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Northward Spread of the Parrotfish *Sparisoma cretense* (Teleostei: Scaridae) in the Mediterranean Sea: An Update on Current Distribution with Two New Records from Sardinia

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Abstract: The parrotfish *Sparisoma cretense*, a marine species native to the eastern and southern coastal areas of the Mediterranean, has extended its distribution northward. Here, we provide an update on its distribution based on currently published data and two new records from the coastline of Sardinia, Italy (central-western Mediterranean). The survey methods were scuba diving and spearfishing: one specimen of *S. cretense* was caught along the Argentiera coastline (northwest Mediterranean) and the others were photographed in the Gulf of Orosei, Osalla Bay (central-eastern Mediterranean). A literature update, together with new records, documents the distribution of this species in the northernmost areas of the Mediterranean. Probably a result of global warming, the ongoing northward expansion of *S. cretense* highlights the need for sampling campaigns to obtain timely updates on population and distribution of this thermophilic species.

Keywords: climate change; marine bio-invasion; Mediterranean parrotfish; tropicalization

check for updates

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1. Introduction

Global climate change has already had observable effects on the environment [1,2]. Temperature plays a fundamental role in marine ecosystem biodiversity [3] and deep-sea environments [4]. Warming of the climate system in all its components (Earth's surface, oceans, and the atmosphere) is manifested: the sea level has risen, the ocean and atmosphere have warmed, the amount of snow and ice has diminished, and the number of extreme events has increased [5]. The period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere [5]. The global average increase in surface temperature, considering land and ocean combined, from 1880 to 2012 was 0.85 °C [5]. Many marine and freshwater species have shifted their geographical range, migration patterns, seasonal activities, species interactions, and abundances in response to ongoing climate change [5,6]. Persistence of the warming trend would likely have a significant influence on the establishment and distribution of thermophilic species and, consequently, on the biodiversity of the Mediterranean Sea. As sea-warming continues, so does the expansion of alien species (AS) [7–9], driven directly or indirectly by human activity as well [10].

Reports of AS are highest for Europe (42%), mostly involving freshwater and marine species [11]. Generally, AS (also known as exotic, allochthonous, non-native, or non-

indigenous) refers to problematic organisms introduced from outside of their natural geographical range [12]. Over the past 50 years, they have been the major direct drivers of change in nature [13] and have made a huge footprint on a global scale. Alien species have a negative impact on local economies [14,15], human health [16,17], livelihood [18], and social and biological settings [14,19–24]. However, not all AS are deemed invasive or associated with adverse impact [25]. Some species, seemingly unproblematic but with a potential for invasiveness, sometimes escape due attention [26].

In general, AS are an ever-increasing problem in the Mediterranean [27–29]. Their impact cannot be adequately described without considering climate change. Some thermophilic species, such as the parrotfish *Sparisoma cretense* Linnaeus, 1758 (Osteichthyes, Perciformes, Scaridae), apparently non-invasive, have expanded their distribution into higher latitudes, where they have formed established populations [30]. This phenomenon has been termed "meridionalization" [28]. *Sparisoma cretense* is native to the Mediterranean Sea along the eastern and southern coasts. It is also widespread along the eastern Atlantic coast from Portugal to Senegal, including the Azores, Madeira, Canaries, and Cape Verde Islands [30]. The ongoing northward range expansion of this species is likely related to global warming [31,32].

Sparisoma cretense is a reef-associated species commonly found at depths of up to 160 ft/50 m along rocky shores or pebble, gravel, and seagrass seabed [33]. It feeds on algae and small invertebrates by excavating or scraping the surface of rocks and carbonate substrate with its fused beak-like jaws [34–38]. Breeding generally occurs from July to September, with juveniles recruiting in the late summer [36,39,40].

With the present study, we provide an update on the distribution of parrotfish *S. cretense* in the Mediterranean based on current published data and two new records from Sardinia (Italy). These kinds of update are crucial to react to invasions by alien species. That means enhancing prompt detection of new incursions and correct taxonomic identification of invaders, ensuring immediate reporting of relevant information to both the scientific community and competent authorities involved in risk assessment and management.

2. Materials and Methods

2.1. Update of Sparisoma cretense: Literature Search

The electronic databases Google Scholar (https://scholar.google.it/ accessed on 15 March 2021) and Scopus (https://www.scopus.com/ accessed on 17 March 2021) were queried using search terms "*Sparisoma cretense*" OR "thermophilic Mediterranean parrotfish" AND "distribution" OR "northernmost record" OR "first record" OR "temperate" OR "Mediterranean Sea" OR "settlement evidence" OR "fishing pressure" OR "abundance" OR "invasive" OR "fish diversity". From the over 600 records retrieved, only those that indicated the geographical location of the species within the Mediterranean and the eastern Atlantic were selected.

2.2. Study Site in Sardinia

2.2.1. Coastal Area of the Argentiera

Argentiera (40°44′22.8″ N, 8°09′03.8″ E; Figure 1) is a small village in the province of Sassari (northwest Sardinia, central-western Mediterranean). It is part of the Geo-Mining Park of Sardinia (approximately 60 km^2) and Argentiera-Nurra. The area is often subject to strong currents and coastal storms, especially in winter. The seabed is characterized by *Posidonia oceanica* meadows, rocks, pebbles, often colonized by photophilic algae (*Padina pavonica*, *Cystoseria* spp., etc.), and sand.

Figure 1. Distribution of recent (Argentiera and Osalla Bay) and earlier (Barisardo and Capo Carbonara) records of *Sparisoma cretense* in Sardinia, Italy. Earlier records based on Murenu et al. [41] and Cabiddu et al. [42].

2.2.2. Coastal Area of the Gulf of Orosei

Osalla Bay is located near the mouth of the Cedrino River, in the northernmost part of the Gulf of Orosei, in the territory of Dorgali. About half a mile from the Punta Nera di Osalla shoal, there is another shallow area (depth 45–78 ft/14–24 m; 40°19′47.49″ N, 9°40′33.65″ E; Figure 1). The sea bottom is characterized by a columnar basalt bank and sand. The rocks and layers are colonized by thick vegetation (photophilic algae and marine phanerogams) and benthic invertebrate fauna.

2.3. Species Detection

One adult specimen of parrotfish *Sparisoma cretense* was caught by local amateur spearfishermen along the Argentiera coastline (40°44′21.8″ N, 8°08′36.6″ E) (Figure 1) in shallow water (depth < 32 ft/10 m) on 13 October 2019, placed in a cold box, and brought to our laboratory for identification to the species level. The specimen was photographed and measured for total length (mm) and total weight (g). Morphometric and meristic characteristics were recorded using a caliper.

The other adult specimens were photographed about half a mile from the Punta Nera di Osalla shoal (40°19′06.78″ N, 9°41′05.19″ E) (depth ≥ 49 ft/15 m) (Figure 1) on 26 July 2020. High-resolution still images were taken by local underwater operators while scuba diving (12.1 Mpix, Sensor type CMOS 1/1.7, screen 1080p full HD video, Canon PowerShot S100, with underwater housing).

3. Results and Discussion

The northward spread of thermophilic species is believed to be an indirect indication of Mediterranean warming [39,43]. Parrotfishes consist of 10 genera and 88 species. Actually, two species are reported in the Mediterranean Sea: *Sparisoma cretense* (native to the eastern and southern coasts) and the lessepsian *Scarus ghobban*. Records of the presence of this latter species in the Mediterranean Sea are increasing [44]. However, reports of *S. ghobban* remain rather contained compared to *S. cretense*.

The parrotfish *Sparisoma cretense* may provide a good model to explain the ongoing changes in water temperature. On this path, estimates based on models claimed that the preferred range temperature for *S. cretense* is 15.1–20.3 °C (mean 17.1 °C) [45]. Indeed, *Sparisoma cretense* has extended its distribution within the Mediterranean basin. Table 1 and Figure 2 present the areas where *S. cretense* has been recorded in the Mediterranean and the Atlantic coast to date. Furthermore, on the basis of available bibliographic data, a population structure was also hypothesized (i.e., established, scattered, and native). Current data suggest that it is now well-established along the Mediterranean and the eastern Atlantic coast.

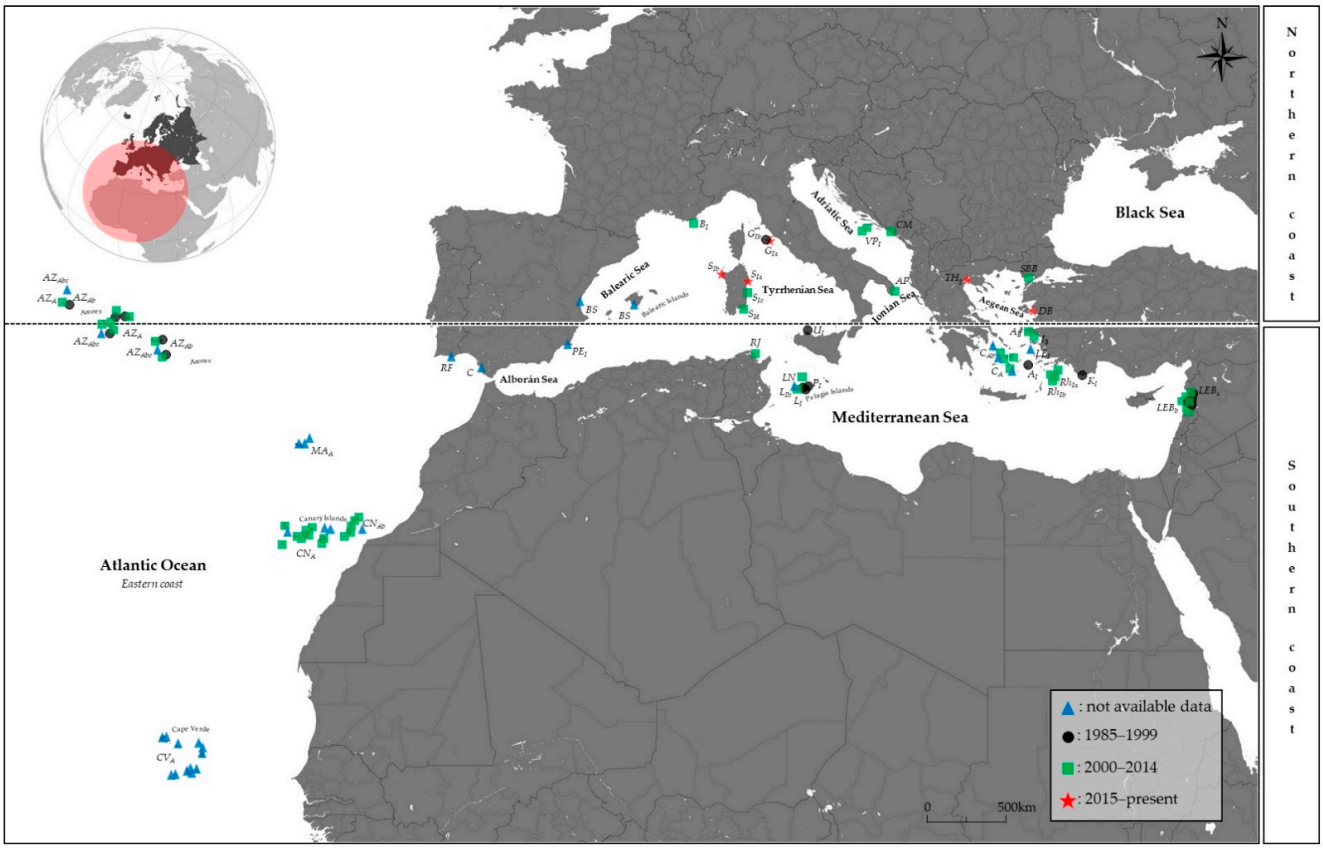

Figure 2. Main distribution of the parrotfish (*Sparisoma cretense*) in the Mediterranean Sea (Northern and Southern coasts) and Atlantic Ocean (Eastern coast). Fifteen-year periods have been defined (1985–1999: black circle, 2000–2014: green square, and 2015–present: red star). The blue triangle represents the reports/sampling without a time reference (see also map code provided in Table 1).

Table 1. Main distribution of the parrotfish (*Sparisoma cretense*) in the Mediterranean Sea (Northern and Southern coasts) and Atlantic Ocean (Eastern coast). The table reports the sampling year, the survey method, GPS coordinates, the depth range, and the morphometric characteristics provided by each reference. In addition, the population structure is also included. T_W = total weight in grams, T_L = total length in millimeters.

Code Map	Discovery Area	Sampling Year	Survey Method	GPS Coordinates	Depht Range	Morphometric Characteristics		Population Structure	References
						T_W	T_L		
Mediterranean Sea									
Northern coast									
S_{Ia}	Osalla, Sardinia, Italy	2020–2015	UVC	40°19′06.78″ N, 09°41′05.19″ E *	≥15	–	–	Established	Present study
S_{Ib}	Argentiera, Sardinia, Italy	2019	Spearfishing	40°44′21.80″ N, 08°08′36.60″ E *	<10	383.4	301	Scattered	Present study
DB	Dikili Bay, Turkey	2019	Long line	39°04′56.00″ N, 26°48′25.00″ E *	–	400	285	Scattered	Tuncer et al. [46]
G_{Ia}	Giglio Island, Italy	2018	UVC: strip transects (50 × 5 m)	42°21′24.72″ N, 10°54′00.53″ E	2–20	–	60–>120	Established	Ventura et al. [30]
TH_g	Thermaic Gulf, Greece	2018	Trammel net	40°04′10.70″ N, 23°19′59.30″ E	30–35	317	262.6	Scattered	Kampouris & Batjakas [47]
B_I	Bagaud Island, France	2014	UVC	43°00′49.68″ N, 06°21′45.08″ E	6–7	–	80	Scattered	Astruch et al. [31]
SBB	Saros Bay, Turkey	2013	Hook and line	40°36′07.80″ N, 26°32′44.30″ E	≃30	–	254	Scattered	Cengiz & Paruğ [48]
CM	Cavtat and Molunat, Croatia	2011	UVC: strip transects	42°35′08.67″ N, 18°11′24.46″ E	3–6	–	≃150	Scattered	Krushel et al. [49]
S_{Ic}	Barisardo, Sardinia, Italy	2004	Trammel net	39°50′11.70″ N, 09°41′26.16″ E	33	226.3 #	239.5 #	Scattered	Cabiddu et al. [42]
S_{Id}	Capo Carbonara, Sardinia, Italy	2003, 2002	UVC	39°06′06.78″ N, 09°31′00.09″ E	–	–	–	Scattered	Murenu et al. [41]
AP	Apulia, Italy	2001, 2000	UVC: strip transects (25 × 5 m)	40°08′30.76″ N, 18°30′19.06″ E	5–15	–	30–150	Established	Guidetti & Boero [50]
AP	Apulia, Italy	2000	UVC: strip transects (25 × 5 m)	40°08′30.76″ N, 18°30′19.06″ E	5–15	–	30–40	Scattered	Guidetti & Boero [39]
VP_I	Vrhovnjaci and Palagruža Islands, Croatia	2000	UVC; fishing	42°34′41.40″ N, 16°30′39.86″ E	4–5	238.8	222 SL	Scattered	Dulčič & Pallaoro [47]
G_{Ib}	Giglio Island, Italy	1991	UVC	42°21′24.72″ N, 10°54′00.53″ E	<10	–	–	Scattered	Bianchi & Morri [43]

Table 1. *Cont.*

Code Map	Discovery Area	Sampling Year	Survey Method	GPS Coordinates	Depht Range	Morphometric Characteristics		Population Structure	References
						T_W	T_L		
BS	Valencia Gulf and Balearic Islands, Spain	–	–	39°16′59.61″ N, 00°50′13.44″ E	–	–	–	Scattered	Otero & Galeote [51]
Mediterranean Sea									
Southern coast									
S_B	Sığacık Bay, Turkey	2014	Trammel net	38°12′04.58″ N, 26°45′03.87″ E	22	226.7 #	237.3 #	Scattered	Yapici et al. [52]
I_B	Izmir Bay, Turkey	2013	Spearfishing	38°26′36.88″ N, 26°50′43.23″ E	19	2200	520	Native	Filiz & Sevingel [53]
RJ	Ras Jebel, Tunisia	2011	Trammel net	37°14′16.47″ N, 10°08′00.29″ E	6	660	335	Native	Rafrafi-Nouira et al. [54]
L_I	Lampedusa Island, Italy	2010	Hook and line	35°31′02.39″ N, 12°35′07.20″ E	0–40	165–330	208–298	Native	La Mesa et al. [55]
Rh_{Ia}	Rhodes Island, Greece	2009–2008	Danish-seine	36°10′10.73″ N, 27°54′39.50″ E	0–35	–	–	Native	Kalogirou et al. [56]
Rh_{Ib}	Rhodes Island, Greece	2008	Danish-seine	36°10′10.73″ N, 27°54′39.50″ E	0–35	–	–	Native	Kalogirou et al. [57]
C_A	Cyclades archipelago, Greece	2008	UVC: strip transects (25 × 5 m)	37°09′49.56″ N, 25°04′00.85″ E	≃3	–	–	Native	Giakoumi [58]
LN	Linosa, Italy	2003	Spearfishing	35°51′58.39″ N, 12°52′07.25″ E	1–8	–	128–253	Native	Azzurro et al. [56]
LEB_a	Nakoura to Ramkine Islands, Lebanon	2001	UVC	34°04′47.44″ N, 35°36′04.47″ E	5.5–32	–	–	Native	HarmelinVivien et al. [59]
LEB_b	Daoura to Selaata, Lebanon	2000, 1999	UVC: strip transects (100 × 5; 50 × 1.5; 25 × 3 m)	34°04′47.44″ N, 35°36′04.47″ E	0–2	–	200–400	Native	Bariche et al. [60]
A_I	Astypalaia Island, Greece	1997	Trawling	36°34′01.38″ N, 26°19′23.62″ E	–	64.5–91.3	159–176 SL	Native	Papoutsoglou & Lyndon [61]
P_I	Pelagie Islands, Italy	1997, 1996	UVC: strip transects (20 × 150-210 m)	35°41′26.44″ N, 12°42′15.99″ E	4.6–8.3	–	40–420	Native	De Girolamo et al. [50]
P_I	Pelagie Islands, Italy	1997, 1996	9600 m^2 grid (four 40 × 60 m rectangles)	35°41′26.44″ N, 12°42′15.99″ E	8.3–17.8	–	40–420	Native	De Girolamo et al. [50]

Table 1. *Cont.*

Code Map	Discovery Area	Sampling Year	Survey Method	GPS Coordinates	Depht Range	Morphometric Characteristics		Population Structure	References
						T_W	T_L		
P_I	Pelagie Islands, Italy	1997, 1996	Handnets, local fishers or hooks	35°41′26.44″ N, 12°42′15.99″ E	–	–	37–315	Native	De Girolamo et al. [50]
U_I	Ustica Island, Italy	1997–1994	UVC: strip transects (250 m^2)	38°42′07.43″ N, 13°11′08.59″ E	3–28	–	70–300	Scattered	Vacchi et al. [62]
K_I	Kastellorizo Island, Greece	1986, 1985	Trammel nets	36°08′54.06″ N, 29°35′21.63″ E	–	–	130–325	Native	Petrakis & Papacostantinou [63]
L_{Ib}	Lampedusa Island, Italy	–	Spearfishing; hand nets	35°31′02.39″ N, 12°35′07.20″ E	–	–	–	Native	Domingues et al. [64]
L_{Ib}	Lampedusa Island, Italy	–	Spearfishing	35°31′02.39″ N, 12°35′07.20″ E	–	–	–	Native	Bernardi et al. [65]
C_{Ab}	Kea, Greece	–	Spearfishing; hand nets	37°36′50.32″ N, 24°19′23.62″ E	–	–	–	Native	Domingues et al. [64]
C_{Ab}	Santorini, Greece	–	Spearfishing; hand nets	36°24′42.91″ N, 25°22′56.63″ E	–	–	–	Native	Domingues et al. [64]
C_{Ab}	Sifnos, Greece	–	Spearfishing; hand nets	36°58′11.63″ N, 24°42′00.97″ E	–	–	–	Native	Domingues et al. [64]
LE_I	Leipsoi Island; Greece	–	Trammel nets	37°18′14.26″ N, 26°44′25.95″ E	15–20	–	202–312	Native	Koumoundouros [66]
Atlantic Ocean									
Eastern coast									
CN_A	Canarian archipelago, Spain	2012	Seine nets	28°18′12.48″ N, 15°17′02.22″ E	10–12	–	10–192	Native	Espino et al. [51]
CN_A	Canarian archipelago, Spain	2011	UVC: strip transects (25 × 4 m); seine nets	28°18′12.48″ N, 15°17′02.22″ E	–	–	≃10–200	Native	Espino et al. [67]
CN_A	Canarian archipelago, Spain	2004, 2003	UVC: strip transects (25 × 4 m)	28°18′12.48″ N, 15°17′02.22″ E	–	–	>20	Native	Tuya et al. [68]
AZ_A	Azorean archipelago, Portugal	2004–2002	UVC: strip transects (50 × 5 m)	38°14′26.40″ N, 26°47′41.86″ E	10–40	–	<70–>440	Native	Alfonso et al. [40]
AZ_{Ab}	Azorean archipelago, Portugal	1999–1997	Spearfishing	38°14′26.40″ N, 26°47′41.86″ E	–	–	31–522	Native	Alfonso et al. [40]

Table 1. *Cont.*

Code Map	Discovery Area	Sampling Year	Survey Method	GPS Coordinates	Depht Range	Morphometric Characteristics		Population Structure	References
						T_W	T_L		
RF	Ria Formosa, Portugal	–	Beach seines	37°00′09.63″ N, 07°50′12.86″ E	–	–	79	Scattered	Abecasis et al. [36]
AZ_{Abc}	Azorean archipelago, Portugal	–	Spearfishing; hand nets	38°14′26.40″ N, 26°47′41.86″ E	–	–	–	Native	Domingues et al. [64]
CN_{Ab}	Canarian archipelago, Spain		Spearfishing; hand nets	28°18′12.48″ N, 15°17′02.22″ E	–	–	–	Native	Domingues et al. [64]
CV_A	Cape Verde archipelago, Africa		Spearfishing; hand nets	15°51′03.43″ N, 23°19′40.01″ E	–	–	–	Native	Domingues et al. [64]
MA_A	Madeira archipelago, Portugal		Spearfishing; hand nets	32°44′44.00″ N, 16°57′23.09″ E	–	–	–	Native	Domingues et al. [64]
C	Cadix, Spain		Fishing	36°34′16.19″ N, 06°17′10.16″ E	–	–	466	Scattered	Otero & Galeote [51]
PE_I	Almería Gulf, Spain		–	36°47′02.99″ N, 02°25′50.70″ E	–	–	–	Scattered	Otero & Galeote [51]

UVC = underwater visual census; ^{SL} = standard length; $^{\#}$ = an average value was calculated; * exact GPS coordinates, the remainder with several sites or absence of GPS coordinates, have approximate one (see related works).

Sparisoma cretense is one of the thermophilic species from the southern Mediterranean that has expanded its native distribution area northward. Over the past 40 years, the surface temperature of the Mediterranean Sea has risen, with the greatest increases noted for the eastern and northwest areas, with a warming trend of 0.035 °C/year [69]. The surface temperature of the Mediterranean Sea is affected by a combination of atmospheric and oceanic processes and displays significant regional and seasonal behavior [69], with the highest values in the eastern Mediterranean and the northern half of the western Mediterranean, and a lowest, but also positive, trend to the south of Italy. Generally, the Mediterranean Sea presents a seasonal surface temperature range of 10 °C, ranging from 15.2 °C in winter, through 18.8 °C in spring and 19.8 °C in autumn, to 25 °C in summer [69]. This would explain the colonization by this species at higher latitudes and in population growth. The expanded area of distribution comprises several islands in the north Mediterranean: Bagaud Islands (France) [31], Giglio Island (Italy) [30,43], Vrhovnjaci and Palagruža Islands (Croatia) [70], and Sardinia (Italy) ([41,42], present study). Its distribution has also expanded along the eastern coast of the Atlantic Ocean, with an initial first report, probably attributable to climate change, for Ria Formosa (southern Portugal) [36].

With the present study, we provide new reports of *S. cretense* along the coasts of Sardinia at about 26–78 ft/8–24 m depth. The fish were photographed off the central-eastern coast and one was caught off the northwest coast in 2020 and 2019, respectively (Figures 3 and 4). It is important to point out that scuba divers have reported this species in Osalla Bay for several years, and in every season (2015–2020). Thus, it is conceivable that a stable population of *S. cretense* is present. An adult specimen of *S. cretense* (total length 381 mm, total weight 383.40 g) was observed and caught in the coastal waters of Argentiera: it was identified as an adult female based on gonadal examination, morphometric, and meristic characteristics [71,72] (Figure 3; Supplementary Table S1). Adult females are typically red in color with a light-grey dorsal saddle edged in yellow and a yellow spot near the caudal fin (Figure 4). These morphological characteristics were shared by the specimens photographed off the shoal of Punta Nera di Osalla—Osalla Bay (Figure 4). Within hours after death, the coloration becomes uniform in color, from dorsal brown to reddish in the ventral aspect (Figure 3). The bathymetry at which the species was recorded was in line with published data for the Mediterranean [30,73] and the eastern Atlantic coast [40,74].

Figure 3. Adult female parrotfish *Sparisoma cretense* caught along the Argentiera coast (northwest Sardinia, Italy). Photo courtesy of Giuseppe Esposito (GIMP 2.10.12—GNU Image Manipulation Program).

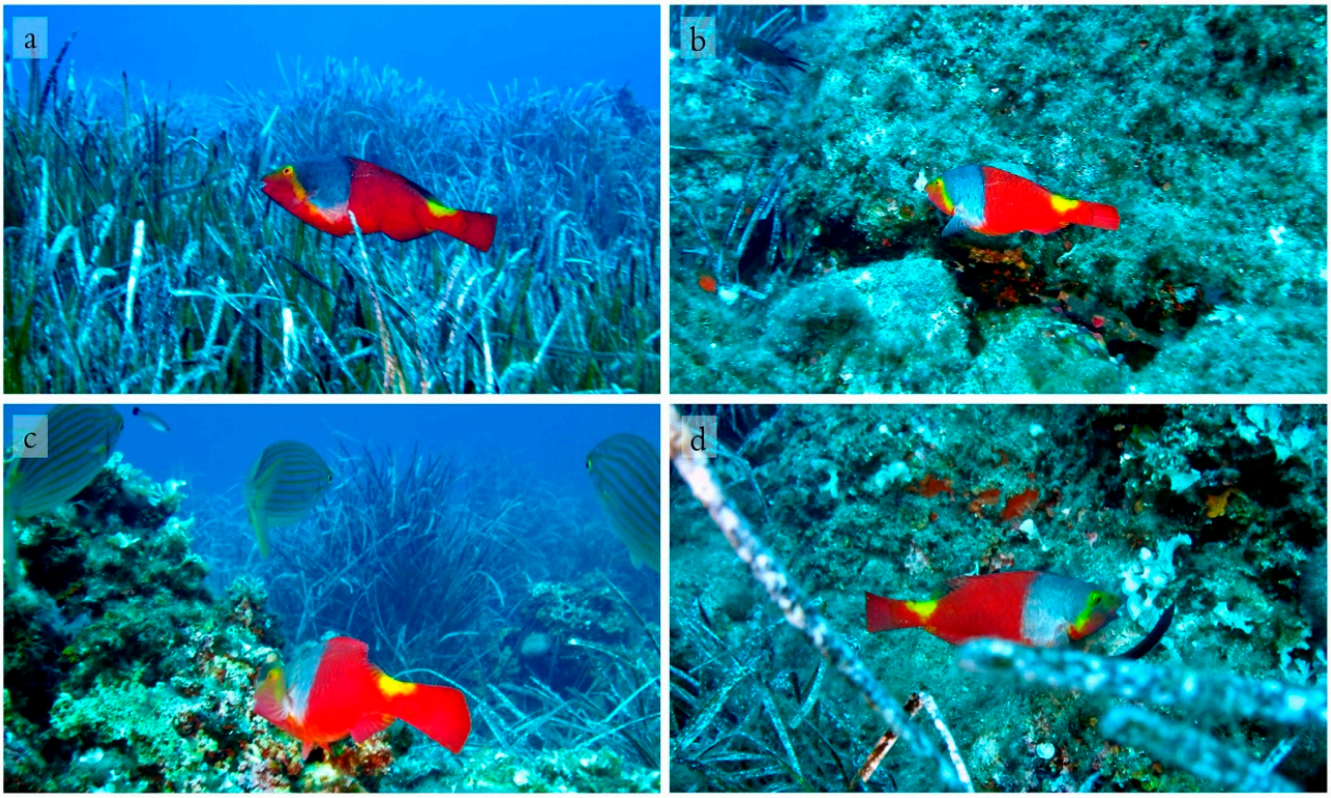

Figure 4. (**a**,**b**) Adult females of parrotfish *Sparisoma cretense* in its natural environment (Osalla Bay, central-eastern Sardinia, Italy). (**c**,**d**) Feeding habits of *S. cretense*. Photo courtesy of Maurizio Uras (Argonauta Diving Sardinia).

In Sardinia, adult *S. cretense* were first observed along the southeast coast of Capo Carbonara in 2002–2003 [41]. In August 2004, specimens were caught along the eastern coast of Sardinia [42]. Both earlier reports, together with the present reports of this study, highlight the expansion of *S. cretense* from the southern to the northern coast of Sardinia.

On a historical note, during the Greco-Roman Era (first century AD), *S. cretense* was introduced to the central Tyrrhenian for use in the local cuisine [75]. Fishing was banned for the first five years to allow the population to establish itself [75]. Some populations in such areas may arise from intentional introduction by humans for recreational fishing and not by natural colonization. According to the latest report issued by the United Nations Food and Agriculture Organization (FAO), catch data from *S. cretense* fishing from 1972 to 2018 are reported only for Cyprus, Lebanon, Libya, Malta, Portugal, and Spain ([76]; Supplementary Table S2), where it is highly prized by local recreational and commercial fisheries [77].

Generally, parrotfish is a daytime feeder, scraping algae (mainly brown algae), seagrasses (i.e., *Posidonia oceanica*), and small invertebrates from the substrate with its fused, beak-like jaws, as demonstrated by analysis of their gut contents [78,79]. Aside from its rapid expansion from south to north in the Mediterranean, we know very little about its possible impact on the structure of rocky bottoms and benthic communities. On this path, Marletta and Lombardo [80] assessed the grazing impact of herbivorous fish on canopy-forming species along the central-eastern sector of Sicily (Italy), observing a lower number of *Sarpa salpa* individuals compared to *S. cretense*. This fact has led the authors to assume that *S. cretense* could be more competitive than *S. salpa.* Additionally, the same authors hypothesize that *S. cretense* could hinder the development and growth of the brown algae *Treptacantha ballesterosi*. There is evidence for a positive effect of the expansion of this thermophilic species: its inorganic gut residue contributes to island-building sediments [81].

4. Conclusions

Global warming plays a key role in the northerly migration of *Sparisoma cretense*. The present update on the distribution of *S. cretense* from the eastern coast of the Atlantic Ocean to the Mediterranean provides new data to better understand colonization by this species. Monitoring and in-depth studies of this thermophilic species will advance our understanding of the population structure and its possible long-term effects on benthic plant and animal communities. These objectives can be advantageously achieved through the involvement of the public in scientific research (citizen science).

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/jmse9050536/s1, Table S1: Morphometric and meristic characters of parrotfish *Sparisoma cretense* from different sites. Specimen measurements in millimeters (mm) and in percentage (%) of the total length (L_T). Table S2: Global capture production of parrotfish *Sparisoma cretense* from 1972 to 2018. Data have been processed using the FAO dataset (FishstatJ) and are given in tons of live weight [72]. Reference [82] is cited in the supplementary materials.

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