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The application of precaution in elasmobranch conservation and management in the Mediterranean Sea

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ABSTRACT

This study examined the integration and application of the precautionary principle at national level for the conservation and management of elasmobranchs. Three countries, Greece, Malta, and Cyprus were assessed. Based on national legislation, policies, and reports, the assessment shows limited integration and application of the precautionary approach for the conservation and management of this group. The review of existing measures and relevant literature revealed potential applications of the precautionary principle for two model species, the blue shark (*Prionace glauca*) and the bull ray (*Aetomylaeus bovinus*). Sixteen measures, ranging from basic to strong precautionary actions, are proposed to aid the conservation and management of these two species.

1. Introduction

The highly complex nature of marine ecosystems and their response to human activities often involve uncertainty on different levels, which calls for the application of a precautionary approach in conservation and management of marine species [1–3]. Intended to apply in situations of uncertainty [4], the precautionary principle (PP), which stipulates the implementation of a precautionary approach (PA), originated out of a need to regulate substances and developments that potentially posed a high risk to human health or damage to the environment [5,6]. The PP evolved and grew to be more widely applied to concerns related to activities threatening ecosystem integrity and biodiversity [7]. Although the principle was formalised prior to the Rio Declaration, it is the most cited basis for the first internationally relevant definition of the principle [8]. The Rio Declaration stipulates that states should not refrain from taking measures due to scientific uncertainty in the case of a potentially serious environmental threat [9]. Despite specific reference to the PP or PA in numerous bi/multilateral environmental measures the status of the principle in international law remains uncertain [10,11]. There remains a tension between its function as a guideline or an obligation and its justiciability [10,12,13]. At European Union (EU) level, the PP is a driver of policy and law to secure the EU's requirement for a high level of environmental protection and is formally included in Article 191 (2) of the Treaty on the Function of the EU (TFEU). In addition, Article 191(2) provides the ancillary requirement that preventative action be taken to avoid environmental harm where the risk is known [14].

In essence, two principal considerations apply to the implementation of the PP. First is the shift in the burden of proof away from the regulator to the party proposing or undertaking the activity; and second, it relies on the availability of cost-effective, practical measures [3,15]. Internationally, there is no generic guideline or accepted framework on the extent to which the PP applies and how much 'precaution' satisfies a precautionary approach [10,16]. This logically depends on the circumstances to which the PP is applied, the different levels of uncertainty, as well as the practicality and feasibility of proposed actions and whether they would work in the relevant circumstances [1]. General aspects of the application of the PP are shown in Fig. 1.

The EU guidance on the PP requires the identification of scientific uncertainty matched to a basic risk assessment (RA) on the applicable levels of decision-making [17], although the guidance is dated and would benefit from being revisited [18]. This is perhaps easier said than done: as De Sadeleer observes, there is an enhanced degree of uncertainty in "genuine environmental cases" noting that "uncertainties are far more pronounced in this area given the difficulties in predicting how ecosystems will react to ecological risks" [12]. Cases determined

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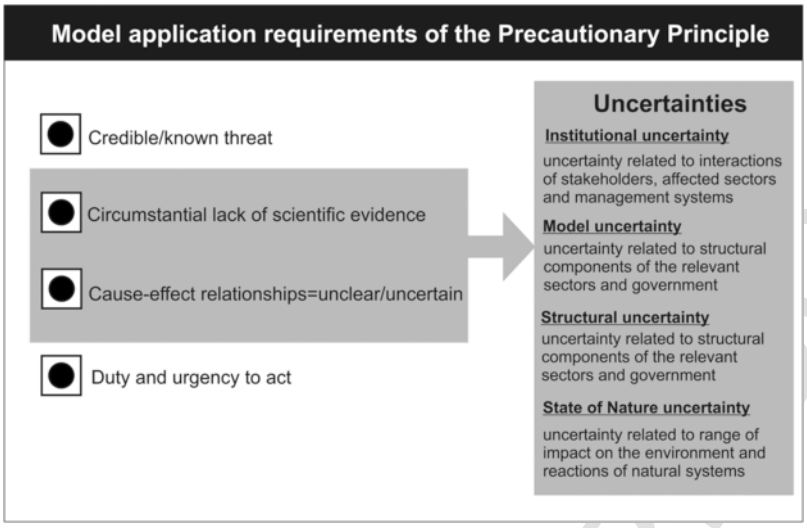

Fig. 1. Model of application requirements of the PP. This is based on fundamental elements of the PP identified by deFur and Kaszuba *[1]*, and levels of uncertainty, as defined by Charles [3].

by the Court of Justice of the European Union (CJEU) do contemplate a degree of RA prior to the application of a precautionary measure, whilst recognising that avoiding unacceptable risk (which will often be subjective and societally driven) [10] may require it [12].

In this context, the application of the PA to fisheries management and species conservation is not simple or well defined but may prove adequate and useful for elasmobranchs [19,20]. The group of elasmobranchs (sharks, rays, and skates) is an important component of the environment [21,22]. As part of the overall marine biodiversity, these species contribute to the control of prey populations, as well as the overall stability and recovery of marine habitats [23–26]. Their life history traits which often entail late maturity, long gestation times, and few offspring, expose them to an elevated risk to fishing [27,28] and other human related pressures, such as pollution, habitat degradation and expedited climate change [29–33]. Therefore, they rely on sustainable management and conservation efforts for future existence [34–36]. This is especially the case in the Mediterranean, where more than half of the occurring elasmobranch species face elevated risks of extinction and continued to decline in the past decades [37]. For elasmobranchs, two legal frameworks must be considered, fisheries management and (marine) conservation.

1.1. The precautionary principle in fisheries management

Internationally relevant instruments for fisheries management that incorporate the PP are the United Nations Agreement of Straddling Fish Stocks (UNFSA) [38], the Code of Conduct for Responsibility Fisheries (CoC) [39], as well as numerous regional fisheries management organisations (RFMOs) . Within these instruments, the PP is presented as a general principle for fisheries management that should be applied widely for the conservation and management of marine resources, and according to De Sadeleer "precaution can be considered as a norm of customary international law in the area of fisheries" [12]. It is specified that a PA should not only apply to target species, but species affected by fishing. The fisheries framework of the EU, the Common Fisheries Policy (CFP), refers to the PP as defined in the UNFSA and highlights its application in relation to establishing harvest limits [40]. Regulation (EU) 2019/1241, designed to aid the implementation of the CFP, suggests that for especially vulnerable species, such as sharks, complete catch bans should be considered, and prohibits the use of entangling gear to catch certain shark species (Art. 9) [41]. However, the general approach of the CFP is science-based and the EU has widely failed to follow a PA in its fisheries management [42], although the CFP has been subject to root and branch reform and is framed by reference to the PA by Regulation 1380/2013 [12]. The RFMO of the Mediterranean, the General Fisheries Commission of the Mediterranean (GFCM), combines both strategies by stating that effective conservation and management should be based on the PA (in line with the CoC) and by reference to the best available science [43]. Although the PP is embedded in fisheries related instruments, examples of the application of a PP are few [44,45] and relate to commercial stocks, rather than affected species, in terms of catch limits and reference points [46–48]. This perhaps reflects the view that organisations still have "significant discretion in deciding how much caution is appropriate" [49].

An International Plan of Action for sharks (IPOA sharks), developed under the CoC, with the objective to ensure a long-term existence (and use) of these species, recognizes the existing knowledge gaps for this group. The IPOA sharks acknowledges an urgency for action and integrates the PP as a guiding principle to identify catch limits [50]. The European Action Plan for Sharks (EPOA sharks), on the other hand, states that a strategy for action should be based on sound scientific information [51].

1.2. The PP and applicable marine conservation law

The regional marine conservation framework in the Mediterranean established under the United Nations Regional Seas Programme, is the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) [52]. The Barcelona Convention contemplates a strong version of the PP in that its application is voiced as an imperative requiring parties to apply a PA through cost-effective measures in cases of risk of serious or irreversible damage to the environment. The Barcelona Convention is implemented through various protocols tackling different environmental issues. Within the Protocol Concerning Specially Protected Areas and Biological Diversity on the Mediterranean (SPA/BD Protocol) the PP is indirectly mentioned stating that the absence of scientific certainty cannot be used to justify inaction [53]. Furthermore, the SPA/BD Protocol establishes a general duty for parties to take action for any threatened species (Article 3 SPA/BD Protocol). In 2003, a regional action plan (AP) for sharks was developed under the SPA/BD Protocol, and has recently been updated in 2020 [54]. This AP refers to the definition of the PP in the FAO CoC, and highlights that any exploitation of sharks, rays and skates should follow a PA. This further applies to the

discard of these species (Part C4 AP). The relevant directives and regulations at EU level include the Habitats Directives (HD) which obliges EU member states (MS) to establish sites for the protection of a number of priority species and habitats that are threatened by extinction (as listed in the Annexes of the Directive), and the Marine Strategy Framework Directive (MSFD), which updated many aspects of the 1992 HD [55,56]. While the HD failed to integrate elasmobranchs, Article 1(e) of the HD implies that for the conservation status of habitats to be favourable, the integrity of the ecosystem (its structure and function) and typical species need to be considered. Furthermore, Article 6 of the HD obliges states to assess and control activities within designated sites that potentially impact the sites' integrity. Article 6(2) imposes a positive obligation on member states to avoid deterioration or disturbance of habitats or species respectively. The European Court of Justice clarified that Article 6 applies to fishing activities within designated sites, even if these activities have been carried out previously [57,58].[1] There remains a tension between the HD and the CFP, which has been the subject of legal commentary in respect of North Sea Fisheries, specifically on the deterioration/disturbance point [59]. The MSFD's objective is to align objectives of the Nature Directives and CFP and achieve good environmental status (GES) by 2020 through the evaluation of eleven descriptors. It encourages states to create marine protected areas (MPAs), take stock assessments, and implement monitoring strategies following an ecosystem-based approach. Two of the MSFD descriptors are directly relevant to elasmobranchs, Descriptor 1 (biodiversity) and Descriptor 3 (healthy population of commercial fish species). Each MS must establish a programme of measures (PoMs) to assess and monitor these descriptors within the specific national context. The PP should be the basis for the development of the PoMs; however, the MSFD stipulates is should simultaneously rely on sound science (Preamble (23) and (27)).

1.3. Aim of this study

While the science-based policies for nature protection have largely failed to implement the necessary protection for the marine environment [60,61], it might be time to implement a wide-ranging PA, especially for elasmobranchs [19,20]. Only few examples demonstrate a PA in the management and conservation of elasmobranchs globally [62–64]. While Mediterranean fisheries are often described as non-elasmobranch-targeting fisheries, there are certainly established markets for elasmobranchs throughout Mediterranean countries [65]. This study aims to evaluate the extent of the integration of the PP in national legislation and its application status in terms of fisheries management and conservation for elasmobranchs. This assessment includes 1) the state regulation system, 2) the level of uncertainty, and 3) applied precautionary measures. Based on this, the aim is to find arguments for the application of the PP for elasmobranchs in the Mediterranean. Precautionary measures are proposed at national level based on two model species.

2. Material & methods

To evaluate the application of the PA national level, the relevant legislation and policies can be used as indicators [66]. Socio-economic considerations on a case-by-case basis are required to assess and advance the application of the PP [3,67]. Therefore, this study considered specific characteristics and uncertainties at national level on a case study basis. The assessment follows the approach of a study conducted in Australia for the International Union for the Conservation of Nature Environmental Law Centre [68]. The analysis evaluated the integration of the PP at the following levels:

- Legal level: integration of the PP in national legislation (directly or indirectly)
- Policy level: reflection in environmental/fisheries policy documents
- Implementation level: whether precautionary measures have been taken in fisheries and conservation management, based on the measures reported.

An evaluation matrix is shown in Fig. 2.
The following data sources were used:

- National legislation (conservation & fisheries);
- National policy documents (e.g., fisheries management plan, MSFD PoMs);
- National reports (e.g., under MSFD, GFCM, Barcelona Convention); and
- Landing statistics [69].

National legislation was obtained directly from government sites [70–72]. Policy documents were retrieved from multiple sources. Fisheries management plans were obtained from either national directorate website's or from the Scientific, Technical and Economic Committee for Fisheries' (STECF) website [73]. MSFD reports and PoMs were sourced from the European Environment Information and Observation Network's Central Data Repository [74]. National biodiversity strategies and reports under the Convention on Biological Diversity (CBD) were obtained from the CBD's repository [75]. Furthermore, specific elasmobranch related measures are listed in the reporting under the Convention on Migratory Species (CMS) [76–78], the report from the focal point meeting on the implementation of the regional action plan under the Barcelona Convention [79], and GFCM reports [80].

Furthermore, the application of the PP for two model species was assessed. This assessment is based on the valuation of the data sources, applicable legal frameworks, and literature.

2.1. Case study

Malta is a small island state of 316 km^2 in the central Mediterranean with a population of 514,564 [81]. The fisheries sector is characterised by a multi-gear, multi-species fisheries that mainly consist of a small-scale, artisanal fleet of 682 operating vessels, including 20 trawlers [82]. The latest national statistics state employment supported by fishing (and aquaculture) is about 809 full-time positions and 630 part-time [81]. Recreational fishing exceeds commercial fishing in number of vessels with over 2000 registered fishing boats [83]. Most of the fishing takes place within the Maltese Fisheries Management Zone which extends to 25 nautical miles [84]. Within Maltese waters about 39 confirmed elasmobranch species are known to occur [85,86].

The Republic of Cyprus is an island state, in the eastern Mediterranean Sea with 840,407 inhabitants with 9251 km^2 area of land [87]. The marine fisheries sector comprises 809 boats [88] with a multi-gear and multi-species nature, like most Mediterranean countries. Only 2 purse seines and 7 bottom trawlers operate in the Cypriot waters, with the majority of the fleet consisting of artisanal boats. Fisheries contributed a total of 32.2 million EUR to the country's gross value added accounting only 0.17% of the total share [89]. About, 500 employees and self-employed individuals are involved in the Cypriot marine fisheries sector. Despite the low number of people involved, in several coastal areas, fisheries continue to be important for the cohesion of the local communities. About 60 species of elasmobranchs exist in the Cypriot waters [90].

Greece is located in the Eastern Mediterranean and is a country with the longest Mediterranean coastline due to the complexity of the

[1] Case C-127/02 Waddenzee [2004] ECR-1–7405

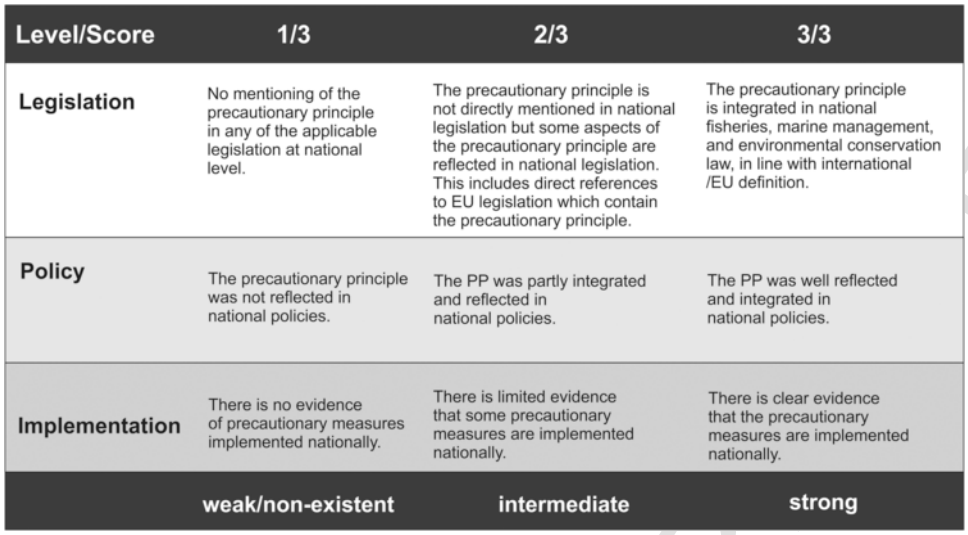

Fig. 2. Evaluation matrix for the application of the PP at national level. A simplified version based on a study for the International Union for the Conservation of Nature Environmental Law Centre *[68]*.

relief, which is comprised by several gulfs, bays and approximately 6000 islands, of which only 27 are inhabited. Greece numbers 10,816,286 inhabitants [91] with the majority located around the two major cities Athens and Thessaloniki. The Greek marine fisheries sector is dominated by marine aquaculture, with the Greek fishing fleet numbering 14,669 boats, of which 94.2% are small scale boats below 12 m [82,88]. In total, 19,396 full-time positions were reported in small-scale fisheries, and 4548 in large-scale fisheries and thus despite the low contribution of the Greek fisheries to the country's gross value added, the activity remain important for the cohesion of the coastal rural communities of the country [92]. The sector displays a multi-gear and multi-species nature, with significant bycatch of vulnerable species [93,94], including chondrichthyans [95,96]. Greece hosts a great biodiversity of chondrichthyans species, with at least 67 confirmed to be present in the Greek territorial waters [97].

2.2. Model organism

The blue shark, *Prionace glauca* (Linnaeus 1758) is one of the widest ranging pelagic shark species, found in all temperate and tropical waters [98]. The species occurs in open seas and inshore areas up to a depth range of 1000 m and performs long range migrations [99,100]. It is one of the most fished shark species, caught in a variety of fishing gears [101] and it is generally retained for its meat but more importantly for its fins [102]. In the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, the species has been listed as Near Threatened [103], while its Mediterranean population has been assessed as Critically Endangered [104]. There are currently no strict species-specific catch limits or other protections in place for the species in the Mediterranean Sea apart from Regulation No. 605/2013 that bans the removal of shark fins on board of vessels. The blue shark is also one of the species for which Art. 9 of EU Regulation 2019/1241 applies. In addition, it is listed under Appendix II of the CMS, in Appendix III of the Bern Convention on the Conservation of European Wildlife and Natural Habitats, and in Annex III of the Barcelona Convention.

The bull ray, *Aetomylaeus bovinus*, is a benthopelagic species with a wide distributional range occurring across the Mediterranean [86,105–107]. It can be found in shallow coastal bays and depths to over 100 m [86,106,108]. The global conservation status under the IUCN Red List assessment categorises *A. bovinus* as Critically Endangered [109], which is in line with the most recent IUCN regional assessment for the Mediterranean [37]. However, *A. bovinus* is not currently listed in any relevant regional legal framework (e.g., Barcelona Convention, Bern Convention).

Blue sharks are fished by Cypriot, Greek and Maltese longlines [83,110,111]. Bull rays occur in national waters [86,112,113] but catch data are limited. In Greece, recent research shows that these are caught in high numbers [97].

3. Results

The analysis of national legislation and applicable policies, as well as implemented measures that are relevant to the conservation and management of elasmobranchs has shown limited effort and evidence regarding the application of a precautionary approach (Table 1).

3.1. Legal integration of the precautionary principle

The Maltese Environmental Protection Act (Chapter 549) incorporates the PP and defines that "appropriate measures are taken […] in

Table 1
Evaluation of the integration and application of the PP at national level (scored out of three).

Country	Level	Score	Justification
Greece	Legislation	2	For Greece and Cyprus, the PP is indirectly integrated in national law. Only Malta makes direct reference to the PP in its national legislation for environmental conservation. National policies for marine conservation and fisheries management make no reference to the application of a PA, apart from the Fisheries management plan by Malta.Some implemented measures that benefit elasmobranchs are precautionary in nature, such as restrictions to trawling, reflecting measures set at regional and EU level.
	Policy	1	
	Implementation	2	
Malta	Legislation	3	
	Policy	2	
	Implementation	2	
Cyprus	Legislation	2	
	Policy	1	
	Implementation	2	

the absence of absolute or conclusive scientific proof of the need for such measures". In line with the PP, the government should prevent any form of environmental degradation (Art. 4) and assigns enforcement power to stop any activity leading to such degradation (Art 75).

Article 24 of the Greek Constitution obliges the state government to take "preventive or repressive measures" to ensure and support sustainability and protect the environment. The Basic Act on Biodiversity Conservation confirms this duty through Art. 15 which states that the state should implement measures to "avoid any risk that threatens the structure of the ecosystems and prevents, reduces or any environmental damage".

Cyprus' laws on the 'Protection and Management of Nature and Wildlife of 2003', integrate a general duty to refine and develop methods that prevent wildlife from any damage (Art. 7). Furthermore, the respective ministry has a duty to act and "to prevent serious damage [...] to fish populations" (Art. 26).

In relation to national legislation regulating fishing, the PP is not directly mentioned, but in the reporting reference is made to the applicable EU legislation. Thereby, a PA is indirectly integrated.

3.2. Policy integration of the precautionary principle and elasmobranchs

All three countries refer to overarching instruments regarding the conservation of biodiversity and management of resources at national level. Therefore, the PA is partially integrated by reference to EU Directives, GFCM recommendations, and obligations under the Barcelona Convention, all of which incorporate a general PA. Although these are not management plans that specifically include elasmobranchs, existing regional management plans for bottom and shrimp trawling established through the GFCM for the Levant Sea, Ionian Sea and Strait of Sicily (GFCM/42/2018/3, GFCM/42/2018/4, GFCM/42/2018/5, GFCM/43/2019/6) incorporate the PA by default in line with the CoC for species affected by those fisheries. The only direct reference to precautionary action is found in the Maltese fisheries management plan for bottom trawling and lampara, which claims to apply a PA in the reduction scheme for these fisheries [114]. In terms of the integration of elasmobranchs in national policies that should follow a PA, limited effort has been made. The MSFD provides an opportunity to consider this species group within D1 and D3, among others. Despite the acknowledgement that elasmobranchs are subject to fisheries and bycatch [76], Cyprus does not include any elasmobranch species within their national programme of measures [115]. A technical assessment of Cyprus' PoMs under the MSFD revealed substantial gaps in the definition of GES at national level and inadequate coverage, especially for fishes under Descriptor 1 and 3 [116]. Although improvements have been made, the amended programme continues to focus on commercial, demersal species [117]. A similar situation is presented in Greece, where the programme of measures for D1 and D3 is considered inadequate [118]. Although Greece's definition for D1 requires that non-target bycatch does not threaten ecosystem integrity, no elasmobranch species is mentioned in the species assessment for fishes. Only for Descriptor 3, *Raja clavata is* assessed for GFCM subarea 22 and 23 [118]. Malta's programme of measures includes several shark and ray species (Table 2) under D1 and D3 and is considered adequate for the purposes of the Directive [119]. However, knowledge gaps and uncertainties in the assessment remain [83].

3.3. Implementation of the precautionary principle and elasmobranch conservation

An overview of measures implemented and reported is shown in Table 2. None of the assessed countries has established a national plan of action for elasmobranchs and the implementation of the regional action plan and GFCM recommendation is limited [79,80]. While some of the applied measures (e.g., genetic databases, and trawling restrictions) might be precautionary in nature, none of the implemented measures concerning elasmobranchs has been reported as an intended precautionary measure. Only the reduction scheme implemented by Malta by 2015 refers to the application of the PA [114]. However, this approach was not initiated at national scale but followed EU Council Regulation (EC) No 1967/2006.

All three countries have designated MPAs for the conservation of important habitats and species; all of which have been designated under the EU Nature Directives, therefore are not specifically aimed at elasmobranch conservation. Nevertheless, some of these MPAs host sharks or rays [86,112]. Greece and Cyprus have management plans in place, while Malta's management plans are under development; even though some of the areas were designated over 10 years ago [120].

Malta and Greece have incorporated at least one elasmobranch species within their PoMs under the MSFD. Beside inclusion of elasmobranchs under D1 and D3, Malta assesses *Mustelus mustelus* meat under D9 for Seafood contamination [83]. Contrary to the PA, Malta implemented a sustainable seafood campaign in 2018 promoting the consumption of two species commonly caught as bycatch of bottom trawling [114,121]. The PP appears misaligned, noting the fishing method (trawling) and the lack of available information on the stock status. A similar approach currently takes place in Greece, in the context of an EU- funded project, in which the consumption of *Mustelus* spp. is promoted by a national institution (https://pericles.inale.gr/en/home_en/).

All three countries protect species listed under relevant conventions (Table 2). Greece and Cyrus have additional conservation measures in place. Under Presidential Decree 67/1981, Greece protects further three species. Cyprus has a recreational fishing ban for all shark species and states to implement bycatch mitigation trials.

3.4. Uncertainties and data gaps

Based on national reporting obligations the management responsibilities for fisheries and marine conservation within national government structure are clear (Fig. 3).

Three types of uncertainty have been identified: 1) Institutional uncertainty, 2) Structural uncertainty, and 3) State of Nature uncertainty:

- Institutional uncertainty: Identified uncertainties reported by the countries are the lack of management plans in Malta and the difficulties of monitoring landing sites in Cyprus [120,128].
- Structural uncertainty: As only few measures have been implemented that specifically target elasmobranch conservation and management, of which most are recent and ongoing (Table 2), it is uncertain how effective these measures are.
- State of Nature uncertainty: All three countries have reported uncertainty of current state of fish stocks and affected species. Cyprus's stated that fisheries impact on bycatch species is unknown [116]. Greece's assessment on stocks is based on short term, modelled data, which is does not adequately reflect current status [118] and does not incorporate non-commercial species [127]. Malta explicitly highlights the lack of discard data and information on non-demersal species, particularly pelagic and coastal elasmobranchs, as well deep-sea elasmobranchs [83,119].

3.5. Proposed precautionary measures for model species

Only Cyprus and Malta report on catches specifically for blue sharks, while Greece reports elasmobranch landings in aggregated groups. According to the FAO database for landings (FishStatJ), Cyprus reports that less than 1% of the total catches are blue sharks, with a total of ten incidents of longline bycatches in 2018 [82], and <1% for

Table 2
Reported and government- led measures that are relevant to elasmobranch conservation and management implemented at national level. (*) Currently, no marine protected areas have been specifically designated for elasmobranchs, but some host elasmobranchs and can therefore be useful for elasmobranch conservation.

Theme	Measure	Country	Details/Project reference	Source	Status	Relevance for elasmobranchs
Biodiversity conservation	Genetic database	Malta	Genetic database by the Conservation Biology Research Group (CBRG-UoM)	CBD report[120]	ongoing	36 elasmobranchs species[122–124]
		Greece	"Batoids on your plate" project funded by "Save Our Seas" foundation, genetic market sampling;	GFCM SAC report[80]; http://saveourseas.com	2018–2020	Ray species caught
	Sighting records	Malta, Greece, Cyprus	MEDLEM Database	SPA/BD Focal point meeting report[79]	ongoing	Elasmobranch specific, all species concerned
	Marine Protected Areas*	Malta	35.5% of Maltese waters (4,138km2), 18 sites designated (2020)	CBD report[120]	Management under development	Not elasmobranch specific (designated under Natura 2000)
		Cyprus	130 km^2 of marine waters, 6 sites	CBD report[125]	All protected sites have management plans	Not elasmobranch specific (designated under Natura 2000)
		Cyprus	6 artificial reef areas (ARAs) (no fishing allowed)	Cyprus Programme of Measures[115]	Some management plans in place (ongoing)	Not elasmobranch specific (designated under Natura 2000)
		Greece	Total Natura 2000 marine areas: 60; 22% of marine area	Updated report on the implementation of the Programmes of Measures in Greece[126]	Specific management bodies established (Law 4519/2018)	Not elasmobranch specific (designated under Natura 2000)
	Species Guide/ ID	Malta	Educational posters in public areas (incl. fish market)	CBD report[120]	ongoing	elasmobranch specific
		Greece	Guide for the Recognition of sharks and skates (publicly available), published by Directorate General for Fisheries of the Ministry of Rural Development & Food	CMS MoU report EU[78]	In place	elasmobranch specific
	Legal protection	Greece	All species listed under Barcelona Convention, Bern Convention, CITES, CMS	Bern Convention ratified by Law 1335/1983; CMS ratified by Law 2719/1999), Barcelona Convention ratified by Law 855/1978 and its relevant protocols Law 1634/1986; ban of their commercial and recreational fishery (Ministerial Decision 4531/83795/20–7–2016)	In place	elasmobranch specific
			Additional species: *Hexanchus griseus, Heptranchias perlo, Tetronarce nobiliana*	Presidential Decree 67/1981, "On the protection of native flora and fauna"	In place	elasmobranch specific
		Cyprus	All species listed under Barcelona Convention, Bern Convention, CITES, CMS	Regulated through fisheries licenses	In place	elasmobranch specific
		Malta	All species listed under Barcelona Convention, Bern Convention, CITES, CMS	Schedule VI and VIII of S.L. 549.44 (Malta)	In place	elasmobranch specific
Fisheries Management	Stock/ population assessments	Malta	PoMs (D1, D3)	MSFP Programme of Measures[83]	Ongoing (last updated report 2020)	*Heptatranchias perlo, Mustelus mustelus, Raja clavata, Raja miraletus, Squalus blainville*
		Greece	PoMs (D3) assessment for GSA 22 and 23	Article 12 Technical Assessment MSFD PoMs Greece[127]	Ongoing	*Raja clavata*
	Reduction fleet capacity/fishing effort	Cyprus	From 2008 until 2018 fishing fleet was reduced by 32% in number of vessels, 41% in tonnage and 26% in power.	Fleet capacity report (2019)[128]	Outdated	All bycatch species
		Cyprus	In 2015 the small-scale fishery fleet was reduced by 66 vessels.	Fleet capacity report (2019)[128]	Outdated	All bycatch species

Table 2 (*Continued*)

Theme	Measure	Country	Details/Project reference	Source	Status	Relevance for elasmobranchs
		Cyprus	Further reduction of trawlers to max of 2 operating vessels	Fleet capacity report (2019)[128]	2004–2006; outdated	All bycatch species
		Greece	Reduction of the total fleet: 22.46% of boats; 23.52% of bottom trawlers	Fisheries Management Plan report (2013)[129]	Outdated	All bycatch species
		Malta	20% reduction by 2015	Malta Fisheries Management Plan for Lampara and Bottom trawl fisheries[114]	Outdated	Significant by-catches of *Scyliorhinus* spp., *Mustelus* spp., and *Raja* spp.; discards of *Scyliorhinus canicula, Galeus melastomus, Etmopterus spinax, Dipturus oxyrinchus*
	Recreational fishing	Cyprus	Prohibition to fish sharks	Terms of fishing licenses and basic provisions of legislation for recreational fishing	In place	All shark species
	Spatial restrictions	Malta, Cyprus	Specific trawling areas	Fisheries management plans[114,130]	In place	Not elasmobranch specific
		Cyprus, Malta, Greece	Prohibition of bottom trawlers to fish less than 50 m depth or close to shore	Council Regulation (EC) No 1967/2006, as amended in 2019[131]	In place	Not elasmobranch specific
	Temporal closures	Malta	Bottom trawl closure 1 month per year	Fisheries management plan[114]	In place	Not elasmobranch specific
		Greece	4 months bottom trawl closure (June-September) plus a ban between 24th to 31st of December	Fisheries management plan[129]	In place	Not elasmobranch specific
		Cyprus	5 months bottom trawl closure (1 June- 7 November)	Fisheries Management Plan[130]	In place	Not elasmobranch specific
	Bycatch mitigation	Cyprus, Greece	Design and testing of selective extraction methods to minimize bycatch in existing fishing activities; LIFE ELIFE Project: testing low impact fishing gears to reduce shark bycatch	Programme of Measures[115]; https://www.elifeproject.eu/en/	ongoing	Not specified
Markets	Food promotion	Malta	EMFF-funded "Treasures of the Sea" Campaign promoting sustainable consumption of *Raja clavata* and *Scyliorhinus canicula* (EMFF 4.3.1)	EMFF report[121]	Implemented by 2018	*Scyliorhinus canicula, Raja clavata*
		Greece	"The Fishing Cultural Heritage of NE Aegean Sea" part of the EU HORIZON 2020 program PERICLES	https://pericles.inale.gr/en/home_en/	Ongoing	*Mustelus* spp.
	Contamination	Malta	PoMs (D9)	MSFP Programme of Measures[83]	Ongoing (last updated report 2020)	*Mustelus mustelus*

groups related to catches of rays [69]. The same applies to Malta with less than 1% of total catches are blue sharks and aggregated groups of rays, which is in line with Malta's reporting under the MSFD [83]. Greek elasmobranch landings also make up less than 1% of total annual catches [69]. Although these figures seem small, they are based on limited data, as indicated through the identified uncertainties for this group.

The precautionary principle is linked to a risk-based approach. The risk for elasmobranchs is the risk of disappearance and subsequent shifts and impacts to the overall marine ecosystem. The level of extinction risk is reflected in the IUCN Red List assessment for the Mediterranean [37]. The PP and applicable approach aim to prevent substantial environmental harm, such as the loss of biodiversity, and have entered, to some extent, EU and regional instruments relevant for elasmobranchs. Yet, it has not been incorporated into relevant policies at national level nor has a PA been applied to elasmobranchs sufficiently to prevent further population decline of threatened species. Some species, such as blue sharks and bull rays, which are considered Critically Endangered in the Mediterranean, remain unmanaged and unprotected [37]. To apply precautionary measures for these and other elasmobranch species, the following problems are considered:

- There is little to no integration of sharks in national policies.
- Species are not protected or regulated.
- Sharks are 'left out' of conservation management.
- Target fisheries and fisheries with high elasmobranch bycatch remain poorly managed.
- Application of effective bycatch mitigation is lacking.
- Species are mislabelled and established markets for sharks that are not regulated/controlled.

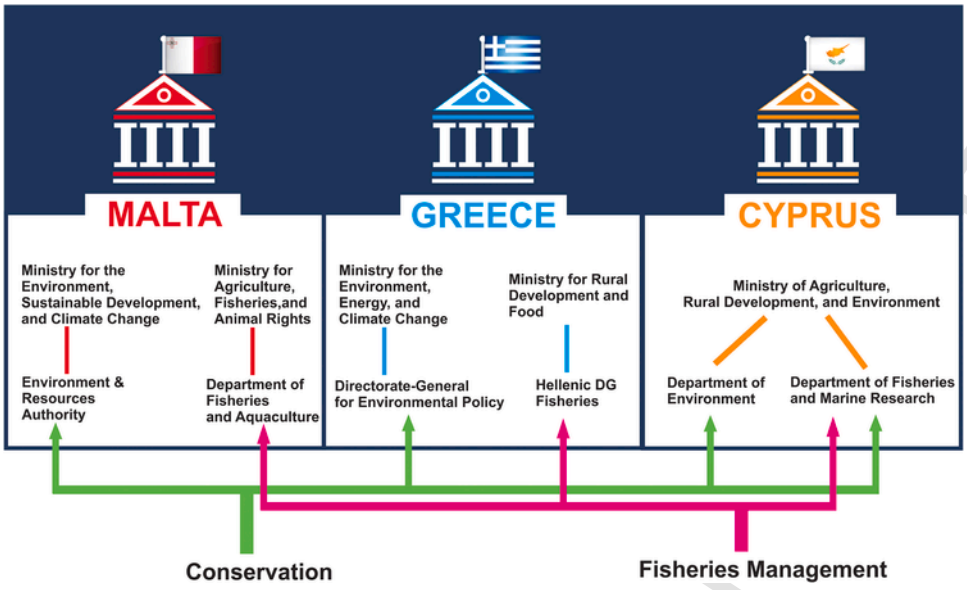

Fig. 3. Governing structure for Malta, Greece, and Cyprus based on the reporting evaluated.

- Recreational fisheries are not regulated.

3.5.1. Conservation management

Although the countries assessed in this study have designated MPAs mainly under the EU habitats Directive, some of the currently designated MPAs host bull rays, which would allow the creation of management measures within these areas to support the conservation of this species [86,112]. In line with the EU HD and the Commission Communication on the application of Article 6, the prohibition of recreational fisheries within these sites could aid the protection of bull rays [132]. While Cyprus do regulate recreational fisheries through a licensing system, there is no evidence that Malta and Greece have any limitations on this kind of fishery. The inclusion of elasmobranchs in national policies, including fisheries management plans, would additionally aid overall conservation and management and could integrate precautionary measures. Furthermore, national legislation in all three countries supports the designation of national species for conservation and countries could protect species within their waters before they are listed on international or regional conventions. A dedicated National Plan of Action for all occurring sharks, in line with the international and regional plans of action, could support elasmobranch conservation through the development of specific, time-bound measures [133]. The creation of a pelagic and coastal network of MPAs for elasmobranchs, which is a measure supported through the SPA/BD protocol for the species listed in Annex II, would be another approach to step up on national conservation of elasmobranchs.

3.5.2. Fisheries management

Related measures that are in line with the PP include safe handling techniques for bycatch, bycatch limits (e.g., Total Allowable Catch (TAC)), minimum landing sizes (MSL), seasonal shifts, and gear modifications [48]. Existing tools for elasmobranch bycatch mitigation, especially longlines which impact blue sharks, are limited [134]. While hook modifications may reduce the catch of some species, they can increase the catch of others [135]. Retention or fishing bans strongly depend on the post release/fishing mortality for bycatch species, which in the case of blue sharks is lhigh, as the majority of sharks released from longlines are in poor condition or dead [136]. For bull rays, there is currently no data on post release mortality. Reduced soak times, temporal closures and overall reduction of fishing effort therefore seem to be the widest-ranging and promising tools to mitigate overall elasmobranch bycatch [134,135,137].

Blue sharks are commonly marketed and often mislabelled [138]. The EU Regulation 1379/2013 states that MS should use all tools available against mislabelling and include, at least, origin, common species name, and catch method for marketed fishery products. However, the regulation also allows and supports that additional information is displayed (Art. 39). If the IUCN Red List status and population trend would be included for the two model species it could help changing consumer behaviour and awareness. Furthermore, there is a health risk associated with the consumption of highly contaminated fishery products [139,140]. Both, blue sharks and bull rays, show high levels of mercury [141–145]. Consumers should be informed about the level of contamination and therefore elasmobranchs would need to be further integrate in the MSFD assessment D9, and potential market bans should be considered. A complete fishing ban can be effective first step, especially for target fisheries, but are of reduced effect for bycatch [146]. An overview of available and relevant precautionary measures for the two model species is shown in Fig. 4.

4. Discussion

The nature of law is reactive, so measures may be designed and implemented at a point where they are too late to address the problem they were applied to. The PP theoretically counters this approach by creating an obligation to act before detriment occurs. As observed through the measures outlined above, however, the PP itself is uncertain in scope and function. There are both ‘strong’ and ‘weak’ applications of the principle. In the case of the former, measures adopted, such as prohibitions on certain activities, would seek to obviate any significant or irreversible environmental harm, and not reflect issues such as cost. A weaker formulation would inbuild that balance and is possibly more aligned with the UNCED principle 15. The weaker approach is the most keenly observable in law and policy and the consistent reliance on the concept of sound science perhaps militates against a stronger application. The difficulty in both applications is the risk element. Total elimination of risk is difficult – particularly with highly mobile species in a dynamic environment. However, appreciating the tipping point when balancing socio-economic and environmental costs become misaligned and impacts tend to the significant and irreversible is hardly an exact science itself. In view of the biological traits of elas-

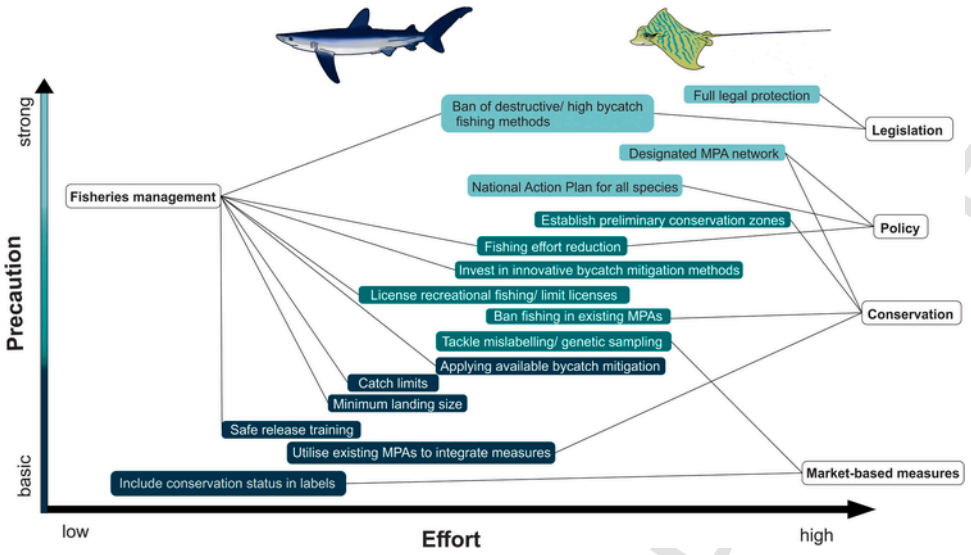

Fig. 4. Proposed precautionary measures for bull rays and blue sharks based on review of applicable policies, literature, and reports. The measures are clustered in different levels of implementation (Legal, Policy, Conservation, Market-based measures, and Fisheries management), and range from basic precautionary actions requiring low effort to stronger measures.

mobranchs, recovery can take decades and therefore, a stronger precautionary approach and foresight to the conservation and management of these species, which are subject to fisheries' pressures, would seem preferable [147]. Legal protection alone does not guarantee effective conservation, and in order for fisheries to be sustainable, specific, wide-ranging measures have to be implemented, enforced, and monitored [35].

This work assessed the level of integration and application of the PP for elasmobranchs within three countries. Based on the evaluation of legal instruments and national policies, the approach taken remains science-based, and uncertainties in form of a lack of data for elasmobranchs seems to continue to be used as an excuse to refrain from specific actions: a difficulty once again with balancing the considerations. A failure to effectively protect nature and manage fisheries is reflected in the most recent review of the EU's effort to implement measures [60,148]. Furthermore, it might be argued that the guiding directive, namely the HD, under which most of the EU countries establish MPAs, has failed to be precautionary by not including the group of elasmobranchs in its Annexes, and that the EU relies on other instruments, non-binding ones, such as EU action plan, to make states act.

Available measures for fisheries, such as catch limits, MLS, and restricted areas, are currently not applied for this species group in any of the countries assessed. At European level, annual TACs are set by the STECF and published within the regulation on "fishing opportunities for certain fish stocks and groups of fish stocks" applicable to EU waters and EU vessels. Catch prohibitions for protected elasmobranchs species are integrated this regulation, in line with regional applicable limits and restrictions, which in the case of the Mediterranean applies to measures established by the GFCM and, to some extent, the International Commission for the Conservation of Atlantic Tunas (ICCAT). Measures for elasmobranchs at regional level through GFCM/42/2018/2, however, only apply to species that already received legal protection through regional and international conventions. EU Regulation 1241/2019 restricts the use of entangling gear (trammel nets, gill nets, drift nets) to catch certain shark species, including blue sharks. However, at national level, there is limited evidence to the extent these measures are integrated and implemented [42]. Similar to the observations by Charles, uncertainties in fisheries management mainly refer to the state of nature uncertainty [3]. This would allow for the application of precautionary measures for elasmobranchs, especially those that are not effectively protected by law, are subject to intense fishing pressures, and continue to decline, such as our two model species. A complete reform to fishing applying a PA for elasmobranchs would require further efforts and broader measures. Currently implemented measures, whether claimed to be precautionary or not, such as the reduction of the fleet capacity, exiting limitations to trawling in coastal areas and below 1000 m (through GFCM/29/2005/1), and the ban of drift nets in high seas, often claimed as PA [149], would need to be extended to adequately cover elasmobranchs. The recently established TAC for blue shark by ICCAT in North and South Atlantic through EU Regulation 123/2020 and continued in 2021 (EU Regulation 92/2021), is a first step. However, Mediterranean longline fisheries require urgent consideration noting that blue sharks are fished unsustainably [150,151]. In line with obligations under the Bern Convention and Barcelona Convention, management measures for blue sharks should be applied. Available mitigation for longline fishing is limited, but new, promising tools are being developed [134]. Bycatch mitigation through spatial closures is a promising, precautionary measure that might cause initial resistance and cost to the fishing sector, but brings long term cost-effectiveness [152]. The same measure could be applied for bull rays, which are subject to fishing pressure by trawling, longlines and gillnets [97,153]. Bull rays, like other coastal batoid species, are an integral part of the marine ecosystem [154]. As coastal species, they could benefit from the integration in exiting MPA management and additional MPAs. In relation to conservation management, there is no evidence that a PA for elasmobranchs has been applied in the countries assessed.

5. Conclusion

Although the PP is integrated in international and regional instruments, and efforts have been made to streamline biodiversity conservation and fisheries management [60,155], early recognized obstacles such as highly politicized fisheries and lack of political will [67,156] seem to remain and hamper the effective application of a PA to fisheries and conservation management.

This study identified sixteen measures that could be applied in the sense of the PP for the two model species. Furthermore, there are ongoing initiatives by local non-governmental organisations that can support measures and inform government action. Such initiatives include, inter alia, the "Fly with bull rays" program of Sharklab-Malta (https://sharklab-malta.org) and bycatch monitoring programme of iSea in

Greece (https://isea.com.gr), as well as projects implemented by Enalia Physis in Cyprus (https://enaliaphysis.org.cy).

Currently, only 24 species are listed in Annex II of the Barcelona Convention, including those that are also listed under the CMS and Convention on the Trade of Endangered Species (CITES). With the majority of the 73 assessed elasmobranchs being threatened by extinction in this region, including species classified as Data Deficient by the IUCN Red List assessment [37], high uncertainties in population assessments and fisheries data, applying precautionary measures for these species might be best way forward to guarantee their continued existence.

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Lydia Koehler: Conceptualization, Methodology, Writing – original draft. **Ioannis Giovos:** Writing – original draft. **Jason Lowther:** Supervision, Writing – review & editing.

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