Journal of Biological Research-Thessaloniki **16**: 224 – 236, 2011
J. Biol. Res.-Thessalon. is available online at http://www.jbr.gr
Indexed in: WoS (Web of Science, ISI Thomson), SCOPUS, CAS (Chemical Abstracts Service) and DOAJ (Directory of Open Access Journals)

Twelve years after the first report of the crab *Percnon gibbesi* (H. Milne Edwards, 1853) in the Mediterranean: current distribution and invasion rates

Stelios KATSANEVAKIS[1*], Dimitrios POURSANIDIS[2,3], Mehmet Baki YOKES[4], Vesna MAČIĆ[5], Sajmir BEQIRAJ[6], Lefter KASHTA[7], Yassine Ramzi SGHAIER[8,9], Rym ZAKHAMA-SRAIEB[8], Ibrahem BENAMER[10], Ghazi BITAR[11], Zoheir BOUZAZA[12], Paolo MAGNI[13,14], Carlo Nike BIANCHI[15], Louis TSIAKKIROS[16] and Argyro ZENETOS[1]

[1] *Institute of Marine Biological Resources, Hellenic Centre for Marine Research, Anavyssos 19013, Greece*

[2] *WWF, Hellas, Ethnikis Antistaseos 82, Heraklion 71601, Crete, Greece*

[3] *Department of Marine Sciences, University of the Aegean, Mytilene, 81100, Greece*

[4] *Department of Molecular Biology and Genetics, Haliç University, 34384, Istanbul, Turkey*

[5] *Institute of Marine Biology, Kotor, Montenegro*

[6] *Biology Department, Faculty of Natural Sciences, University of Tirana, Bulevardi Zog I, Tirana, Albania*

[7] *Research Center for Flora and Fauna, Faculty of Natural Sciences, University of Tirana, Bulevardi Zog I, Tirana, Albania*

[8] *Research Unit of Animal Biology and Systematic Evolutionary, Faculty of Sciences of Tunis, Campus Universitaire, 2092 Manar II, Tunisia*

[9] *Regional Activity Centre for Specially Protected Areas (RAC/SPA), Boulevard du Leader Yasser Arafat, BP 337, 1080 Tunis Cedex, Tunisia*

[10] *Faculty of Natural Resources and Environmental Science, University of Omar Mukhtar (OMU), Libya*

[11] *Lebanese University, Faculty of Sciences (Section I), Department of Biology, Hadath, Beirut, Lebanon*

[12] *Département des Ressources Halieutiques, Faculté des Sciences Exactes, de la Nature et de la Vie, Université Abelhamid Ibn Badis-Mostaganem, BP 300 rue Hocine Hamadou, 27000, Mostaganem, Algérie*

[13] *National Research Council, Institute for Coastal Marine Environment (CNR-IAMC), Torregrande, 09072 Oristano, Italy*

[14] *National Research Council, Institute of Marine Sciences (CNR-ISMAR), Arsenale di Venezia, Tesa 104, 30122 Venezia, Italy*

[15] *DipTeRis (Dipartimento per lo studio del Territorio e della sue Risorse), University of Genoa, Corso Europa 26, 16132 Genova, Italy*

[16] *4, Michael Koutsofta, Mesa Yitonia, 4000, Limassol, Cyprus*

Received: 17 November 2010 Accepted after revision: 13 January 2011

The distribution of the alien crab *Percnon gibbesi* in the Mediterranean Sea was assessed, based on new data from four independent surveys in Albania-Montenegro, Tunisia, Libya, and Crete (Greece), personal observations of the authors and a thorough compilation of existing information. The species is reported herein for the first time from Albania, Algeria, Cyprus, Israel, and Lebanon. *Percnon gibbesi* rapidly increased its spatial distribution in the Mediterranean Sea after its first report in 1999. At present, twelve years after its introduction, *P. gibbesi* is established

* Corresponding author: tel: +30 210 9856701, fax: +30 210 9811713, email: stelios@katsanevakis.com

in most Mediterranean coasts, especially in middle latitudes. It is absent from the Adriatic Sea (except from its southern limit in the Albanian part of Otranto Strait), the Ligurian Sea, the Corsica Island, and the northern Aegean Sea, possibly because of the low winter temperatures prevailing in these areas. In the North African coasts, *P. gibbesi* has not yet been observed in Morocco. After its initial introduction, its further spreading in the Mediterranean basin seems to be governed primarily by natural dispersal via larval transport by currents. The invasion rate of *P. gibbesi* was assessed in the Kaş – Kekova Marine Protected Area in southern Turkey, based on a time series of monitoring data from 2002 to 2010. The species was first observed in 2006 in two sites and rapidly increased its occupancy and abundance the following years. Its occupancy (probability of presence in 500 m length of coastline) reached 23% within four years from its first sighting. Its abundance increased exponentially with an intrinsic rate of increase $r = 0.79$, corresponding to more than doubling of the population per year.

Key words: alien, Decapoda, invasion rate, *Percnon gibbesi*, Mediterranean Sea.

INTRODUCTION

The Mediterranean Sea is one of the most severely affected by alien marine invasions regions worldwide, fostered by the opening of the Suez Canal, fouling and ballast transportation along shipping routes, aquaculture, aquarium trade and global climate change (Streftaris *et al*., 2005; Galil, 2009; Zenetos *et al*., 2009; Por, 2010). Nearly 1,000 alien marine species have been recorded in the Mediterranean up to now, of which more than 500 are considered to be established and spreading (Zenetos, 2010; Zenetos *et al*., 2010). The reported marine alien species in the Mediterranean Sea represent approximately 6% of the known biodiversity, which is estimated to approximately 17,000 species (Coll *et al*., 2010). However, this percentage is higher for certain taxa and may exceed 20% as for example in fish (140 introduced *vs* 534 native) (HCMR database). The number of recorded alien species in the Mediterranean Sea keeps increasing with a rate of one new record every 1.5 weeks (Zenetos, 2010). As most of these species are of tropical affinity and origin, their high incidence is driving the Mediterranean biota towards a phase of 'tropicalization' (Bianchi & Morri, 2003). Many of the marine alien species exhibit aggressive invasive behaviour, leading to alterations in ecosystem functioning, biodiversity loss and negative impact to human activities such as fisheries, tourism, and aquaculture (Streftaris & Zenetos, 2006).

Percnon gibbesi (H. Milne Edwards, 1853) is a primarily algivorous crab of the shallow infra-littoral rocky shores. It is a widely distributed species, its range extending from Cape San Lucas (Baja California) to Chile, including the Galapagos islands in the eastern Pacific, from Fort Macon (North Carolina), Bahamas and Bermuda to Fernando de Noronha Archipelago, Brazil, including Antilles in the western Atlantic, and from Azores and Madeira to Angola in eastern Atlantic (Nizinski, 2003). It was first recorded in the Mediterranean Sea in 1999 in Linosa Island (Sicily Strait), southeastern Sicily, and the Balearic Islands (Relini *et al*., 2000; Garcia & Reviriego, 2000; Müller, 2001; Mori & Vacchi, 2002). Since then, its population in the Mediterranean Sea has expanded rapidly (Katsanevakis *et al*., 2010).

The aim of this work was to study the distribution of *P. gibbesi* in the Mediterranean Sea and assess its invasion rate, by conducting targeted surveys in many Mediterranean countries and compiling existing information.

MATERIALS AND METHODS

The present study of the distribution of *Percnon gibbesi* was based on a thorough compilation of existing information and on personal observations by the authors during either targeted surveys for *P. gibbesi* or occasional observations during surveys for other purposes.

To compile existing information, apart from scientific literature, we searched various sources of grey literature such as conference proceedings, academic dissertations, newsletters, newspapers, online databases and internet forums. Records made by non-experts were acceptable only if verified by samples or photos. We also contacted experts all over the Mediterranean requesting information on possible new records of the species.

The targeted surveys conducted by the authors included (Fig. 1):

1. A survey in the Tunisian coastline during July-August 2010. In ten study sites, standardized one-hour transects of various lengths along the coast-

line were surveyed by snorkeling, at depths between 0.5-3 m.

2. A two-week survey along the coastline of Albania and Montenegro (NE Ionian Sea and SE Adriatic Sea). The aim of this survey was the rapid assessment of alien marine species in the Albanian and Montenegrin coast; *P. gibbesi* was among the target species of the study. There was no previous record of the species from Albania or Montenegro. The distributional patterns of the target species were investigated by surveying 30 sites along the rocky coasts of Albania and Montenegro during September 2010 at depths between 0-5 m. At each site, transects of 200 m length were defined along the coastline with the use of a diving reel and were surveyed by three independent trained observers by snorkeling during standardized 20-min dives.
3. A two-day survey in western Crete. Katsanevakis *et al*. (2010) reported the presence of *P. gibbesi* in eastern Crete but relevant information for the western part of the island was missing. Therefore, a dedicated survey to document the possible presence of the species in the western part of the island was conducted in October 2010. In eight sites, standardized 30-min transects of various lengths were surveyed by snorkeling, at depths between 0-3 m.
4. A survey in the northeast part of Libya (Cyrenaica). In the framework of field work for biological monitoring of the Al-Koof national park, the potential presence of *P. gibbesi* was investigated in July 2010 in four line transects during one-hour dives by snorkeling, at depths between 1-5 m.

Distribution maps of *P. gibbesi* in the Mediterranean were created based on available information. In these maps, when there was a series of records (>5) with a maximum distance between consecutive records less than 50 km, it was assumed that the species was present along the entire coastline; this was depicted with a line along the coastline. In all other cases, records of the species were illustrated as dots.

The invasion rate of *P. gibbesi* was assessed in the Kaş-Kekova Marine Protected Area (MPA) in southern Turkey (Fig. 2) by processing a time series of presence/absence data. The entire MPA was divided into 118 sections of 500 m coastline length. The 0-6 m depth zone of the protected area has been regularly monitored by snorkeling since 2002. The start and end points of the sections were marked and divers swam between marks without any interruption. Divers recorded the number of *P. gibbesi* individuals observed within each section. The species was first recorded and collected in the area in 2006 (Yokes & Galil, 2006). The occupancy of the species in the area was estimated as the percentage of the sites where the species was present; a time series of occupancy between 2002 and 2010 was estimated.

The relative abundance of the species in the entire Kaş-Kekova MPA (defined as the total number of recorded individuals in all 500 m sections) was used to estimate the intrinsic rate of increase *r* of the local population. This was done by fitting the equation $N(t) = N_0 e^{rt}$, by non-linear least squares with iterations by means of Marquardt's algorithm, where $N(t)$ is the relative abundance at time t and N_0 the relative abundance at time 0 (i.e., the year of first sighting).

RESULTS

In the Tunisian coastline, *P. gibbesi* was observed in 6 out of 10 surveyed sites (Table 1, Fig. 1A). The species seemed to be very well established. It was highly abundant, widely spread throughout the study area, and many ovigerous females and small-sized individuals were observed. In total, 155 individuals were counted; the number of individuals per site varied between 2 and 50.

During the survey of the Albanian and Montenegrin coastline, *P. gibbesi* was found in 6 sites, all of them in the Albanian coastal waters (Table 1, Fig. 1B). The northernmost site of the species presence was Sazani Island on the southern limit of the Adriatic Sea, where many individuals, including ovigerous females, were observed. This record is the northernmost in the Ionian-Adriatic basin and the first record of the species in the Adriatic. No individuals were observed along the rocky coasts of Montenegro although the habitat was ideal in many surveyed sites (boulders with low algal cover).

In western Crete, the species was observed in all eight surveyed sites (Table 1, Fig. 1C) and thus the species may be considered as present along the rocky coastline of the entire island. Markedly large individuals (with carapace lengths often exceeding 40 mm) were observed in many sites in Crete, indicating favorable conditions for its growth.

In the Al-Koof National Park survey (Libya), *Percnon gibbesi* was recorded in all four transects. A total of 107 individuals of various size classes was recorded; the number of individuals per transect varied

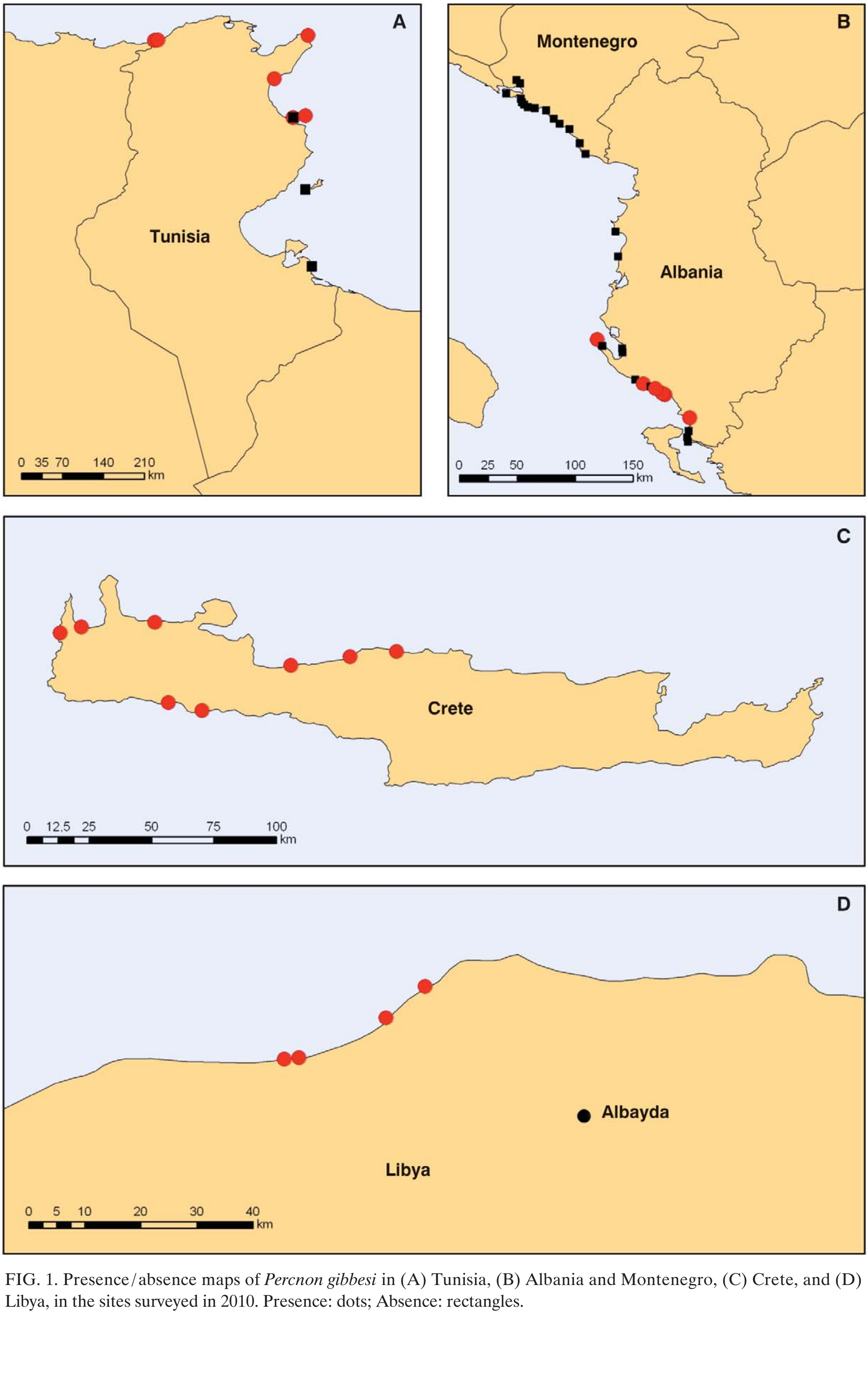

FIG. 1. Presence/absence maps of *Percnon gibbesi* in (A) Tunisia, (B) Albania and Montenegro, (C) Crete, and (D) Libya, in the sites surveyed in 2010. Presence: dots; Absence: rectangles.

TABLE 1. New records of *P. gibbesi* presented in this study

Country	**Site**	**Lat**	**Lon**	**Year**	**Source**
Albania	Saranda	39.8731	20.0077	2010	this study
Albania	Porto Palermo	40.0627	19.7947	2010	this study
Albania	Dhermi	40.1377	19.6458	2010	this study
Albania	Himara Port	40.0990	19.7410	2010	this study
Albania	Sazani Island	40.4807	19.2871	2010	this study
Albania	Shen Jani	40.4325	19.3285	2010	this study
Algeria	Skikda Bay	37.0252	6.5574	2010	Z. Bouzaza, pers. obs.
Cyprus	Dhekelia (Larnaca)	34.9909	33.7322	2006	L. Tsiakkiros, pers. obs.
Cyprus	Lemessos	34.5843	33.0227	2007	L. Tsiakkiros, pers. obs.
Greece	Limani Platanou (Crete)	35.4789	23.5681	2010	this study
Greece	Limani Kastelliou (Crete)	35.5001	23.6441	2010	this study
Greece	Agia Marina (Crete)	35.5177	23.9096	2010	this study
Greece	Petres (Crete)	35.3614	24.4005	2010	this study
Greece	Agios Nikolaos (Crete)	35.3928	24.6137	2010	this study
Greece	Bali (Crete)	35.4119	24.7824	2010	this study
Greece	Agia Roumeli (Crete)	35.2267	23.9586	2010	this study
Greece	Loutro (Crete)	35.1970	24.0789	2010	this study
Greece	Chania old harbour (Crete)	35.5178	24.0177	2010	S. Katsanevakis, pers. obs.
Greece	Kato Galatas (Crete)	35.5135	23.9649	2010	S. Katsanevakis, pers. obs.
Greece	Sougia (Crete)	35.2455	23.8050	2010	Y. Issaris, pers. comm.
Greece	Kastellorizo	36.1499	29.5903	2004	G. Apostolopoulos, pers. comm.
Greece	Pesatha (S Kefalonia)	38.1071	20.5899	2010	A. Panou, pers. comm.
Greece	Eastern Saronikos Gulf	37.8115	23.8335	2010	G. Apostolopoulos, pers. comm.
Israel	Nahariya	33.0124	35.0891	2009	B. Yokes, pers. obs.
Italy	Carloforte port (W Sardinia)	39.1459	8.3089	2005	P. Panzalis, pers. comm.
Italy	Asinara Island (N Sardinia)	41.0582	8.2855	2005	E. Azzurro, pers. comm.
Lebanon	El Heri	34.3112	35.7150	2010	G. Bitar, pers. obs.
Lybia	Rass Amer	32.9400	21.7110	2008	I. Benamer, pers. obs.
Lybia	Sosah	32.9150	21.8002	2009	I. Benamer, pers. obs.
Lybia	Rass Al-helal	32.9089	22.1679	2009	I. Benamer, pers. obs.
Lybia	Rass Alteen	32.6299	23.1140	2009	I. Benamer, pers. obs.
Lybia	El Marakeb Island	32.2339	23.2739	2010	Y.R. Sghaier, pers. obs.
Lybia	El Bardaa Island	32.3744	23.2333	2010	Y.R. Sghaier, pers. obs.
Lybia	El Hania	32.8808	21.5703	2010	this study
Lybia	El Hania	32.8353	21.5061	2010	this study
Lybia	JarJar Ommah Island	32.7767	21.3383	2010	this study
Lybia	JarJar Ommah	32.7789	21.3619	2010	this study
Tunisia	Malloula	36.9631	8.7142	2010	this study
Tunisia	Tabarka	36.9633	8.7619	2010	this study
Tunisia	El Houaria	37.0411	11.0661	2010	this study
Tunisia	Yasmine Hammamet	36.3733	10.5492	2010	this study
Tunisia	Monastir marina	35.7794	10.8356	2010	this study
Tunisia	Kuriat Island	35.8031	11.0289	2010	this study
Turkey	Finike	36.2898	30.1495	2003	G. Apostolopoulos, pers. comm.

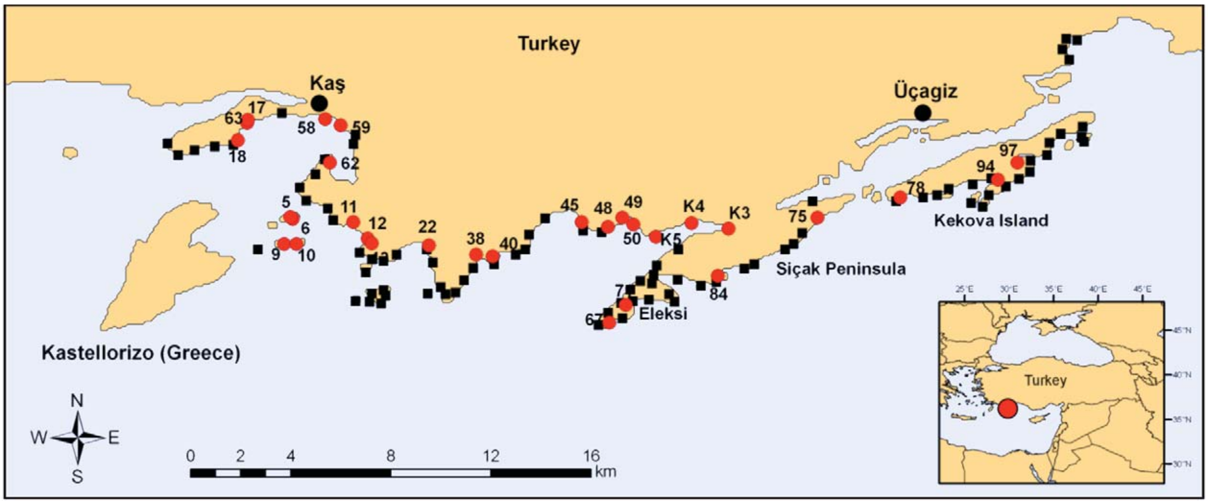

FIG. 2. Presence/absence map of *Percnon gibbesi* in the Kaş-Kekova Marine Protected Area in southern Turkey, based on annual monitoring during the period 2002-2010. For clarity reasons the site codes are given only for the stations where the species was observed at least once. Presence (at least once during 2006-2010): dots; Absence: rectangles.

between 5 and 45. *P. gibbesi* was first recorded in northeastern Libya in 2004 (Elkrwe *et al*., 2008). Since then, it has been observed in a few other sites (Elkrwe *et al*., 2008; present study, Table 1), its abundance has increased rapidly and it now seems to be well established.

Additionally, many unpublished records of *P. gibbesi* were revealed by our investigation in Algeria, Cyprus, Greece, Israel, Italy, Lebanon, Libya, and Turkey (Table 1). Thus, taking into account all previously published records of *P. gibbesi* in the Mediterranean Sea (Relini *et al*., 2000; Garcia & Reviriego, 2000; Müller, 2001; Pipitone *et al*., 2001; Mori & Vacchi, 2002; Bellantoni & Corazza, 2002; Borg & Attard-Montalto, 2002; Galil *et al*., 2002; Abelló *et al*., 2003; Cannicci *et al*., 2004; Catalano, 2004; Deudero *et al*., 2005; Russo & Villani, 2005; Cannicci *et al*., 2006; Thessalou-Legaki *et al*., 2006; Yokes & Galil, 2006; Faccia & Bianchi, 2007; Sciberras & Schembri, 2007; Crocetta & Colamonaco, 2008; Elkrwe *et al*., 2008; Katsanevakis & Tsiamis, 2009; Katsanevakis *et al*. 2010; Félix-Hackradt *et al*., 2010; Azzurro *et al*., 2011) and all new information presented herein, the temporal evolution of *P. gibbesi* invasion in the Mediterranean and the present distribution of the species were assessed (Fig. 3). The species is reported herein for the first time from Albania, Algeria, Cyprus, Israel, and Lebanon.

In the Kaş-Kekova Marine Protected Area, *P. gibbesi* was absent before 2006. At that year, two individuals were observed at two sites (Yokes & Galil, 2006). Both occupancy and abundance increased rapidly the following years; in 2010 the species was observed in 27 of the 118 sites that were surveyed (Table 2). During the monitoring period (2002-2010), *P. gibbesi* was observed in 30 sites at least once (Table 2, Fig. 2). Within four years from its first sighting in the area, *P. gibbesi* occupancy reached 23% (Fig. 4). Considering that this naive estimator of occupancy (percentage of sites where the species was present) ignores the fact of recording false absences due to imperfect detectability (MacKenzie *et al*., 2006), our occupancy estimates might be biased low, and thus real occupancies might be even higher than those presented in Figure 4.

The relative abundance of the species reached 112 individuals in 2010, from 2 individuals in 2006. Its abundance has been increased exponentially since 2006 (Fig. 4); the equation of population growth was estimated as $N = 4.9e^{0,79t}$, with adj-$R^2 = 95\%$. The intrinsic rate of increase of the local population (± SE) was $r = 0.79 \pm 0.14$, which corresponds to more than doubling of the population between two consecutive years (the growth rate of the population was $\lambda = e^r = e^{0.79} = 2.2$).

DISCUSSION

Percnon gibbesi rapidly increased its spatial distribution in the Mediterranean Sea after its first records in 1999. In that year it had only been reported from Linosa Island, southeastern Sicily, and the Balearic Islands (Relini *et al*., 2000; Garcia & Reviriego, 2000;

Müller, 2001; Mori & Vacchi, 2002) (Fig. 3A). Within six years (by 2005) it had expanded in several regions, mainly of middle latitudes, especially along the coasts of Sicily, Tyrrhenian Sea, Balearic Sea, southern Aegean Sea and southwestern Turkey (Fig. 3B). Between 2005 and 2010 the species has further expanded along the coastlines of the Ionian Sea, central Aegean Sea, and many sites in the Levantine Sea and the African coasts (Fig. 3C). At present, twelve years after its first report, *P. gibbesi* seems to have colonized most Mediterranean coasts, especially of middle latitudes, while it is absent from the Adriatic Sea (Kirinčić & Stevčić, 2008; C Froglia, F Crocetta, pers. comm.) except from its southern limit (Albanian part of the Otranto Strait), the Ligurian Sea (CN Bianchi, pers. obs.; P Chevaldonne, pers. comm.), the Corsica Island, and the northern Aegean Sea (Th Koukouras, pers. comm.). The species had been previously reported along the

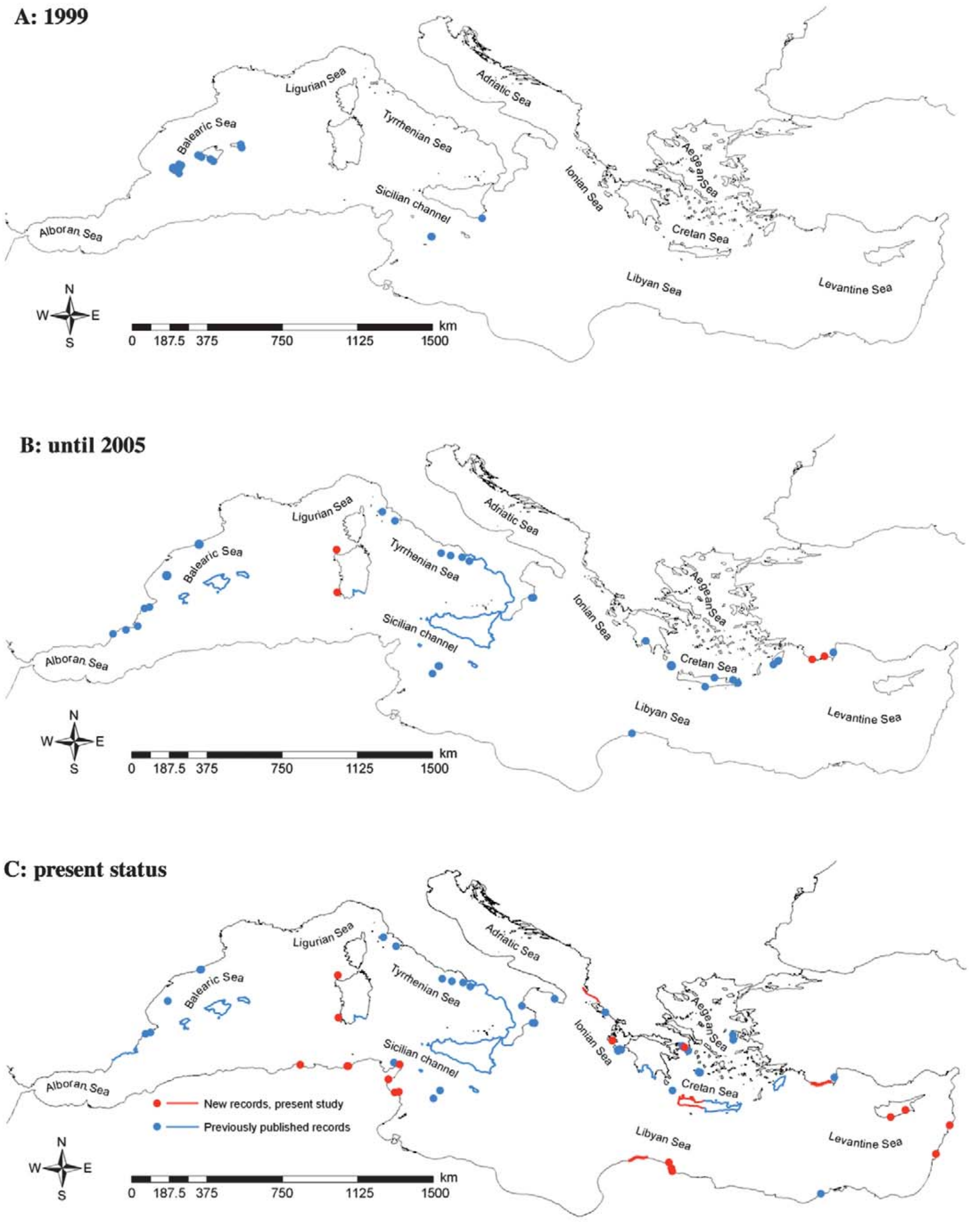

FIG. 3. The spatial expansion of *Percnon gibbesi* in the Mediterranean Sea from the year of first sighting (1999) until now (based on new and published records until October 2010). A: 1999; B: until 2005; C: present status.

entire Italian coast of the Tyrrhenian Sea (Galil *et al*., 2002; Cannicci *et al*., 2006; Katsanevakis *et al*., 2010). However, to the north of the Gulf of Naples the species has only been recorded on the islands of Ischia, Procida, Vivara, Ventotene, Ponza and single records at Giglio and Elba; thus, its distribution northern of the Gulf of Naples is given herein as not continuous.

The part of Albania northern of the Otranto Strait is characterized by sandy/muddy coasts, large estuarine areas and substantial freshwater input. It is quite possible that the low salinity surface layer and the inappropriate substrate have become a barrier for the further distribution of *P. gibbesi* northwards along the eastern Adriatic coastline. In the northern African coasts, *P. gibbesi* has not yet been observed in Morocco (H Bazairi, pers. comm.). Its absence from many northern African sites cannot be definitive, as it is suggested that many invaded locations still remain unreported.

Two vectors of introduction of *P. gibbesi* have been speculated, either through shipping (Mori & Vacchi, 2002; Galil *et al*., 2002) or by larval drift by the Atlantic surface current that enters the Mediterranean Sea through the strait of Gibraltar (Pipitone *et al*., 2001; Abelló *et al*., 2003). A third possible vector that may not be excluded is aquarium trade, as for other Mediterranean aliens (Jousson *et al*., 1998; Padilla & Williams, 2004). The species is commonly captured and traded by aquarium dealers (Calado, 2006) but large-sized individuals, which may prey on aquarium invertebrates and small fish, are often removed from their tanks and maybe released to the sea. Regardless of the mode of introduction, its further spreading in the Mediterranean basin seems to be primarily the result of natural dispersal via larval transport by currents. Ovigerous females have been observed in most sites of the species occurrence in the Mediterranean Sea (e.g., Balearic Islands: Deudero *et al*., 2005; Sicily: Deudero *et al*., 2005; Rhodes: Thessalou-Legaki *et al*., 2006; southern Turkey: Yokes & Galil, 2006; Malta: Sciberras & Schembri, 2007; Libyan coast: Elkrwe *et al*., 2008; Zakynthos: Katsanevakis *et al*. 2010; Albanian coast: present study; Tunisian coast: present study).

The wide distribution of breeding populations in the Mediterranean Sea and the large duration of the larval phase (Paula & Hartnoll, 1989), allowing for long dispersal, justify the very rapid increase of both occupancy and abundance of *P. gibbesi*. While recent immigrants normally tend to remain concentrated in the proximity of the area of their first entry, *P. gibbesi* has rapidly invaded the whole Mediterranean basin, with the exceptions of its northern reaches such as the central and northern Adriatic Sea, the Ligurian Sea and the northern Aegean Sea (Fig. 3). Its present distribution conforms to that of many warm water species within the Mediterranean Sea (Bianchi *et al*., 2010). Bianchi (2007) suggested that the February surface isotherms of 15°C and 14°C can be taken as the 'divides' between a warmer and a colder water biota within this basin. Satellite observations have shown that surface water temperatures of the Mediterranean Sea have increased to around 0.8-1°C in the period 1985 to 2006 (Nykjaer, 2009) and, consequently, both the 15°C and the 14°C divides have apparently moved northward in recent times (Coll *et al*., 2010). Warming has been shown to favour both the entry and the dispersal of tropical species in the Mediterranean Sea (Ben Rais Lasram *et al*., 2008; Raitsos *et al*., 2010), several of which have already reached the northernmost sectors of the Mediterranean Sea (Dulčić *et al*., 2008; Daniel *et al*., 2009; Lipej *et al*., 2009; Puce *et al*., 2009). The on-going northward range extension of warm water species is favoured not only by the direct influence of increased temperature (some warm water species therefore succeeding reproduction in the northern sectors – Sara *et al*., 2005), but also by modifications in the emphasis of water flow and in the pattern of water circulation forced by climate change (Astraldi *et al*., 1995); this mechanism may play a major role for species with prolonged larval phase. Should the present trend of seawater warming continue, it is likely that *P. gibbesi* populations will be established also along the northern Mediterranean shores, where currently Sea Surface Temperature (SST) falls well below 14°C during February (Fig. 5).

Percnon gibbesi appears to be an opportunistic feeder, feeding primarily on algae, including a wide variety of algal meals, such as filamentous algae, calcareous algae, corticated macrophytes, and foliose algae (Puccio *et al*., 2006), but also on animal food such as pagurids, polychaetes, gastropods, crustaceans, and jellyfish (Cannicci *et al*., 2004; Deudero *et al*., 2005; Sciberras & Schembri, 2008). Some of the possible reasons explaining the successful establishment of the species in the Mediterranean Sea are (i) the flexibility of *P. gibbesi* in feeding, (ii) the high fecundity of the species, (iii) the large duration of the larval phase (Paula & Hartnoll, 1989), (iv) the exceptionally large megalopa from which a robust first crab stage is produced (Hartnoll, 1992), (v) favorable environmental

TABLE 2. Number of *P. gibbesi* individuals recorded in each of the 30 sites, where the species was observed, in the Kaş-Kekova Marine Protected Area in southern Turkey during 2002-2010 (maximum number of individuals observed in one dive)

Station	Coordinates (deg.min.sec)	Number of individuals observed in years								
		2002	2003	2004	2005	2006	2007	2008	2009	2010
5	36.09.41N 29.37.43E	0	0	0	0	0	2	4	4	6
6	36.09.44N 29.37.40E	0	0	0	0	1	3	2	6	5
9	36.09.09N 29.37.32E	0	0	0	0	0	0	1	2	3
10	36.09.09N 29.37.48E	0	0	0	0	0	0	1	0	1
11	36.09.37N 28.39.01E	0	0	0	0	0	0	2	2	4
12	36.09.16N 29.39.20E	0	0	0	0	0	0	0	1	3
13	36.09.10N 29.39.25E	0	0	0	0	0	0	0	2	1
17	36.11.45N 29.36.44E	0	0	0	0	0	1	2	2	1
18	36.11.23N 29.36.32E	0	0	0	0	0	0	0	3	4
22	36.09.07N 29.40.39E	0	0	0	0	0	0	0	4	6
38	36.08.55N 29.41.40E	0	0	0	0	0	0	0	3	8
40	36.08.53N 29.42.01E	0	0	0	0	0	0	0	0	2
45	36.09.37N 29.43.56E	0	0	0	0	0	0	0	2	4
48	36.09.31N 29.44.30E	0	0	0	0	0	0	0	0	1
49	36.09.43N 29.44.49E	0	0	0	0	0	0	0	1	0
50	36.09.34N 29.45.03E	0	0	0	0	1	0	0	0	0
58	36.11.50N 29.38.25E	0	0	0	0	0	0	0	4	7
59	36.11.42N 29.38.45E	0	0	0	0	0	0	0	3	2
62	36.10.54N 29.38.31E	0	0	0	0	0	0	0	1	2
63	36.11.49N 29.36.45E	0	0	0	0	0	0	0	6	8
K3	36.09.29N 29.47.06E	0	0	0	0	0	0	0	2	5
K4	36.09.36N 29.46.18E	0	0	0	0	0	0	1	0	1
K5	36.09.18N 29.45.32E	0	0	0	0	0	0	0	1	0

(cont.)

67	36.07.27N 29.44.32E	0	0	0	0	0	0	0	1	3
71	36.07.50N 29.44.53E	0	0	0	0	0	0	0	4	8
75	36.09.43N 29.49.01E	0	0	0	0	0	0	0	2	4
78	36.10.09N 29.50.48E	0	0	0	0	0	0	0	3	7
84	36.08.28N 29.46.52E	0	0	0	0	0	0	0	5	11
94	36.10.32N 29.52.54E	0	0	0	0	0	0	0	1	3
97	36.10.54N 29.53.19E	0	0	0	0	0	0	0	1	2
TOTAL		**0**	**0**	**0**	**0**	**2**	**6**	**13**	**66**	**112**

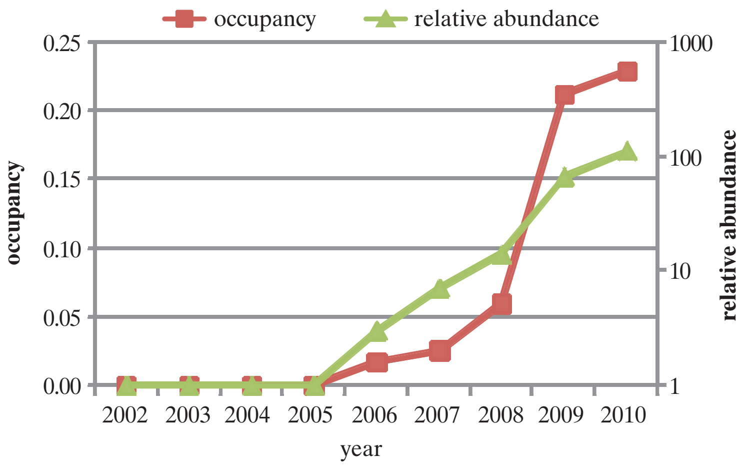

FIG. 4. Time series of occupancy (probability of presence) [scale in left axis] and relative abundance (N, defined as the total number of observed individuals in all sites) [logarithmic scale in right axis; log(1+N)] of *Percnon gibbesi* in the Kaş-Kekova MPA in southern Turkey.

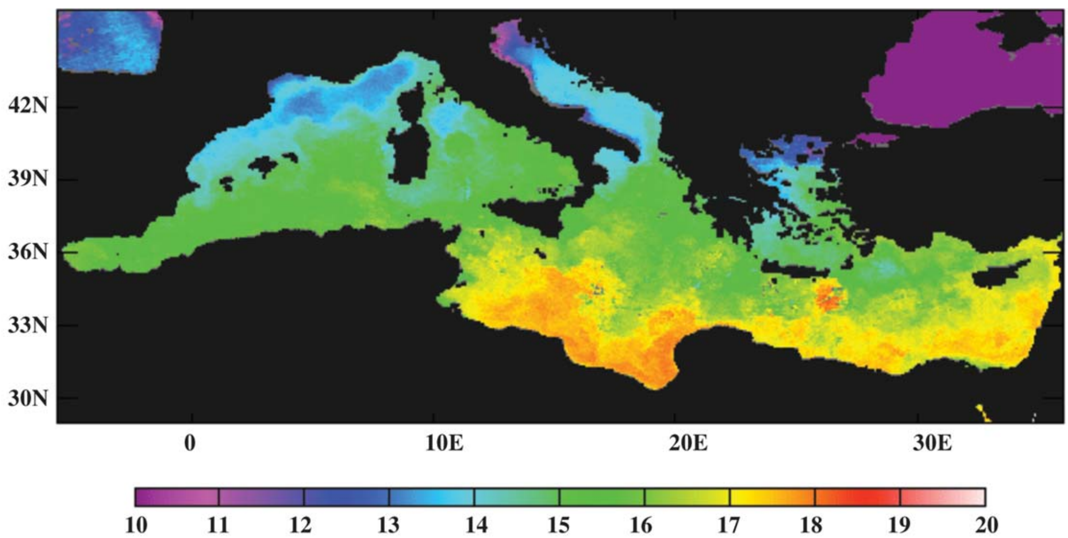

FIG. 5. Sea Surface Temperatures (in °C; monthly average) in the Mediterranean Sea, during February 2007. Nighttime SST data, retrieved from the NASA Physical Oceanography Distributed Active Archive Center, based on the Advanced Very-High-Resolution Radiometer (AVHRR) Pathfinder 5 dataset.

conditions, especially due to the warming of the Mediterranean Sea, in particular after 1998 (Raitsos *et al*., 2010), and (vi) absence of substantial competition (Pipitone *et al*., 2001) and predation.

The structure of the Mediterranean coastal food webs has been dramatically degraded in recent times, mainly because of the impacts of fishing (Sala, 2004; Guidetti, 2006). The most dramatic change is the shift from shallow algal forests (such as *Cystoseira* communities) to rocky barrens (Sala *et al*., 1998; Sala, 2004; Yildirim *et al*., 2010). In many parts of the eastern Mediterranean Sea, the large abundance of the Lessepsian herbivorous rabbitfish *Siganus luridus* and *S. rivulatus* has been proved an important obstacle for the recovery and growth of *Cystoseira* forests. Based on caging experiments, Yildirim *et al*. (2010) concluded that these alien herbivores were able to sustain barrens and contribute to the transformation of the ecosystem from one dominated by lush and diverse brown algal forests to another dominated by bare rock.

The invasion of yet another herbivore species in the shallow rocky infralittoral zone of the Mediterranean Sea may add further stress to the already altered ecosystems. Although, herbivore crabs in both temperate and tropical shores generally consume a small fraction of primary production, direct and indirect effects of their foraging may affect the structure of benthic communities (Wolcott & O'Connor, 1992). *Percnon gibbesi* keeps expanding rapidly and may reach densities of many individuals per m^2 (Sciberras & Schembri, 2008; Raineri & Savini, 2010). Its widespread and expanding distribution along the Mediterranean coasts and the high rates of increase in abundance denote a highly invasive species. The magnitude of its impact on shallow hard-substrate benthic communities and possible cascade effects on trophic webs may not yet be predicted in the absence of information on its grazing intensity and the trophic interactions with other species. Further research is needed to assess the impact of *P. gibbesi* invasion; it is certain that this species will stay under the spotlight of marine ecologists in the Mediterranean Sea for long.

ACKNOWLEDGEMENTS

The survey of the Albania/Montenegrian coastline in September 2010 was conducted in the framework of a trilateral collaboration project (Greece, Albania, Montenegro) funded by UNEP/MAP RAC/SPA (contracts No 37, 38, 39/2010/RAC/SPA). The surveys of the Kuriat (Tunisia) and the Libyan coastline in October 2010 were conducted in the framework of the MedMPAnet Project implemented by RAC/SPA funded by UNEP/MAP-RAC/SPA, the European Commission (EC), the Spanish Agency for International Cooperation to Development (AECID), and the French Global Environment Facility (FFEM). Marine Biodiversity Research of Kaş-Kekova MPA was funded by WWF-Turkey. The contribution by C. N. Bianchi is partly supported by the project "The impact of biological invasions and climate change on the biodiversity of the Mediterranean Sea" (Italy-Israel co-operation) funded by the Italian Ministry of the Environment. We thank U. Tural, V. Demir, S.U. Karhan, E. Kalkan and Bogazici University Diving Club for their invaluable help in Kaş-Kekova field studies. We are grateful to G. Apostolopoulos (Greece), A. Panou (Greece), Y. Issaris (Greece), Th. Koukouras (Greece), C. Froglia (Italy), F. Crocetta (Italy), C. Pipitone (Italy), P. Panzalis (Italy), E. Azzuro (Italy), E. Garcia Raso (Spain), O. Ocaña (Gibraltar, Spain), P. Chevaldonne (France), H. Zibrowius (France), C. Delongueville (Belgium), S.E. Ramadan (Egypt), F. Aly (Egypt), H. Zakaria (Egypt), H. Kara (Algeria), K. Mezali (Algeria), H. Bazair (Morocco) and I. Ammar (Syria) for providing useful information. We also thank three anonymous reviewers for their useful comments.

REFERENCES

Abelló P, Visauta E, Bucci A, Demestre M, 2003. Noves dades sobre l'expansió del cranc *Percnon gibbesi* (Brachyura: Grapsidae: Plagusiinae) a la Mediterrània occidental. *Bolleti de la Societat d'Historia Natural de les Balears*, 46: 73-77.

Astraldi M, Bianchi CN, Gasparini GP, Morri C, 1995. Climatic fluctuations, current variability and marine species distribution: a case study in the Ligurian Sea (northwest Mediterranean). *Oceanologica Acta*, 18: 139-149.

Azzurro E, Milazzo M, Maynou F, Abelló P, Temraz T, 2011. First record of *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Percnidae) from Egyptian waters. *Aquatic Invasions*, 5: S123-S125.

Bellantoni N, Corazza C, 2002. Segnalazione del granchio *Percnon gibbesi* (H. Milne-Edwards, 1853) (Decapoda, Grapsidae) nello Stretto di Messina, versante calabrese. *Annali del Museo Civico di Storia Naturale di Ferrara*, 5: 129-130.

Ben Rais Lasram F, Tomasini JA, Guilhaumon F, Romdhane MS, Do Chi T, Mouillot D, 2008. Ecological correlates of dispersal success of Lessepsian fishes. *Marine Ecology Progress Series*, 363: 273-286.

Bianchi CN, 2007. Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia*, 580: 7-21.

Bianchi CN, Morri C, 2003. Global sea warming and 'tropicalization' of the Mediterranean Sea: biogeographic and ecological aspects. *Biogeographia*, 24: 319-327.

Bianchi CN, Morri C, Chiantore M, Montefalcone M, Parravicini V, Rovere A, 2010. Mediterranean Sea biodiversity between the legacy from the past and a future of change. In: Stambler N, ed. *Life in the Mediterranean Sea: a look at habitat changes*. Nova Science Publishers, New York: in press.

Borg JJ, Attard-Montalto J, 2002. The grapsid crab *Percnon gibbesi* (Milne-Edwards, 1853) (Crustacea, Decapoda, Brachyura), a new addition to the marine fauna of Malta. *Central Mediterranean Naturalist*, 3: 159-160.

Calado R, 2006. Marine ornamental species from European waters: a valuable overlooked resource or a future threat for the conservation of marine ecosystems? *Scientia Marina*, 70: 389-398.

Cannicci S, Badalamenti F, Milazzo M, Gomei M, Baccarella A, Vannini M, 2004. Unveiling the secrets of a successful invader: preliminary data on the biology and the ecology of the crab *Percnon gibbesi* (H. Milne-Edwards, 1853). *Rapport et Procès-Verbaux des Réunions. Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 37: 326.

Cannicci S, Garcia L, Galil BS, 2006. Racing across the Mediterranean – first record of *Percnon gibbesi* (Crustacea: Decapoda: Grapsidae) in Greece. *Journal of Marine Biological Association 2 – Biodiversity Records:* 5300.

Catalano D, 2004. Osservazioni su *Percnon gibbesi* (H. Milne-Edwards, 1853) (Crustacea: Decapoda: Brachiura), nuova specie aliena nel litorale di Augusta (Sicilia Orientale). *Bollettino dell'Accademia Gioenia di Scienze Naturali di Catania*, 37: 191-196.

Coll M, Piroddi C, Steenbeek J, Kaschner K, Ben Rais Lasram F, Aguzzi J, Ballesteros E, Bianchi CN, Corbera J, Dailianis T *et al*., 2010. The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats. *PLoS ONE*, 5: e11842.

Crocetta F, Colamonaco G, 2008. *Percnon gibbesi* (Crustacea: Decapoda) and *Aplysia dactylomela* (Mollusca: Gastropoda) in the Taranto Gulf (Italy, Ionian Sea): new populations incoming. *Journal of the Marine Biological Association 2 – Biodiversity Records*: 6465.

Daniel B, Piro S, Charbonnel E, Francour P, Letourneur Y, 2009. Lessepsian rabbitfish *Siganus luridus* reached the French Mediterranean coasts. *Cybium*, 33: 163-164.

Deudero S, Frau A, Cedra M, Hampel H, 2005. Distribution and densities of the decapod crab *Percnon gibbesi*, an invasive Grapsidae, in western Mediterranean waters. *Marine Ecology Progress Series*, 285: 151-156.

Dulčić J, Scordella G, Guidetti P, 2008. On the record of the Lessepsian migrant *Fistularia commersonii* (Rüppell, 1835) from the Adriatic Sea. *Journal of Applied Ichthyology*, 24: 101-102.

Elkrwe HM, Elhawaj HM, Galil BS, ben Abdallah A, 2008. The first record of *Percnon gibbesi* (H. Milne-Edwards, 1853) (Crustacea: Decapoda: Plagusiidae) from the southern rim of the Mediterranean. *Aquatic Invasions*, 3: 243-245.

Faccia I, Bianchi CN, 2007. Prima segnalazione del granchio *Percnon gibbesi* (Milne H.-Edwards, 1853) nella Calabria Ionica. *Thalassia Salentina*, 30: 39-43.

Félix-Hackradt FC, Hackradt CW, Treviño-Otón J, García-Charton JA, 2010. Continued expansion of *Percnon gibbesi* (Crustacea: Decapoda: Plagusiidae) into western Mediterranean waters. *Marine Biodiversity Records*, 3: e22.

Galil BS, 2009. Taking stock: inventory of alien species in the Mediterranean sea. *Biological Invasions*, 11: 359-372.

Galil B, Froglia C, Noel PY, 2002. *CIESM Atlas of exotic species in the Mediterranean. Volume 2 Crustaceans: decapods and stomatopods*. CIESM Publishers, Monaco.

Garcia L, Reviriego B, 2000. Presència del cranc subtropical *Percnon gibbesi* (H. Milne-Edwards, 1853) (Crustacea, Decapoda, Grapsidae) a les Illes Balears. Primera cita a la Mediterrania occidental. *Bolleti de la Societat d'Història Natural de les Balears*, 43: 81-90.

Guidetti P, 2006. Marine reserves reestablish lost predatory interactions and cause community changes in rocky reefs. *Ecological Applications*, 16: 963-976.

Hartnoll RG, 1992. Megalopae and early postlarval stages of East African *Percnon* (Decapoda: Brachyura: Grapsidae). *Journal of Zoology, London*, 228: 51-67.

Jousson O, Pawlowski J, Zaninetti L, Meinesz A, Boudouresque CF, 1998. Molecular evidence for the aquarium origin of the green alga *Caulerpa taxifolia* introduced to the Mediterranean Sea. *Marine Ecology Progress Series*, 172: 275-280.

Katsanevakis S, Tsiamis K, 2009. Records of alien marine species in the shallow coastal waters of Chios Island (2009). *Mediterranean Marine Science*, 10: 99-107.

Katsanevakis S, Poursanidis D, Issaris Y, Tsiamis K, Salomidi M, Maroulakis M, Kytinou E, Thessalou-Legaki M, Zenetos A, 2010. The invasive crab *Percnon gibbesi* (Crustacea: Decapoda: Plagusiidae) is spreading in the Aegean and Ionian Seas. *Marine Biodiversity Records*, 3: e53.

Kirinčić M, Stevčić Z, 2008. Fauna of the Adriatic decapod crustaceans (Crustacea: Decapoda)-status and outlook. *Natura Croatica*, 17: 131-139.

Lipej L, Mavrič B, Orlando Bonaca M, 2009. Recent changes in the Adriatic fish fauna: experiences from Slovenia. *Varstvo Narave*, 22: 91-96.

MacKenzie DI, Nichols JD, Royle JA, Pollock KH, Bailey LL, Hines JE, 2006. *Occupancy estimation and modeling*. Elsevier Academic Press, Burlington.

Mori M, Vacchi M, 2002. On a new occurrence of the alien flat crab *Percnon gibbesi* (H. Milne-Edwards), in the southern Sicily (Central Mediterranean Sea). *Annali del Museo Civico di Storia Naturale 'Giacomo Doria'*, 94:

295-301.

Müller C, 2001. Erstnachweis der Flachkrabbe *Percnon gibbesi* (Crustacea: Decapoda: Grapsidae) für die Balearischen Inseln. *Senckenbergiana Maritima*, 31: 83-89.

Nizinski MS, 2003. Annotated checklist of decapod crustaceans of Atlantic coastal and continental shelf waters of the United States. *Proceedings of the Biological Society of Washington*, 116: 96-157.

Nykjaer L, 2009. Mediterranean Sea surface warming 1985-2006. *Climate Research*, 39: 11-17.

Padilla DK, Williams SL, 2004. Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems. *Frontiers in Ecology and the Environment*, 2: 131-138.

Paula J, Hartnoll RG, 1989. The larval and post-larval development of *Percnon gibbesi* (Crustacea, Brachyura, Grapsidae) and the identity of the larval genus *Pluteocaris*. *Journal of Zoology*, *London*, 218: 17-37.

Pipitone C, Badalamenti F, Sparrow A, 2001. Contribution to the knowledge of *Percnon gibbesi* (Decapoda, Grapsidae), an exotic species spreading rapidly in Sicilian waters. *Crustaceana*, 74: 1009-1017.

Por FD, 2010. Climate Optimum rejuvenates the Mediterranean marine world. *Integrative Zoology*, 5: 112-121.

Puccio V, Relini M, Azzuro E, Orsi Relini L, 2006. Feeding habits of *Percnon gibbesi* (H. Milne Edwards, 1853) in the Sicily Strait. *Hydrobiologia*, 557: 79-84.

Puce S, Bavestrello G, Di Camillo CG, Boero F, 2009. Long-term changes in hydroid (Cnidaria, Hydrozoa) assemblages: effect of Mediterranean warming? *Marine Ecology*, 30: 313-326.

Raineri P, Savini D, 2010. *Percnon gibbesi* (H. Milne Edwards, 1853) in Linosa Island ten years after its first record. *Rapport et Procès-Verbaux des Réunions. Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 39: 643.

Raitsos DE, Beaugrand G, Georgopoulos D, Zenetos A, Pancucci-Papadopoulou AM, Theocharis A, Papathanassiou E, 2010. Global climate change amplifies the entry of tropical species into the eastern Mediterranean Sea. *Limnology and Oceanography*, 55: 1478-1484.

Relini M, Orsi L, Puccio V, Azzurro E, 2000. The exotic crab *Percnon gibbesi* (H. Milne Edwards, 1853) (Decapoda, Grapsidae) in the Central Mediterranean. *Scientia Marina*, 64: 337-340.

Russo GF, Villani G, 2005. Spreading of the allochthonous species *Percnon gibbesi* in the central Tyrrhenian Sea. *Biologia Marina Mediterranea*, 12: 329-330.

Sala E, 2004. The past and present topology and structure of Mediterranean subtidal rocky-shore food webs. *Ecosystems*, 7: 333-340.

Sala E, Boudouresque CF, Harmelin-Vivien M, 1998. Fishing, trophic cascades, and the structure of algal assemblages: evaluation of an old but untested paradigm. *Oikos*, 82: 425-439.

Sara G, Bianchi CN, Morri C, 2005. Mating behaviour of the newly-established ornate wrasse *Thalassoma pavo* (Osteichthyes: Labridae) in the Ligurian Sea (northwestern Mediterranean). *Journal of the Marine Biological Association of the UK*, 85: 191-196.

Sciberras M, Schembri PJ, 2007. Observations on the alien crab *Percnon gibbesi* (Decapoda, Brachyoura, Grapsidae) from the Maltese Islands. *Rapport et Procès-Verbaux des Réunions. Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 38: 594.

Sciberras M, Schembri PJ, 2008. Biology and interspecific interactions of the alien crab *Percnon gibbesi* in the Maltese Islands. *Marine Biology Research*, 4: 321-332.

Streftaris N, Zenetos A, 2006. Alien marine species in the Mediterranean – the 100 'worst invasives' and their impact. *Mediterranean Marine Science*, 7: 87-118.

Streftaris N, Zenetos A, Papathanassiou E, 2005. Globalisation in marine ecosystems – The story of non-indigenous marine species across European Seas. *Oceanography and Marine Biology: An annual Review*, 43: 419-453.

Thessalou-Legaki M, Zenetos A, Kambouroglou V, Corsini-Foka M, Kouraklis P, Dounas C, Nicolaidou A, 2006. The establishment of the invasive crab *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Grapsidae) in Greek waters. *Aquatic Invasions*, 1: 133-136.

Wolcott DL, O'Connor NJ, 1992. Herbivory in crabs: adaptations and ecological considerations. *American Zoologist*, 32: 370-381.

Yildirim ZD, Kizilkaya ZA, Sala E, Sukatar A, 2010. Causes of infralittoral barrens in the Turkish Mediterranean and potential for ecosystem restoration. *Rapport et Procès-Verbaux des Réunions. Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 39: 810.

Yokes B, Galil BS, 2006. Touchdown – first record of *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Grapsidae) from the Levantine coast. *Aquatic Invasions*, 1: 130-132.

Zenetos A, 2010. Trend in Aliens species in the Mediterranean. An answer to Galil, 2009 "Taking stock: inventory of alien species in the Mediterranean Sea". *Biological Invasions*, 12: 3379-3381.

Zenetos A, Pancucci-Papadopoulou MA, Zogaris S, Papastergiadou E, Vardakas L, Aligizaki K, Economou AN, 2009. Aquatic alien species in Greece (2009): tracking sources, patterns and effects on the ecosystem. *Journal of Biological Research-Thessaloniki*, 12: 135-172.

Zenetos A, Gofas S, Verlaque M, Çinar ME, García Raso E, Azzurro E, Bilecenoğlu M, Froglia C, Siokou I, Bianchi CN, Morri C, Sfriso A, San Martin G, Giandgrande A, Katağan T, Ballesteros E, Ramos-Esplá A, Mastrototaro F, Ocaña O, Zingone A, Gambi MC, Streftaris N, 2010. Alien species in the Mediterranean by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. *Mediterranean Marine Science*, 11: 381-493.