolata*, *Halimeda tuna* and *Peyssonnelia* spp. (basically, *Peyssonnelia squamaria*). This community can cover from the subsuperficial levels until 25 m in depth. In the deepest areas of the relief bottom (28 m), we can observe the presence of hard substrate communities without bioconcretioning or precoralline, this term refers to a "new" substrate which in most cases is prior to the settlement of the typical coralline communities. The prevailing species of algae are *Mesophillum lichenoides*, *Udotea petiolata*, *Halimeda tuna*, *Peyssonnelia squamaria* and *Vidalia volubilis*. Generally, rocks have few algae which show a mixture of photophiles and sciaphilic algae. What should be pointed out is the presence of huge thallus of *Codium bursa* and sciaphilic algae, *Halimeda tuna* and *Udotea petiolata*. The soft relief bottoms are found at 25 m in depth and they are represented by facies of coastal detritus. Facies that are characterized by the phaeophyceae *Arthrocladia villosa* and *Sphorus pedunculatus*. These indicate the presence of relief bottom currents. And finally, in the deepest areas, we find small grottos and underwater crevices which are examples of biocenosis of semi dark grottos. The lack of light makes any development of algae impossible. This is the reason why this community consists of a distinguished filtering fauna, to which we must add numerous species that find their specific habitats in these enclaves. They are basically sponges (*Petrosia dura*, *Verongia aerophoba*, *Clathrina coriacea* and *Dysidea* sp.), cnidaria (*Parazoanthus axinellae*, *Caryophyllia smithi*, *Leptosamia pruvoti*, *Madracis pharensis* and *Polyciathus muerellae*), bryozoans (*Yugula turbinata* y *Myriapora truncata*) and ascidians (*Halocynthia papillosa*).

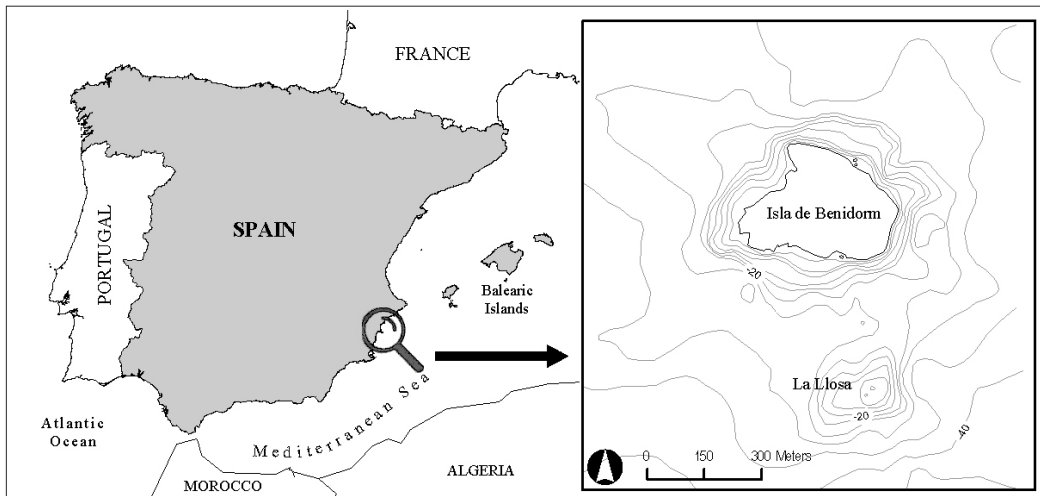


Figure 1. Location of La Llosa diving's area (Benidorm).



## Diver samples

The data were collected during the diving high season (June-October) in the year 2005 and on the immersion site called La Llosa. The days chosen for taking samples along with a particular diving centre were selected at random during the high season. Subsequently, notes were taken about the type of day (holiday or working day) on which the tasks were carried out. All the immersions were done during the daytime and from boats. Before the immersion and during the sea trip to the sample point, which took about 20-30 minutes, the divers, who would then be tracked, were randomly assigned to one of the two observers who would participate in each of the immersions. At no time, were the divers aware that they were being observed and if, by chance, a diver noticed this, he was eliminated from the sample (in practice, only the elimination of one diver was required), because the natural tendency of divers is to look straight ahead or below their field of vision. During the immersion, the divers, who were in groups of two, were followed by the divers in charge of the sample at 3-5 m above them. The individual behaviour of each diver was observed under water during 10 minutes of the immersion following the methods proposed by Rouphael and Inglis, 2001.

When the present study was carried out, the diving site of La Llosa did not have any effective figure of conservation. During the month of July of 2005, this site was declared a protected marine area inside the natural park of Serra Gelada and also its Littoral Environment. This fact did, however, not affect this study. At the present time, there is no kind of internal rule in the park, managing or controlling, the diving activity in its waters. There was no type of restriction of activities when this study took place.

## Factors recorded

The following details were noted: depth, date, gender of the diver and the number of contacts they made as perceived in each of the immersions. In all cases, the observations started once the divers had adjusted their equipment under water and had reached the immersion zone.

The noted actions were divided into two groups:

- a) Number of contacts with different parts of the body (hands, knees) or equipment (fins, octopus, console tank air), but without taking into account the derived consequences on the sea bottom, and
- b) Resulting actions (turbidness, the taking or alteration of benthic organisms).

Other notes also considered were the absence or not of a briefing prior to the immersion, use of torch or camera and the type of camera.

Once the underwater tracking to observe the divers' behaviour concluded and the divers were identified in the notes of the observers, the divers were asked on board the boat about their certifications regarding the activity (in 10 cases they refused to provide the information) and the organization to which they belonged. We assigned this information to the data collected during the immersion of each diver.

## Data processing

The divers were classified according to the number of contacts with each of the following parts of their body or equipment: hands, knees, fins, octopus, console and air tank.

The intervals to be considered for this classification were based on the experience of two of the authors (diving instructors with more than two thousand immersions accumulated) as well as the observations carried out during the samplings. According to the number of contacts with their hands, divers were classified as involuntary (0-2 contacts), medium (3-5) and high ( $\geq 6$ ). On the other hand, for feet-fins, knees, console, and air tank, the number and the values of the intervals determined were different. The reason is that the diver has less vision and, thus, less control, over these parts of their body. Therefore, what was taken into account was: involuntary contacts (between 0-3), medium (4-6), high (7-8) and very high ( $\geq 9$ ).

Diving certifications were divided into three categories. The level was contrasted according to the organization to which each diver belonged. In this way, in level 1, Open Water Diver (SSI), Open Water (PADI), one star diver (Spanish Federation of Subaquatic Activities-CMAS) were included; in level 2, the Advanced Open Water Diver (SSI), Advanced (PADI) and 2 star diver (Fedas-CMAS); and finally in level 3 higher or professional levels of Divecon (SSI), Divemaster (PADI), instructor assistant and instructors of all the organizations were included.

## Statistical analyses

Statistical techniques instead parametric ones were used due to the fact that the hypotheses required by most of the parametric tests (normality and homocedasticity) are not fulfilled. All of the statistical tests and analyses were carried out by the SPSS 15.0 software for Windows, version 15.0.1.

Given that the assumption of normality is not fulfilled, in order to compare two (hypothetical) populations by means of both samples obtained individually, we resorted to the Mann Whitney test, which is an excellent alternative to the t test about differences of averages for individual samples.

For the same reason (absence of normality), to compare two or more populations (assuming K) by means of the corresponding samples we resorted to the Kruskal-Wallis test, similar to ANOVA of a completely randomized factor. This test allows us to compare if K populations are identical or some of them present different averages.

When the Kruskal-Wallis test rejects the null hypotheses of equality of averages, it is necessary to compare the two K populations (by means of their corresponding samples) two by two. We resort to the Bonferroni correction to control for error rate + (error probability of the Type I) in such a way that if the global probability,  $\alpha = 0,05$  of incorrectly rejecting the null hypotheses has to be maintained, the level of significance of each comparison has to be

given in  $\alpha^* = \left(\frac{K}{2}\right) / 0,05$ , if K = 3, then  $\alpha^* = 0.017$ . Finally, for

the analyses of categorical data (independence of characters observed in the individuals of a population), the Chi-square test was used.



Table 1. Results of Kolgomorov-Smirnov and Shapiro Wilks test of normality for the number of contacts made with hands, fins, octopus, console and tank air. Significance level: \* = P < 0.05; \*\* = P < 0.01; \*\*\* = P < 0.001.

|          | Kolgomorov-Smirnov |             | Shapiro-Wilk |             |
|----------|--------------------|-------------|--------------|-------------|
|          | d.f.               | Estadístico | d.f.         | Estadístico |
| Hand     | 217                | 0.136***    | 21           | 0.898***    |
| s        |                    |             | 7            |             |
| Knee     | 217                | 0.186***    | 21           | 0.829***    |
| s        |                    |             | 7            |             |
| Fins     | 217                | 0.153***    | 21           | 0.882***    |
|          |                    |             | 7            |             |
| Oc-topus | 217                | 0.454***    | 21           | 0.375***    |
|          |                    |             | 7            |             |
| Con-sole | 217                | 0.482***    | 21           | 0.299***    |
|          |                    |             | 7            |             |
| Tank     | 217                | 0.493***    | 21           | 0.352***    |
|          |                    |             | 7            |             |

**RESULTS**

**Description of the sampling data**

As we can observe in table 1, the rejection of the null hypotheses of normality was carried out safely (p – valor < 0.000).

The total number of divers observed was 217. Taking gender into account, 182 were men and 35 women (Table 2)

Regarding the depth at which divers were observed, the following categories were coded:

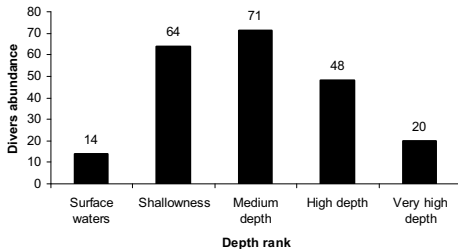


Figure 2. Number of SCUBA divers sampled according to the depth where the monitoring was done.

- Superficial: between 5 and 10 meters
- Low: between 11 and 15 meters
- Medium: between 16 and 20 meters
- High: between 21 and 25 meters
- Very high: between 26 and 30 meters

Table 2. Number and percentage of SCUBA divers observed in La Llosa’s diving area.

|       | Frecuency | Percentage (%) |
|-------|-----------|----------------|
| Women | 35        | 16,1           |
| Men   | 182       | 83,9           |
| Total | 217       | 100            |

According to these intervals, the majority of the divers carried out their immersions reaching 20 meters in depth; and a lower number of divers carried out their immersions deeper than 21 meters.

Depending on the number of contacts with different parts of the divers’ bodies and their equipment, these were divided into voluntary and involuntary (Table 3). One can observe how contacts with octopus, tank and console were mainly involuntary. Consequently, we determined to focus the study on the variables hands, fins and knees.

Table 3. Frequency (number) and percentage of SCUBA divers’ contacts every 10 minutes with differents body parts and diving equipment. (a) = involuntary; (b) = Medium; (c) = High; (d) Very High.

|         | Frecuency                       | Percentage (%)                       |
|---------|---------------------------------|--------------------------------------|
| Hands   | 71 (a);75 (b); 20 (c)           | 32.7 (a); 34.6 (b); 32.7 (a)         |
| Fins    | 120 (a); 54 (b); 20 (c); 23 (d) | 55.3 (a); 24.9 (b);9.2 (c);10.6 (c)  |
| Knees   | 170 (a); 34 (b); 8 (c); 5 (d)   | 78.3 (a); 15.7 (b); 3.7 (c); 2.3 (d) |
| Console | 211 (a);4 (b); 2 (d)            | 97.2 (a); 1.8 (b); 0.9 (d)           |
| Tank    | 216 (a); 1 (d)                  | 99.5 (a); 0.5 (d)                    |
| Octopus | 210 (a); 4 (b); 2 (c);1 (d)     | 96.8 (a); 1.8 (b); 0.9 (c); 0.5 (d)  |

The diving certification level of the divers was primarily level 1, with 108 divers, followed by those of level 2 with 64 divers. The number of certifications for the professional level or level 3 (Dive-master, Instructor), with a total of 35 divers (Table 4), was lower.

Out of the total number of divers that were sampled, 95 % made some type of contact during the ten minutes in which their behaviour was being observed. The highest average of number contacts, during the 10-minute tracking, were the ones made by hands (4.6 ± 3.9 contacts), fins (3.9 ± 3.6) and knees (2.15 ± 2.10). (Fig. 3).

The confidence interval per diver for the number of contacts (voluntary or not), with the hands during the 10 minutes of observed immersion (α = 0.05) is (4.07;5.13). It was estimated that the number of immersions in the area was about 7,000 (TRIVIÑO *et al*, 2006). For that reason, we reached the conclusion that the number of contacts with hands is between 28,490 and 35,910. We proceeded in the same way with knees and fins and we estimated that the total number of contacts were between 58,000 and 84,000 (rounding up), and this was taking into account, only the 10 minutes of immersion we sampled. Consequently, we have to consider this estimate as being very conservative.



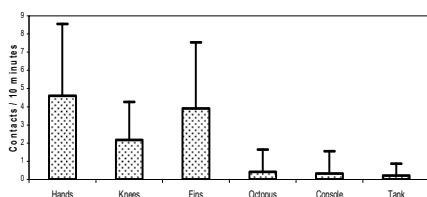


Figure 3. Average contacts every 10 minutes sampled in La Llosa diving’s area for hands, knees, fins, octopus, console and tank air.

Table 4. Diving certification level sampled in La Llosa’s diving area by gender and total number of SCUBA divers.

|        |           | Diving certification level |         |         |       |      |
|--------|-----------|----------------------------|---------|---------|-------|------|
|        |           | Level 1                    | Level 2 | Level 3 | Total |      |
| Gender | Women     | Divers                     | 21      | 7       | 5     | 33   |
|        |           | Gender (%)                 | 63.6    | 21.2    | 15.2  | 100  |
|        |           | Certification level (%)    | 19.4    | 10.9    | 14.3  | 15.9 |
|        |           | Total (%)                  | 10.1    | 3.4     | 2.4   | 15.9 |
|        | Men       | Divers                     | 87      | 57      | 30    | 174  |
|        |           | Gender (%)                 | 50      | 32.8    | 17.2  | 100  |
|        |           | Certification level (%)    | 80.6    | 89.1    | 85.7  | 84.1 |
|        |           | Total (%)                  | 42      | 27.5    | 14.5  | 84.1 |
| Total  | Divers    | 108                        | 64      | 35      | 207   |      |
|        | Total (%) | 52.2                       | 30.9    | 16.9    | 100   |      |

**Number of contacts with the relief bottom according to depth**

Kruskal-Wallis (KRUSKAL and WALLIS, 1952) test, obtained the following results: Knees ( $p = 0.116$ ,  $\alpha = 0.05$ ), feet-fins ( $p = 0.097$ ,  $\alpha = 0.05$ ), hands ( $p = 0.048$ ,  $\alpha = 0.05$ ). As a result, we assume that the average number of contacts, which were measured by the median, do not depend on the depth.

**Number of contacts according to gender**

The Mann-Whitney test was applied in order to confirm the hypotheses of the existence of differences between genders and for the number of contacts. The results obtained from this test show that there are no significant differences between the two genders in the total number of contacts made ( $p = 0.233$ ,  $\alpha = 0.05$ ), neither are there significant differences between the two genders regarding the number of contacts with hands ( $p = 0.235$ ,  $\alpha = 0.05$ ), knees ( $p = 0.750$ ,  $\alpha = 0.05$ ) and feet-fins ( $p = 0.892$ ,  $\alpha = 0.05$ ).

In conclusion, men and women have the same behaviour during the immersion regarding the total contact rate with the relief bottom.

The possibility of the existence of differences between genders regarding the voluntary contacts with hands, fins and knees was also analyzed. The result obtained was a similar behaviour between men and women. However, the null hypotheses of equality of behaviour in men and women regarding the number of voluntary contacts either for hands (Chi-Square Test,  $p = 0.358$ ,  $\alpha = 0.05$ ), fins (Chi Square Test,  $p = 0.750$ ,  $\alpha = 0.05$ ) or for knees (Chi Square Test,  $p = 0.623$ ,  $\alpha = 0.05$ ) cannot be rejected.

**Behaviour regarding the diving certification**

The average number of contacts with hands, fins, knees, octopus, and tank was analyzed and was measured by the median in accordance with the certification levels of the divers. Only a slight difference in the case of fins (Kruskal-Wallis test,  $p = 0.03$ ,  $\alpha = 0.05$ ) was detected. From the total number of contacts estimated, almost 60 % were made with fins and in an involuntary way.

Regarding the number of voluntary contacts (more than 4 contacts with the relief bottom per 10 minutes of immersion) which were made with fins, we detected slight differences amongst the different levels of diving certification (Kruskal-Wallis test,  $p = 0.003 < 0.05$ ).

To analyze which groups of divers were different from the others, the Man-Whitney test was applied for two individual samples. The Bonferroni correction was used in order to control for the error rate of type I. Three comparisons of the median were carried out in pairs, confronting all the diving levels existent among themselves. The significance level was:  $\alpha = 0.05 / 3 = 0.017$ , thus, the groups differed significantly when  $p < 0.017$ . The differences regarding voluntary contacts with fins in levels 1 and 2 were not detected (Mann-Whitney U test,  $p = 0.113$ ), but for levels 1 and 3 (Mann-Whitney U test,  $p = 0.016$ ) and levels 2 and 3 (Mann-Whitney U test,  $p = 0.001$ ,  $\alpha = 0.05$ ) differences were discovered. This proved that divers with the highest diving certification level were those who produced a higher number of contacts.



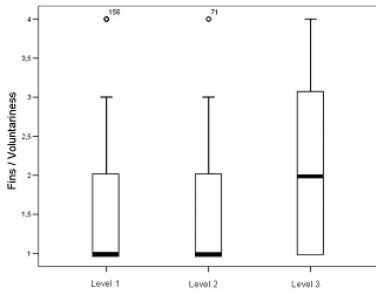


Figure 4. Box whisker plot representation of dichotomic values (0 = no contact; 1 = contact) of the fin's contacts for the three diving certification levels (1 = open; 2 = advanced; 3 = professional).

### Use of underwater lighting equipment

The use of torches implied a higher number of contacts with hands (Chi Square test,  $p = 0.022$ ,  $\alpha = 0.05$ ). To find out within which interval significant differences took place regarding the number of contacts (involuntary, medium, high), some bilateral comparison trials amongst the divers who used a torch or who did not were carried out. The result obtained was a higher number of voluntary contacts with hands for those divers who carried a torch during the immersion.

However, significant differences were not detected amongst the divers who used a torch, regarding the contacts made with knees (Chi Square test,  $p = 0.333$ ,  $\alpha = 0.05$ ) or fins (Chi Square test,  $p = 0.183$ ,  $\alpha = 0.05$ ).

### Use of photographic cameras

The average number of contacts was slightly superior for those divers who used cameras (Fig. 5). Significant differences were not detected in the number of contacts with hands (Chi Square test,  $p = 0.366$ ,  $\alpha = 0.05$ ), knees (Chi Square test,  $p = 0.751$ ,  $\alpha = 0.05$ ), fins (Chi Square test,  $p = 0.240$ ,  $\alpha = 0.05$ ) considering the use of cameras. That is the reason why the proportions of contacts produced by the divers with these three elements did not have any relation to the use of cameras during the immersion.

### The effect of briefings on divers' behaviour.

The briefing prior to immersion was carried out in 20 % of the cases ( $n = 217$ ). In those immersions where briefings took place, we analyzed the number of contacts with hands and, then, we compared these analyses with the cases in which briefings were not offered. The independence of both variables was confirmed. In that way, the quantity of contacts made with hands does not depend on the existence of a previous briefing (Chi Square test,  $p = 0.073$ ,  $\alpha = 0.05$ ). Taking into consideration that hands are the best indicator for the effectiveness of these speeches, we must conclude that the existence of a briefing does not modify divers' behaviour.

## DISCUSSION

The area of La Llosa has a high diving density during the peak months of the high season. The total number of accesses by divers

who carry out immersions in such an area should be considered very high. Taking into account the conservative character of our estimation, we must conclude that it would be necessary to implement some policies for the reduction and redistribution of this practice throughout the year.

The majority of studies about how the impact of diving activity can affect a specific area have been developed in coral reefs such as those in the Caribbean Dixon et al. (1993) the limit of immersions is established between 4,000 and 6,000 immersions per year, meanwhile Hawkins et al (1999) for the same year established the limit at 5,000 immersions, or the 15,000 (Hawkins and Roberts, 1992) proposed for the Red Sea reefs. The number of immersions in La Llosa during the high season (5 months) could not be compared to other specific places in the Red Sea, such as Eliat (Israel, Northern Red Sea), where up to 250,000 immersions can take place during a year along the 12 km coast (Zakai and Chadwick-Furman, 2002). However, a high concentration could equally be implied if we take into consideration the physical limitations of the diving site, which has a true practising area of not more than 9,000 m<sup>2</sup> for the activity and, where concentrations of more than 80 divers at a time can coincide in the same space during the high season. Given the approximate figures in the number of contacts, we consider that it is highly probable that in the small caves above all of this site, both elevated levels of stress on the benthic organisms as well as impact occur.

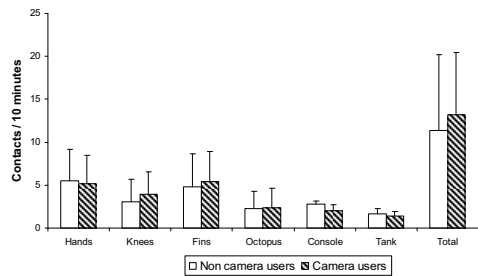


Figure 5. Average contacts with different body parts and SCUBA diving equipment every 10 minutes sampled.

The number of divers who made some type of contact was quite high (95 %). This percentage was also similar to that of other works carried out in the region of Florida (USA), where Talge (1991) verified that 90 % of the divers made some kind of contact. This percentage was higher than in other highly frequented diving areas, such as the Australian reefs (Rouphael and Inglis, 1997), in which 73 % of the divers also made some kind of contact. The average total of contacts per ten minutes of immersion ( $12.2 \pm 8.31$ ) was, in the same way, higher than in other diving sites (Zakai and Chadwick-Furman, 2002; Rouphael and Inglis, 1997, 2001), the maximum averages of which were for the same period of time less than half of those calculated in the area of La Llosa.

When the contacts made with parts of the diver's equipment or with the parts of their body were analyzed, we observed that there existed differences regarding the most studied diving sites, such as coral reefs. On these sites, the most usual contacts were made with fins (Harriot et al., 1997; Rouphael and Inglis, 2001; Zakai and Chadwick-Furman, 2002). However, in the present study, the highest number of contacts was made with the hands. The reason could lie in the fact that divers perceived an apparent increase in the fragility of coral reefs, which could provoke a lower number of



contacts of this type, because divers are more sensitive and tend to control this class of contacts. Besides, in those areas, the existence of species which can cause itching and burning sensations is frequently observed. In this way, divers are more careful when resting their hands. However, in the Mediterranean region, divers do not have this type of problem when they have to rest their hands somewhere, because their diving sites are characterized by rocky relief bottoms. These sites are not so fragile in structure as the ones found on coral reefs, where divers experience more evident consequences, for example, of partial or total breakage of fragile reef structures. The rest of the elements of the diving equipment, with which contact with the relief bottom is made (octopus, console, air tank), would lead to certain errors in the first stage of the immersion (before the immersion), where the appropriate checking regarding the adjustment of the equipment was not carried out. In this way, the result would cause an error in the buddy system which is basic for this activity. At the same time, this would also derive in serious complications for some divers in order to keep neutral buoyancy.

The voluntariness of the contacts is another important factor to be considered, because it shows divers' technical preparation as well as environmental awareness there of. Almost 68 % of contacts with hands were made voluntarily. This value is much higher than that of others obtained in different works carried out with similar sampling techniques, such as Medio et al., (1997), in which voluntary contacts with the hands were about 60 %. However, if we consider voluntary contacts with the fins, the percentages obtained were strongly disparate; 70 % in La Llosa and 30 % in the national park of Rass Mohamed (Egypt). As mentioned above, it is probable that, in areas of coral reefs areas or protected marine zones there could be a tendency to higher sensitivity and appreciation by divers. In these areas, the existence of an increased perception of the fragility of these ecosystems is higher than in underwater Mediterranean environments, without protective measures. This occurs in spite of the ecological value of our environments, which could lead to the appreciation of these areas and sites by divers and, therefore, to the modification of their behaviour during immersions.

All the data, apart from the number of voluntary and involuntary contacts, show a generally low level of technical knowledge as well as poor environmental awareness by those divers who carry out their immersions in the diving site of La Llosa.

According to Rouphael and Inglis (2000), in shallow areas the number of contacts is higher due to the adjustment of the equipment and the divers' buoyancy. Although it is true that, a priori, an increase in depth and thus, an increase of negative buoyancy could cause a higher number of contacts in the deepest areas, especially with fins. In the present study, the depth does not seem to be a determining factor in the number of contacts with the relief bottom except for the hands, where the level of significance was almost reached. This was probably due to the low number of contacts occurring in the interval of maximum depth, in which there are relief bottoms where rocky areas are almost nonexistent. Therefore, divers do not show much interest in such places, and contacts with the hands, therefore, were scarce.

One of the causes of the non-existence of differences in the number of contacts between shallow and deep areas is the result of the particular topographical characteristics of these diving sites. Divers reach all depth ranges where they enjoy places or sites of interest, locating areas in which it is necessary to come closer to

the relief bottom and, in this way, make contacts. Most divers carried out their immersions in depths higher than 10 m due to the fact that they, after initiating the immersion, had to descend rapidly along a wall until 24 m in depth. At this point, there is a group of frequently visited rocks containing a high number of small caves as well as crevices through which divers can snoop. It is here that they make most of the contacts with the relief bottom. In the shallowest part of this relief bottom, we could distinguish two types of behaviour leading to contacts with the relief bottom. In the first part of the immersion, divers adjust their equipment, therefore making contacts with their legs. In this zone, they wait for the rest of their buddies who form the group to descend rapidly to the previously described area. This zone of shallow waters is used once again in the last stage of the immersion. Divers should stop here as a security measure and use up the remaining time of the immersion. Under these circumstances we found divers who leaned on the relief bottom observing the benthic fauna.

Some studies have shown better behaviour in women, not only technically but also regarding their respectful attitude towards the mean. They carried out a lower number of contacts with the relief bottom and caused less serious damage to the coral reefs (Rouphael and Inglis, 2001). In the present study, the conclusion that was reached was different. No type of significant differences regarding the gender of divers was detected. This was quite a logical consequence, because, if men as well as women receive the very same technical and environmental preparation, they should behave in the same way, without the existence of differences between them. In the same way, the results show that in the diving site of La Llosa, divers did not pay special attention to the contacts made in the relief bottom. This fact reflects low environmental awareness by divers, without this being a positive or a negative determining factor for the two genders..

Surprisingly, the results were the same for divermasters or instructors, without there being any kind of relationship between experience or certification levels and the damage caused on benthic organisms (Rouphael and Inglis, 2001). The most probable cause of this elevated number of contacts by divers with a higher diving certification would be the observation of the general pattern of their behaviour. Their concern is to keep an eye on the group of which they are in charge, which in many cases, it is the result of either it being the first time they dive on this site or not having enough experience even to control their own buoyancy. Another reason for the higher number of contacts would be the poor preparation and environmental awareness as well as some work habits, which could be noticeably improved. In this sense, we can observe how diving guides lean on the relief bottoms and attract species. Guides also urge divers to go into caves while they are lighting these spaces with their torches. It would be of great importance if this behaviour changed, because most divers act like their leaders (Barker et al., 2004), who are models for many of them.

The use of photographic cameras is a factor which could mean a more elevated number of contacts with the relief bottom (Medio et al. 1997). Although in the present study, coinciding with Rouphael and Inglis (2001)'s results, this aspect did not imply a higher number of contacts for divers who carried a camera. The type of photography under water as well as the equipment used was a determining factor. Nowadays, cost and size of underwater photography equipment has been reduced, thus, its utilization has been generalized amongst divers and the type of photography is also different. The option taken by most professional equipment is the macro photography type, for which divers need to either lean the



camera or them selves in order to capture a good image. In the area of La Llosa, we could check how the photographic equipment, which constituted only a complementary part, was mostly for digital formats and small in size. The type of photography analyzed was quite different from that of divers with professional or semiprofessional equipment. The technical equipment as well as the preparation of the divers were limited and the objective when taking the pictures was not artistic. In the majority of these pictures the prevailing images were underwater landscapes and the typical photo as a souvenir of the immersion; the resting of the camera on a surface was not necessary in these cases.

The use of torches or lighting equipment is not a present variable present in the majority of the works published, because it is highly probable that they affect the environmental conditions where these works have been conducted, generally coral reefs without many caves where immersions used to take place at daytime. Immersions on such sites are carried out at a minimum depth and their waters are characterized by high transparency. Those divers who carried torches made a higher number of contacts with their hands, because the mere fact of carrying torches makes divers' behaviour vary. They became more curious and had more access to cracks, caves or crevices, which could go unnoticed under other circumstances. During the sampling, we could verify that many divers coincided in a similar action, which was to grab a rock with one hand and use the other on to point the torch towards some kind of organism or formation hidden in the dark. Thus, contact with the hands was basic in this type of underwater relief where caves that are big in size are not frequently found, but cracks and crevices are. Therefore, the prohibition of the use of torches or the restricting of their use to diving leaders would imply a decrease in the number of contacts with hands, but this does not mean a decrease in the quality of the immersion.

A briefing prior to immersion was not an effective element to decrease the number of contacts with the relief bottom. This coincides with other works about divers' behaviour (Barker and Roberts, 2004). Briefings were performed in a short time and did not take longer than three minutes. They were offered on board right before the immersion, and they only gave technical advice, such as: immersion duration, underwater orientation in the area, pair system. Only on one of the occasions, environmental recommendations were proposed. The current briefings offered in the diving area of La Llosa are inappropriately conceived and designed. For their effectiveness contents as well as duration and the moment they are carried out should change. However, this objective could never be achieved, unless diving leaders receive better environmental preparation. Apart from the improvement in briefings, which would increase the environmental awareness of divers (Medio et al, 1997), another aspect that should be considered is the participation in all of the immersions of underwater guides with environmental preparation. This would be an effective tool for decreasing the number of diver contacts (Barker and Roberts, 2004) and also for reducing the size of the diver groups concentrated in the same interval of time. This would help to improve the quality of the immersion as well as the environmental conservation of the diving site.

## CONCLUSIONS

The greater number of contacts is made by divers with higher level of expertise. Instructors' and guides' way of working should be restated. The gender of divers does not determine the behaviour of the diver. The use of torches means a greater number of hand

contacts. It would be advisable to restrict their use. The use of cameras did not mean a greater number of contacts with the substratum. The kind of camera mostly used by divers was a determining factor. The briefings prior to immersion have proved to be useless in the way they are done at the moment. Their contents and methodology should change. It is advisable to carry out a study about the impact of diving on the marine ecosystems in the area for better planning and management of diving. Environmental awareness at all levels and among all participants (users, companies) is a key tool for diminishing the negative effects of diving.

## ACKNOWLEDGEMENTS

This study was funded by Fundació La Caixa. We thank the diving centers Poseidon (Benidorm) and Alisub's staffs (La Vila Joiosa) for providing logistical support for this study. We also thank Ana Codina and Mercedes Montero for the field work and collecting information from the divers. The field work would not have been possible without the support of Joaquín Martínez, Yolanda Múgica, Pau Fluixá, Enrique Díaz, Felio Lozano and Jaume Izquierdo.

## LITERATURE CITED

- BARKER N.H.L., ROBERTS C.M. 2004. SCUBA diver behaviour and the management of diving impacts on coral reefs. *Biological Conservation*, 120(4): 481-489.
- DAVIS D., TISDELL C. 1996. Economic management of recreational scuba diving and the environment. *Journal of Environmental Management*, 48: 229-248.
- DIXON, J.A. AND SHERMAN, P. B. 1990. Economics of protected areas: a new look of benefits and costs. Earthscan Publications, London.
- DIXON, J. A., SCURA, L. F., VAN'T HOF, T. 1993. Meeting ecological and economic goals: marine parks in the Caribbean. *Ambio*; 22: 117-125.
- ESTEBAN, J.L., DIOSDADO, G., GINER I. 1999. Estudio previo para la revisión de los criterios del buceo autónomo en la reserva de la isla de Tabarca (Alicante). In *I Jornadas Internacionales sobre Reservas Marinas*, Murcia (Spain), 1999. Secretaría General de Pesca Marítima (MAPA): Madrid, pp 147-162.
- FRANCOUR P., KOUKOURAS, A. 2000. Methods for studying the impact of diver frecuentation and mooring on coralligenous communities. In: R. Goñi, M. Harmelin-Vivien, F. Badalamenti, L. Le Diréach, G. Bernard (Eds.). *Introductory guide of methods for selected ecological studies in marine reserves*. *Gis Posidonie Publ.* Marseille: 69-74.
- GARCÍA PÉREZ, A. 1992. *Estadística aplicada: conceptos básicos*. UNED, Madrid. 405 p.
- Garrabou, J., SALA, E., ARCAS, A., ZABALA, M. 1998. The impact of diving on rocky sublittoral communities: a case study of a bryozoan population. *Conservation Biology*, 12(2): 302-312.



- HARRIOT, V., DAVIS, D., BANKS, S. 1997. Recreational diving and its impact in marine protected areas in Eastern Australia. *Ambio*, 26: 173-179.
- HAWKINS J.P., ROBERTS, C.P. 1992. Effects of recreational SCUBA diving on fore-reef slope communities of coral reefs. *Biological Conservation*, 26: 171-178.
- HAWKINS, J.P., ROBERTS, C.M., VAN, T HOF, T., DE MEYER, K., TRATALOS, J., ALDAM, C. 1999. Effects of recreational SCUBA diving on Caribbean coral and fish communities. *Conservation Biology*, 13: 888-897.
- HAWKINS, J.P., ROBERTS, C.M., KOOISTRA, D., BUCHAN, K., WHITE, S. 2005. Sustainability of SCUBA diving tourism on coral reefs of Saba. *Coastal Management*, 33(4): 373-387.
- JAMESON, S.C., AMMAR, M.S.A., SAADALLA, E., MOSTAFA, H.M., RIEGL, B. 1999. A coral damage index and its application to diving sites in the Egyptian Red Sea. *Coral Reefs*, 18: 333-339.
- KRUSKAL, W. H., WALLIS, W.A. 1952. Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, 47 (260): 583-621.
- LLORET, J. MARÍN, A., MARÍN-GUIRAO, L. CARREÑO M.F. 2006. An alternative approach for managing scuba diving in small marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 16: 579-591.
- MEDIO, D., ORMOND, R.F.G., PEARSON, M. 1997. Effect of briefings on rates of damage to corals by scuba divers. *Biological Conservation*, 79: 91-95.
- MEINESZ, A., BODERESQUE, C.F., FALCONETTI, C., ASTIER, J.M., BAY, D., BLANC, J.J., BOURCIER, M., CINELLI, F., CIRIK, S., CRISTIANI, G., GERONIMO, I., GIACCONE, G., HARMELIN, J.G., LAUBIER, L., LVORIC, A.Z., MOLINIER, R., SSYER, J., VAMVAKAS, C. 1983. Normalisation des symboles représentation et la cartographie des biocénosis benthiques littorales de la Méditerranée. *Ann. Inst. Océanogr.*, 59 (2): 155-172.
- MILAZZO, M., RAMOS-ESPLÁ A. 2000. Methods for studying the impact of trampling on rocky shallow areas. In: R. Goñi, M. Harmelin-Vivien, F. Badalamenti, L. Le Diréach, G. Bernard (Eds.). *Introductory guide of methods for selected ecological studies in marine reserves*. *Gis Posidonie Publ.* Marseille: 63-68.
- MILAZZO, M., CHEMELLO, R., BADALAMENTI, F., CAMARDA, R., RIGGIO, S. 2002. The impact of human recreational activities in marine protected areas: what lessons should be learnt in the Mediterranean Sea?. *Marine Ecology*, 23 (1): 280-290.
- MUNDET, L., RIBERA, L. 2001. Characteristics of divers at a Spanish resort. *Tourism Management*, 22: 501-510.
- PHILIPS, S. 1992. The dive tourism of Byron Bay: a management strategy for the future. Unpublished integrated project dissertation, Faculty of Resource Science and Management, University of New England-Northern Rivers, Australia.
- ROBERTS, L., HARRIOT, V.J. 1994. Recreational SCUBA diving and its potential for environmental impact in a marine reserve. In: Belwood, O., Choat, H., Saxena, N. (Eds.). *Recent Advances in Marine Science and Technology 1994*. James Cook University of North Queensland, Townsville, Australia, pp 695-704.
- ROUPHAEL, A.B., INGLIS, G.J. 1997. Impacts of recreational SCUBA diving at sites with different reef topographies. *Biological Conservation*, 82: 329-336.
- ROUPHAEL, A.B., INGLIS, G.J. 2001. "Take only photographs and leave only footprints": an experimental study of the impacts of underwater photographers on coral reef dive sites. *Biological Conservation*, 100: 281-287.
- SALA, E., GARRABOU, J., ZABALA M. 1996. Effects of diver frequency on Mediterranean sublittoral populations of the bryozoan *Pentapora fascialis*. *Journal of Marine Biology*, 126 (3): 451-459.
- SALM, R. V. 1986. Coral reefs and tourist carrying capacity: the Indian Ocean experience. *Industry and Environment*, 9: 11-14.
- SCURA, L. F., VAN 'T HOF, T. 1993. The ecology and economics of Bonaire Marine Park. Divisional Paper No. 1993-44. Washington D.C.: Environment Department, The World Bank, Washington D.C.
- TALGE, H. 1991. Impact of recreational divers on scleractinian corals of the Florida Keys. M. Sc. Thesis, University of South Florida, St. Petersburg, USA, pp. 92.
- TRATALOS J. A., AUSTIN T.A. 2001. Impacts of recreational SCUBA diving on coral communities of the Caribbean island of Grand Cayman. *Biological Conservation*, 102: 67-75.
- TRIVIÑO A., JIMÉNEZ-GUTIERREZ, S.V., LÓPEZ HERNÁNDEZ, N.E., MARTÍNEZ, J. 2006. Caracterización del turismo subacuático en Benidorm. In Troitiño-Vinuesa, M.A., García-Marchante, J.S. y García-Hernández, M. (Eds.). *Destinos turísticos : viejos problemas ¿nuevas soluciones ?*. Universidad Católica-La Mancha. 1-16 pp.
- UYARRA, C., CÔTÉ I.M. 2007. The quest for cryptic creatures: impacts of species-focused recreational diving on corals. *Biological Conservation* 136, 77-84.
- ZAKAI, D., CHADWICK-FURMAN, N.E. 2002. Impacts of intensive recreational diving on reef corals at Eilat, northern Red Sea. *Biological Conservation*, 105: 179-187.