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The Marine Environment Assessment in the Areas with Insufficient Data: The Results of Assessment for IMAP Common Indicator 20 in the Mediterranean

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List of Abbreviations / Acronyms

ADR	Adriatic Sea sub-region
AEL	Aegean and Levantine Seas Sub-region
BaP	Benzo(a)pyrene
BDL	Below Detection Limit
CEN	Central Mediterranean Sea Sub-region
CI	Common Indicator
CORMON	Correspondence Group on Monitoring
COP	Conference of the Parties
CP	Contracting Parties
CEN	Central Mediterranean Sea Sub-region
DD	Data Dictionary
dl	Dioxin like
DS	Data Standard
dw	Dry weight
EAC	Environmental Assessment Criteria
EC	European Commission
EDI	Estimated daily intake
EIONET	European Environment Information and Observation Network
EMODnet	European Marine Observation and Data Network
EO	Ecological Objective
EWI	Estimated weekly intake
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
GES	Good Environmental Status
GFCM	General Fisheries Commission for the Mediterranean
HCB	Hexachlorobenzene
HI	Total risk
HQ	Hazard quotient
IMAP	Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria
JRC	Joint Research Centre
MAP	Mediterranean Action Plan
MED	Mediterranean
MB	*Mullus barbatus*
MED POL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean Sea
MG	*Mytilus galloprovincialis*
MRL	Maximum residue limit
MSFD	Marine Strategy Framework Directive
OSPAR	Convention for the Protection of the Marine Environment for the North- East Atlantic
PAHs	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PCDD	Polychlorinated dibenzo-para-dioxins
PCDD/Fs	Polychlorinated dibenzo-para-dioxins and dibenzofurans
PCDF	Polychlorinated dibenzofurans
PDBE	Polybrominated diphenyl ethers
PFAS	Per- and polyfluorinated alkyl substances
POPs	Persistent organic pollutants
QSR	Quality Status Report
TEF	Toxic equivalency factor
THQ	Target hazard quotient
TM	Trace metals
UNEP	United Nations Environmental Program

WHO	World Health Organization
WMS	Western Mediterranean Sea sub-region
ww	Wet weight

1. Introduction

1. Updated Guidance Fact sheet for IMAP CI 20[1] provided in 2019, stated that the initial target of GES under this CI " will be to maintain the chemical contaminants of human health concern under regulatory levels in seafood set/recommended/agreed by national and/or international authorities and their trends with regard their occurrence should decrease pointing towards zero events".

2. CI 20 status should be assessed based on the following sub-indicators: number of detected regulated contaminants in commercial species and the number of detected regulated contaminants exceeding regulatory limits. Both are determined via monitoring by national regulatory and inspection bodies through statistics and databases. The indicator units were defined as frequencies (%) of the number of detected contaminants in individual commercial species and frequencies (%) of the number of detected contaminants exceeding regulatory limits.

3. Updated Data Standards and Data Dictionaries (DSs & DDs) aimed at collecting data on actual levels of contaminants that were detected and number of contaminants which exceeded maximum regulatory levels in commonly consumed seafood in the Mediterranean Sea were approved by the Meeting of CorMon Pollution (27 and 30 May 2022) (UNEP/MED WG 533/10, Appendix VI). The list of contaminants includes Cd, Hg, Pb, four PAHs (benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene), dioxins, dioxin-like (dl) and non dioxin-like PCBs (PCB 28, PCB 52, PCB 101, PCB 138, PCB 153 and PCB 180) and radionuclides. Non-regulated contaminants could be included in the IMAP CI 20 monitoring programme, but for the time being no concentration limits are set in the EU legislation. The concentration limits for the regulated[2] contaminants in the EU used for the preparation of Data Standards and Data Dictionaries for IMAP CI 20 are presented in Annex I of this document.

2. The assessment related to IMAP CI 20 provided in the MED QSR 2017 (https://www.medqsr.org/assessment-methods-ci20)

4. The previous assessment of CI 20, performed during the preparation of the 2017 Mediterranean Quality Status Report (2017 MED QSR), was based on bibliographic studies and scientific documents in the Mediterranean Sea. There were no data sets reported to MEDPOL for IMAP CI 20.

5. In the 2017 MED QSR it was concluded that " a few research studies and EU policy driven reports i.e., related to MSFD in some Mediterranean countries investigated the occurrence of contaminants in seafood from an environmental perspective i.e., the ecosystem approach, which are exceeding the maximum regulatory levels established within regulatory standards. Overall, from available studies, no major significant concerns or extreme high levels were observed within these recent research studies by different authors and no confirmation based on temporal trends have been performed yet".

3. The assessment methodology applied for present assessment of IMAP CI 20

6. Given the lack of data reported in IMAP IS by the CPs prevents implementation of the recommendations of COP 19 related to integrated assessment based on quality assured data, the input for the 2023 Mediterranean Quality Status Report (2023 MED QSR) related to the assessment of CI20 was performed by using the following two approaches:

i) Assessment of the status based on data reported to IMAP-IS for CI 17 contaminants in biota up to 31st, October 2022, the cutoff date for data reporting, using the EU concentration limits for regulated contaminants, as presented in Annex I;
ii) Assessment of present status based on bibliographic studies, following the same approach applied for preparation of the 2017 MED QSR, however by using newer available scientific literature.

[1] UNEP/MED WG473/7 Annex I "IMAP Guidance Factsheets: Update for Common Indicators 13, 14, 17, 18, 20 and 21; New proposal for Candidate Indicators 26 and 27
[2] EU Directives 1881/2006, 835/2011, 1259/2011, 488/2014, 1005/2015

7. Both approaches consider the definition of GES for IMAP CI 20, as given in the Updated Guidance Fact sheet, according to which it is necessary to keep the concentrations of contaminants within the regulatory limits for consumption by humans i.e. initial GES target is to maintain the chemical contaminants of human health concern under regulatory levels in seafood that are set/recommended/agreed by national and/or international authorities; their trends with regard to their occurrence should decrease pointing towards zero events.

8. Within the present efforts to set the baseline to measure the trends of the concentrations of contaminants in seafood, account is taken of the JRC (2010)[3] which suggests to take into account "the frequency that levels exceed the regulatory levels, the actual levels that have been detected, the number of contaminants for which exceeding levels have been detected and in parallel the origin of the contamination (geological versus anthropogenic, local versus long distance)". It also stipulates that "Further an intake assessment taking into account the importance in the human diet of the species showing the exceeding levels could be taken into account. If regulatory levels are exceeded in one specie, that doesn't mean that all seafood consumption from this sub-region is dangerous".

9. The present lack of data availability in IMAP IS and relevant scientific studies do not allow proposing boundary limit between GES and non-GES status for IMAP CI 20. The boundary limit should be primarily based on the frequency of contaminants` appearance. However, more substantive considerations need to be undertaken further to expected future sufficient data reporting by the CPs in order to propose GES-non-GES boundary limit based on the frequency of contaminants` appearance. All relevant national and international practices need to be taken into account, along with gathering information on cumulative impact of the contaminants on different seafood species and undertaking computation of daily/monthly intake and related risk analysis.

10. Hence , the present initial marine environment assessment for IMAP CI 20 is based on calculation of number of data points exceeding the criteria i.e. the concentration limits for the regulated contaminants in the EU by considering data points extracted from IMAP IS CI 17 database, that are found relevant for assessment of CI 20, and from data based on the literature.

11. Monitoring of future trends of the contaminants` concentrations in seafood should be established in relation to such determined initial status, along with making efforts to set a GES-non GES boundary limit.

12. The present assessment effort related to the preparation of the 2023 MED QSR can be further upgraded depending on the status of data availability from the two following data sources:

i) Data/reports that might be available from https://cdr.eionet.europa.eu/ (MSFD) that should be further discussed with EIONET;
ii) Data that might be available at GFCM-FAO data base for the Mediterranean Sea.

3.1 Assessment of the status based on data reported to IMAP-IS for contaminants in biota (CI 17)

13. The data reported to IMAP-IS for CI-17 was investigated and the available relevant data extracted and used for present initial marine environment assessment for IMAP CI 20. The relevant data consisted of the concentrations of trace metals (Cd, Hg and Pb) in fish and molluscs; PAHs in molluscs and PCBs in fish and molluscs. It should be emphasized that these data were collected within IMAP monitoring programs to assess the status of the marine environment and not to protect human health.

3.1.1 The mandatory monitoring species *Mytilus galloprovincialis* (MG) and *Mullus barbatus* (MB)

14. The available data for the mandatory species *M. galloprovincialis* and *M. barbatus* are summarized in Table 1 along with the number of data points that exceeded the concentration limits for human consumption (Annex I).

Table 1. Number of data points extracted from IMAP-IS CI17 database, of relevance for IMAP CI 20, are shown in black. Assessment findings are shown in red and indicate the number of data points

[3] https://mcc.jrc.ec.europa.eu/documents/201406241428.pdf

exceeding the criteria i.e. the concentration limits for the regulated contaminants in the EU. Table is sorted by species and alphabetical order of CPs. MG – *Mytilus galloprovincialis*; MB- *Mullus barbatus*. No criteria are specified in the EU regulations for Hg and Σ_6 PCBs in *M. galloprovincialis* nor for PAHs in *M. barbatus*.

CP	**Year**	**Species**	**Cd**	**Hg**	**Pb**	**Σ_4 PAHs**	**Benzo(a) pyrene**	**Σ_6 PCBs**
Albania	2020	MG	2	2	2			2
			0		0			
Croatia	2019-2020	MG	37	35	37			19
			0		0			
France	2015, 2017-2018	MG	50	50	50	25	25	23
			0		0	0	0	
Italy	2015-2019	MG	33	170	33		53	
			0		0		0	
Montenegro	2018-2020	MG	28	28	28	21	21	21
			0		4	0	0	
Morocco	2017-2021	MG	27	27	27	6	6	
			0		0	0	0	
Slovenia	2016-2021	MG	21	21	15	12	12	
			0		0	0	0	
Spain	2015-2017,2019	MG	70	70	70	42	42	40
			0		6	6	1	
Croatia	2019-2020	MB	11	10	11			
			0	0	0			
Cyprus	2020-2021	MB	14	14	14	12	12	12
			0	1	0			0
Israel	2015, 2018-2020	MB	58	60				
			0	0				
Lebanon	2019	MB	14	14	14			
			0	0	0			
Malta	2017, 2019	MB	5	5	5			
			#	0	0			
Montenegro	2018	MB	8	8	8			
			0	0	0			
Turkiye (AEL)	2015	MB	25	25	25		8	
			0	0	0			

#All data were reported to IMAP-IS as below detection limit. Detection limit was higher than the EU maximum regulatory level criteria.

15. Most of the measured concentrations were below the concentration limits for the regulated contaminants in the EU, with a few exceptions in Cyprus, Montenegro, and Spain. The maximal percentage of values above the EU criteria for one specific contaminant was low (14%).

3.1.2 Other species reported to IMAP-IS

16. The biota files from the IMAP-IS database were screened again for species other than the mandatory monitoring species, *M. galloprovincialis* and *M. barbatus,* for CI 17. Additional species were reported as shown here-below.

17. Cyprus (2020-2021). Cd, Hg and Pb were measured in the muscle of the fish *Boops boops* (n=13), *Thynnus alalunga* (n=52) and *Merluccius merluccius* (n=1). All the concentrations were below the concentration limits for the regulated contaminants in the EU, except for Hg in 6 samples of *T. alalunga*. Σ_4 PAHs and Σ_6 PCBs were reported for *Boops boops* (n=10) and *T. alalunga* (n=15). All concentrations were below detection limit and for Σ_6 PCBs also below the concentration limits in the EU. No criteria were given for PAHs in fish (Annex I).

18. Croatia (2019). Cd and Pb were measured in the muscle of the fish *Merluccius merluccius* (n=3), *Mullus surmuletus* (n=1), *Pagellus erythrinus* (n=3), *Sparus aurata* (n=9). All concentrations were below the concentration limits for the regulated contaminants in the EU.

19. France (2017)[4]. Cd, Hg, Pb (n=6 each) and Σ_4 PAHs and Σ_6 PCBs (n=4 and n=2, respectively) were measured in the mollusc (bivalve) *Crassostrea gigas* and Cd, Hg, Pb were measured in 7 samples of the mollusc (bivalve) *Venerupis decussata*. All concentrations were below the concentration limits for the regulated contaminants in the EU.

20. Israel (2015, 2018, 2020). Cd and Hg were measured in 6 samples of the mollusc (bivalve) *Donax trunculus*, and Cd and Hg were measured in 26 samples of the mollusc (bivalve) *Mactra corallina*. All concentrations were below the concentration limits for the regulated contaminants in the EU.

21. Lebanon (2019). Cd, Hg, Pb (n=11 each) and Σ_6 PCBs (n=3) were measured in the fish *Diplodus sargus* and Cd, Hg, Pb (n=15 each) and Σ_6 PCBs (n=13) were measured in the fish *Euthynnus alletratus*. All concentrations were below the concentration limits for the regulated contaminants in the EU.

22. Malta (2017 and 2019). Cd, Hg, Pb (n=4 each), dioxin like PCBs and Total dioxins and furans (n=1 each) were measured in the fish *Merluccius merluccius.* All concentrations were below the concentration limits for the regulated contaminants in the EU.

23. Morocco (2019-2021). Cd, Hg, Pb (n=30 each) were measured in the mollusks *Callista chione* (n=30) and petite praire (n=6). All concentrations were below the concentration limits for the regulated contaminants in the EU. Σ_4 PAHs were reported for *C. chione* (n=15) and petite praire (n=3). All concentrations were below the concentration limits for the regulated contaminants in the EU.

3.2 Assessment of the status based on bibliographic studies as applied towards the 2017 MED QSR

24. The literature search on seafood quality in the Mediterranean Sea focused on the studies that reported data from 2016/2017 onward, emphasizing contaminants that are regulated in the EU (Annex II). Previous studies have been used in the preparation of the 2017 MED QSR. The studies reported concentrations of contaminants and compared *them* to EU regulation (Annex I) while some also addressed national regulation as well as international regulations or advisories (De Witte et al. 2022). Most of the studies provided also risk assessments to human health from consumption of the seafood by calculating the estimated daily intake (EDI), target hazard quotient (THQ), total risk (HI), Cancer risk, among others.

25. This emphasizes the fact that the risk to human health (and hence GES- non GES statuses) should not be evaluated based on concentration of a single contaminant but evaluated together with other factors such as synergy with other contaminants, temporal and spatial scales.

26. Another point to make is that recent literature emphasizes the connection between seafood safety and quality and the presence of microplastics in the marine environment (i.e.Wakkaf et al. 2020 among many others). Human health may be impacted either by consuming seafood with microplastic content, or seafood with contaminants that were leached from the microplastic to the organism. This sets an interrelation of CI 20 with CI 23 and should be further pursued.Table 2 provides a summary of the studies published in the peer-reviewed literature. Thirty-six studies from 11 CPs were found relevant for the present work, with 1-4 studies each, except for Italy that had 14 studies. Most (25) reported concentrations of trace metals (TM) and 12 on organic contaminants (PAHs, PCBs, PBDEs,

[4] Data from EMODNet.

PCDD/Fs). Concentrations in fish were reported in 26 studies and concentrations in molluscs were reported in 17 studies.

Table 2. The number of studies, per country, on seafood quality and safety in the Mediterranean which findings were used to support present assessment.

Country	Total Number of studies	Number of studies reporting on:		Number of studies reporting on:		
		Trace metals	Organic contaminants	Fish	Mollusc	Other (crustaceans, cephalopods)
Algeria	3	3	0	3	0	0
Croatia	2	2	0	2	0	0
Egypt	1	0	1	1*	1	1
France	1	0	1	1	0	0
Greece	2	2	0	2	0	0
Italy	14	9	7	9	9	3
Lebanon	3	3	0	2	2	2
Morocco	3	3	0	1	2	0
Spain	1	1	0	1	0	0
Tunisia	2	0	2	2	1	1
Turkiye	4#	2	1	2	2	1

*fresh water fish; #one study on radioactivity as contaminants in fish.

27. In the context of CI 20, to protect human health, trace metals in fish were reported for many species across the Mediterranean countries: Algeria, Croatia, Greece, Italy, Lebanon, Morocco, Spain and Turkiye. Trace metals in molluscs were reported in various species from Italy, Lebanon, Morocco and Turkiye. Organic contaminants in fish were reported for various species from France, Italy and Tunisia, and in molluscs for Egypt, France, Italy, Tunisia and Turkiye. Trace metals and organic contaminants were reported also for some crustaceans and cephalopod species. Information on consumers` health risk was available for Algeria, Croatia, Italy, Tunisia and Turkiye only. The literature review is presented in Annex II and summarized here-below and in Table 3 and Figure 1.

28. **Algeria (WMS):** Cd, Hg, Cu were reported in *Sardina pilchardus* and in M*ullus barbatus* collected from the Algerian coast (2017-2018). Concentrations were below the concentration limits for the regulated contaminants in the EU, except concentrations of Cd in some specimens from the bay of Algiers that were higher than the EU regulatory threshold. The average Pb concentrations did not exceed the regulatory value, although some specimens had concentrations higher than the threshold. Consumption of *S. pilchardus* from Algerian coast was not likely to have adverse effect on human health and a few risks were assigned to the consumption of contaminated *M. barbatus* (Hamida et al. 2018, Aissioui et al. 2021, Aissioui et al. 2022).

29. **Croatia (ADR):** Cd, Hg and Pb were reported for fish from 11 species[5] purchased in 2016 from supermarkets located in different Croatian cities. Hg and Pb concentrations were below the concentration limits for the regulated contaminants in the EU. Mean Cd levels in bluefin tuna exceeded the EU limit. Consumer health risk calculated from the dietary intakes for Cd was low, with exception of bluefin tuna. For Hg, frequent consumption of European sea bass, carp and bluefin tuna over a long period may have toxicological consequences for consumers. In a different study in 2016, the concentration of Hg did not exceed EU regulations in European pilchard and European anchovy (Bilandžić et al. 2018, Sulimanec Grgec et al. 2020).

[5] Hake (Merluccius merluccius, n=7), Atlantic mackerel (Scomber scombrus, n=7), cod (Gadus morhua, n=7), chub mackerel (Scomber japonicas, n=7), fresh and canned sardine (Sardina pilchardus, n=7), European sea bass (Dicentrarchus labrax, n=13), gilthead sea bream
(Sparus aurata, n=11), bluefin tuna (Thunnus thynnus, n=8), salmonbass (Argyrosomus regius, n=8), rainbow trout (Oncorhynchus mykiss, n=7) and carp (Cyprinus carpio, n=7).

30. **Egypt (AEL):** Persistent organic pollutants were reported in the mollusc *Donax trunculus* at the Rosetta Nile branch estuary. PCBs levels were well below tolerable average residue levels established by FDA and FAO/WHO for human fish consumption (Abbassy 2018).

31. **France (WMS):** Persistent organic pollutants (POP[6]s) were evaluated in six fish and two cephalopods species from an impacted area in NW Mediterranean Sea (Rhone river estuary vicinity). For Atlantic bonito (*Sarda sarda*) and chub mackerel (*Scomber colias*), the estimated weekly intakes of dioxin-like POPs for humans overpassed the EU tolerable weekly intake. Concentrations of nondioxin-like PCBs in *S. sarda* were above the EU maximum levels in foodstuffs, pointing to a risk (Castro-Jiménez et al. 2021).

32. **Greece (AEL)**: Cd, Hg and Pb were reported in 4 fish species[7]. Concentrations in *S. aurata* and *D. labrax* were below the concentration limits for the regulated contaminants in the EU. In sardine and anchovy, nutritional benefits seem to outweigh the potential risks arising from fish metal content (Renieri et al. 2019, Sofoulaki et al. 2019).

33. **Italy (ADR, CEN, WMS) (TM in fish and mussel):** Hg, Cd, Pb were determined in 160 specimens of fish belonging to sixteen species collected in 2018 from commercial centers of South Italy. The concentrations were below the EU regulation, except for Cd in bluefin tuna, which exceeded the tolerable value. The estimated hazard quotient of Hg indicated a high probability of experiencing non-carcinogenic health risks (Storelli et al. 2020). Hg was measured in 42 commercial fish species caught off the Central Adriatic and Tyrrhenian coasts of Italy and in 6 aquaculture species. Hg levels exceeding the EC regulation limits were found in large-size specimens of high trophic-level pelagic and demersal species. An estimation of the human intake of mercury associated to the consumption of the studied fish and its comparison with the tolerable weekly intake is provided (Di Lena et al. 2017). Hg measured in European hake (*Merluccius merluccius*) caught in the northern and central Adriatic Sea were lower than the level set by EU regulations (Girolametti et al. 2022). Cd, Pd measured in the swordfish *Xiphias gladius* muscles were lower than the levels set by EU regulations. Hg in 32% of samples exceeded European maximum limits. Risk assessment indicates hazardous state concerning Hg (Di Bella et al. 2020).

34. Cd, Hg, Pb in *Mytilus galloprovincialis* did not exceed the maximum limits as established by EU regulation from the Gulf of Naples and Domitio littoral (2016-2019) nor in specimens from the Claich Lagoon (Sardinia, 2017), the Marche (2016-2017) nor in Sicily (2016) (Esposito et al. 2020, 2021; Cammilleri et al. 2020).

35. **Italy (ADR, CEN, WMS) (Organic contaminants in fish and mollusc).** PAHs were measured *Sardina pilchardus and Solea solea* caught in the Catania Gulf (Sicily, 2017) (Ferrante et al. 2018). EU criteria for PAH the protection of human health exist only for mollusc and not for fish. Polychlorinated dioxins and furans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (dl-PCBs) measured in fish[8] were below the maximum limits set by the EC for human consumption (Barone et al. 2021). Σ_6 PCBs and dioxins and dioxin-like PCBs were lower than the values in the EU regulation in specimens of 3 edible fish species[9] samples in 2017 in the Northern Tyrrhenian Sea (Bartalini et al. 2020). PCDD/Fs, PCBs, measured in fish[10] from Taranto (2016) and PCDD/Fs and dl-PCBs) measured in fish[11] from Southern Italy (2019) were below the regulatory limits specified for these contaminants within the EU (Ceci et al. 2022, Barone et al. 2021). Σ_6 PCBs in in marine organisms[12]

[6] Polybrominated diphenyl ethers (PBDEs), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs)
[7] Seabream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*) sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*)
[8] rosefish, Euro-pean hake, red mullet, common sole, bluefin tuna
[9] Sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and bogue (*Boops boops*).
[10] hake, mullet, sea bream, bogue, red mullet mackerel, sardines and sand steenbras
[11] rosefish, Euro-pean hake, red mullet, common sole, bluefin tuna
[12] In 2017, mussels (*Mytilus galloprovincialis*) obtained from a commercial farm and transplanted to two sites in Augusta Bay and resampled after 5 weeks and 7 months. Fish: 96 specimens of finfish (*Sphyraena sphyraena*, *Trigla lucerna*, *Mullus barbatus*, *Pagellus* spp., *Diplodus* spp.) and shellfish (*Parapaeneus kerathurus* and *Sepia* spp.) were obtained through local fishermen

collected from the contaminated Augusta Bay (Southern Italy, 2017) showed variable concentrations with a mean value above EU regulation in 2 fish species. Benzo[*a*] Pyrene (BaP) in mussels exceed threshold limit of the EU regulation. No risk analysis was performed. (Traina et al. 2021).

36. PCBs, dioxins and PAHs in *Mytilus galloprovincialis,* farmed in the waters of the Gulf of Naples and Domitio littoral (2016 to 2019), did not exceed the maximum limits as established by EU regulation, except for PAHs in a localized are in the winter (Esposito et al. 2020). Concentrations of Benzo(a)pyrene (BaP) and Σ4PAHs[13] exceeded the limit reported in EC in the Regulation for the mollusk *Donax trunculus,* caught in the Catania Gulf (Sicily, 2017). Risk assessment indicated concern for the health of high frequency molluscs consumers (Ferrante et al. 2018). PCDD/Fs and dl-PCBs in seafood[14] from Southern Italy (2019) and in mussel from Taranto (2016) were below the maximum limits set by the EC for human consumption except for a single sample taken from a known specific contaminated site in Taranto (Barone et al. 2021; Ceci et al. 2022).

37. **Lebanon (AEL):** Pb, Cd, and Hg were determined in three fish species (*Siganus rivulatus, Lithognathus mormyrus* and *Etrumeus teres),* in shrimp (*Marsupenaeus japonicus*) and in bivalve (*Spondylus spinosus*) commonly consumed by the local population. Trace metals concentrations were found to be below the maximum levels set by the EU (Ghosn et al. 2019, 2020a, 2020b).

38. **Morocco (WMS):** Cd and Pb concentrations were measured in soft tissues of *M. galloprovincialis.* Concentrations did not exceed EU regulations (Azizi et al. 2018; 2021). Cd, Hg and Pb concentrations measured in the fish *Liza ramada* were also below the values set in the EU regulation (Mahjoub et al. 2021).

39. **Spain (WMS):** The concentrations of Pb, Cd and Hg measured in the highly migratory *Thunnus alalunga* and *Katsuwonus pelamis* were below the tolerable limits considered by EU regulation (Chanto-García et al. 2022)

40. **Tunisia (CEN):** Organic contaminants (PAHs, PCBs and pesticides) were measured in fish (*Sparus aurata* and *Sarpa salpa*) muscle tissue collected from five stations along the Tunisian coast between (2018-2019). Σ_6 PCBs for the fish were below the EC regulations. (Jebara et al. 2021). Concentrations of 21 legacy and emerging per- and polyfluorinated alkyl substances (PFAS)[15] were measured in in 9 marine species (3 fish, 2 crustaceans and 4 mollusks)[16] collected from Bizerte lagoon, Northern Tunisia (2018). Exposure to PFAS through seafood consumption indicates that it should not be of concern to the local consumers (Barhoumi et al. 2022).

41. **Turkiye (AEL):** Concentrations of Cd, Pb and Hg levels were measured in 9 fish, 1 mollusc and 1 shrimp species[17] from the Aegean and Levantine Seas. All the results were found compatible with the Turkish Food Codex and EU Regulation limits except for Cd in two samples from the Mediterranean Sea. As a whole, the seafood was found to be safe for human consumption (Kuplulu et al. 2018). Cd and Pb measured in the fish *Trachurus mediterraneus, Sparus aurata* and *Pegusa lascaris* were below the values set in the EU regulation (Karayakar et al. 2022). *Mytilus galloprovincialis,* were transplanted from a clean site to the 3 sites in Nemrut Bay, known to be impacted by of industrial activities. Benzo(a)pyrene and Σ_4 PAHs levels in the mussels from the clean site were below the EU regulations while in the transplanted mussels PAHs were higher than the concentrations in the EU regulation in certain occasions. The results suggest that mussels were unsafe for human consumption during the time of the experiment (Kucuksezgin et al. 2020).

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[13]benzo(a)pyrene (BaP), benz(a)anthracene (BaA), benzo(b)fluoranthene (BbF) and chrysene (CH)
[14] (cephalopods: common octopus, common cuttlefish, European squid), (shellfish: Mediterranean mussel, striped venus clam, common scallop), (crustaceans: red shrimp, spottail mantis shrimp, Norway lobster)
[15] PFASs are not addressed in the EU regulation
[16] Fish: European eel (*Anguilla anguilla*), common sole (*Solea solea*), sea bass (*Dicentrarchus labrax*); crab (*Carcinus maenas*), shrimp (*Penaeus notialis*), common cuttlefish (*Sepia officinalis*) gastropod mollusc- banded dye-murex (*Hexaplex trunculus*), clam (*Ruditapes decussatus*) and farmed mussel (*Mytilus galloprovincialis*)
[17] Fish: mullet (Mugil cephalus), shad (Alosafallax), hake (Merluccius merluccius), whitting (Merlangius euxmus), seabass (Dicentrarchus labrax), turbot (Scophthalmus maximus), red mullet (Mullus barbatus), blue fish (Pomatomus saltatrix), seabream (Sparus auratus). Mussel: (Mytilus galloprovincialis). Shrimp (Penaeus indicus)

42. **Turkiye (AEL):** Specific natural radionuclide (^{226}Ra, ^{232}Th and ^{40}K) concentrations were measured in wild and farmed European seabass collected from the Mediterranean coast of Turkiye (AEL) in 2018. From the radiological point of view, the radioactivity doses measured and the consumption of both wild and farmed seabass from the Mediterranean coast of Turkiye do not pose any risk to human health (Ozmen and Yilmaz 2020).

3.3 National data reported following the Meeting of CorMon Pollution (1-2 March 2023).

At the time the assessment for CI 20 was prepared no national data were available in IMAP-IS. Italy submitted data for CI-20 after the Meeting of CorMon Pollution (1-2 March 2023, Athens). The data were not uploaded on the IMAP-InfoSystem because they were found not compliant given the lack of complementary data (D.O., T, S) that are considered mandatory by the System The data included, among others, concentrations of all the contaminants regulated by the EU, as listed in Annex I. Those were measured in different species of fish, molluscs, crustaceans and echinoderm and tunicates sampled in 2020. Out of 3,785 relevant entries (including all species and relevant EU contaminants), 11 entries (0.3%) were found to exceed the EU regulations for the protection of human health. The analyzes of additional national data of Italy confirmed the assessment based on CI17 and on the scientific literature, which found that most of the measured concentrations were below the concentration limits for the regulated contaminants in the EU in the Mediterranean Sea.

Table 3. Summary of the findings from the scientific literature (elaborated Annex II), used to support present assessment, arranged alphabetically by country. The findings of some of the studies were summarized in more than one row, to allow for the separation of taxa (i.e. fish from mollusc) and contaminants (trace metals from organics). It includes sum of 4 PAHs (benzo(a)pyrene (BaP), benz(a)anthracene (BaA), benzo(b)fluoranthene (BbF) and chrysene (CH) (Σ_4 PAHs); Benzo(a)Pyrene (B(a)P); sum of 6 non dioxin like PCBs (Σ_6 PCBs); sum of polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans (PCDD/Fs) and Σ (PCDD/Fs and dioxin like (dl) PCBs).
Cells in blue: values below EU criteria; cells in green: values above EU criteria but no health risk detected; cells in yellow: values above EU criteria, risk analysis was not reported; cells in red: above EU criteria with risk to human health.

Country	Sampling Year	Species	Cd	Hg	Pb	Σ_4 PAHs	B(a)P	Σ_6 PCBs	PCDD/Fs	Σ (PCDD/F and dl PCBs)
Algeria		sardines	√		√					
	2017-2018	*S. pilchardus*	√*	√	√					
	2017-2018	*M. barbatus*	√*	√	√*					
Croatia	2016	11 fish species	√#	√	√					
	2016	European pilchard, European anchovy	√							
Egypt	2017	*Donax trunculus*						√		
France^		Fish and cephalopods						√&	√&	
Greece	2017-2018	*Sparus aurata, Dicentrarchus labrax*	√	√	√					
		Sardina pilchardus, Engraulis encrasicolus	√	√	√					
Italy	2018	16 fish species	√#	√&	√					
		42 fish species		√&						
	2018-2019	*M. merluccius*		√						
	2017	*Xiphias gladius*	√	√&	√					
	2016-2019	*M. galloprovincialis*	√	√	√					
	2017	*M. galloprovincialis*	√	√	√					
	2016-2017	*M. galloprovincialis*	√	√	√					
	2016	*M. galloprovincialis*	√	√	√					
	2017	*S. pilchardus, S. solea*				√%				
	2019	5 fish species							√	√

Country	**Sampling Year**	**Species**	**Cd**	**Hg**	**Pb**	**Σ$_4$ PAHs**	**B(a)P**	**Σ$_6$ PCBs**	**PCDD/Fs**	**Σ (PCDD/F and dl PCBs)**
	2017	3 fish species						√		√
	2016	7 fish species						√	√	
	2019	5 fish species							√	√
^	2017	5 fish species						√+		
^	2017	*M. galloprovincialis* and other shellfish					√+	√+		
	2016-2019	*M. galloprovincialis*				√*		√		√
	2017	*Donax trunculus*				√&	√&			
	2019	Cephalopods, shellfish and crustaceans							√	√
	2019	*M. galloprovincialis*						√	√	
^	2017	*M. galloprovincialis*		√+		√	√+	√		
Lebanon	2016-2017	3 fish, 1 shrimp, 1 bivalve species	√	√	√					
	2017	1 bivalve, 1 shrimp species	√	√	√					
	2017	2 fish species	√	√	√					
Morocco	2016	*M. galloprovincialis*	√		√					
	2018	*M. galloprovincialis*	√							
	2018	*L. ramada*	√	√	√					
Spain		*T. alalunga, K. pelamis*	√	√	√					
Tunisia	2018-2019	*S. aurata*, S. *salpa*						√		
^^	2018	3 fish, 2 crustaceans and 4 mollusks species								
Turkiye	Not reported	9 fish, 1 mollusc and 1 shrimp species	√*	√	√					
^	2016-2017	*M. galloprovincialis*				√&	√&			
	2016-2017	3 fish species	√		√					

* Specific sampling area or organism or size class, no health risk detected; # Cd exceeded EU regulation in bluefin tuna; & Risk for human consumption, specific species and size class; % No EU regulation concerning PAHs in fish, only in mollusc; + Exceeded EU regulation, specific organism or size class, no risk analysis performed; ^ Specimens collected from known impacted area; ^^Study measured organics not addressed in EU regulations, no risk to health detected.

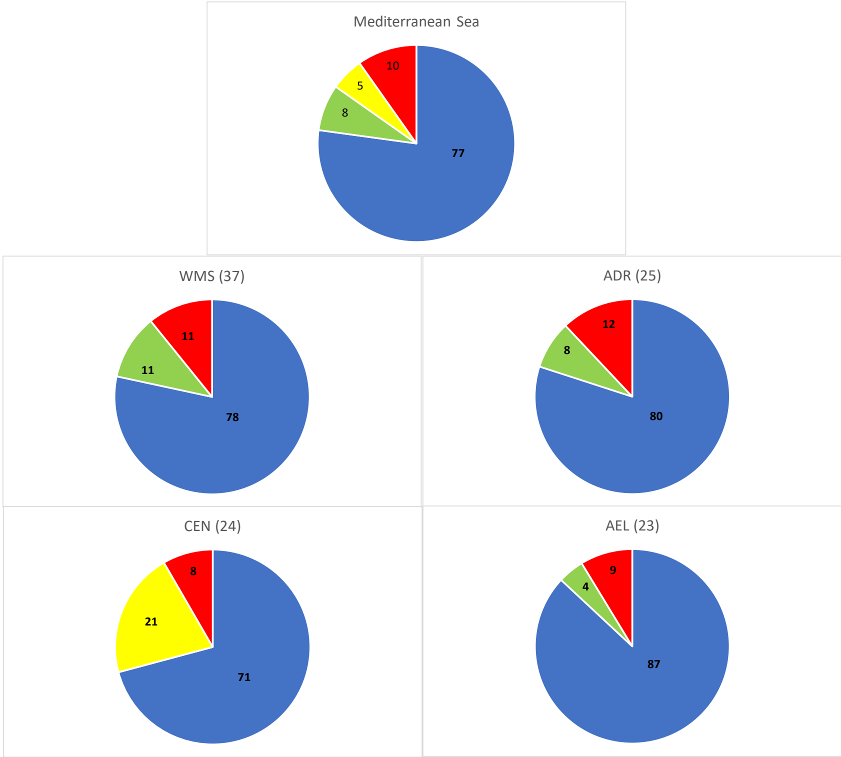

Figure 1. Assessment of CI 20 in the Mediterranean Sea and sub-regions based on recent peer-reviewed literature (elaborated in Annex II). Seventeen studies from Italy had results for 2 different sub-regions. Numbers in the chart are the percentage from total entries in each status. Number in parenthesis, the number of studies for each sub-region. Blue: values below EU criteria; green: values above EU criteria but no health risk detected; yellow: values above EU criteria, risk analysis was not reported; red: above EU criteria with risk to human health.

4. The key findings

43. Further to the elaboration of available data and relevant sources of literature as provided above in section 3, the below key findings can be highlighted.

44. No data were available in IMAP IS to perform an assessment of Common Indicator 20[18].

45. Assessment of CI 20, based on data reported for CI 17 contaminants in biota, found that most of the measured concentrations were below the concentration limits for the regulated contaminants in the EU.

46. Examination of CI 17 data i.e. data for TM and organic contaminants per sub-regions showed that data for *M. galloprovinciallis* were available only for the WMS and the ADR. Values above the concentration's limits were found for only 14 data points out of 1002 (1.4%).

47. Examination of the CI-17 data i.e. only data related to TM were available, per sub-regions showed that data for *M. barbatus* were available for the ADR (56 data points), CEN (15 data points) and AEL (213 data points). All concentrations were below the EU concentration limits.

48. Assessment of CI-20 based on recent peer reviewed literature found 36 relevant studies. Most (25) reported concentrations of trace metals while 12 studies reported on organic contaminants. Concentrations in a wide variety of fish species were reported in 26 studies and concentrations in molluscs in 17 studies. Data on crustaceans and cephalopods were reported in 8 studies.

49. Most of the studies found that the concentrations of the contaminants were below the concentration limits for the regulated contaminants in the EU (24 studies), or if some of the contaminants were higher than regulation, risk analysis showed no risk to human health (7 studies). Only 6 studies reported on possible risk for human health from the consumption of seafood.

50. Examination of the literature data per sub-regions was performed by counting the number of times contaminants (Cd, Hg, Pb, B(a)P) and the number of-group of contaminants (Σ_4 PAHs, Σ_6 PCBs, PCDD/Fs and Σ (PCDD/F and dl PCBs**))** (see table 3) were addressed in the literature. There were 37 entries for the WMS, 25 for the ADR, 24 for the CEN and 23 for the AEL sub-region. The percentages of blue status from the total entries were high: 78, 80, 71 and 87% for the WMS, ADR, CEN and AEL, respectively. Red status was assigned to 11, 12, 8 and 11% of the entries for the WMS, ADR, CEN and AEL, respectively (Fig. 1).

5. Recommendations

51. IMAP Guidance Factsheet (UNEP/MED WG.473/7) sets the future goals for the assessment of CI 20 as follows: "As this is a new Common Indicator within the context of marine environmental protection policy (*ca*. Ecosystem Approach and IMAP implementation), its applicability beyond food consumer protection and public health would need to be determined, although intuitively reflects the health status of the marine environment in terms of their delivery of benefits (e.g. fisheries industry). Thus, monitoring protocols, risk-based approaches, analytical testing and assessment methodologies would need to be further examined between the Contracting Parties` national food safety authorities, research organisations and/or environmental agencies".Further to this general goal, the following practical steps are recommended to improve the assessment of IMAP CI 20 and to set GES/ nonGES boundaries:

- Determine contaminants in commercial species, with size classes and in tissues consumed by humans;
- If possible, harmonize choice of species among CPs, including through reporting harmonized data in Data Dictionaries developed for CI 20;
- Recommend the maximal percentage of detected regulated contaminants exceeding regulatory limits in seafood, above which the location is nonGES. The IMAP Guidance Factsheets for CI 20 does not set a maximal percentage. The same is true for MSFD descriptor 9[19];

[18] Italy submitted data for CI-20 after the Meeting of CorMon Pollution (1-2 March 2023, Athens) (Section 3.3).
[19] https://www.gov.scot/publications/scottish-marine-freshwater-science-volume-5-number-15-development-sampling/pages/3/, Maggi et al., 2015; Tornero Alvarez et al., 2021.

- Report data to IMAP-IS in Data Dictionaries developed for CI 20;
- Provide reports on national seafood safety (or access to national reports). They may exist from national health authorities.

Annex I:

The concentration limits for the regulated contaminants in the EU used for preparation of Data Standards and Data Dictionaries for IMAP Common Indicator 20 as provided in UNEP/MED WG.533/10, Appendix VI

The elements of Data Standards (DS) and Data Dictionaries (DDs) specific for CI 20 are based on the concentration limits for the contaminants regulated in the EU, as defined in EU Commission Regulations (EC) No 1881/2006[20], (EC) No 835/2011[21] and EC No 1259/2011[22].

Maximum Levels of Heavy Metals – (EC) Regulation 1881/2006

	Foodstuffs	Maximum levels mg kg^{-1} wet weight		
		Cadmium	Lead	Mercury
1	Muscle meat of fish (1)	0.050 Excluding species listed in 2 and 3	0.30	0.50 Excluding species listed in 4
2	Muscle meat of the following fish (1) anchovy (*Engraulis species*) bonito (*Sarda sarda*) common two-banded seabream (*Diplodus vulgaris*) eel (*Anguilla anguilla*) grey mullet (*Mugil labrosus labrosus*) horse mackerel or scad (*Trachurus species*) louvar or luvar (*Luvarus imperialis*) sardine (*Sardina pilchardus*) sardinops (*Sardinops species*) tuna (*Thunnus species, Euthynnus species, Katsuwonus pelamis*) wedge sole (*Dicologoglossa cuneata*)	0.10		
3	Muscle meat of swordfish (*Xiphias gladius*) (1)	0.30		
4	Muscle meat of the following fish: anglerfish (*Lophius species*) atlantic catfish (*Anarhichas lupus*) bonito (*Sarda sarda*) eel (*Anguilla species*) emperor, orange roughy, rosy soldierfish (*Hoplostethus*			1.0

[20] Commission Regulation (EC) No 1881/2006, setting maximum levels for certain contaminants in seafood
[21] Commission Regulation (EC) No 835/2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs;
[22] Commission Regulation (EC) No 1259/2011, amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs

	species) grenadier (*Coryphaenoides rupestris*) halibut (*Hippoglossus hippoglossus*) marlin (*Makaira species*) megrim (*Lepidorhombus species*) mullet (*Mullus species*) pike (*Esox lucius*) plain bonito (*Orcynopsis unicolor*) poor cod (*Tricopterus minutes*) portuguese dogfish (*Centroscymnus coelolepis*) rays (*Raja species*) redfish (*Sebastes marinus, S. mentella, S. viviparus*) sail fish (*Istiophorus platypterus*) scabbard fish (*Lepidopus caudatus, Aphanopus carbo*) seabream, pandora (*Pagellus species*) shark (all species) snake mackerel or butterfish (*Lepidocybium flavobrunneum, Ruvettus pretiosus, Gempylus serpens*) sturgeon (*Acipenser species*) swordfish (*Xiphias gladius*) tuna (*Thunnus species, Euthynnus species, Katsuwonus pelamis*)			
5	Crustaceans, excluding brown meat of crab and excluding head and thorax meat of lobster and similar large crustaceans	0.50	0.50	0.50
6	Bivalve molluscs	1.0	1.5	
7	Cephalopods (without viscera)	1.0	1.0	

(1) Exclusion of liver. Where fish are intended to be eaten whole, the maximum level shall apply to the whole fish

Maximum Levels of Benzo(a)pyrene and sum of four PAHs (benzo(a)pyrene, benz(a)anthracene, benzo(b)fluorantheneand chrysene) Regulation No 835/2011 amending Regulation (EC) 1881/2006

Foodstuffs	Maximum levels (μg kg^{-1})	
	Benzo(a)pyrene	Sum of benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene *
Bivalve molluscs (fresh, chilled or frozen)	5.0	30.0

* Lower bound concentrations are calculated on the assumption that all the values of thefour substances below the limit of quantification are zero

Maximum Levels of Dioxins and PCBs - Regulation (EC) 1259/2011 amending Regulation (EC) 1881/2006

Foodstuffs	Maximum levels		
	Sum of dioxins (WHO-PCDD/F-TEQ) (1)	Sum of dioxins and dioxin-like PCBS (WHO-PCDD/F-PCB-TEQ) (1)	Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES 6)
Muscle meat of fish and fishery products and products thereof (2) with the exemption of: • wild caught eel • wild caught fresh water fish, with the exception of diadromous fish species caught in fresh water • fish liver and derived products • marine oils The maximum level for crustaceans applies to muscle meat from appendages and abdomen. In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) it applies to muscle meat from appendages.	3.5 pg g^{-1} wet weight	6.5 pg g^{-1} wet weight	75 ng g^{-1} wet weight

(1) Dioxins (sum of polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), expressed as World Health Organisation (WHO) toxic equivalent using the WHO-toxic equivalency factors (WHO-TEFs)) and sum of dioxins and dioxin-like

PCBs (sum of PCDDs, PCDFs and polychlorinated biphenyls (PCBs), expressed as WHO toxic equivalent using the WHO-TEFs). WHO-TEFs for human risk assessment based on the conclusions of the World Health Organization (WHO) (For TEF values see note 31, (EC) Regulation 1259/2011 – Annex 1.1.9.).

(2) Where fish are intended to be eaten whole, the maximum level shall apply to the whole fish.

Annex II:

Survey of relevant Scientific Literature

Algeria (WMS). Cd and Pb (and Cu and Zn) were measured in the muscle of sardines collected from the bay of Boumerdés (Algeria). The analysis revealed the presence of metal trace elements in the muscles of species at concentrations below the thresholds established by national and international regulations (Hamida et al. 2018)[23].

Algeria (WMS). The concentrations of Pb, Cd and Hg were measured in in the muscle and the liver of 872 specimens of sardine (*Sardina pilchardus*) collected from the Algerian coast at 3 sites (Algiers, Dellys and Bejaia), between October 2017 and September 2018. The highest average muscle concentrations of Pb and Cd (0.25 ± 0.29 µg/g ww and 0.31 ± 0.29 µg/g ww respectively) were found in Algiers. For Hg, the specimens from Bejaia (0.50 ± 0.0001 µg/g ww) and Dellys (0.20 ± 0.07 µg/g ww) presented the highest concentrations. The concentrations in the muscle were below the maximum levels set by the EC for the three elements, except for Cd in Algiers in large specimens (Length > 15 cm). The calculated target hazard quotients (THQs) and estimated weekly intake (EWI) were below the provisional tolerable weekly intake (PTWI) indicating that the consumption of S. pilchardus from Algerian coast was not likely to have adverse effect on human health (Aissioui et al. 2022)

Algeria (WMS). The concentrations of Pb, Cd and Hg were measured in in the muscle and the liver of 424 specimens of red mullet (*Mullus barbatus*) collected from the Algerian coast at 3 sites (Algiers, Dellys and Bejaia), between October 2017 and September 2018. Hg concentrations in muscle did not exceed the EU regulatory value threshold. The average Pb concentrations did not exceed the regulatory value, although some specimens had concentrations higher than the threshold. Cd in the muscle of the three size classes in the Bay of Algiers, and in small specimens in the Gulf of Bejaia and Dellys Bay were higher than the EC regulatory threshold (representing 66% of fish.) Despite the average concentrations of Pb and Cd exceeded the recommended regulatory values, few risk related to the consumption of contaminated *M. barbatus barbatus* inhabiting the Algerian coasts were demonstrated (Aissioui et al. 2021).

Croatia (ADR). Cd, Hg and Pb were measured in the muscle tissue of 96 specimens of fish from 11 species[24] purchased in 2016 from supermarkets located in different Croatian cities. The mean concentration was calculated for each species and the mean values ranged for Cd from 0.61 to 123 ug/kg ww; for Hg from 17 to 130 ug/kg ww; and for Pb from 2.0 to 59 ug/kg ww. Hg and Pb concentrations in all the specimens did not exceed the EC limit for human consumption. Mean Cd levels of 123 $\mu g\ kg^{-1}$ ww for bluefin tuna exceeded the EC limit. The concentrations of Cd in the bluefin tuna ranged from 6.3 to 875 ug/kg ww Evaluation of the consumer health risk by calculation of the dietary intakes for Cd through fish consumption was low, with exception of bluefin tuna. For Hg, frequent consumption of European sea bass, carp and bluefin tuna per week over a longer period may have toxicological consequences for consumers. Low risk for consumer health was estimated for the consumption of sea fish such as hake, Atlantic mackerel, cod and sardine, as well as freshwater fish trout and carp (Bilandžić et al. 2018).

Croatia (ADR). Hg (and Se) were measured in 717 individuals of 12 fish species collected by pelagic trawl net at 48 different locations in the coastal and open waters of the eastern part of the Adriatic Sea in September 2014 and 2016, within the framework of the European Union MEDiterranean International Acoustic Survey (MEDIAS) project. The species sampled in 2016 were the European pilchard and the European anchovy with Hg concentration ranges of 0.037–0.151 mg/kg ww and 0.015–0.126 mg/kg ww, respectively. Concentrations did not exceed EU regulations (Sulimanec Grgec et al. 2020)

Egypt (AEL). Persistent organic pollutants were measured in the freshwater fish *Oreochromis niloticus* (*Tilapia* spp.) and the marine mollusc *Donax trunculus* at the Rosetta Nile branch estuary. Samples were purchased from fishermen in 2017. α-HCH, p,p′-DDE and polychlorinated biphenyls were

[23] No access to full manuscript
[24] Hake (Merluccius merluccius, n=7), Atlantic mackerel (Scomber scombrus, n=7), cod (Gadus morhua, n=7), chub mackerel (Scomber japonicas, n=7), fresh and canned sardine (Sardina pilchardus, n=7), European sea bass (Dicentrarchus labrax, n=13), gilthead sea bream (Sparus aurata, n=11), bluefin tuna (Thunnus thynnus, n=8), salmonbass (Argyrosomus regius, n=8), rainbow trout (Oncorhynchus mykiss, n=7) and carp (Cyprinus carpio, n=7).

the predominant compounds detected at ranges 2.19–28.11 ng/g ww. β and γ-HCHs, endosulfan compounds, heptachlor and heptachlor epoxide were at low detection frequencies. Totally, the organochlorine pollutants were at high levels and abundances in *Donax* spp. than in *Tilapia* spp. These levels were well below its tolerable residue levels in fish, based on the recommended maximum residue limits (MRLs) and tolerable average residue levels or limits (TARLs) of OCPs and PCBs established by FDA and FAO/WHO for human fish consumption (Abbassy 2018).

France (WMS). Persistent organic pollutants (POP[25]s) have been evaluated in a well-characterized pelagic food web (including phytoplankton, zooplankton, six fish, and two cephalopods species) from an impacted area in NW Mediterranean Sea (Rhone river estuary vicinity). For the edible species: Atlantic bonito (*Sarda sarda*) and chub mackerel (*Scomber colias*), the estimated weekly intakes of dioxin-like POPs for humans based on national consumption standards overpassed the EU tolerable weekly intake. Moreover, the concentrations of nondioxin-like PCBs in *S. sarda* were above the EU maximum levels in foodstuffs, pointing to a risk (Castro-Jiménez et al. 2021).

Greece (AEL). Seabream (*Sparus aurata*) (n = 47) and sea bass (*Dicentrarchus labrax*) (n = 54) samples were collected from aquaculture sites and from the fish market of Heraklion, Crete during the period August 2017–March 2018. All collection sites are located in the Aegean Sea and the Sea of Crete. Cd, Hg and Pb concentrations determined in fish muscle of both species, in all cases, were below the established safe limits for food consumption (Renieri et al. 2019)

Greece (AEL). Concentrations of 26 metals and elements were measured in sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) sampled from 6 Greek coastal areas in order to assess public health risks and benefits. Nutritional benefits seem to outweigh the potential risks arising from fish metal content, since various risk parameters[26] indicated mostly safe consumption of the studied species. Weekly consumption of 480.76 g of sardine and anchovy poses minor risks (due to increased levels of essential metals like Fe and Zn in some cases) but great benefits regarding intake of essential elements like Mg, Fe, Cu, Zn, Mo, Ca, P, Se. The traces of inorganic As detected were well below all safety limits. Hg toxicity symptoms are not likely to appear and Se benefits are not likely to be compromised (Sofoulaki et al. 2019)[27].

Italy (CEN). The sixteen PAHs, defined priority by the U.S.- EPA, where measured in two fish species: *Sardina pilchardus and Solea solea*, and one bivalve mollusk *Donax trunculus*, caught in the Catania Gulf (Sicily). The samples were purchased from fish market in April 2017. EU criteria for PAH the protection of human health exist only for mollusc and not for fish. In *D. trunculus* the concentrations of BaP (29.94-23.97 μg/kg ww) exceed the limit reported in EC Regulation as well as the Σ4PAHs[28] (35.45-48.18 μg/kg ww). Risk for human health, evaluated through exposure daily intake (EDI) and Target Hazard Quotient (THQ) showed low risk to develop chronic systemic effects, but the cancer risk could be of health concern especially for high frequency molluscs consumers (Ferrante et al. 2018)

Italy (ADR). Hg, Cd, Pb and other elements were determined in 160 specimens of fish belonging to sixteen species[29]. The specimens were collected in 2018 from commercial centers of South Italy (Apulia). The concentrations fell under the maximum permissible levels (MPLs) for human consumption recommended by European Union, with an only exception regarding Cd, which exceeded the tolerable value in Atlantic bluefin tuna samples. Estimated weekly intakes of metals were all below Provisional

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[25] Polybrominated diphenyl ethers (PBDEs), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs)
[26] Safety Standards, Estimated Daily Intake, Maximum Safe Consumption, Hazard Quotient, Metal Pollution Index, As Carcinogenic Risk, Mercury toxicity – Selenium benefits, Nutrient Reference Values
[27] No access to full manuscript
[28] benzo(a)pyrene (BaP), benz(a)anthracene (BaA), benzo(b)fluoranthene (BbF) and chrysene (CH)
[29] *Mullus barbatus, Lepidus's caudatus, Helicolenus dactylopterus, Raja asterias, Raja clavata , Lepidorhombus boscii, Lepidorhombus whiffiagonis, Lophius budegassa, Micromesistius poutassou, Merluccius merluccius, Scomber scombrus ,Sardina pilchardus, Engraulis encrasicolus ,Sparus aurata ,Thunnus thynnus, Xiphias gladius,*

Tolerable Weekly Intakes (PTWIs). The estimated hazard quotient (HQ) of Hg indicated a high probability of experiencing non-carcinogenic health risks, but not for other metals (Storelli et al. 2020).

Italy (ADR, WMS). .Total Hg concentrations were measured in 42 commercial fish species caught off the Central Adriatic and Tyrrhenian coasts of Italy and in 6 aquaculture species. Total mercury concentrations in the muscle of wild fish showed a high variability among species (0.025–2.20 mg kg^{-1} ww). The lowest levels were detected in low trophic-level demersal and pelagic–neritic fish and in young individuals of high trophic-level species. Levels exceeding the EC regulation limits were found in large-size specimens of high trophic-level pelagic and demersal species. Fish from intensive farming showed low levels of total mercury (0.008–0.251 mg kg^{-1}). An estimation of the human intake of mercury associated to the consumption of the studied fish and its comparison with the tolerable weekly intake is (Di Lena et al. 2017)[30].

Italy (ADR, CEN). Polychlorinated dioxins and furans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (dl-PCBs) were measured in fish and seafood acquired in supermarkets representing the five most popular retailer brands in Italy during May–July 2019. The supermarkets were located in 6 cities (Bari, Lecce, Taranto, Foggia, Brindisi and Matera) of Southern Italy. A total of thirty-five types of foods classified in the following groups: fish (rosefish, Euro-pean hake, red mullet, common sole, bluefin tuna) and seafood (cephalopods: common octopus, common cuttlefish, European squid), (shellfish: Mediterranean mussel, striped venus clam, common scallop), (crustaceans: red shrimp, spottail mantis shrimp, Norway lobster). The levels measured in the composite samples were below the maximum limits set by the EC for human consumption (Barone et al. 2021).

Italy (ADR). Total mercury (THg) concentrations was measured in 74 specimens of European hake (*Merluccius* merluccius) caught in the northern and central Adriatic Sea in 2018-2019. The mean THg concentration found was 0.64 ± 0.29 mg kg^{-1} dw (range, 0.20–1.53 mg kg^{-1} dw or 0.04-0.33 mg/kg ww). The concentrations were lower than the level set by EU regulations, demonstrating that that European hake caught in the northern and central Adriatic is safe for human consumption (Girolametti et al. 2022).

Italy (WMS). PCBs (eighteen congeners) were measured in the muscle of 48 specimens of 3 edible fish species[31]. Samples were collected in the spring of 2017 in the Northern Thyrrenian Sea. PCB values followed the same order, i.e. sardine (0.410–1.24, range in pg/g ww > anchovy (0.0778–0.396) ~ bogue (0.0726–0.268). These concentrations lied below the EC regulation limits of 75 ng/g (ww) for the six indicator PCBs and 6.5 pg/g WHO-TEQ for dioxins and dioxin-like PCBs in muscle meat of fish (Bartalini et al. 2020)

Italy (ADR, WMS). Cd, Pd and Hg in 28 samples of swordfish *Xiphias gladius* muscles from the Adriatic and Tyrrhenian Seas collected in 2017. The concentrations of Hg ranged from 0.222 to 1.947 mg kg^{-1}ww and Pb from 0.010 to 0.057 mg kg^{-1}. Cd was below detection limit (0.01 mg kg^{-1}). 32% of samples exceeded European maximum limits set for Hg (1 mg kg^{-1} ww for predatory fish) while Pb concentrations were always under specific ML. Risk assessment (Tolerable weekly intake and THQ) showed hazardous state concerning Hg (Di Bella et al. 2020).

Italy (WMS). *Mytilus galloprovincialis,* farmed into the waters of the Gulf of Naples and Domitio littoral, areas heavily influenced by human activities, were analyzed for Cd, Hg, Pb, PCBs, dioxins and PAHs. Samples (100 mussels) were collected in three different sites, from 2016 to 2019. In the four years of the investigation, the concentrations of all contaminants measured did not exceeded the maximum limits as established by EU regulation. The only exception were the PAH concentrations which, in relation to a well-defined area of the Gulf of Pozzuoli, during the winter season reached high levels, in some cases above the maximum limits. For this reason, the area is subject to monthly monitoring in order to identify non-compliant mussel farms (Esposito et al. 2020).

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[31] Sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and bogue (*Boops boops*).

Italy (ADR, CEN). This study presents the analytical methodology to determine Polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), polybrominated dibenzo-*p*-dioxins and dibenzofurans (PBDD/Fs) and polybrominated diphenyl ethers (PBDEs) simultaneously in a sample. As part of the method development mussel and fish were analyzed. Mussel samples (n = 9) were collected from mussel farms in the Taranto area and fish (n = 19) were sourced from the Mediterranean Sea coasts of Abruzzo, Apulia and Sicily and included hake, mullet, sea bream, bogue, red mullet mackerel, sardines and sand steenbras. Samples were collected between January 2014 and February 2016. Apart from a single sample of mussels which was taken from an aquaculture farm near the industrial area of Taranto, a location of known PCDD/F and PCB contamination, all samples were within the regulatory limits specified for these contaminants within the EU (Ceci et al. 2022).

Italy (WMS). Trace metals (Cd, Hg, Pb) were measured in the mussel *M. galloprovincialis* collected from the euthrophic Calich Lagoon, northwest Sardinia, in 2017. The concentration ranges reported were: Cd – 0.014-0.20 mg/kg ww; Hg- 0.011-0.021 mg/kg ww and Pb- 0.041-0.71 mg/kg ww. The maximum limits set by EU regulations were never exceeded. (Esposito et al. 2021).

Italy (ADR). In 2008–2018, 1458 georeferenced samples of clams and 343 of mussels (*M. galloprovincialis*) were harvested in Italy from classified areas along Marche coast and analyzed. Pb and Cd median levels (mg/ kg ww) were 0.09 and 0.08, for Pb and Cd, respectively in clams and 0.16 and 0.15, for Pb and Cd, respectively in mussels. Ranges of averages for 2016-2017 were 0.098-0.26 mg/ kg ww and 0.103-0.199 mg/ kg ww for Pb and Cd in mussel and 0.029-0.088 mg/ kg ww and 0.03 and 0.08 mg/ kg ww for Pb and Cd in clams. Hg was below LOQ (0.025 mg/ kg wet wt). All concentrations did not exceed the EU regulation (Tavoloni et al. 2021)

Italy (WMS, CEN). A total of 3180 samples of *Mytilus galloprovincialis* of similar size were sampled during 2016 from 10 large urban agglomerations, high industrial activities and national interest sites of Sicily (Barcellona Pozzo di Gotto, Catania, Gela, Licata, Messina, Milazzo, Palermo, Siracusa, Termini Imerese and Trappeto). Hg, Cd, Pb (and V, Cr, Mn, As, Sn, Sb) were measured. Maximal average Cd, Hg and Pb concentrations were 0.2, 0.015 and 0.37 mg/kg ww, respectively. The average values obtained in this study were lower than the limits imposed by the EU, suggesting the absence of important risks in the sampling areas studied (Cammilleri et al. 2020).

Italy (CEN). Organochlorine contaminants (PCBs, HCB), PAHs and Hg were analyzed in marine organisms[32] collected from the contaminated Augusta Bay (Southern Italy) in 2013 and 2017. In most cases, the Hg levels exceed the threshold limits set by EU regulation for contaminants in seafood. The ΣNDL-PCBs showed variable concentrations among the analyzed species, with a mean value above the limit of 75 ng/g ww measured in *S. sphyraena* (168 ng/g ww) and *M. barbatus* (88.2 ng/g ww). All the analysed species exceeded Σ7PCBs threshold limit (10 ng/g ww) this value represents the limit above which effects on marine organisms might be expected according to the Ecotoxicological Assessment Criteria (EACs) of the OSPAR Convention. Benzo[*a*] Pyrene (BaP), in mussels exceed threshold limit of the EU regulation. No risk analysis was performed (Traina et al. 2021).

Lebanon (AEL). Pb, Cd, and Hg were determined in three fish species[33], one shrimp and one bivalve commonly consumed by the local population. The samples were collected from three sites along the Lebanese coastline: Tripoli, Beirut and Saida in 2016-2017. The bivalve species showed the highest concentrations of Cd ($0.09 - 1.19$ μg g^{-1} ww) and Pb ($0.02 - 0.56$ μg g^{-1} ww), whereas fish exhibited

[32] In 2017, mussels (*Mytilus galloprovincialis*) obtained from a commercial farm and transplanted to two sites in Augusta Bay and resampled after 5 weeks and 7 months. Fish: 96 specimens of finfish (*Sphyraena sphyraena*, *Trigla lucerna*, *Mullus barbatus*, *Pagellus* spp., *Diplodus* spp.) and shellfish (*Parapaeneus kerathurus* and *Sepia* spp.) were obtained through local fishermen

[33] Fish: marbled spinefoot (*Siganus rivulatus*), sand steenbras (*Lithognathus mormyrus*) and the redeye round herring (*Etrumeus teres*). Shrimp: kuruma shrimp (*Marsupenaeus japonicus*). Bivalve: spiny oyster (*Spondylus spinosus*).

higher Hg concentrations (< 0.0084 − 0.25 μg g^{-1} ww) compared to crustaceans and bivalves (0.02 − 0.06 μg g^{-1} ww and < 0.008 − 0.023 μg g^{-1} ww, respectively). Trace metals concentrations were found to be below the maximum levels set by the EU. (Ghosn et al. 2019)

Lebanon. Trace metals (Cd, Hg, Pb) were measured in the soft tissue of bivalve (*Spondylus spinosus*) and the shrimp (*Marsupenaeus japonicus*) collected from 3 sites along the Lebanese coast during the dry and wet seasons in 2017. The concentrations measured were below the EU criteria: Bivalve average of 3.00, 0.07 and 0.89 mg/kg dw for Cd, Hg and Pb, respectively and Shrimp: 0.02, 0.15 and 0.04 mg/kg dw for Cd, Hg and Pb, respectively (Ghosn et al. 2020b)

Lebanon. Trace metals (Cd, Hg, Pb) were measured in liver and muscle tissue of two demersal fish species (*Siganus rivulatus* and *Lithognathus mormyrus*) and one pelagic species (*Etrumeus teres)* collected from 3 sites along the Lebanese coast during the dry and wet seasons in 2017. The concentrations measured were below the EU criteria for all 3 metals in all the sites (Ghosn et al. 2020a)

Morocco (WMS). Cd and Pb concentrations were measured in soft tissues of *M. galloprovincialis* collected from an aquaculture farm in Cala Iris sea of Al Hoceima. The mussels were sampled monthly from January to December 2016. Cd concentrations depended on the season, and ranged from an average 0.89 mg/kg dw in winter to 0.65 mg/kg dw in summer. Pb concentrations were <0.03 mg/kg dw. Concentrations did not exceed EU regulations (Azizi et al. 2018)

Morocco (WMS). The monthly variations of Cd (and Zn and Cr) were determined in tissues of *Mytilus galloprovincialis* obtained from the mussel farm installed along the Al Hoceima coasts, during the sampling period of 2018. Average Cd concentration 0.812 mg/kg dry wt (0.162 mg/kg ww), with no value above 1 mg/kg dw. The concentrations of Cd lower than EU regulations (Azizi et al. 2021)

Morocco (WMS). Hg, Pb, and Cd were measured in 25 specimens of *Liza ramada* collected from two stations (port of Béni Ansar and Ras Kebdana) at the Northeastern Moroccan Mediterranean coast in 2019. Hg ranged from 0.003 to 0.010 mg/kg ww, Pb from 0.006 to 0.029 mg/kg ww and Cd from 0.001 to 0.005 mg/kg ww. All concentrations were below the values set in the EU regulation. Risk analysis suggest that this species do not pose a health risk (Mahjoub et al. 2021).

Spain (WMS). The concentrations of Pb, Cd and Hg were measured in the highly migratory *Thunnus alalunga* (n=26) and *Katsuwonus pelamis* (n=26) collected in the Mediterranean Sea, probably in Spain. *T. alalunga* accumulated higher concentrations of Hg (0.1996 ± 0.0602 mg/kg ww), while *K. pelamis* accumulated higher concentrations of Cd (0.008 ± 0.005 mg/kg ww) and Pb (0.003 ± 0.002 mg/kg ww). Heavy metal concentrations were below the tolerable limits considered by EU regulation (Chanto-García et al. 2022)[34].

Tunisia (CEN). Organic contaminants (PAHs, PCBs and pesticides) were measured in sediments and in fish (*Sparus aurata* and *Sarpa salpa*) muscle tissue collected from five stations along the Tunisian coast between May 2018 and March 2019. Sigma 6 PCBs for the fish were below the EC regulations. Maximal average value was 16.3 mg/kg ww (Jebara et al. 2021).

Tunisia (CEN). Concentrations of 21 legacy and emerging per- and polyfluorinated alkyl substances (PFAS) PFAS were measured in in 9 marine species (3 fish, 2 crustaceans and 4 mollusks)[35] collected from Bizerte lagoon, Northern Tunisia in 2018. Although these substances are not addressed in the EU regulation, it is important to summarize the results. Twelve out of the 21 targeted PFAS were detected, at low concentrations. The Σ21PFAS concentrations in all seafood samples ranged from 0.202 to 2.89 ng/g dw, with a mean value of 1.10 ± 0.89 ng/g dw. Exposure to PFAS through seafood consumption indicates

[34] No access to full manuscript

[35] Fish: European eel (*Anguilla anguilla*), common sole (*Solea solea*), sea bass (*Dicentrarchus labrax*); crab (*Carcinus maenas*), shrimp (*Penaeus notialis*), common cuttlefish (*Sepia officinalis*) gastropod mollusc- banded dye-murex (*Hexaplex trunculus*), clam (*Ruditapes decussatus*) and farmed mussel (*Mytilus galloprovincialis*)

that it should not be of concern to the local consumers. In addition, the perfluorooctane sulfonate (PFOS) concentrations measured (0.007–0.195 ng/g ww) were also far below the threshold value set by the environmental quality standard (EQS) of PFOS in biota (9.1 ng/g ww) (Barhoumi et al. 2022)

Turkiye (AEL). Concentrations of Cd, Pb and Hg levels were measured 9 fish, 1 mollusc and 1 shrimp species[36] from the Aegean and Levantine Seas. The specimens were purchased from fishermen of fish markets during 3 fishing seasons (no years reported). All the results were found compatible with the Turkish Food Codex and EU Regulation limits except for Cd in two samples from the Mediterranean Sea (*Scophthalmus maximus* and *Mullus barbatus*) that was higher than the limits (0,076 mg/kg and 0,064 mg/kg, respectively). As a whole, the seafood were found to be safe for human consumption (Kuplulu et al. 2018).

Turkiye (AEL). *Mytilus galloprovincialis* were sampled from a nonpolluted area (Foca) located out of the southern Candarlı Gulf in April 2016 and April 2017. Specimens were transplanted to 3 sites in Nemrut Bay, known to be impacted by of industrial activities, to measure the effect of pollution on the levels of PAHs in the mussel. PAHs (benzo(a)pyrene and Sum of 4 PAHs (benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene) in the mussels from Foca area were low and below the EU regulations, while the mussels transplanted accumulated PAHs, at times at levels higher than the concentrations in the EU regulation. It was concluded that the PAH levels in the mussels suggest that they are unsafe for human consumption during the time of the experiment (Kucuksezgin et al. 2020)

Turkiye (AEL). Heavy metal (Cu, Zn, Cr, Cd, Pb and As) levels were measured in the muscle of economically important fish species (*Trachurus mediterraneus, Sparus aurata* and *Pegusa lascaris*) living in different water columns in the North-East Mediterranean Sea. Fish were bought from local fishermen between September 2016-August 2017 in Karataş region (Adana, Turkiye). The lowest and highest levels of Cd, Pb in the muscle of fish were 0.002–0.03 and 0.04–0.11 (μg/g w.w.), respectively. These concentrations were lower than the EU regulations. Heavy metal levels in the studied species do not pose any risk to both fish and human health points of view (Karayakar et al. 2022).

Turkiye (AEL). Specific natural radionuclide (^{226}Ra, ^{232}Th and ^{40}K) concentrations were measured in wild and farmed European seabass collected from the Mediterranean coast of Turkiye in 2018. From the radiological point of view, the radioactivity doses measured and the consumption of both wild and farmed seabass from the Mediterranean coast of Turkiye do not pose any risk to human health (Ozmen and Yilmaz 2020).

[36] Fish: mullet (Mugil cephalus), shad (Alosafallax), hake (Merluccius merluccius), whitting (Merlangius euxmus), seabass (Dicentrarchus labrax), turbot (Scophthalmus maximus), red mullet (Mullus barbatus), blue fish (Pomatomus saltatrix), seabream (Sparus auratus). Mussel: (Mytilus galloprovincialis). Shrimp (Penaeus indicus)

Annex III:

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