

2020-02-10

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<http://hdl.handle.net/10026.1/15377>

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10.3390/jmse8020107

Journal of Marine Science and Engineering

MDPI AG

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Article

# Filling the Gap of Data-Limited Fish Species in the Eastern Mediterranean Sea: A Contribution by Citizen Science

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Received: 8 January 2020; Accepted: 5 February 2020; Published: 10 February 2020

**Abstract:** The biodiversity of the Mediterranean Sea is rapidly changing due to anthropogenic activity and the recent increase of seawater temperature. Citizen science is escalating as an important contributor in the inventory of rare and data-limited species. In this study, we present several records of five data-limited native fish species from the eastern Mediterranean Sea: *Alectis alexandrina* (Geoffroy Saint-Hilaire, 1817), *Ranzania laevis* (Pennant, 1776), *Dalatias licha* (Bonnaterre, 1788), *Lophotus lacepede* (Giorna, 1809), and *Sudis hyalina* (Rafinesque, 1810). All of the records were collected by a participatory process involving fishers and validated by associated taxonomic experts of the citizen science programme “Is it Alien to you? Share it!!!”. This study fills an important gap for the distribution of the reported species and signifies the important role of citizen participation as a tool for extending marine biodiversity knowledge and fisheries management in an area with several gaps of knowledge on targeted and non-targeted species.

**Keywords:** Alexandria pompano; Slender sunfish; Kitefin shark; Crested oarfish; Barracudina; eastern Mediterranean Sea

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## 1. Introduction

The Mediterranean Sea is facing several unprecedented anthropic pressures (e.g. pollution, habitat destruction, and geographical reshuffling of species) [1,2]. Along with climate change, species community shifts are regularly observed, leading to the tropicalization of the Mediterranean Sea [3,4]. Projections have indicated that at least 25% of the Mediterranean continental shelf might experience a total modification of species assemblages by the end of the 21<sup>st</sup> century [5]. Major gaps exist regarding deep species assemblages [6], particularly rare and data-limited species. This is mainly attributed to fragmented research, scarcity of observations, less fishing pressure, and practical difficulties in monitoring deeper waters.

Historically, the low economic value of non-targeted species has led to less data and a lack of vulnerability assessments. Some progress has been made in recent years to develop methods on status and risk assessments [7], such as mixed fisheries [8] and policy requirements [9,10]. Thus, the

methodology has been developed, including time-series catch data [11], life history aspects [12], and size structure [13]. Another aspect is the willingness by citizens to pay for climate adaptation and fisheries resources, as shown by Tulone et al. [14].

Citizen science is emerging as a key component for the exploration of marine biodiversity, being widely acknowledged by scientists, policy-makers, and conservationists, due to its capacity to address conservation issues that are related to rare species, climate change, and coastal systems [15–17]. Currently, there is an increasing number of citizen science efforts in the Mediterranean Sea focused on various topics that are related to the marine environment [18–20]. This provides high potential for addressing data gaps related to least studied species. However, citizen science data should be carefully treated, since they often incorporate taxonomic uncertainties and misidentification due to photographic identification [21,22].

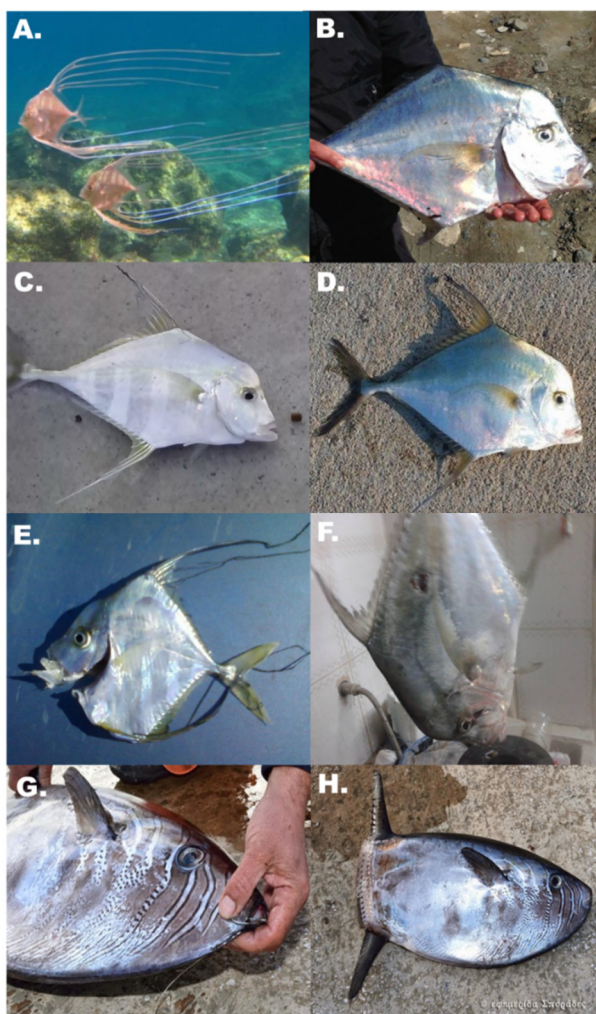
Here, we report several records of five data-limited fish species in the eastern Mediterranean Sea and highlight the use of citizen science as an emerging scientific tool for increasing our understanding on species distributions and contributing to fisheries management in the Mediterranean Sea. In addition, we used current published literature to highlight and give a quantitative aspect of current and historical knowledge of the studied species distribution in the eastern Mediterranean Sea (Supplementary Table S1).

## 2. Materials and Methods

The citizen-science programme “Is it Alien to you? Share it!!!” was initially launched in May 2016 by the Environmental Organisation iSea, with the aim of recording information on the occurrence, distribution, and expansion of marine non-native and rare species in Greece. An online easy-to-upload data repository was generated for citizens that allowed for records with pictures to be tracked. In addition, a Facebook group was created and all of the uploaded pictures to the group were automatically uploaded to the same data repository. At the time, this manuscript was written, this project’s Facebook group numbers > 10,000 members, among which approximately 5000 are actively engaged. Each observer is requested to provide for each photo information on species size in total length (TL in cm.) and/or wet weight (WW; in g.). It is also requested to provide more information regarding the depth (D; in meters), the number of individuals (N), the location in latitude and longitude (LAT: LON), the date (DD: MM: YYYY), and the type of observation, as: underwater observation (UW), stranded (S) (i.e. found deceased on shore). Trained observers with silhouettes measured all of the individuals that were categorized as UW. If fishing gear/practice was provided, each observation was categorized following the FAO classification: longline (LL), bottom longline (bLL), surface longline (sLL), harpoons (HAR), and handlines and pole-lines that are hand-operated (LHP) (Figure 1, Table 1). All of the records are pre-scanned for quality and sent out for external evaluation to taxonomic experts prior to the inclusion in the final dataset of iSea. Only confirmed observations are recorded in the dataset, either through photo-identification or in-situ validation.

**Table 1.** Records of five rare species in the eastern Mediterranean Sea with information on number of individuals (N), depth (m.), total length (cm.), area, coordinates (lat: lon) in decimal degrees and type of observation (underwater, UW; shore fishing, SF; spearfishing,; demersal longline, LL; Otter bottom trawl OTB).

n	Species	N Individuals	Depth	TL	Area	Coordinates	Type of Observation
1	<i>A. alexandrina</i>	2	N/A	10	Protaras, Cyprus	35°00'48.6" N, 34°02'14.6" E	UW
2	<i>A. alexandrina</i>	1	N/A	45	Zygi, Cyprus	34°43'35.3" N, 33°20'15.0" E	SF
3	<i>A. alexandrina</i>	1	5	45	Old port of Limassol, Cyprus	34°40'13.8" N, 33°02'34.8" E	SF
4	<i>A. alexandrina</i>	1	N/A	50	Port of Kos Island, Greece	36°53'43.8" N, 27°17'19.0" E	SF
5	<i>A. alexandrina</i>	1	N/A	22	Zygi, Cyprus	34°43'41.5" N, 33°20'25.8" E	S
6	<i>A. alexandrina</i>	1	5	60	Akrotiri Bay, Cyprus	34°33'20.2" N, 33°00'59.8" E	SF
7	<i>A. alexandrina</i>	1	4	15	Ayia Napa, Cyprus	34°58'53.0" N, 34°00'17.9" E	SF
8	<i>A. alexandrina</i>	1	N/A	45	Zygi, Cyprus	34°40'15.7" N, 33°02'39.4" E	S
9	<i>A. alexandrina</i>	1	3,5	6,5	Protaras, Cyprus	35°00'30.1" N, 34°03'48.4" E	UW
10	<i>R. laevis</i>	1	200	53	Psathoura island, Greece	39°26'46.0" N, 24°04'46.1" E	LL
11	<i>D. licha</i>	1	612	150	Levitha island, Greece	36°58'23.2" N, 26°29'11.4" E	LL
12	<i>D. licha</i>	1	580	150	Amorgos island, Greece	36°46'25.7" N, 26°02'38.0" E	LL
13	<i>L. lacepede</i>	1	500	160	Between Skopelos and Euboea island, Greece	36°46'25.7" N, 23°34'44.0" E	LL
14	<i>L. lacepede</i>	1	500	140	Between Skopelos and Euboea island, Greece	36°46'25.7" N, 23°34'44.0" E	LL
15	<i>L. lacepede</i>	1	540	60	Between Santorini and Anafi island, Greece	36°22'39.4" N, 25°35'44.5" E	LL
16	<i>L. lacepede</i>	1	300	100	Chalkidiki Peninsula, Greece	39°44'10.7" N, 23°22'56.6" E	LL
17	<i>L. lacepede</i>	1	540	140	Crete island, Greece	35°34'58.0" N, 23°29'29.1" E	LL
18	<i>L. lacepede</i>	1	40	25	Rhodes island, Greece	36°27'21.6" N, 28°13'05.5" E	BS
19	<i>S. hyalina</i>	1	700	N/A	Kastellorizo island, Greece	35°51'41.4" N, 30°06'32.0" E	LL
20	<i>S. hyalina</i>	1	200	30	Akrotiri Bay, Cyprus	34°32'46.0" N, 32°56'56.4" E	SF
21	<i>S. hyalina</i>	1	100	N/A	Crete island, Greece	35°31'20.8" N, 24°00'55.5" E	BS
22	<i>S. hyalina</i>	1	300	40	Morfou Gulf, Cyprus	35°13'43.4" N, 32°52'01.1" E	BS
23	<i>S. hyalina</i>	1	400	N/A	Crete island, Greece	34°54'55.1" N, 24°54'50.6" E	BS
24	<i>S. hyalina</i>	1	100	N/A	Saronikos Gulf, Athens	37°50'12.0" N, 23°18'50.7" E	BS
25	<i>S. hyalina</i>	1	612	35	Levitha island, Greece	37°00'02.9" N, 26°27'32.6" E	LL



**Figure 1.** (A,B): *Alectis alexandrina* juvenile sighted in Protaras, Cyprus; (B,C): *Alectis alexandrina* adults caught in Zygi and Limassol port (Cyprus) respectively; (D): *Alectis alexandrina* adult captured in the harbour of Kos Island, Greece; (E): *Alectis alexandrina* juvenile sighted in Zygi, Cyprus; (F): *Alectis alexandrina* captured by spearfishing in Akrotiri Bay, Cyprus; (G,H): *Ranzania laevis* individual captured with surface longline in Psathoura Island, Greece.

All of the data used in this study has been uploaded to an electronic repository (<https://wp.me/P94Vaj-1Mm>).

### 3. Results

#### 3.1. *Alectis Alexandrina*

On 20th November 2012, two juvenile individuals ( $\approx 10$  cm TL) were sighted and photographed near Protaras, Cyprus (Levant Sea,  $35^{\circ}00'48.6''$  N,  $34^{\circ}02'14.6''$  E) (Figure 1A; Table 1). On 4th February 2015, an individual with a TL of 45 cm was caught by a recreational fisherman at Zygi, Cyprus (Levant Sea,  $34^{\circ}43'35.3''$  N,  $33^{\circ}20'15.0''$  E), while a second individual, approximately of the same size, was caught on 30th May 2015 in the old port of Limassol (Levant Sea,  $34^{\circ}40'13.8''$  N,  $33^{\circ}02'34.8''$  E) (Figure 1B, C). On July 2016, a single individual with a TL of  $\approx 50$  cm and 1100 g in weight was caught by a recreational fisherman at the port of Kos Island (Aegean Sea;  $36^{\circ}53'43.8''$  N,  $27^{\circ}17'19.0''$  E; Figure 1D). On 16th March 2017, a juvenile individual ( $\approx 22$  cm TL for 100 g) was found stranded near to Zygi village, Cyprus (Levant Sea,  $34^{\circ}43'41.5''$  N,  $33^{\circ}20'25.8''$  E) (Figure 1E). On 11th October 2017, an individual ( $\approx 60$  cm TL) was captured by spearfishing at a depth of 5 m at Akrotiri Bay in Limassol (Levant Sea,  $34^{\circ}33'20.2''$  N,  $33^{\circ}00'59.8''$  E). During 2018 there had been two more records that were collected on 9th of October an individual of  $\approx 15$  cm TL by a spear fisher and



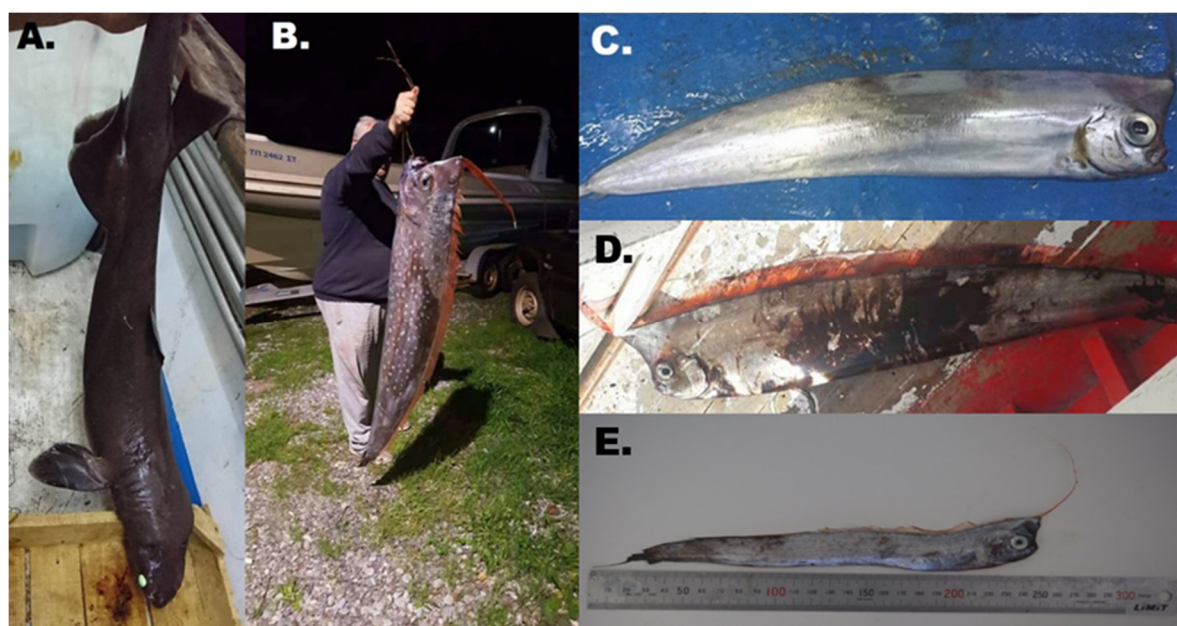
another individual  $\approx 6.5$  cm TL was photographed by a diver; both occurrences were in Cyprus Ayia Napa, (Levant Sea,  $34^{\circ}58'53.0''$  N,  $34^{\circ}00'17.9''$  E) and Portaras Bay, (Levant Sea,  $35^{\circ}00'30.1''$  N,  $34^{\circ}03'48.4''$  E), accordingly (Table 1). Finally, there has been another stranded individual of 45 cm TL, in Zygi, Cyprus (Levant Sea,  $34^{\circ}40'15.7''$  N,  $33^{\circ}02'39.4''$  E), (Table 1; Fig. 4).

### 3.2. *Ranzania Laevis*

On 21<sup>st</sup> December 2014, an individual of *R. laevis* was captured with a surface longline near Psathoura Island in North Aegean Sea ( $39^{\circ}26'46.0''$  N,  $24^{\circ}04'46.1''$  E) at a depth of approximately 200 m and landed at Skopelos Island (Figure 1G, H). The specimen was 53 cm in TL. The fisherman and a local journalist contacted the local authorities, which identified the species as “Propela”, the common Greek name for *Mola mola*. On 29<sup>th</sup> of July 2017 the journalist contacted iSea, in the context of the citizen science project “Is it Alien to you? Share it!!!” for sharing a log of rare species observations from Skopelos Island. Among the observations, the record of *R. laevis* was found and all of the available information was collected.

### 3.3. *Dalatias Licha*

On 5<sup>th</sup> November 2016, a single male individual of *D. licha* ( $\approx 150$  cm TL) was caught by a demersal longline at a depth of 580 m off Amorgos Island (Aegean Sea,  $36^{\circ}46'25.7''$  N,  $26^{\circ}02'38.0''$  E) (Figure 2A). On 29<sup>th</sup> August 2019 an individual was caught off Levithas island at a depth of 612 m in depth by a demersal longline over muddy substrate (Aegean Sea;  $36^{\circ}58'23.2''$  N,  $26^{\circ}29'11.4''$  E) (Table 1; Fig. 4).



**Figure 2.** (A): Male *Dalatias licha* caught with demersal longlines off Amorgos Island, Greece; (B): *L. lacepede* caught with demersal longlines between Skopelos and Euboea Islands, Greece; (C): *L. lacepede* caught with demersal longlines between Santorini and Anafi Islands, Greece; and, (D): *L. lacepede* caught off the Coast of Chalkidiki Peninsula, Greece; (E): *L. lacepede*, Rhodes Island, Greece.

### 3.4. *Lophotus Lacepede*

Demersal longlines set at 500 m deep bottoms between Skopelos and Euboea Islands (Aegean Sea,  $36.7738^{\circ}$  N,  $23.5789^{\circ}$  E) allowed for the capture of a large individual ( $\approx 160$  cm TL, 10 kg WW) (Figure 2B) on 3<sup>rd</sup> March 2017. A few days later, on 9<sup>th</sup> March 2017, a slightly smaller individual (approximately 140 cm in TL and 8 kg in WW) was collected from the same area while using the same fishing gear. A third, distinctly smaller individual ( $\approx 60$  cm in TL) (Figure 2C) was captured by demersal longlines at a depth of 540 m between Santorini and Anafi Islands (Aegean Sea;  $36.3776^{\circ}$  N,

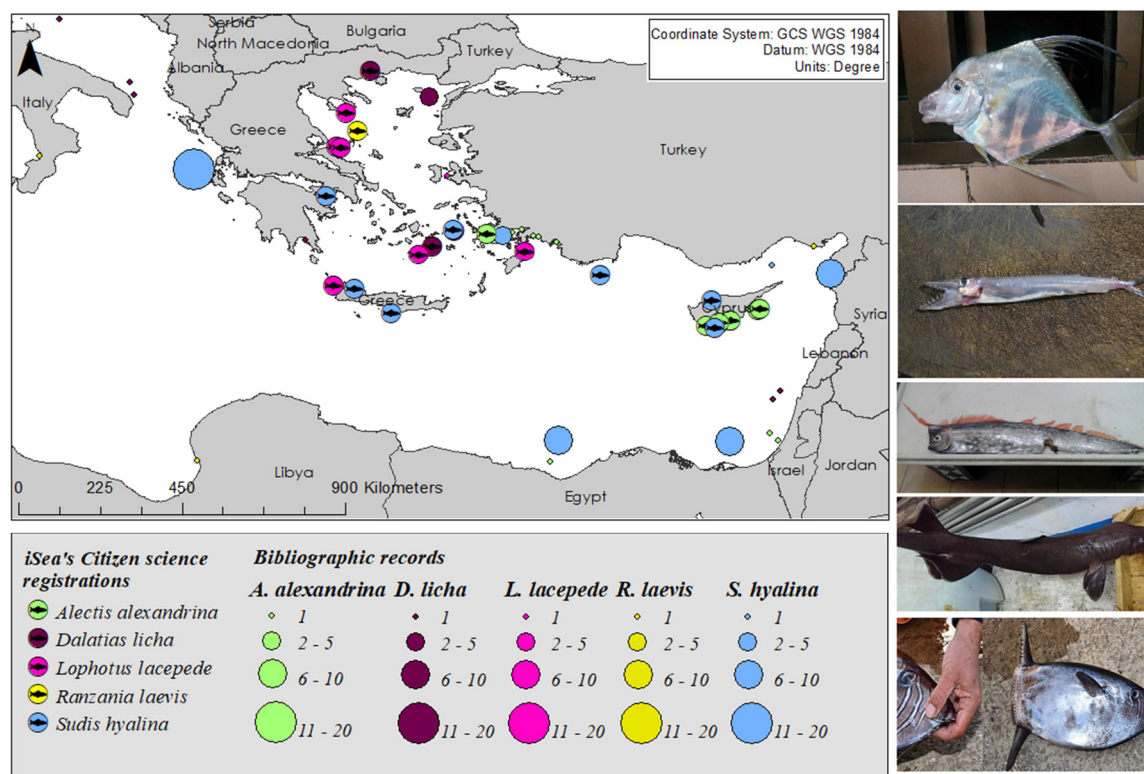
25.5957° E). Lastly, on 6<sup>th</sup> October 2017, a fourth large individual (approximately 100 cm in TL and 6kg in WW) (Figure 2D) was captured by a longline targeting swordfish off the coast of Chalkidiki Peninsula towards Sporades Islands (North Aegean Sea; 39°44'10.7"N, 23°22'56.6" E) at a depth of approximately 300 m. On September 12, 2017 an individual of  $\approx$  25 cm in TL was caught outside Rhodes Island, Greece (36°27'21.6" N, 28°13'05.5" E) (Figure 2E). On 1<sup>st</sup> of November 2018, an individual of  $\approx$  140 cm in TL was caught by a professional fisher with a demersal longline at a depth of 540 m (Cretan Sea, 23°29'29.1" N, 35°34'58.0" E) (Fig. 4).

### 3.5. *Sudis Hyalina*

On 1st July of 2014, an individual was caught at 100 m in depth by demersal longline of a recreational fisher, off Crete Island (Aegean Sea, 35°31'20.8"N, 24°00'55.5" E). On 6<sup>th</sup> November 2016 an individual was caught by demersal longline approximately 30 miles south-east from Kastellorizo Island and at approximately 700 m in depth (Aegean Sea; 35°51'41.4"N, 30°06'32.0"E) (Figure 3A). The specimen was found mutilated by another fish, possibly a scabbardfish (*Lepidopus caudatus*; Euphrasen, 1788), but features of the head allowed for a uniequivocal identification. On 17th August 2017, another individual of *S. hyalina* ( $\approx$  30 cm TL) was captured at Akrotiri, Cyprus (34°32'46.0"N, 32°56'56.4" E) by a recreational fisher at an approximate depth of 200 m (Figure 3B, C). During 2018, another record was added from Morfou in Cyprus; the individual was approximately 40 cm in TL and it was caught at 300 m in depth (Levantine Sea, 35°13'43.4" N, 32°52'01.1" E). On 19th May 2019, another individual was caught in 400 m by shore-based fishing off Crete island (Cretan Sea, 34°54'55.1" N, 24°54'50.6" E); on 29th August 2019, an individual was caught off Levithas island at 612 m in depth with demersal longline over muddy substrate along with a *D. licha* individual (Aegean Sea, 37°00'02.9" N, 26°27'32.6" E), (Table 1; Figure. 4). The latest record was on 17th September 2019, where another individual of  $\approx$  20 cm in TL was caught by demersal longline at 100 m in depth at Saronikos Gulf (Aegean Sea, 37°50'12.0" N, 23°18'50.7" E).



**Figure 3.** (A): Head of *Sudis hyalina* collected from demersal longlines off Kastellorizo Island, Greece; (B) individual captured in Akrotiri Bay, Cyprus; and, (C): individual captured in Chalkidiki Peninsula, Greece.



**Figure 4.** Geographic density dependent bubble plot on five uncommon data-limited species (*Alectis alexandrina*, *Dalatias licha*, *Lophotus lacepede*, *Ranzania laevis* and *Sudis hyalina*) in the eastern Mediterranean Sea.

We found that, based on current literature (Supplementary Table S1), the reported number of individuals in this study contributed 21.6% of the reports the species in the eastern Mediterranean Sea and 27.3% to the total number of reports during the last decade. For some species, the contribution to the total number of reports in the eastern Mediterranean was higher: (a) *A. alexandrina* contributed 34.4% of the reports the species in the eastern Mediterranean Sea and 35.7% to total number of reported species in the eastern Mediterranean Sea during the last decade, (b) *R. laevis* contributed 11.1% of the reports of the species in the eastern Mediterranean Sea and 20% of the reports of the species in the eastern Mediterranean Sea during the last decade, (c) *D. licha* contributed 18.9% of the reports of the species in the eastern Mediterranean Sea and 28.6% of the reports of the species in the eastern Mediterranean Sea during the last decade, (d) *L. lacepede* contributed 46.1% of the reports of the species in the eastern Mediterranean Sea and 75% of the reports of the species in the eastern Mediterranean Sea during the last decade and (e) *S. hyalina* contributed 11.9% of the reports of the species in the eastern Mediterranean Sea and 14% of the reports of the species in the eastern Mediterranean Sea during the last decade.

#### 4. Discussion

The present work provides additional information on five uncommon fish species for the Aegean and Levantine Sea. Rare species are often considered to be data-limited. However, spatial and temporal variations in the distribution of rare species might provide relevant signs of climate and environmental change [23,24]. Until recently, the scarce communication between researchers and citizens entailed the loss of an important part of available information on these species, while the recent increase in the use of social networks allowed for a closer communication that can result in an increase of records of rare and non-native species [20,25–28]. To date, the project “Is it Alien to you? Share it!!!” has gathered a vast amount of information regarding the distribution and establishment of species, including several first records, as well as expansion evidences [20].



*Alectis alexandrina* is a thermophilic species with a rather sporadic occurrence in the Mediterranean Sea. Fishers state that the species is increasingly caught the last years, being very common in Cyprus and rather sporadic in southern Aegean Sea, despite the few observations from the northeast Mediterranean Sea.

*Ranzania laevis* commonly known as slender sunfish (Fam. Molidae) is a pelagic-oceanic cosmopolitan species found in tropical and temperate seas and feeding on small fish, planktonic crustaceans, and jellyfish. It is one of the two Molidae species occurring in the Mediterranean Sea; however, reports of *R. laevis* from the eastern basin are scarce. Occasional records from Greece [29], Cyprus and Israel [30], Turkey [31], and Lybia [32] have been reported. Current distribution of *R. laevis* covers the whole Mediterranean Sea while quantitative information has revealed a rather sporadic occurrence and local peaks of abundance with increased zooplankton biomass [23]. The reported species is the second record from the north Aegean Sea [29].

The remaining three species reported are typical rare deep-water species in the eastern Mediterranean Sea [6]. Recent studies demonstrated the occurrence of these deep-water species, as previously overlooked in the eastern Mediterranean Sea [33,34].

*Dalatias licha*, commonly known as the kitefin shark, is one of the largest deep-sea sharks occurring in the Mediterranean Sea, being distributed at depths between 200 and 900 m, where it can be considered a top predator. It is although an uncommon species in the western and central part of the basin [35,36], while its presence in the eastern Mediterranean Sea is considered as very scarce [37,38], signifying any reports as highly valuable, also given the conservation status of the Mediterranean population of the species as vulnerable [39].

*Lophotus lacepede*, commonly known as the crested oarfish, is a large bathypelagic species that is remarkably sporadic in the whole Mediterranean Sea. Similarly, to the majority of deep-sea fish species it is more regularly observed in the western Mediterranean Sea, with only a few records in the eastern part of the basin. Currently, only four published records are known, all being from the Aegean Sea [40]. The observations that are reported in the current work highlight the deep waters between Chalkidiki Peninsula and Evoia Islands as an important area for the species.

*Sudis hyalina*, which is a rare bathypelagic cosmopolitan fish species, is considered to be regular in the western part of the Mediterranean basin, while only five documented records of the species exist from the eastern Mediterranean basin [41]. In the Aegean Sea only two records of the species have been published [29]. Consequently, the record presented in this study is the third record of the species from the Aegean Sea. Interestingly, the report from Cyprus is the first record of the species from the Cypriot territorial waters, most possibly an overlooked species.

## 5. Conclusions

This study reveals that the contribution of citizen-science accounts for 45.4% of the total number of the studied species published records and 58.5% of the total number of published records during the last decade in the eastern Mediterranean Sea. This signifies the important role of citizen-science efforts, both for scientific and public awareness. Nine more records of the reported species have been published since “Is it Alien to you? Share it!!!” was launched [38,42–46], whereas, in this article, we report the occurrence of 26 individuals contributing with 74.2% during the same period. Of course, it can be hard to determine whether the species density in the region has increased or if the reports were overlooked before pictures of the species were circulated on social media as something rare. Thus, post-hoc interviews with citizens and fishermen who report catches can be used to reconstruct species distributions and densities.

**Author Contributions:** Conceptualization, S.K., I.G., and R.N.A.S.; methodology, S.K. R.N.A.S.; software, R.N.A.S.; validation, S.K. and R.N.A.S.; formal analysis, S.K. and R.N.A.S.; investigation, S.K.; R.N.A.S., I.G., J.L. D.B.; resources, S.K.; R.N.A.S., I.G., J.L. D.B.; data curation, R.N.A.S., S.K.; writing—original draft preparation, S.K.; R.N.A.S., I.G., J.L. D.B.; writing—review and editing, S.K.; R.N.A.S., I.G., J.L. D.B.; visualization, S.K., R.N.A.S.; supervision, S.K.; project administration, I.G.; funding acquisition, I.G.. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by iSea, Environmental Organisation for the preservation of the aquatic ecosystems—“Is it Alien to you? Share it!!!”.

**Acknowledgements:** We are grateful to the fisherman Nikolas Katsillis (Greece) for sharing his pictures and data for three specimens of *S. hyalina*, *L. lacepede* and *D. litcha*, Antonis Voutsas (Greece) for sharing his picture and data of *L. lacepede*, to Werner Wolf (Austria), Pabos Charalambous (Cyprus), Savvas Ioannou (Cyprus), Michalis Iliia (Cyprus) and Antonis Salachoris (Greece) for sharing data and pictures of the *A. alexandrina* specimens, Angelos Kouriefs (Cyprus) for sharing data and pictures of *S. hyalina* specimen and Georgios Poullos (Greece) for sharing data and pictures of *R. laevis* and all the other citizen scientists who contributed in gathering the information needed.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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