



The impact of quad tourism: a preventive action for the Mediterranean

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Abstract

The Mediterranean region attracts annually more than 400 million tourists. In recent decades, quad tourism has grown, favoured by poor regulations. Environmental impacts of off-road vehicles have been widely studied in the USA, but not in the Mediterranean. This paper addresses that gap through a literature review on the impacts of motorized recreation, and an analysis of the current implementation of quad tourism in the region and of advertising topics. Main impacts were reported on soils, vegetation and wildlife. We have registered 337 quad agencies in 20 Mediterranean countries, with important concentrations in some regions. Half agencies promote their tours with images driving out of the trails, 22% crossing rivers, 9% driving on the beach, 7% on dunes and 23% sell the activity as an extreme adventure. It is necessary a stronger authorization framework, including the environmental impact assessment of these activities, more involvement of tour operators in environmental protection and greater education of the participants about the impacts of off-road driving and the importance of their behaviour. Further research in the region is also convenient.

Keywords Quad-bikes · ATV · Off-road driving · Motorized recreation · Environmental impact assessment

1 Introduction

The Mediterranean offers many hours of sunshine, drier climates than central and northern Europe, a beautiful nature, including extensive coastal areas, mountains, forests and deserts, and a rich cultural heritage, being the cradle of western civilizations

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like the Egyptians, Phoenicians, Greeks or Romans. As a result, the region annually attracts large numbers of tourists, who come to visit its cities, landscapes and coasts; the countries considered in this paper account more than 400 million tourists a year (WTO 2019), including the two countries with the most tourists in the world, France and Spain. Tourism is an essential economic activity in the region, and it has been promoted in all countries, with greater or lesser environmental respect. An increasing modality is adventure tourism (Williams and Soutar 2009), which includes activities that may be “soft”, such as hiking, cycling, scuba-diving, four-wheel driving, or “hard” like mountaineering, white-water rafting, kayaking, sky-diving. In recent decades, tourism associated with the use of quads (and buggies to a lesser extent) has proliferated in the Mediterranean region, as a fun, affordable and exciting alternative of outdoor leisure. Off-road driving is a popular activity in the USA for a long time, somewhat less widespread in Europe, although with a substantial annual increase currently.

Motorized recreation implies driving motor vehicles that can be operated cross-country, without the need for roads or trails, known as off-road vehicles (ORV) or off-highway vehicles (OHV). This group includes 4WDs, dirt bikes and light vehicles; military and professional vehicles are excluded. ORVs differ in dimensions, weight and power. 4WDs are cars adapted to off-road driving by incorporating four-wheel drive, and often differential locker and reduction gear; light types usually weigh 1200–1600 kg with 60–100 kW power, and conventional 1600–2500 kg and 100–200 kW, although some of them exceed 5000 kg and 300 kW. Light ORV included two main types, all-terrain vehicles (ATV) or quads and utility task vehicles (UTV) or buggies. In the 1970s, trikes were developed as an evolution of motorcycles; its success was great, but also the number of accidents due to stability problems. In the late 1980s, manufacturing was abandoned, giving way to ATVs, four-wheeled motorbikes, with a straddle seat and a handlebar for steering control. Initially used in agricultural tasks, recreational use soon became popular, firstly in the USA and Japan and later everywhere. UTVs are small cars, with a steering wheel. They have a double origin: buggies emerged in the 1950s as light cars based on a 4WD for recreational driving in the dunes (a after for desert racing); and an evolution of quads with a lower seat and a steering wheel. Light ORV regulations vary by country; in Europe usually light ATVs weigh less than 350 kg, displacement is lower than 50 cm³ and speed up to 45 km/h, and heavy ATVs and UTVs weigh less than 400 kg (550 kg in cargo), power up to 15 kW and speed of up to 70 km/h.

Almost half a century ago authors such as Stebbins (1974) or Busack (1975) already wrote about the environmental effects of off-road vehicles. Since then much has been published about the impacts of motorized recreation, especially in the USA. Off-road driving produce significant environmental impacts, especially on soils, vegetation and wildlife: vehicle circulation destroys the vegetation, compacts the soils and causes loss of organic matter, damages dunes, reduces air and water quality, and affects wildlife, by direct mortality, nuisance and loss of habitats. The damage caused by all these vehicles is similar, although the magnitude depends on vehicle characteristics and circulation intensity. Individual damage to soils or vegetation is usually more important in a 4WD due to its higher weight and grip; however, lightweight OTVs are more manoeuvrable and easier to drive off-road, accessing a larger area of the territory, and are more affordable, so their number is growing up faster. Wildlife mortality and noise disturbance are similar in light and heavy ORV; the main differences are traffic intensity and speed, both often higher in light vehicles when driving off-road. For example, 4WD tours typically involve few vehicles, while quad tours may include dozens. Consequently, although

damages of a single 4WD may be higher, the greater number of light ORVs implies that their impacts may be equal, or even greater.

The environmental regulation of quad tourism in the Mediterranean presents gaps. There are countries where tourism is not well planned or controlled, resulting in environmental pressures even on fragile ecosystems (Scoullou 2020). In addition, this activity is outside the scope of environmental impact assessment (EIA), and therefore is frequently subject to authorization without knowing its environmental impacts. Control measures are different between countries (and even regions in the same country) in requirements and time of application, *ex ante* or *ex post* (Bonnet et al. 2018). In the EU it is considered desirable to include biodiversity protection in the code of conduct for tour operators, identifying products with damage risks, such as excursions with motor vehicles (Styles et al. 2013), but this voluntary regulation is weak. The regulatory framework focuses more on economic and consumer protection aspects than on environmental protection, which have allowed a proliferation of motorized tourism in some areas, with debatable sustainability.

Motorized recreation, especially quad tourism, is proliferating in the Mediterranean, but their environmental effects, which undoubtedly occur as it happens in other regions, are not attracting the researchers' attention here, as evidenced by the low production of literature.

The aim of this study is highlighting the environmental impacts of quad tourism, assess its importance and extent in the Mediterranean region and draw attention to the need for regulations and environmental assessments to guarantee its sustainability. To achieve this, we have analysed, on the one hand, the environmental impacts of off-road motorized recreation reported in the literature, and on the other hand, the current implementation of quad tourism in the region, linking both aspects.

2 Methods

2.1 Research questions

This paper analyses the environmental impacts associated with quad tourism, especially in the Mediterranean region. There are two research questions: what are the environmental impacts caused by off-road motorized recreation, answered through a review of the existing academic literature; and what is the current degree of implementation of quad tourism in the Mediterranean, and the potential effects on the environment, answered through a search for quad agencies in the region, and by analysing the advertising of their activities. In the discussion, both results have been analysed together.

2.2 Study area

The study area includes all the countries that border the Mediterranean Sea. As an exception, we have included three countries not bordering the Mediterranean, but culturally and functionally included in the region (Andorra, Portugal and San Marino). The Atlantic islands of Spain and Portugal (Canary Islands, Madeira and Azores), as well as the French overseas territories, have been excluded. As a result, 26 countries have been considered (2 of them with limited international acceptance): Albania, Algeria, Andorra, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Northern Cyprus, Palestine, Portugal, San Marino, Slovenia, Spain, Syria, Tunisia and Turkey.

2.3 Literature review

Literature searches have been conducted using Scopus, a database and search engine that collects most of what is considered academic literature, and more extensive in content than Web of Science. Searches have been carried out combining two terms, one first related to vehicles, and one second related to the environment or vehicle impacts (Table 1). This study considers the term “quad” in the broad sense, including ATVs for tourist use or quads in the strict sense and buggies or UTV. However, these vehicle types are too restrictive to carry out literature searches, so we have included also ORV and OHV. The terms “quad” and “buggy/buggies”, and the abbreviations “ATV”, “ORV” and “OHV” produce a large number of results, most of them unrelated to the research topic, so we have avoided or used the full names. For the literature review no spatial limits have been established; in fact, as indicated below, most studies refer to the USA, and to a much lesser extent Australia, with a low representation of studies from Africa, Asia or Europe.

Combining both terms 25 searches were performed, obtaining 1917 results. The results were exported to Refworks, removing duplicates, which reduced them to 1291. After that, a review was made based on document titles, eliminating those not related to the study topic, which reduced the sample to 273 results. The elimination criteria were based on the topic addressed in the papers, which was sometimes unrelated to this study despite some keywords coinciding. In any case, it was always chosen to keep the papers with a doubtful relationship with the topic for a subsequent in-depth analysis. Finally, these results were analysed in detail, reading the abstracts and, in case of doubt, the text, reducing the sample to 176 results. A list of these references is included in the Supplementary Data 1.

2.4 Quad agencies and activities in the Mediterranean

We searched agencies that rented quads or organized tours in each of the countries included in the study area; dealers selling these vehicles have not been considered. To locate the agencies we have used a general search engine (Google). Searches have been carried out country by country, or by region (such as departments in France, regions in Italy or autonomous communities in Spain) in large countries. In each case, two search terms have been used, one related to the type of vehicle and the other to the activity offered (Table 2).

We assume that these activities are focused to tourists, national or international; consequently, the agencies need to advertise their services or at least their location on the internet, because otherwise tourists could hardly know that they exist. In most cases, the terms used in advertising are English and easy to understand (almost always “quad” and “tour” or “rental”); however, we have also used terms in French, Italian and Spanish in the countries where these languages are official, because they are the three most

Table 1 Search terms for the literature review

Search term 1		Search term 2
Quad-bike/s		Impact/s
All-terrain vehicle/s		Environment
Off-road vehicle/s	AND	Environmental
Off-highway vehicle/s		Ecosystem/s
Motorized recreation		Wilderness

Table 2 Search terms for quad agencies and activities

Country			Search term 1		Search term 2	
Albania	Greece	Northern Cyprus				Rental
Algeria	Israel	Palestine				Balade/s (Fr)
Andorra	Italy	Portugal	AND	Quad/s ATV Buggie/s	AND	Escursioni (It)
Bosnia and Herzegovina	Lebanon	San Marino				Excursion/es (Sp)
	Libya	Slovenia				Excursion/s
Croatia	Malta	Spain				Percorso (It)
Cyprus	Monaco	Syria				Randoneé/s (Fr)
Egypt	Montenegro	Tunisia				Ruta/s (Sp)
France	Morocco	Turkey				Tour/s

important countries in number of tourists in the region (and two of them in the world), with great weight also of national tourism. The searches were carried out throughout March 2020.

We have consulted the available information of each agency (website or Google references) and the attached photographs. Firstly, we registered if the agency rented the quads, organized tours or both. To assess the potential significance of the environmental impacts of the quad tours a first random analysis of photographs used in advertising was made, identifying the aspects most commonly shown. Based on this, we have established five indicators, easy to detect through the agencies' advertising: driving out of the trails (not on unpaved tracks); crossing rivers or streams (not puddles on the trails); driving on the beach or along coastal dunes; driving on desert dunes; and promoting the activity as an extreme adventure (e.g. jumping with quads, driving on two wheels, extreme river crossings, mud-covered drivers, high-speed driving...). Each tour can be included in one, several or none of these categories.

We have also considered the landscapes that appear in the photographs. Firstly, it was analysed whether natural areas appeared, which occurred in all cases. Some landscapes have been selected because they appear frequently in the images and are often cited in the literature regarding their environmental impacts: coastal areas, forests and deserts. Each agency was included in one, several, or none of these categories, which do not include all of the landscapes represented, but the most significant for the impacts cited.

We calculated the number of agencies that rented or organized tours and their percentages for each country and for the whole. For organized tours, we have also calculated the percentages of impact indicators and landscape types. The list of agencies and tour characteristics is included in the Supplementary Data 2.

Based on data from the World Tourism Organization (2019), we have collected the number of international tourists for each country in 2018 (latest figure available). Four countries had not information for 2018: Algeria had data for 2017, Syria in 2010 (before the war broke out) and Libya and Northern Cyprus had no information at all. In any case, none of these countries have records of quad agencies.

Finally, we have included all the collected agencies in a GIS layer, obtaining a distribution map. In locations with more than one agency we used larger symbols, proportional to their number, to visually show the areas with the highest intensity of quad tourism.

3 Results

3.1 Environmental impacts of off-road motorized recreation

The environmental impact of tourism is a topic that has attracted the attention of researchers for decades, whose have highlighted the problems associated with displacements and the effects on the environment, cultural heritage or the local population. In recent years, there has been a growing interest regarding its contribution to climate change. Mc Kercher (1993) presents several reasons for these impacts, and for the difficulty in reducing them: is an industry, and consumes resources (some of them scarce or that may be over consumed), generates waste and requires infrastructure; there is a dominance of the private sector, which seeks to maximize profits; is a multi-faceted character; tourists are consumers seeking entertainment; and generates income by importing clients.

The impact of tourism depends on its typology, with a wide range of possibilities (e.g. cultural, environmental, gastronomic, relaxation, adventure) and intensities (individual, group, massive). An important type of tourism is that based on the contact with nature, through outdoor activities, traditionally hiking, camping or cycling, although there is a growing trend towards adventure tourism, and within it, to off-road driving, especially quads.

We analysed 176 literature references on off-road motorized recreation impacts, from 1974 to 2020. There is increasing attention to this topic over time (Fig. 1, left), with a qualitative leap from the 2000s, specifically in 2007. The USA is the main country in studying this topic; references related to the USA were 91% in 1980, 86% in 1990, 73% in 2000 and 64% nowadays. It is followed at a long distance from Australia (12.5%) and Canada (6.3%); South Africa, Kuwait and Saudi Arabia have more than one reference and the rest of countries only one (Fig. 1, right). In the Mediterranean, there were only 3 references (Israel, Portugal and Spain), none specifically referring to ATVs, and the second two dealing very briefly the topic.

The ecological areas most frequently studied (Fig. 2, left) were beaches (24%) and deserts (15%). Regarding to affected environmental resources (Fig. 2, right), the most studied were fauna (33%), followed by vegetation (29%) and soils (26%).

The effects of off-road motorized recreation on the environment can be very significant, affecting mainly soils, vegetation, wildlife and landscape, especially when vehicles circulate off existing trails. As an example, Gilbertson (1981) considered that historical activities in an Australian dune system (European and pre-European) had a minor impact

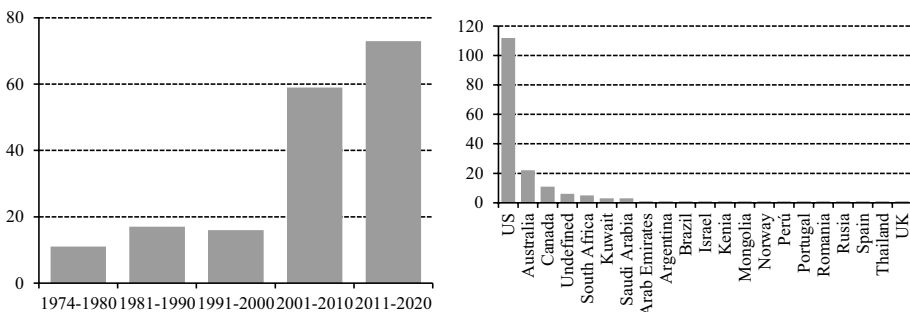


Fig. 1 Literature references to off-road motorized recreation impacts by years (left) and countries (right)

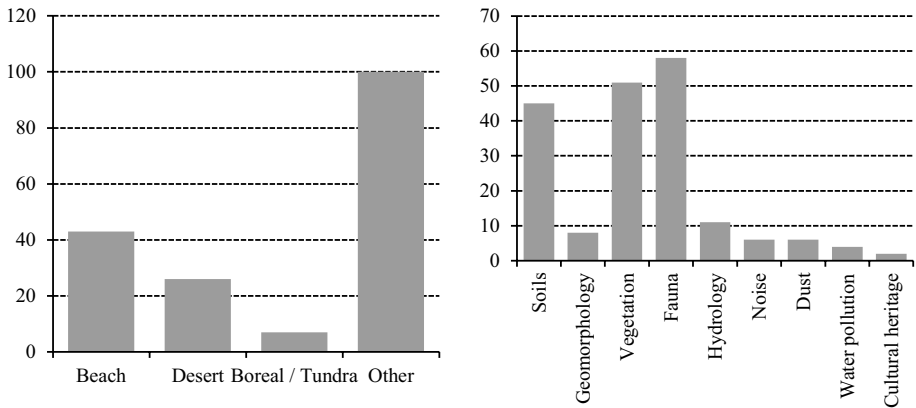


Fig. 2 Literature references to environmental impacts of off-road motorized recreation by zones (left) and resources (right)

compared to the use of off-road recreational vehicles. These impacts have sometimes been undervalued; in three motorcycle races in the Mojave Desert (US) the damages exceeded the expectations of the managing agency between 360 and 640% (Wilshire 1983). Table 3 summarizes the main impacts of motorized recreation reported in the literature.

Vehicle circulation produces direct effects on soils, depending on the weight, power, grip and number of vehicles. Weight and circulatory intensity produce compaction, closing soil pores and thereby increasing bulk density up to 18–38% (Wilshire et al. 1978; Assaeed et al. 2019); on average a single vehicle pass was equivalent in density increase to 10 human footprints (Lei 2004), although the vehicle has a more spatially concentrated effect. In addition, compaction reduces infiltration and soil moisture up to 43% (Wilshire et al. 1978). Tire grip erodes the soils, especially in manoeuvring areas (Berno et al. 1996) or when much traction is applied, resulting also in loss of organic matter and nutrients, which produces up to 33% reduction in organic carbon (Wilshire et al. 1978). Damage depends on soil characteristics and traffic, but sometimes a single vehicle pass cause disruption (Webb et al. 2013). Soils of arid and semiarid zones are prone to degradation by off-road traffic (Belnap 1995; Whitbeck and Fehmi 2016; Kobryn et al. 2017; Switalski 2018; Assaeed et al. 2019). Recovery can be slow; nitrogen fixation capability, for example, requires at least 50 years (Belnap 1995), and plant recolonization may be difficult if not impossible. In soft soils, with low bearing capacity, vehicles sink and form deep ruts; that occurs in wet areas, river beds, after heavy rains and in northern areas as a result of permafrost thawing (Slaughter et al. 1990; Hambleton and Drescher 2008; Arp and Simmons 2012).

Coastal systems were the geomorphological elements most commonly cited as damaged in the literature. Vehicles cause sand displacement in the dunes, reducing their size and producing blowouts (Araujo et al. 2006); dunes were systematically destroyed in some areas (Vogt 1979), affecting the coastal landscape, vegetation and the evolution of the dune system. The same process also occurs in desert dunes. Beaches were also affected: Schlacher and Morrison (2008) detected damages in 15% of the intertidal zone after 10 vehicle passes, and up to 85% after 100 passes. In addition, tracks can persist in the wind-tidal flats for at least 38 years (Martin et al. 2008).

A repeatedly reported effect in the literature was the alteration or destruction of vegetation. The weight of the vehicles crushes the plants, and the grip of the tires can rip

Table 3 Main environmental impacts of off-road motorized recreation

Factor	Impacts	References ^a
Soils	Compaction, reduction of pore space and increase in bulk density	2, 5, 13, 18, 28, 43, 68, 78, 87, 91, 93, 99, 112, 121, 125, 132, 133, 143, 147, 152, 153, 166, 167, 172, 173
	Increased wind and water erosion, gully formation and soil loss	10, 18, 52, 61, 77, 78, 87, 93, 99, 117, 121, 143, 147, 152, 156, 166, 167, 172
	Reduction of organic carbon and nitrogen, and nitrogenase activity	5, 18, 19, 78, 173
	Reduction of water infiltration	18, 28, 47, 93, 173
	Reduction of organic layer, slowed decomposition, lower nutrient levels	18, 78, 160, 167
	Reduction of moisture content	5, 167, 173
	Change in soil structure and horizon destruction	50, 172
	Decreased diversity and abundance of soil biota	18, 143
	Increased diurnal temperature fluctuations	167, 173
	Increased bare ground	13, 110
	Higher soil electrical conductivity	13
	Destruction of soil stabilizers	93
	Permafrost thawing	10
	Reduction of soil pH	112
Geomorphology	Dune modification or destruction, blowout formation, sand displacement	6, 7, 9, 57, 58, 67, 133, 160
Vegetation	Vegetation trampling, damage and/or destruction and cover reduction	7, 10, 13, 23, 24, 31, 43, 50, 61, 68, 87, 89, 93, 112, 121, 125, 130, 147, 152, 153, 156, 160, 161, 172, 173
	Increases of weeds, ruderal and alien species (introduction and dispersal)	13, 53, 56, 97, 112, 121, 122, 129, 152
	Difficulty in regeneration, slow recovery and poorer new vegetation	53, 83, 125, 160, 167
	Reduction of plant species diversity	8, 53, 68, 99, 112
	Changes in vegetation composition, structure and species dominance	99, 112, 121
	Plant height reduction	13, 130
	Reduction of plant species abundance and density	62, 103
	Increased access, allowing tree cutting	14

Table 3 (continued)

Factor	Impacts	References ^a
Fauna	Reduction of animal species abundance and density	16, 41, 54, 66, 76, 79, 85, 93, 136, 148, 155, 161, 163
	Direct mortality: crushing, burying or slaughter	86, 107, 118, 136, 137, 144, 147, 172, 176
	Animal disturbance	14, 92, 126, 127, 142, 145, 147, 165, 170
	Habitat degradation or loss and animal displacement	10, 14, 17, 60, 86, 144, 147, 150, 174
	Alteration of reproductive cycle, productivity, growth and/or survival	29, 95, 102, 118, 128, 144, 164
	Nest/burrow damage and abandonment	16, 29, 172
Hydrology	Reduction of animal species diversity	25, 41, 99
	Reduction of preys or food availability	86, 174
	Dispersal of invasive animal species	15
	Hunting from vehicles	14
	Increased sediment contribution in channels	28, 47, 48, 61, 87, 96, 131, 132
	Runoff increase	10, 28, 87, 153
	Gullying and alluvial fan formation	61,77
	Alteration of channel morphology and riverbed	96
	Alteration of downstream flow regimes	10
	Dust	40, 46, 59, 111, 117
Pollution	Water pollution	10, 52, 108, 152
	Noise	14, 92, 93
	Damage to cultural resources	100, 147
Cultural heritage	Damage to cultural resources	12, 20, 32, 33, 36, 37, 40, 42, 49, 55, 70, 72, 73, 82, 84, 119, 138, 139, 141, 147, 158, 162, 169, 175
	Conflicts between off-road recreation a conservation and/or other uses	40, 42, 67, 119, 135, 162
Social impacts	Ignorance or disregard of the environmental impact	117
	Human health risk (dust)	

Table 3 (continued)

Factor	Impacts	References ^a
Other impacts	Environmental or ecosystem damage (not detailed)	4, 12, 20, 21, 32, 33, 36, 37, 40, 42, 49, 51, 52, 55, 70, 75, 84, 88, 90, 92, 101, 115, 116, 119, 123, 139, 141, 146, 147, 158, 159, 169,
	Creation of unplanned trails and/or widening of existing ones	52, 77, 110, 121, 157, 169, 171
	Introduction and spread of pathogens	35, 121, 152
	Landscape degradation and visual impacts	13, 87, 172
	Habitat fragmentation	99

^aReferences can be found in the Supplementary Data 1

them off. Damage depends on the number of vehicle passes (Onyeanusu 1986; Anders and Leatherman 1987; Rickard et al. 1994), up to a threshold in which becomes catastrophic (Dickson et al. 2008); Brodhead and Godfrey (1977) quantified this threshold in a dune system between 300 and 700 passes. Some authors considered this impact devastating (Vogt 1979; Dewidar et al. 2016). Soil moisture and circulation speed also influence damage (Dickson et al. 2008; St-Louis et al. 2013). Plant cover and richness (Hosier and Eaton 1980; Navas et al. 2019) and even height (Rickard et al. 1994) were significantly lower in disturbed sites; when fences were placed plant abundance and richness inside them were significantly higher (Brooks 1995; McGrann et al. 2005). In addition, threatened species may be affected; Groom et al. (2007) points to a reduction in one species by 4–5 times, and Hernández-Yáñez et al. (2016) estimate that off-road vehicles affect 19% of threatened species from the continental US. The greatest impacts are registered on the vegetation of arid and coastal areas, because it grows in difficult conditions, near the physiological limit of subsistence, and therefore it is very sensitive to any alteration, and recovery is difficult. Also humid areas are sensitive ecosystems, especially when driving on wet soils. Vegetation recovery is slow; vehicle tracks damage soil seed banks (Kinugasa and Oda 2014), and soil degradation hinders germination of seedlings (Webb et al. 2013). The type of plant community (Dickson et al. 2008) and the species present is highly relevant, since they may have greater or less resistance to crushing and regeneration capacity; however, in bared surfaces few types other than ruderal grasses colonize (Forbes 1992), and after recovery the vegetation may present less floristic diversity (Andreyashkina 2012).

Effects on fauna can be significant and even critical if affecting threatened species. Off-road traffic produces noise and increases human presence, which frighten animals, leading to lower abundance, diversity and species richness (Davies et al. 2016). Different studies showed reductions in the populations of beetles (Knisley et al. 2018), crabs (Steiner and Leatherman 1981; Foster-Smith et al. 2007), birds (Tarr et al. 2010; Jones 2015), foxes (Jones et al. 2017) or macrobenthos (Walker and Schlacher 2011). Damages to vegetation and soils involve habitat disturbance, affecting wildlife (Preisler et al. 2013). Off-road traffic disturbances are especially important during the reproductive period, producing greater nest abandonment (Barton and Holmes 2007), shorter incubation time (McGowan and Simons 2006; Hillman et al. 2015), lower productivity (Pauli et al. 2017) and smaller size of individuals (Lucrezi and Schlacher 2010), and affecting species movement, such as turtles displacement to the ocean (Hosier and Kochhar 1981). Another effect associated with off-road traffic is mortality, by collision or crushing, such in beetles (Knisley and Hill 2001), birds (Melvin et al. 1994), crabs (Wolcott and Wolcott 1984, Schlacher et al. 2007; Steiner and Leatherman 1981) or lizards (Wilshire 1983), by nest destruction (up to 81% on a beach, Buick and Paton 1989) or by crushing burrows (crabs buried shallow were killed by 10 vehicle pass; Schlacher et al. 2007). Other reported effects were the reduction of preys (Knisley and Hill 2001; Grant and Doherty 2009) and the spread of invasive species (up to 92 km away; Banha et al. 2014).

Off-road traffic produces several effects on environmental quality. An impact highlighted by several authors was dust emission, which affects air quality, causing discomfort to animals and even locally may threaten human health (Padgett et al. 2008). Dust levels are 61–80 times greater in areas with off-road traffic (Nauman et al. 2018; Duniway et al. 2019). Emissions are greater in quads than in buggies, with major influence of speed (Goossens and Buck 2009). Another noted impact is water pollution (Foltz and Yanosek 2005; Miniati et al. 2019), produced by watercourses crossing (turbidity may be increased by sediment stirring and there is a risk of oil and fuel spillage) and silting due to increased

erosion in disturbed soils. Vehicle circulation raises noise levels (Attum 2007; Lerdsuchatavanich et al. 2017), affecting fauna and population, both residents and visitors.

An uncontrolled movement of off-road vehicles can cause impacts on cultural heritage; the reference to damage to a geoglyph from the Nasca period in Peru was remarkable (Masini and Lasaponara 2020).

Motorized and non-motorized recreation is antagonistic, so conflicts between users are frequent when both coincide in the same territory (Shilling et al. 2012). Many works (see Table 3) analysed the conflicts between supporters and detractors of motorized recreation, and the way to confront and regulate them, especially in protected areas and federal lands in the USA. There is no agreement between the authors in this regard, where environmental, social, economic and even political aspects are mixed: while some authors propose uses regulation or highlights the economic importance of motorized recreation, others propose restrictions due to the environmental damage caused, and even consider it an activity simultaneously “environmentally destructive, a substantial health burden, socially disruptive and economically unjustified” (Bissix 2012).

Although not the aim of this research, we want to highlight the high number of papers about ATV accidents, even in children. As an example, Müller et al. (2010) indicate as accident reasons the few active and passive safety measures, the limited user experience and the recreational use that leads to risky driving behaviour (in the US alcohol abuse and limited use of helmets were also reported). Quads are vulnerable to rollover, to the point that Hicks et al. (2018) indicated that they should not be considered suitable for farm tasks.

3.2 Quad tourism in the Mediterranean

We have registered 337 quad agencies in 20 countries (Fig. 3). Coastal areas have the greatest number of agencies, with major concentrations on southern Turkey, Cyprus, Greek Islands, Dalmatia (Croatia), Gozo (Malta), Sicily, Sardinia, Corsica, Djerba (Tunisia), Rousillon (France), Balearic Islands, Catalonia and Malaga (Spain), Algarve (Portugal) and the Atlantic coast of Morocco. Outside coastal areas there are concentrations

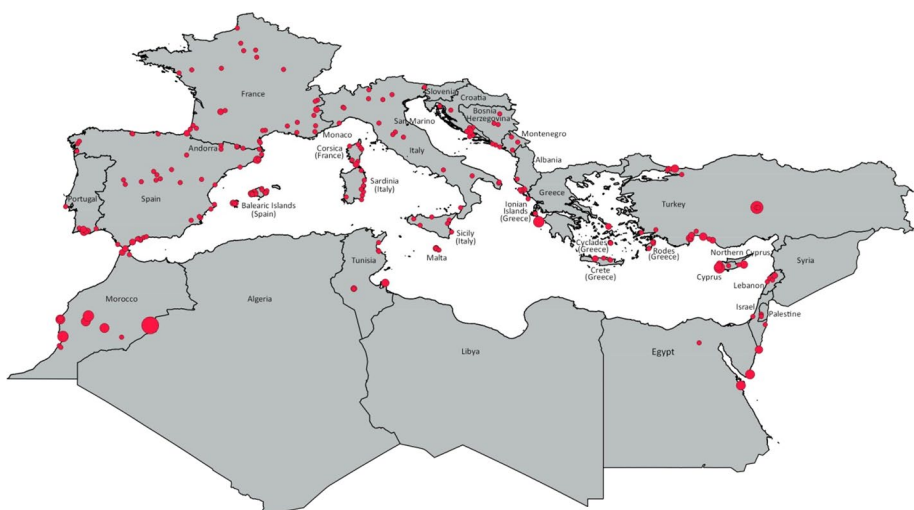


Fig. 3 Quad agencies in the Mediterranean. Dot size is proportional to the number of agency in each place

in Cappadocia (Turkey), desert areas of Tunisia and Morocco and the Egyptian resorts of Sinai and the Red Sea. The countries with the largest number of tourists (France, Spain and Italy) have agencies scattered throughout their territory, although with large empty areas. Results by country are summarized in Table 4.

Spain was the country with more quad agencies, and is the second in the region, and in the world, by number of tourists; the first was France, third in this list (Fig. 4). Morocco, Greece, Italy or Turkey, had also a high number of tourists and agencies. Cyprus had a high number of agencies for a small country, with much less tourism. In six countries, no agency were detected: Libya and Syria are at war; Algeria has security problems due to terrorism; Northern Cyprus has very little international recognition; and Monaco and San Marino are very small. In Palestine, the only agency is located in an Israeli settlement within its territory.

All the analysed tours are advertised with photographs in natural landscapes, although sometimes images of villages are also included; it is an activity developed in nature. Images of coastal areas (30%), forests (21%) and deserts (15%) are the most common (Fig. 5).

Regarding to impact indicators in tour advertising (Fig. 6), off-trail driving is an attraction in 51% of cases; only two countries do not use it, while in some regions such as the Balkans, Egypt, Israel, Tunisia or Morocco exceeds 75%. River crossing, an impressive activity, is advertised in 22% of cases, and is common in almost all countries, especially in Spain, France and Turkey; where it is not advertised usually is due to the scarcity of permanent watercourses. Beach driving is widely offered in Morocco and Tunisia, and less in Spain, Cyprus, Egypt, Israel, Italy and Turkey. Driving on desert dunes is dominant in Morocco (55% of tours). Shocking photographs of quads jumping, skidding in the mud or crossing rivers at high speed were included by 23% of the agencies, to sell the activity as an extreme adventure; it is difficult to achieve an environmentally respectful behaviour in the participants if they are looking for adventure. On small islands this lure is usually scarce: quads are offered as a funny means of transport.

4 Discussion and conclusions

Analysing the two parts of this research together we find a disagreement: research on environmental impacts of off-road recreation is concentrated in the USA, with minimal production in the Mediterranean countries, but this region accounts for 30% of world tourism and quad biking is a frequent activity. Are Mediterranean drivers much more respectful than US drivers, or are the impacts of this activity going unnoticed? It seems more like the second.

Several reasons can explain this situation, varying by country. In the USA, there has been a great fondness for off-road driving for decades. In addition, the country is reluctant to governmental limitations. As a consequence, although the environmental impacts of off-road driving are known, is a regulated activity, allowed in certain areas, but not prohibited. Much research tries to demonstrate the impacts of these activities to force regulations, but not so much to prohibit them. EU governments are much more interventionist in environmental protection, and in fact, off-road driving is prohibited in much of the territory. However, those prohibitions focused on the traditional 4WD use. Quad bikes have emerged recently, entering in the tourist market, and avoiding the most controlled areas, such as protected areas, to circumvent the prohibitions. However, it seems that they are usually little controlled activities, and even for their advertising near to illegality. In

Table 4 Quad agencies, tour characteristics and international tourists per country

Country	Type of quad agencies ^a				Quad tour characteristics ^a							Country tourists			
	All Rental		Tours		Tour advertising aspects							Tour environment		Tourists in 2018 (×1000)	Ratio ^c (×1000)
	No	%	No	%	Off-trail	River crossing	Beach driving	Desert dunes	Extreme driving	Coast	Forest	Desert			
Albania	1	100%	0	0%	-	-	-	-	-	-	-	-	5.340	5.340	
Algeria	-	-	-	-	-	-	-	-	-	-	-	-	2.451	-	
Andorra	3	33%	3	100%	33%	33%	0%	0%	33%	0%	67%	0%	3.042	1.014	
Bosnia & H.	3	0%	3	100%	100%	33%	0%	0%	100%	0%	100%	0%	1.053	351	
Croatia	13	2	15%	12	92%	83%	25%	0%	42%	25%	25%	0%	16.645	1.280	
Cyprus	16	7	44%	11	69%	18%	0%	9%	0%	82%	9%	0%	3.939	246	
Egypt	9	0	0%	9	100%	89%	0%	11%	11%	0%	100%	0%	11.346	1.261	
France	40	4	10%	36	90%	64%	28%	0%	39%	19%	28%	0%	89.400	2.235	
Greece	33	24	73%	11	33%	9%	9%	0%	9%	73%	9%	0%	30.123	913	
Israel	7	2	29%	5	71%	80%	40%	20%	20%	20%	40%	80%	4.121	589	
Italy	31	3	10%	28	90%	43%	7%	4%	25%	11%	36%	0%	62.146	2.005	
Lebanon	5	0	0%	5	100%	40%	40%	0%	40%	20%	0%	0%	1.964	393	
Libya	-	-	-	-	-	-	-	-	-	-	-	-	Unknown	-	
Malta	5	3	60%	2	40%	0%	0%	0%	0%	100%	0%	0%	2.599	520	
Monaco	0	-	-	-	-	-	-	-	-	-	-	-	347	-	
Montenegro	3	0	0%	3	100%	100%	33%	0%	67%	0%	67%	0%	2.077	692	
Morocco	43	1	2%	42	98%	76%	10%	17%	5%	29%	0%	57%	12.289	286	
N Cyprus ^b	-	-	-	-	-	-	-	-	-	-	-	-	Unknown	-	
Palestine ^b	1	0	0%	1	100%	0%	0%	0%	100%	0%	0%	0%	606	606	
Portugal	13	0	0%	13	100%	38%	31%	0%	15%	31%	8%	0%	22.800	1.754	
San Marino	-	-	-	-	-	-	-	-	-	-	-	-	84	-	
Slovenia	1	0	0%	1	100%	100%	100%	0%	0%	0%	100%	0%	4.425	4.425	

Table 4 (continued)

Country	Type of quad agencies ^a				Quad tour characteristics ^a						Country tourists				
	All		Tours		Tour advertising aspects						Tourists in 2018 (×1000)	Ratio ^c (×1000)			
	No	%	No	%	Off-trail	River crossing	Beach driving	Desert dunes	Extreme driving	Coast			Forest	Desert	
Spain	70	11	16%	59	84%	37%	35%	3%	0%	25%	38%	20%	0%	82.773	1.182
Syria ^c	-	-	-	-	-	-	-	-	-	-	-	-	-	Unknown	-
Tunisia	9	0	0%	9	100%	78%	0%	44%	22%	0%	67%	11%	33%	8.299	922
Turkey	31	2	7%	29	94%	31%	31%	3%	0%	28%	10%	34%	0%	45.768	1.476
Global	337	61	18%	283	84%	51%	22%	9%	7%	23%	30%	21%	15%	413.637	1.227

^a Agencies can be included in one or both categories at the same time; tours in one, several or none of the categories

^b Limited recognition

^c The number of tourists in 2010 (before the war) was 8,546,000

^d Number of tourist/Number of quad agencies

Fig. 4 Number of quad agencies. Orange: Tours. Blue: Rental

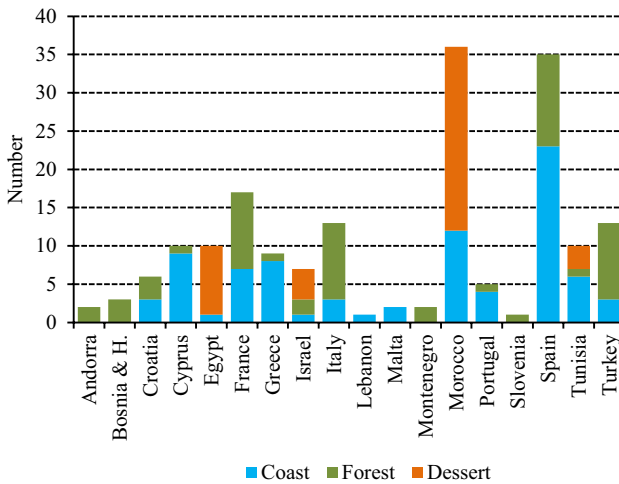
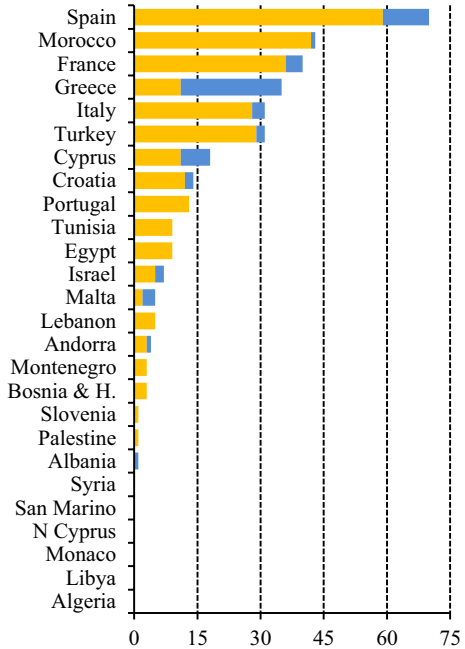


Fig. 5 Main quad tour landscapes in advertising (tours can be included in one, several or none of them)

non-EU Mediterranean countries, environmental regulations are less stringent, allowing a more impactful quad tourism, such as dunes or beach driving, frequent for example in Tunisia and Morocco. It is not always so; quad tours in Cappadocia (Turkey) are intense, with significant dust or noise problems, but off-road driving is rare.

It is easy to blame governments for their laxity in environmental protection regulations; a duality between conservationist EU countries and non-member countries, less concerned

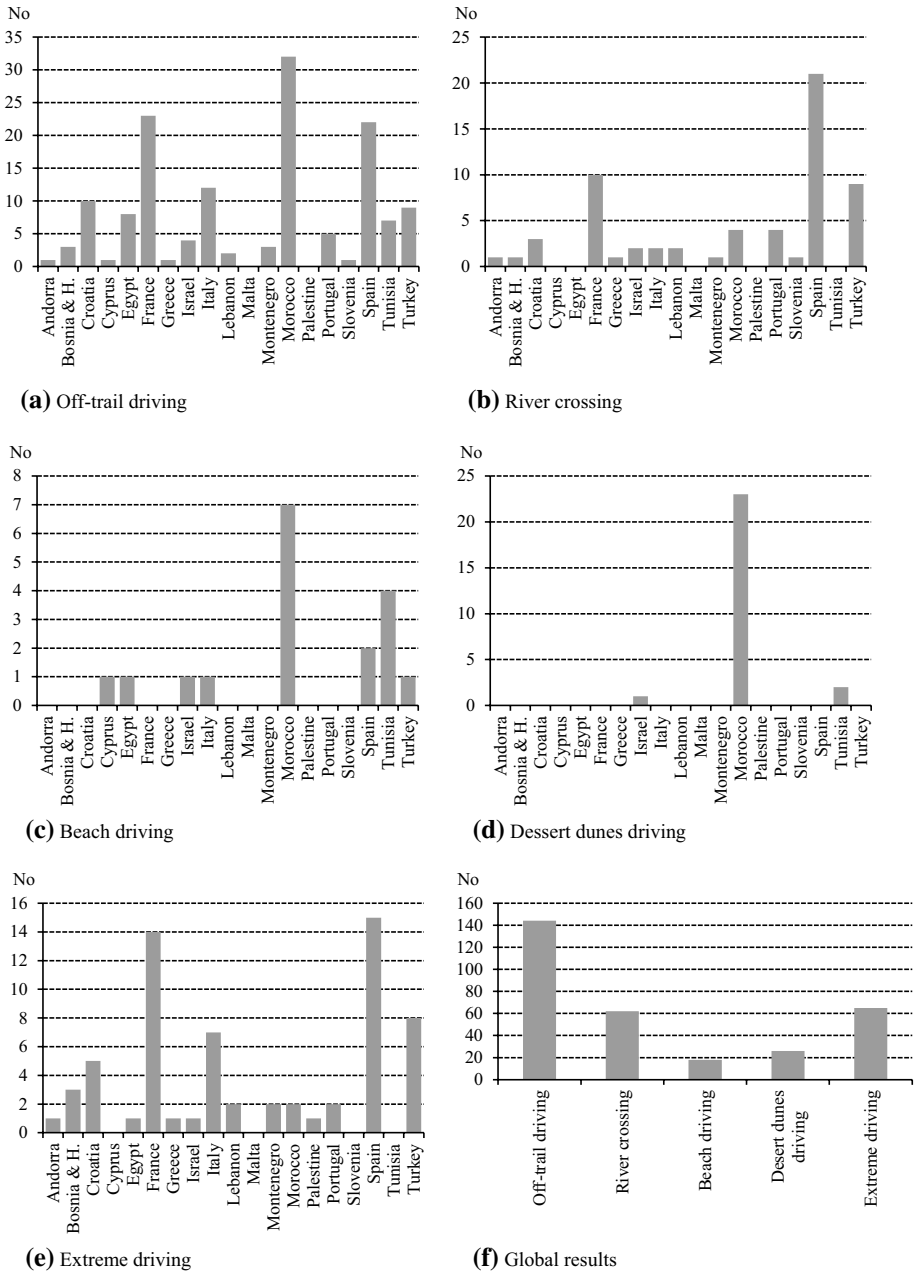


Fig. 6 Impact indicators in quad tours advertising

about the environment. However, the complexity in responsibilities is greater. The states' environmental regulations have an undoubted influence, but even EU does not have a legal framework that guarantees adequate environmental protection against these activities, proposing a voluntary code of conduct for tour operators (Styles et al. 2013), which does

not provide reliable guarantees. A complex discussion is whether quad tourism should be banned, limited or regulated. It is an old discussion in the USA, where there are specific OHV trails, even in national parks, something unthinkable in the EU. But quad tourism exists, and at the moment is poorly regulated. There are major impacts that can be significant, and little or no compatibility with other uses, such as non-motorized outdoor activities. But this activity has also become a magnet for tourism, especially in certain areas of Turkey, Egypt or Morocco, but also in many parts of France, Italy or Spain. The key to determining if a quad activity is sustainable is to know its environmental effects, that is, to carry out an environmental impact assessment (EIA). However, as an activity, and not as a project, it falls outside the scope of EIA. Only adequate evaluation of impacts, alternatives and mitigation measures should allow authorizations with guarantees of environmental protection. Consequently, it would be necessary to incorporate these activities, like many others, into the cases subject to EIA; new activities arise, and regulations should be adapted to achieve effective environmental protection.

Other responsible for the impacts are tour operators, which sometimes offer not sustainable activities, which may generate significant effects on the environment. There has been an explosive growth in adventure tourism, and as part of it of quad tourism, creating a competitive market that forces cuts in terms of safety and sustainability to be financially viable (Williams and Soutar 2009); competition also leads to impressive advertising, such as highlighting the adventurous aspects of the activity. This is especially noticeable in locations with a high number of agencies. Advertisements that match consumer wishes are more likely to get the desired response (Blackwell et al. 2006), so agencies promote their products in the most attractive way; tourism experiences are constructed in the imagination through advertising (Morgan and Pritchard 2000). Quad agencies often advertise their tours with photographs of off-trail driving (which affects soils and vegetation), river crossings (which affect watercourses and water quality), driving on beaches or dunes (which disturbs or kills wildlife and destroys dunes) and extreme or aggressive driving (which multiplies the impacts of the activity). Some photographs in the advertisements may not correspond to the tours offered; however, for the most part they are non-professional photographs that seem to refer to them, and only occasionally spectacular driving photographs, apparently professional, are used. Consequently, the main tourist lures used are closely related to the greater environmental impacts of this activity. It is difficult to require agencies, private companies competing in an often saturated market, to change their way of acting, or to adopt codes of good conduct; this would require positive reinforcement from its clients.

It is necessary to ask, therefore, who causes the impacts, the countries, the agencies, or the tourists who participate in these activities. And it is also necessary to ask where these tourists come from; in this region the answer is clear: mainly from the EU. In other words, citizens of EU countries do not hesitate to carry out activities prohibited in their own countries, such as driving on the beach, in the countries they visit as tourists. Even within the EU, in Spain or Portugal, for example, the areas with the highest concentration of quad agencies are those preferred by Central European tourists, and even some agencies are owned by foreigners and advertising and language are focused on their compatriots.

If these activities have a significant environmental impact, why do tourists practice them? Tourists come mainly from wealthy countries or social strata, frequently living in urbanized areas with a lack of outdoor component; they are “cash-rich and time-poor” (Buckley 2003), and outdoor adventure is an attractive claim. Off-road driving is attractive to many people; it provides a feeling of freedom and adventure in natural environments, often of great beauty. Adventure tourism offers mainly low-difficulty products for a wide range of consumers; customers seek fear and thrills but no actual risks (Cater 2006;

Buckley 2007). Burgin and Hardiman (2012) point to a trend to the enjoy natural areas through extreme sports, with greater environmental impacts, instead of traditional motives such as rest, relaxation, reinvigoration, solitude and escape, with low impacts; this had led to tensions in land-use management between conservation and tourism (Cloke and Perkins 1998). Quad tours meet most of these tourist's requirements: contact with nature, real thrill, a feeling of adventure and little difficulty for a normal driving. In some Mediterranean coastal areas, like most of the Aegean, quads are often just a fun way to get around, but frequently tourists seek strong emotions and enjoy driving (Albritton and Stein 2011), even if that involves significant environmental impacts. Tourists' behaviour differs according to their interests, influencing the impacts generated. Petch et al. (2018) defined several groups of off-road vehicle users on a beach; the speed in those whose main activity was off-road driving was almost double that in the rest, and produce 70% of wildlife disturbance. The reasons for these impactful behaviours may be ignorance of the environmental impact of this activity (Waight and Bath 2014) or the priority of drivers' interests regardless of its consequences (Dávid et al. 2010). Tourists seek excuses for not behaving an environmentally friendly behaviour, such as denial of consequences, responsibility or control (Juvan et al. 2016). Even tourists with positive attitudes towards sustainable tourism and engaged in environmental protection at home rarely act accordingly on vacation, with a behaviour that can have negative environmental consequences (Budeanu 2007; Barr et al. 2010; Juvan and Dolnicar 2014), maybe because tourism is not seen as a major environmental concern (McKercher and Prideaux 2011).

This discussion leads to the need for a change in tourists' behaviour, to enjoy quad tourism in a more sustainable way. Education must serve to raise awareness of the environmental impacts of motorized recreation, and especially on the influence of drivers' behaviour; quiet driving on a track can be sustainable, while driving off-road at high speed in the same area can be unsustainable. Driving off the trails and crossing rivers and dunes can be fun, but effects on soils, vegetation, wildlife, water or dunes are not funny. It is also necessary to change the current vision of society: whoever drives at high speed through the dunes is not a hero but a villain. But do not be fooled; education should not be concentrated in the countries where more activities of this type are carried out, but in the countries of origin of the participants. Tourists' education in their home areas is essential to obtain a major shift in attitudes (Butler 1991), and to counteract unsustainable behaviour excuses, although even after being exposed to information, they should continue using justifications rather than change behaviour (Juvan et al. 2016). Information campaigns, even if carefully designed, hardly result in behaviour changes; information, prompts, incentives and persuasion must be combined, as well as giving feedback to people about the consequences of their behaviour (Stern 1999; Budeanu 2007; Steg and Vlek 2009).

There is no one to blame for environmental damage. Furthermore, the perception of responsibilities for impacts varies according to stakeholders, as pointed out by Kavallinis and Pizam (1994) in Greece for tourists, entrepreneurs and residents. Instead of blame, it is necessary to act on all fronts: legislation and authorizations, good environmental practices and responsible tourism.

A final conclusion is that there is a big information gap on the environmental impacts of off-road motorized recreation in much of the world and in the Mediterranean region in particular. A basic tool for the environmental assessment and regulation of these activities is to know their real effects, so further research, outside the US, is required.

Availability of data and materials Information used in the research is included as supplementary data.

Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

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