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Review

Tracing Patterns and Biodiversity Aspects of the Overlooked Skates and Rays (Subclass Elasmobranchii, Superorder Batoidea) in Greece

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Abstract: Species belonging to the superorder Batoidea have been poorly assessed due to the lack of information on their life history aspects and their limited economic value. This work presents an overview of skates and rays inhabiting the marine Greek waters and reports biodiversity issues requiring resolution for conservation purposes. Overall, 30 species from nine families and 16 genera have been documented within the past 22 years, based on the available literature and technical reports from research surveys of the Hellenic Centre for Marine Research (HCMR). However, 28 species are currently confirmed, since the presence of two rajids has not been sufficiently demonstrated and hence is considered as doubtful. Recent changes in nomenclature allowed us to replace old with new names in four species on the Greek list; patterns in the frequency of occurrence were observed and species were assigned into five categories; and diversity and misidentification issues were reported by family. Although Greek waters are oligotrophic and not considered a biodiversity hot spot for elasmobranchs, a high number of batoid species is documented in the area; therefore, the need to reinforce knowledge on biological aspects of skates and rays, define their status and identify their main threats is essential.

Keywords: batoids; diversity; occurrence; taxonomy; conservation; eastern ionian; Aegean Sea

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1. Introduction

Chondrichthyans are one of the most vulnerable taxa worldwide, with a third of them being threatened with extinction [1]. Their slow growth rate, late maturity and low offspring production [2,3] along with an increase in fishing effort over the last 50 years [4] elevates risks in individual species. The superorder Batoidea is the largest subgroup with 26 families and 665 valid species globally [5]. Due to the high fishing pressure on the continental shelf, many batoid species are driven to extinction; more specifically, five of the seven most endangered chondrichthyan families belong to this superorder [6,7]. The General Fisheries Commission for the Mediterranean has recently adopted measures to reduce chondrichthyan bycatch (Recommendation GFCM/42/2018/2) and has banned the capture and sale of the shark and ray species listed in Annex II of the Protocol of the Barcelona Convention [8]. Still, no effective management measures against the overexploitation of many commercial species have been successfully implemented and data on the stock status of sharks and rays remain poor or non-existent, a problem that is progressively aggravated in the Mediterranean Sea [9–12].

The Mediterranean Sea is considered a hot spot for cartilaginous fish diversity, with 88 validated species in the area (~7% of the global diversity) [13,14]. However, it hosts the highest percentage of threatened species worldwide (53%) [15]. Despite the presence of unique breeding grounds for species such as the great white shark, *Carcharodon carcharias* (Linnaeus 1758), and the thornback ray, *Raja clavata* (Linnaeus 1758) [3,16], knowledge on

the life-history characteristics of many species is limited. Skates and rays have received less attention than sharks, even if they are considered more threatened [17]. Additionally, skates (Rajiformes), which exhibit higher biodiversity and endemism richness than their relatives, are most diverse at higher latitudes and in deep waters; yet they are often replaced by stingrays (Myliobatiformes) in shallower, warm temperate to tropical waters [18]. Problems emerging in batoid stock assessments in the Mediterranean Sea are mainly attributed to regular classification changes and to extended misidentification occurring due to high levels of resemblance among closely related taxa [14,19]. Diagnostic characters visible in adult specimens are reported to be less evident in juveniles [19], lowering taxonomic resolution and catch statistics and impeding conservation management [11].

Batoids have been reported to be extirpated from various parts of the Mediterranean Sea [14], such as the endemic Maltese skate *Leucoraja melitensis* (Clark 1926), which is currently absent from its previous geographic distribution [14,20,21]. Moreover, the occurrence of some species remains questionable due to a lack of observations within the last decade (such as the common skate *Dipturus batis* Linnaeus 1758). Other endemic species inhabiting the Mediterranean Sea are the speckled skate *Raja polystigma* (Regan 1923) and the rough ray *Raja radula* (Delaroche 1809), currently evaluated as Least Concerned and Endangered [14], respectively. The starry ray *Raja asterias* (Delaroche 1809), once considered endemic, has been recently documented outside the Mediterranean basin in the southern part of Portugal [22] and the Atlantic coasts of Morocco [23]. Similarly, the devil ray *Mobula mobular* (Bonnaterre 1788), also considered endemic in the area [24] and synonymized with *Mobula japonica* (Müller and Henle 1841) [5,25], is now considered a species with a global distribution in warm temperate and tropical waters [26].

Although the western Mediterranean Sea hosts the greatest diversity of elasmobranch species (84%), the highest proportion of batoids is found in the eastern and central parts of the basin (79% each) [14]; yet, biological information on this group is scarce in the eastern basin, such as the Aegean and the Levantine Seas. However, life history traits of skates and rays have been studied in the Adriatic, Tyrrhenian and Ligurian Seas, the Algerian basin, the Strait of Gibraltar and the Gulf of Taranto, and limited information exists from the southern Tyrrhenian and Ionian Seas [27]. Distribution and abundance data are mainly available in the literature [12,28–37], but biological and ecological aspects of skates and rays were studied only recently [38–46].

In Greece, 60% of elasmobranch catches originate from the bottom trawl fishery, and even if they are not targeted, their contribution to the total catches (averaging 14% in weight) remains substantial [9]. Extended monitoring studies targeting sharks and rays are currently missing from the Greek fisheries sector, despite being indispensable for species stock assessments [11,19,47]. An updated checklist of chondrichthyans recently presented a different number of cartilaginous fish occurring in Greek waters [48] compared to the previous list published in 2014 [49].

This work presents an overview of the status of batoids in Greek waters, taking into account the most recent taxonomic classifications [5,50], the latest checklist of the Greek ichthyofauna [49], recently published records [14,37,51] and authors' expertise on this group of marine organisms. It also underscores important aspects associated with species misidentification and reveals the need to update regularly the list of skates and rays in the Mediterranean Sea, as the classification of the superorder Batoidea is still in flux, and special attention is required in future assessments and management efforts.

2. Materials and Methods

An extensive and systematic survey was conducted to collect all available information on batoid occurrence and distribution in Greek waters (Figure 1), from (i) technical reports (INTERREG, 2001; DEEPEASTMED, 2019) from recent research surveys of the Hellenic Centre for Marine Research (HCMR), (ii) sources from the Greek press on batoid incidental catches, and (iii) peer-reviewed journals, using Scopus and Google Scholar, up to spring 2022. The search keywords used to obtain this information included "skate* OR ray* OR

batoid* OR Elasmobranch*"AND "eastern Mediterranean Sea OR Aegean Sea OR eastern Ionian Sea", AND "the batoid species name". Wildcards were used to broaden the search and include variations of specific words. Overall, 30 species are currently mentioned in the literature [46,49] and are listed herein (Table 1). These include 15 skates, ten stingrays, three electric rays, and two guitarfishes out of the 38 batoid species reported in the Mediterranean Sea [14]. Subsequently, the abstracts of all papers from this search were read, and studies focusing on batoid biodiversity and distribution in Greece were selected. The reference lists of the selected articles were reviewed for possible undetected relevant studies.

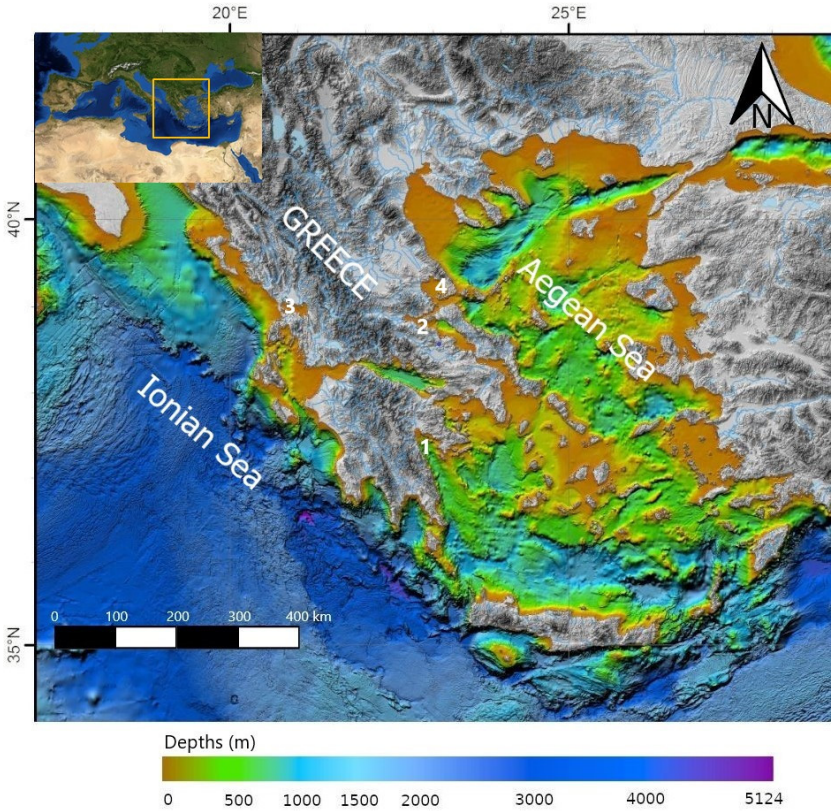

Figure 1. The study area of batoid diversity overview in the eastern Mediterranean Sea, indicating the two main districts: eastern Ionian Sea and Aegean Sea (Gulfs: 1 = Argolikos, 2 = Maliakos, 3 = Amvrakikos, 4 = Pagasitikos).

The presence and frequency of observations of each species in Greek waters (eastern Ionian and Aegean Seas) appeared to form patterns of occurrence (Table 1). Therefore, we divided the observed patterns into five categories: Category 1 (C1) represents regular observations of species in field surveys; Category 2 (C2) stands for species that are occasionally caught in the study area (i.e., every few years); Category 3 (C3) includes those species rarely sighted or caught in fishing gear, or even absent in the literature within the past 10–15 years; Category 4 (C4) reports species with a high possibility of misidentification; and Category 5 (C5) documents species with a local distribution (i.e., with limited migratory behaviour, restricted to specific coastal areas, gulfs or semi-enclosed gulfs, Figure 1).

The results of this analysis are presented for each family in order to discuss and review their status. New information and observations collected through time and changes in nomenclature were used to corroborate the checklist of the skates and rays of Greece. Additionally, cases of incorrect species identification are highlighted to resolve the confusion between closely related taxa (Table 2).

Table 1. Skates and rays of Greek waters divided into five patterns based on their frequency of occurrence from the available literature (C1 = regularly observed; C2 = occasionally observed; C3 = absent from surveys/observations for the past 10 years; C4 = high possibility of misidentification; C5 = local occurrence). The latest global and Mediterranean IUCN Red List assessments are also included (Conservation status categories: CR = critically endangered, EN = endangered, NT= near threatened, LC= least concern, NE = not evaluated, VU = vulnerable, DD = data deficient).

			Superorder Batoidea			
Order	**Family**	**Species**	**Ionian Sea**	**Aegean Sea**	**Global IUCN Status**	**Med. Sea IUCN Status**
Rajiformes	Rajidae	*Leucoraja circularis*	C2	C2	EN	CR
		Leucoraja fullonica	C3	C2	VU	CR
		Leucoraja melitensis		C4	CR	CR
		Leucoraja naevus	C3	C2	LC	NT
		Raja asterias	C1	C1	NT	NT
		Raja brachyura	C2	C1	NT	NT
		Raja clavata	C1	C1	NT	NT
		Raja miraletus	C1	C1	LC	LC
		Raja montagui	C2	C2	LC	LC
		Raja polystigma	C2	C1	LC	LC
		Raja radula	C1	C1	EN	EN
		Raja undulata	C3	C3	EN	NT
		Dipturus batis	C4	C4	CR	CR
		Dipturus oxyrhinchus	C1	C1	NT	NT
		Rostroraja alba	C3	C2	EN	EN
Rhinopristiformes	Rhinobatidae	*Rhinobatos rhinobatos*	C3	C5	CR	EN
	Glaucostegidae	*Glaucostegus cemiculus*	C3	C5	CR	NE
Myliobatiformes	Dasyatidae	*Bathytoshia lata*	C2	C2	LC	NE
		Dasyatis marmorata		C5	DD	NE
		Dasyatis pastinaca	C1	C1	DD	VU
		Dasyatis tortonesei	C1	C1	NE	NE
		Pteroplatytrygon violacea	C2	C2	LC	LC
	Myliobatidae	*Aetomylaeus bovinus*	C2	C1	CR	CR
		Myliobatis aquila	C5	C5	CR	VU
	Gumnuridae	*Gymnura altavela*	C5	C5	EN	CR
	Rhinopteridae	*Rhinoptera marginata*	C3	C3	NT	DD
	Mobulidae	*Mobula mobular*	C2	C2	EN	Decreasing
Torpediniformes	Torpedinidae	*Tetronarche nobiliana*	C2	C2	NE	NE
		Torpedo marmorata	C1	C1	DD	LC
		Torpedo torpedo	C2	C2	DD	LC

Table 2. Identification issues documented by fisheries observers, due to the high morphological variability of the external features in skates and rays.

Misidentified Species	Status	Species with Similar Morphological Characteristics with Closely Related Species												
		R. clavata	*R. asterias*	*R. montagui*	*R. brachyura*	*R. undulata*	*L. fullonica*	*L. melitensis*	*L. circularis*	*L. naevus*	*R. alba*	*D. oxyrinchus*	*M. aquila*	*D. pastinaca*
Rajiformes														
R. asterias	NT	X												
R. brachyura	NT	X	X	X										
R. montagui	LC	X			X									
R. polystigma	LC	X		X										
R. radula	EN					X				X				
L. fullonica	CR								X		X			
L. circularis	CR						X							
L. naevus	NT							X						
R. alba	EN						X							
D. batis	CR											X		
Myliobatiformes														
R. marginata	DD												X	
B. lata	NE													X
D. tortonesei	NE													X

3. Results

3.1. Order Rajiformes

Family Rajidae

The greatest challenge faced when listing rajids is the taxonomic confusion prevailing due to high morphological variability in this group (Table 2). The Rondelet's ray, *Raja rondeleti* (Bougis 1959), is a doubtful validated species [52] mentioned in Greek technical reports [53] and Mediterranean distribution research surveys [28]. It is believed to have been confused with the shagreen ray, *Leucoraja fullonica* (Linnaeus 1758), and should not be considered a valid species [51].

Genus *Leucoraja*

Leucoraja circularis

The sandy ray, *Leucoraja circularis* (Couch 1838), appears to be frequently observed in the northern part of the Aegean Sea [12,54,55] and is occasionally caught in the eastern Ionian Sea [55] (Table 1). Misidentification issues were recently documented (Table 2) during the Mediterranean Bottom Trawl Survey (MEDITS), when an individual caught in Argolikos gulf (Figure 1) was initially recorded as *L. fullonica* [56]. At a later stage, though, DNA sequencing was applied and the specimen was identified as *L. circularis* [57], indicating that genetic markers can be excellent tools to identify species already existing in a DNA sequence library.

Leucoraja fullonica

Occasional catches of the shagreen ray *L. fullonica* (Table 1) are published in reports of the MEDITS survey, with low density or biomass indices in the Greek GSAs [12,55]. Due to its rarity, the species is sometimes confused with the white skate *Rostroraja alba* (Lacepède 1803) and *L. circularis* (Table 2).

Leucoraja melitensis

The Maltese ray is reported to be restricted to the continental shelf of the central Mediterranean Sea [21], mainly in the Strait of Sicily [5,14], rare in Malta and rare or absent in Tunisia [20]. Therefore, records of *L. melitensis* reported in Greek waters [9,12,49] have been possibly confused with individuals with similar patches on their pectoral fins belonging to the Cuckoo ray *Leucoraja naevus* (Műller and Henle 1841; Table 2). The species has not been reported in Greek waters for over a decade now (personal communication with fisheries observers and authors' participation in the MEDITS surveys). The species is rarely caught off the coasts of Malta [12] and thus it is recommended to be removed from the list of chondrichthyan species of Greece.

Leucoraja naevus

The confusion between the Cuckoo ray, *L. naevus,* and the Maltese ray, *L. melitensis* (Near Threatened and Critically Endangered, respectively; Figure 2) might have affected the true documentation of the Cuckoo ray's occurrence (Table 1). The need to resolve this confusion is vital to assess its status. However, *L. naevus* is often reported in surveys of the Aegean Sea [9,55,58] with a higher frequency of occurrence than the other species of the genus *Leucoraja* [12]. Moreover, the knowledge gaps in the genus *Leucoraja* are extensive due to their rarity and status (three of them assessed as Critically Threatened and one Near Threatened; Table 2).

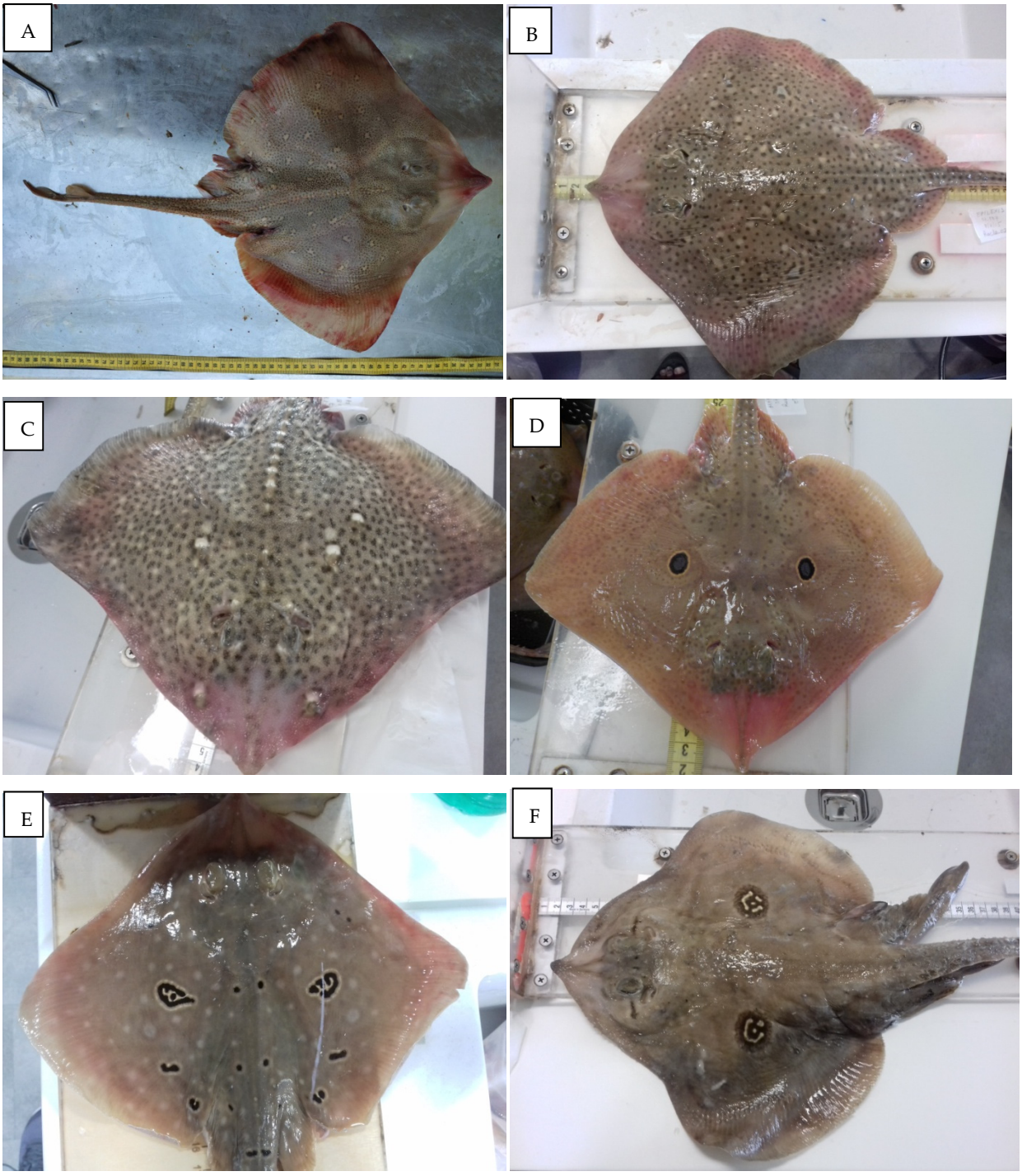

Figure 2. *Cont*.

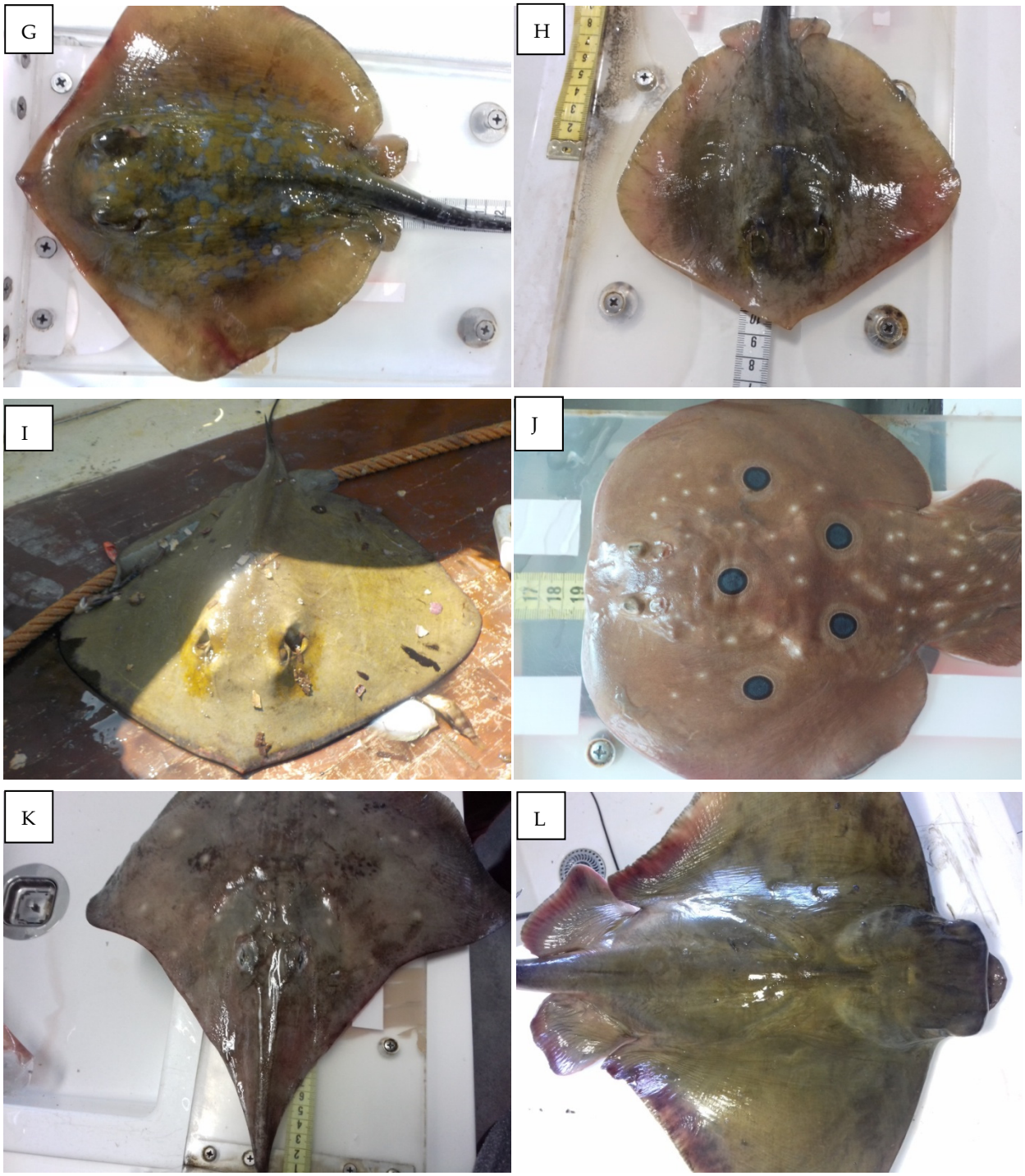

Figure 2. Skates and rays caught in bottom trawling surveys (MEDITS) and in gillnets in the eastern Ionian and Aegean Seas for the period 2017–2020: (**A**) *Raja asterias*, (**B**) *Raja brachyura*, (**C**) *Raja clavata*, (**D**) *Raja miraletus*, (**E**) *Raja polystigma*, (**F**) *Leucoraja naevus*, (**G**) *Dasyatis marmorata*, (**H**) *Dasyatis tortonesei*, (**I**) *Dasyatis pastinaca*, (**J**) *Torpedo torpedo*, (**K**) *Dipturus oxyrinchus*, (**L**) *Myliobatis aquila* (photos: A. Chatzispyrou).

Genus *Raja*

Raja asterias

The starry ray *R. asterias* (Figure 2) is often reported in both the eastern Ionian [55,59] and the Aegean Seas [9,54,60] and occupies mainly the coastal zones [12]. It has been

occasionally confused with *R. clavata* and the blonde ray *Raja brachyura* (Lafont 1871) for the similar morphological characters and patches on the pectoral fins they share.

Raja brachyura

The blonde ray *R. brachyura* is more commonly caught in the Aegean Sea [12,55] than in the eastern Ionian Sea [36,59]. The species's resemblance to the external features of *R. clavata* (Figure 2) might have caused some misidentification by fisheries observers, and the real state of the species has to be reassessed.

Raja clavata

Information on the distribution and abundance of the thornback ray *R. clavata* (Figure 2) are reported regularly in the literature [29,33,36,37,54,58,59,61]. It is the species with the highest percentage of catch per unit effort [9] and frequency of occurrence [12] amongst all batoid fish (Table 1).

The confusion reported over the years for the thornback ray may be due to the variety of coloration and patterns exhibited on the pectoral fins (and absence of thorns in some cases), characterized as polychromatism [62,63]. This condition is possibly attributed to fluctuations of environmental conditions, food preferences and phenotypic plasticity [63]. As a result, *R. clavata* has sometimes been misidentified in the past either as *R. polystigma*, the spotted ray, *Raja montagui* (Fowler 1910) or *R. brachyura* (Table 2). By applying DNA sequencing and morphometric measures on specimens difficult to identify macroscopically, the confusion between these species has been occasionally resolved [64]. These findings suggest the importance of using molecular tools combined with biometric measures for resolving taxonomic uncertainties.

Raja miraletus

The brown ray *Raja miraletus* (Linnaeus 1758) is a common species of the coastal areas of Greece and deep waters (Figure 2), found down to 200 m in depth [9,54,59,65]. Its frequency of occurrence is quite high in all three Greek GSAs [12]. Its characteristic blue spots on its pectoral fins prevent its confusion with other rajids, and it is observed regularly in hauls of the MEDITS survey in Greek waters (personal observations).

Raja montagui

The spotted ray *R. montagui* appears to be rare in the north part of the Mediterranean Sea, but frequently observed in the south basin, specifically off the coasts of Algeria and Tunisia [14]. In Greece, its biomass appears to be higher in the north Aegean Sea [12,32,65,66], less abundant in the south [32] and with scarce reports in the eastern Ionian Sea [59]. Its identification was troubling experts for many years, since it was confused with *R. polystigma* [14] and occasionally with *R. clavata* (Table 2).

Raja polystigma

The speckled skate *R. polystigma* (Figure 2) appears to be more frequently observed in surveys of the Aegean Sea [32,54,58] and is less common in the eastern Ionian Sea [12,59]. Its morphological features are similar to those observed on specimens of *R. clavata* and require great attention when identifying the species (Table 2).

Raja radula

The rough ray *R. radula* is another common species of the Aegean and the eastern Ionian Seas (Table 1), but with low densities in both areas [53,54,58,59]. It exhibits several coloration patterns, like *R. clavata*, and therefore it is possible to have been confused with the undulate ray, *Raja undulata* (Lacepède 1803) or *L. naevus*, and thus reported inaccurately in fisheries data collection (Table 2).

Raja undulata

The undulate ray *R. undulata* has limited information on its distribution and abundance in the study area [28]. Scarce information has been collected in the Data Collection

Framework (DCF) programme [12,59]; however, *R. undulata* has not been reported in research surveys of Greece within the past 10 years.

Genus Dipturus
Dipturus batis

The occurrence of the blue skate *D. batis* was documented in Greek fisheries about a decade ago [24,53], but nowadays its presence is questionable in the area. The species has historical records in most of the European Atlantic and Mediterranean Sea waters; however, it is believed that its current distribution is restricted to parts of the Atlantic Ocean [67]. These findings suggest that juvenile specimens possibly have been confused with those of the longnosed skate, *Dipturus oxyrinchus* (Linnaeus 1758), and mistakenly reported as *D. batis* in the Greek waters. At the moment, the species is included in the batoid checklist (Table 1) but is considered doubtful, until further investigation clarifies the absence or extirpation of *D. batis* from the area.

Dipturus oxyrinchus

The longnosed skate *D. oxyrinchus* (Figure 2) is regularly caught in deep water surveys [12,29,36,68], distributed in areas greater than 100 m in depth [53,58,59,69]. The species might have been affected by deep water fisheries within the past few decades and its abundances need to be looked over in every GSA of Greece, since this is a slow-growth species with a low reproductive rate [28,69].

Genus *Rostroraja*
Rostroraja alba

The white skate *R. alba* is a very rare species in Greek waters. Due to its scarcity, biological data and species population structure are unavailable in the literature. Scattered observations are reported mainly from the Aegean Sea in depth zones greater than 200 m [9,28,53,70].

3.2. Order Rhinopristiformes

The two species of guitarfishes inhabiting the eastern Ionian and the Aegean Seas (and a few other parts of the Mediterranenan Sea) are the common guitarfish *Rhinobatos rhinobatos* (Linnaeus 1758) and the blackchin guitarfish *Glaucostegus (Rhinobatos) cemiculus* (Geoffroy Saint-Hilaire 1817). They are both globally listed as Critically Endangered [71,72], but in the Mediterranean only *R. rhinobatos* has been assessed and reported as Endangered [73]. Historical data placed the distribution of both species mainly to the southern and eastern parts of the basin, where the waters are warmer.

3.2.1. Family Rhinobatidae

Genus *Rhinobatos*
Rhinobatos rhinobatos

The common guitarfish (*R. rhinobatos*) is no longer so common in Greek waters. Based on interviews with fishermen in the eastern Ionian Sea, the occurrence of the species in the brackish waters of the Ionian islands was frequent 10–15 years ago, but nowadays guitarfishes do not exist in the area. Sporadic reports of the species also existed in the late 1990s off the north of Rhodes island in the south Aegean Sea [68], whilst more recently individuals have been reported near Kos, Chios and Lesvos islands [74], based on citizen science reports.

3.2.2. Family Glaucostegidae

Genus *Glaucostegus*
Glaucostegus cemiculus (Rhinobatos cemiculus)

Similarly to the occurrence of *R. rhinobatos*, the blackchin guitarfish *G. cemiculus* is limited in the Greek waters [68]. Updated records from observations in the Aegean Sea

highlighted the presence of a significant small population, distributed between the Greek islands and the coasts of Turkey [74].

3.3. Order Myliobatiformes

3.3.1. Family Dasyatidae

The dasyatids are represented by five species in the eastern Ionian and the Aegean Seas (four of them are included in the book "Fauna Graeciae") [49]. At the young stage of their life (juveniles) they face difficulties in their classification, except for the pelagic stingray *Pteroplatytrygon violacea* (Bonaparte 1832), a morphologically distinct species from all other dasyatids.

Genus *Bathytoshia*

Bathytoshia lata (Dasyatis centroura)

Historical information collected from the Aegean Sea in the 1940s describes the presence of large-bodied stingrays (identified as the roughtail stingray, *Dasyatis centroura* Mitchill 1815) swimming in Greek waters [75]. Seventy years ago Haa's film and book on sharks accidentally presented a conspicuous number of oversized rays (*D. centroura* and the bull ray, *Aetomylaeus bovinus* Geoffroy Saint-Hilaire 1817) swimming in the area [75]. Today, such findings in Greek waters are scarce and the size of many potentially large-bodied species is usually very small [76]. This evidence showing the previous sizes of stingrays occupying the area is disconcerting based on how the fishery sector has affected the biological and evolutionary aspects of batoids and other large-sized sharks [6].

A revised classification of the family Dasyatidae recently documented that the roughtail *D. centroura* is reclassified as the brown stingray *Bathytoshia lata* (Garman 1880) based on morphological and molecular data [5,77]. Furthermore, molecular insights on specimens collected globally provided evidence that the roughtail, *Bathytoshia centroura* (Mitchill 1815), occupies the western Atlantic Ocean [78], and its congener *B. lata* is widely distributed in the eastern Atlantic, Mediterranean Sea and Indo-Pacific Ocean [48,78].

Therefore, all specimens previously reported as *D. centroura* in the Mediterranean basin are now classified as *B. lata* [77], while *B. centroura* individuals are studied in the western coasts of the Atlantic Sea [78]. Further investigation is required to confirm the validation of *B. lata* in Greece; however, acquiring samples from large dasyatids can be time consuming, since they are apparently rare in these waters.

Genus *Dasyatis*

Dasyatis marmorata

A rare finding in Maliakos Gulf (central Aegean Sea) was the first report of the marbled ray, *Dasyatis marmorata* (Steindachner 1892), in Greek waters [50]. The specimen was initially identified macroscopically (Figure 2) and later confirmed through DNA sequencing [50], and thus is now added to the list of batoids of Greece (Table 1). The geographical distribution of the species has been reported in the south-east part of the Mediterranean Sea [79–81], extending later to the southern coasts of Turkey [43,82–84] and appearing to have migrated further north to the eastern Mediterranean Sea [50,85]. This finding highlights the importance of carrying out surveys in coastal ecosystems to document the presence of skates and rays in gulfs and enclosed areas.

Dasyatis pastinaca

The common stingray, *Dasyatis pastinaca* (Linnaeus 1758), is widely distributed in Greek waters (Figure 2) and caught regularly in research surveys (Table 1) [58,59] at low density and biomass levels [12]. Young specimens have troubled fisheries observers, for they are easily confused with those of the tortonese's ray, *Dasyatis tortonesei* (Capapé 1978), or with the brown stingray *B. lata* (Table 2).

Dasyatis tortonesei

The tortonese's ray, *D. tortonesei*, is believed to have been confused for many years with the common stingray *D. pastinaca* (Figure 2). For this reason, good identification

methodologies have to be applied to ensure the correct report of both species during fisheries data collection. *Dasyatis tortonesei* was first described by Capapé in 1978, but was considered an invalid species [86]; however, recent morphological studies described differences with the closely related *D. pastinaca* [87]. Additionally, comparison of the complete mitochondrial genomes of these species confirmed the validity of *D. tortonesei*, suggesting that the tortonese's ray might be endemic to the Mediterranean Sea [88].

Information on *D. tortonesei* is scarce, due to its misidentification as *D. pastinaca*, and new data has to be collected to examine the prospect of endemism. In Greece, few published records exist for the presence of *D. tortonesei* in the north and south Aegean Sea, with low frequency of occurrence [36,49]; sporadic captures of individuals have also been recorded in the eastern Ionian Sea from the MEDITS surveys, for which morphological measures and DNA sequencing were performed, validating the presence of *D. tortonesei* in the area (authors' personal investigation).

Genus *Pteroplatytrygon*
Pteroplatytrygon violacea

The pelagic stingray *P. violacea* is rarely captured in bottom trawling surveys [89,90], and unfortunately regularly recorded in discards of longline fisheries [91]. Its occurrence appears to be greater in the south Aegean Sea where a significant number of stingrays have been caught in research surveys [91].

3.3.2. Family Myliobatidae

Two species represent this family in Greek waters, the bull ray *A. bovinus* (previously known as *Pteromylaeus bovinus*) and the common eagle ray, *Myliobatis aquila* (Linnaeus 1758).

Genus *Aetomylaeus*
Aetomylaeus bovinus (Pteromylaeus bovinus)

Sporadic reports are available in the literature for the bull ray, *A. bovinus* [92–97], according to which the species shows a preference for the coastal semi-enclosed areas, such as Amvrakikos gulf in the eastern Ionian Sea [94] and Pagasitikos gulf [95], Argolikos gulf [96] and Izmir bay [97] in the Aegean Sea.

Genus *Myliobatis*
Myliobatis aquila

The common eagle ray (*M. aquila*) is no longer very common according to existing published records (Figure 2). Scattered observations come from the Aegean Sea [49], parts of the Aegean Sea from the MEDITS surveys [12], the Cretan shelf and slope [58], Kalymnos island [98] and recently the North Aegean Sea [86]. In general, studies on stingrays inhabiting Greek waters are limited, but efforts have been initiated to collect important information for management purposes.

3.3.3. Family Gymnuridae

Gymnura altavela

Concerning the occurrence of the spiny butterfly ray *Gymnura altavela* (Linnaeus 1758) in coastal Greece, the limited available data [49] confirm its scarcity and conservation status (Table 1), being evaluated as Critically Endangered in the Mediterranean Sea [99]. Few recent observations have been added to the list of records on the species [68,96,100,101], showing its preference for the shallow waters of enclosed gulfs, such as Maliakos [100] and Amvrakikos gulfs [102].

3.3.4. Family Rhinopteridae

Rhinoptera marginata

The Lusitanian cownose ray, *Rhinoptera marginata* (Geoffroy Saint-Hilaire 1817), is a bathypelagic species with limited information on its occurrence and distribution in the

whole Mediterranean Sea [14]. The last specimen caught in the MEDITS survey was in 1994 [28], whereas in Greece there is no record of the cownose ray within the past ten years [49]. Sporadic reports are coming from the southeastern Mediterranean Sea [14] and recently a great number of animals were accidentally caught during an experimental survey in the Mersin Bay (southeastern Mediterranean Sea) of Turkey [103]. The fact that the species has been absent in the fisheries in many parts of the basin for a great period of time suggests its extirpation from sub-areas; however, the capture of a whole group of cownose rays in Mersin bay reinforces the need to take immediate conservation measures for *R. marginata*.

3.3.5. Family Mobulidae

Mobula mobular

Sporadic information exists on the presence of *M. mobular* in the Greek waters. Within the past five years, sightings of devil rays are reported more regularly, possibly due to social media and the public interest in these gigantic migrating rays. Published records from experimental surveys include the eastern Ionian Sea [104], where 17 individuals were encountered swimming in a protected area, and the Dodecanese islands (southeastern Aegean Sea), with two individuals incidentally captured in 1995 [68]. The most recent observation of *M. mobular* was recorded in 2017, when an individual was entangled in fishing nets in Saronikos gulf [105]. Other information on the devil ray distribution around Greek waters is collected from videos uploaded on the internet (such as the video from the Cyclades in 2016), communication with fishermen and periodicals (Meganisi in 2013, Crete in 2017, Elafonissos in 2018 and Saronikos gulf in 2022).

3.4. Order Torpediniformes

Family Torpedinidae

Genus *Tetronarce*

Tetronarce nobiliana (Torpedo nobiliana)

The Atlantic torpedo, *Tetronarce (Torpedo) nobiliana* (Bonaparte 1835), is a rare species in Greek waters, with sporadic reports in the eastern Ionian Sea [59,106] and a low frequency of occurrence in the north and south Aegean Sea [12,49,55,68].

Genus *Torpedo*

Torpedo marmorata

The marbled electric ray, *Torpedo marmorata* (Risso 1810), is the most frequently caught electric ray in Greek waters [9,46,54,66,106–108], occupying many depth strata [46,59] and even reported to occur in gulfs and semi-enclosed areas, such as the Amvrakikos gulf (Figure 1) [49]. The species may be prevailing over the two other electric ray species due to its life history strategy (bearing a high number of pups) and its distribution from coastal areas down to 300 m in depth [46,106].

Torpedo torpedo

The common torpedo, *Torpedo torpedo* (Linnaeus 1758), is occasionally caught in research surveys (Figure 2) and is less common than *T. marmorata* in Greek waters [9,32,53,59]. However, *T. torpedo* has been documented in several parts of the Aegean and the eastern Ionian Seas [28,106], and coastal areas such as the Amvrakikos, Saronikos and Patraikos gulfs [49].

3.5. Order Rhinopristiformes

Family Pristidae

Sawfishes are on the list of the most threatened elasmobranchs globally [109]. Two species are reported from the Mediterranean Sea, the smalltooth sawfish *Pristis pectinata* (Latham, 1794) and the common or largetooth sawfish *Pristis pristis* (Linnaeus, 1758), both criticaly endangered according to the IUCN Red List of Species. *Pristis pectinata* appears

to be extirpated from large areas of its former range, and it is believed to have been misidentified and never existed in the Mediterranean basin. However, *P. pristis*, which was once common in the whole basin, is now presented to be extinct [20]. There are no records of sawfish species since the 1960s–1970s and they are not reported in the Greek literature either [49]. Thus, both species are considered extinct and are not included in the revised checklist (Table 1).

4. Discussion

Despite the high level of biodiversity and endemism exhibited in skates and rays, their conservative body morphology challenges species' identification in some cases, and this may lead to market mislabeling [67]. Marketing of protected species is common worldwide. In Greece, 19.8% of landed samples collected in markets (DNA barcoding) belonged to threatened skates and rays, including three species listed as Critically Endangered [110]. Despite national and European legislation for the conservation of sharks and rays in Greece, these practices have negative impacts on vulnerable species and need immediate action to prevent biodiversity loss [110].

The present study showed that a great number of skates and rays are well distributed and more frequently observed in the Aegean Sea (30 species in total) relative to the eastern Ionian Sea (Table 1). This can be attributed to the higher inorganic and organic nutrient concentrations supplied through the inflow of Black Sea Water, and riverine inputs in the surface waters of the north Aegean Sea [111]. The combination of the north Aegean rivers and the inflow of low-salinity Black Sea water create within the Aegean Sea a complex system (N–S gradient) regarding its hydrology and biological, chemical and sedimentological processes [112]. The skates and rays distributed in the Aegean Sea also had higher biomass indices [53] than those of the Ionian Sea [12,28]. However, two species included in the list of skates and rays of Greece are questionable (*D. batis* and *L. melitensis*), suggesting that they might have been either extirpated from the area or misidentified.

Conversely, the eastern Ionian Sea is characterized by a narrow continental shelf and very steep slope known as the deep Hellenic Trench with a maximum depth of 5121 m [113]. The Ionian Sea is the largest in volume and the deepest area of the Eastern Mediterranean basin; the oxygen and nutrient pattern is affected by the presence of mesoscale cyclonic and anticyclonic gyres in the area, and it is characterized as a highly oligotrophic environment, where phytoplankton growth depends mainly on regenerated nutrients [114]. The zooplankton abundance is higher in the northeastern Ionian Sea compared to those in the central and southern areas, which are considered among the most oligotrophic regions of Hellenic waters [114]. In total, 28 skates and rays have been reported to date in the literature [36,59], adapted to the oligotrophic conditions of the area, the hydrographic features [29] and the deep-sea waters of the Hellenic trench [59].

Concerning the frequency of occurrence categories observed, C3 had a low percentage (6.67%) in the Aegean Sea and most species belonged to category C1 (36.67%), indicating a greater number of species in the area than in the eastern Ionian Sea; category C2 followed with 33.33% and C5 with 16.67%. Additionally, 6.67% of species occurring in the Aegean Sea have a high possibility of misidentification (C4), a condition that has been disregarded in the past and has to be immediately resolved. In contrast, most species of skates and rays in the eastern Ionian Sea were found to fall into category C2 (occasionally observed) with 35.71%, followed by category C1 (28.57%) and C3 with 25%. Categories C5 and C4 showed low percentages (7.14% and 3.57%, respectively) suggesting that few species have been misidentified through the years and one species has a narrow distribution (local occurrence). However, this categorization reports that a quarter of the 28 species recorded in the area are not observed often or have been missing from the surveys for a decade, something that requires clarification to report the true status of these species. Monitoring batoid populations in both areas is crucial, due to the high number of species listed as Near Threatened (25%), Critically Endangered (21%) and Endangered (13%) according to the IUCN Red List of species in the Mediterranean Sea [115].

Furthermore, morphological similarities reported by fisheries observers showed identification problems in ten species of skates and three species of stingrays (Table 2), exhibiting a broad range of shapes and coloration patterns in comparison to other elasmobranchs. Three of these are assessed as Critically Endangered, two are evaluated as Endangered and three are considered Near Threatened (Table 2) [115]. In total, 66.67% of skates (Order Rajiformes) had misidentification issues, whereas 30% of stingrays (Order Myliobatiformes) presented taxonomic uncertainties, specifically at the juvenile stage of their life. These issues demand further investigation, especially for vulnerable or threatened species, as they might have insufficient data to support their status and could be driven to extinction before any conservation plans can be applied.

Compared to a recently presented list of batoid species in Greek waters [48], the present work is based on a more extensive literature compilation and the use of additional information from the MEDITS surveys and actions carried out in the DCF context. The current study also reveals misidentification issues that could be important for the status evaluation and monitoring of scarce sensitive species. Additionally, a comparison of skate and ray biodiversity in the Aegean and Ionian Seas is presented.

This overview highlights the importance of identifying species properly, assessing their distribution/abundance in all areas and recording biodiversity issues based on consistent fisheries data collection. The identification of skates and rays solely based on the available field guides, that present diagnostic characters mainly from the adult stage of fishes, should be avoided [14]. Persistent problems regarding the classification of species and genera are often resolved by combining morphological measures and genetic markers [7,14]. Updated information on species status is also essential, for proposing measures and mitigating the negative impacts of anthropogenic effects on marine biodiversity, especially for threatened species and fragile ecosystems.

Overall, little attention has been given to the potential effects of misidentifications, which can be common in field surveys and commercial landings, causing bias in estimations of population trends [67]. Proper species reporting can be hindered by non-distinctive morphology and variation in coloration (Figure 2), as well as observer-level factors, such as experience. Therefore, efforts to improve identification methods, a key tool for fisheries observers, need to be applied through continuous workshops and training.

5. Conclusions

Batoid fishes may not have major economic value to the fishery sector in Greek waters, yet measures to prevent overexploitation should be introduced immediately, since catches remain unreported and unregulated and may lead to depletion of populations from sub-areas. Recovery from a severe depletion might take a very long time, especially for species that produce few offspring in their lifetime (usually viviparous species, such as the stingrays). The lack of national implementation and regulations for cartilaginous species in many countries, including Greece, is attributed to poor or absent landing data. Without the appropriate information from exploitation, incidental catches and discards, effective management and conservation cannot be applied. Moreover, landing reports usually depend on the biodiversity of an area; the fewer the species and the interspecific diversity, the easier to record sufficiently the catches. Therefore, effective management and conservation strategies should be encouraged by i) re-evaluating the methods and field guides used to report batoid observations, ii) introducing new, more advanced methods to resolve taxonomic problems and iii) enriching the existing knowledge for this group of elasmobranchs to assess their status and mitigate bycatch. Unfortunately, at the moment, very few species are prohibited from being landed and sold in Greek markets, while others are declining dramatically.

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