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The Lost Fish of Turkey: A Recent History of Disappeared Species and Commercial Fishery Extinctions for the Turkish Marmara and Black Seas

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A timeline of commercial fisheries extinctions and a list of threatened or extirpated marine species are presented to document the rapidly declining abundance of marine resources in the Turkish part of the Black Sea and Marmara Sea. Turkish nationally reported fisheries data were compared over a 50-year period from 1967 (the first year data were spatially allocated) to 2016 to assess which species are now extirpated (i.e., earlier present, and now absent from reported catch data), and which species have become commercially extinct (i.e., whose catch declined by 80.0–99.9%). The size of bony fish caught in Turkish waters has also strongly declined. Other important taxa, specifically big sharks and mammals, not covered by fisheries statistics, or currently under protection, but also exhibiting worrisome declining trends, are discussed based on accounts based on peer-reviewed and gray literature and personal accounts from local scientists and fishers. Overall, the Turkish parts of the Black Sea lost 17 extirpated species and 17 commercially extinct marine species, while the Sea of Marmara lost 19 extirpated species and 22 commercially extinct species. This study commemorates the many lost species of the Black and Marmara Seas, and may be seen as a warning call to prevent dozens of others species to be lost. We urge the Turkish authorities to take measures to effectively reduce fishing effort and thus to allow for a natural rebuilding of what remains of the fish stocks exploited by commercial fisheries.

Keywords: endangered species, extirpations, fisheries management, elasmobranches, overexploitation

INTRODUCTION

There are two different types of loss: one where the lost item can be recovered, the other where it cannot, because it is gone. Since the onset of industrial fisheries at the end of the 19th century, marine resources in many regions have been exploited more rapidly than they could replenish themselves, resulting in a reduction of biodiversity, regime shifts and even total ecosystem transformations (Daskalov et al., 2008; Bianchelli et al., 2016). The most extreme marine ecosystem transformations happened in Turkish waters, i.e., in the Black Sea, Marmara Sea and also the Levantine Sea (Eastern Mediterranean) (Ulman and Pauly, 2016). However, the losses, which have occurred over several generations, have not been documented, or their documentation suffered

from shifted baselines (Pauly, 1995). The aim of this study is to explain the sequential losses and threatened commercial marine species from the Turkish portion of Black Sea and the important gateway to it, Marmara Sea.

The Turkish fisheries used to be extremely productive, due to Istanbul's strategic position on the Bosphorus Strait, which is a unique corridor for migrating pelagic fish. In the 2nd century A.D., Dionysios wrote that fishing was the main income around the Bosphorus (Tunalidir, 2014). There is a message dated from the 17th century on an Istanbul fountain (in the Üsküdar area) which reads: "The Bosphorus is full of fish." Fish were so abundant then that people could catch fish just by lowering baskets into the Golden Horn inlet of the Bosphorus (Gilles, 2000; Özdağ, 2013). Also, there was another historically remarkable fish-filled period named "the bluefish era" for half a century (1859–1909) when the Golden Horn and Bosphorus area were teeming with them (Güler, 2014). The inhabitants of Istanbul in the Ottoman period were known to consume a lot of fish, especially during the migrations of bluefish, mackerel and bonito, on their return from the Black Sea. Poorer families, and the average worker who could not afford other types of meat, remained healthy from fish. Bluefish and mackerel were often eaten in sandwich form in Istanbul- a tradition that continues to this day, but only now using imported mackerel (Ünsal, 2010). Currently, one would describe the Bosphorus as being full of boats, pollutants, or even jellyfish, but certainly, no longer full of fish.

Without a doubt, not all these losses and reductions can be attributed solely to fishing (Solan et al., 2012). Many other stressors plague these waters, and the contribution of each stressor is difficult to quantify. The Marmara and Black Seas are unique in their distance to the global ocean, yet have strong pressure exerted from human disturbance such as pollution leading to eutrophication. Also, most of the Black Sea water column is very unique as depths greater than ~150 m are devoid of multicellular life due to its anoxic condition. A former view of changes in Black Sea biodiversity attributed its major predatory losses to anthropogenic eutrophication (Caddy, 1993; Zaitsev, 1993), induced by high levels of terrigenous nutrients in the 1980s (Llope et al., 2011). However, later research points to overfishing as the likely dominant stressor on the marine ecosystem resulting in reduced resilience and trophic cascades (Daskalov, 2003; Eremeev and Zuyev, 2007; Llope et al., 2011). It must be stressed that what occurs in the Black Sea will be reflected in the Sea of Marmara, as these two seas are intimately connected, with Marmara Sea being the Black Sea's gateway to the Mediterranean.

Following the decline, then disappearance of top predators in the 1960s, the Black Sea ecosystem was simplified in terms of its trophic structure, which ceased to be top-down controlled, i.e., with forage fish (e.g., anchovy and sprat) kept relatively low by abundant predatory fish. Low forage fish biomass allowed herbivorous zooplankton to thrive, which kept phytoplankton in check. Loss of top-down control led to bottom-up control, with zooplanktivorous fish experiencing a population explosion (Bǎnaru et al., 2010), which predictably resulted in reduced grazing pressure on the phytoplankton, which also benefited from

terrigenous nutrients. The result was eutrophication, which made the system susceptible to further enrichment by a succession of cold winters in 1985 to 1987 (Oguz et al., 2008). In the early 1990s, the invasive ctenophore *Mnemiopsis leidyi* invaded the Black Sea and, by consuming their eggs and larvae, reduced the population of Black Sea fish, inducing a short-lived pelagic fisheries crisis from 1989 to 1990 (Oguz et al., 2008).
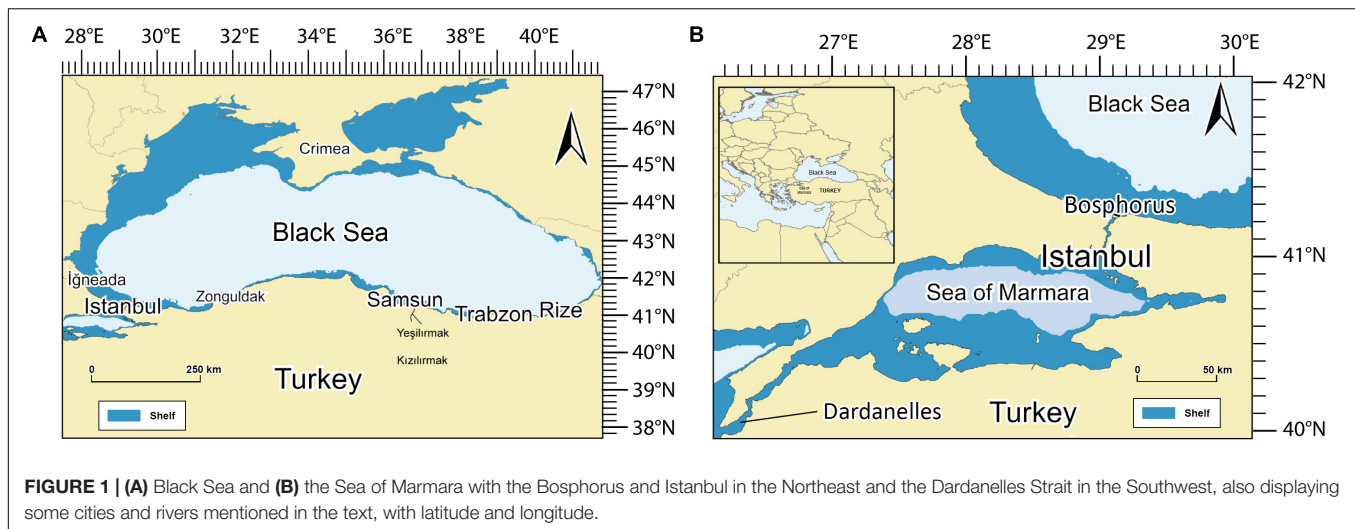
The Black Sea and Marmara Sea were chosen as our two study areas, the latter including catches from the Bosphorus and the Dardanelle Straits (**Figure 1**) due to their near fully enclosed nature, which present a clear picture of the most drastic changes which occurred in Turkish fisheries. The Marmara Sea serves as a transition zone for many medium to large pelagic fish migrating between the Aegean and Black Seas, but rarely mixing with populations in the Eastern Mediterranean, and jointly with the Bosphorus Strait, can be seen as an 'ecological gateway' (Şekercioğlu et al., 2011; Kabasakal, 2016a).

The aim of this study is to show a timeline of species disappearance and decline from the Black Sea and Marmara Sea. We hope that documenting these losses may provide more evidence for the need to rebuild their stocks. Knowledge of local extinctions and transformations are critical in understanding modern day ecosystem structure and function, as one removal can affect a number of other processes such as energy flow, predator-prey interactions and migrations (Carlton et al., 1999).

Turkish and other Black Sea fisheries were radically transformed by post WWII technological advances, which allowed the massively overfishing of the larger pelagic fish from the 1950s to the early 1970s (Costello et al., 2010; Llope et al., 2011; Tsikliras et al., 2015). Prior to the mid-1950s, Turkish fishers were relatively few and they used small wooden boats less than 15 m in length, with engines not exceeding 120 hp, and cotton nets (Can, 2013). They located fish schools at night by the phosphorescent glow fish emanate at night from their movements, requiring a combination of luck and skill. However, on March 20, 1954, sonar was introduced to Black Sea purse seiners, and fishers catch rates instantly increased threefold (Çakıroğlu, 1969, Can, 2013), removing luck from the equation. Consequently, due to an over-supply of fish, the first fishmeal factories started grinding up an abundant supply of raw material (Tezel, 1954). Similarly, the Bulgarian and Romanian industrial fishing fleets started to modernize only in the 1950s; however, they did not grow much, and did not exert much fishing pressure on Black Sea stocks (Keskin et al., 2017).

On the other hand, historical sources document that fleets from the former USSR (here: Russia, Ukraine and Georgia), which were industrialized even before WWII, removed a large fraction of the large pelagic fish from the Black Sea basin even before the 1950s (Oguz, 2017).

Around 1970, the Turkish government provided bank credit to anyone with assets such as land to promote the fisheries (Knudsen, 2009). Many new entrants rushed into the industry with modernized gear such as larger engines, nylon nets and fish finders (Can, 2013). The new nylon nets allowed for the first major exploitation of bluefish (*Pomatomus saltatrix*), one of Turkey's favored species, which could only be caught either

FIGURE 1 | (A) Black Sea and **(B)** the Sea of Marmara with the Bosphorus and Istanbul in the Northeast and the Dardanelles Strait in the Southwest, also displaying some cities and rivers mentioned in the text, with latitude and longitude.

by line or trammel net before, as they would use their teeth to shred cotton nets. By 1975, fish supply exceeded demand, which resulted in plummeting prices and massive amounts of waste as the extra fish were either sent to charities, discarded in the sea or even hauled to landfills to be buried (Can, 2013). The less valuable fish at this time, for which there was little demand, such as horse mackerels (*Trachurus* spp.), were mostly discarded near the fish hall or buried in garbage dumps.

There was until recently a dearth of scientific studies dealing with the impacts of fishing on species. Examples of earlier studies are stock evaluations of turbot (*Scophthalmus maximus*), whiting (*Merlangius merlangus*) and red mullet (*Mullus barbatus*) in the Turkish Black Sea littoral zone, the first of which pertained to changes in estimated biomass and abundances of turbot stocks from the west to middle of the Turkish Black Sea coast from 1969 to 1973 (Kutaygil and Bilecik, 1979). To understand potential catches of demersal fish stocks, the central part of the Turkish Black Sea's littoral zone was sampled (Kara, 1980), which was later extended to the entire Turkish coastline in Black Sea (Acara, 1985). Bingel et al. (1995) conducted the first comprehensive study from 1990 to 1992 estimating total trawlable biomass of demersal fish using the swept-area method; this study was notable for being the first following the Turkish military coup of 1980, when an economic policy was introduced which combined 'free markets' with subsidies in the form of credit and gear modernization to fishers (Knudsen, 2009; Zengin, 2011).

These support from these subsidies resulted in a rapid expansion of the trawling fleet, and the result, as could be expected, was the overexploitation of most commercial stocks beginning in the 1990s. This was aggravated by a lack of long-term fisheries management plans and policies, such as monitoring, control and surveillance, by socio-economic issues such as limited employment in the Black Sea region, and by coastal habitat degradation which began in the late 1980s (Zengin, 2006). A government buy-back plan of active fishing vessels from 2012 to 2018, intended to lower overall fishing effort, was unsuccessful as mostly small-scale boats (89%) were retired. Indeed, the government money that fishers received

for decommissioning and selling their boats was often used to purchase more powerful vessels (Göktay et al., 2018).

As a result, fishing effort remained excessive, and based on recent stock assessments using the Catch-MSY method, the overwhelming majority of fish populations in Turkish waters are severely overfished, with biomasses much lower than required to extract maximum sustainable yields (Demirel et al., 2020).

This overfishing had a large impact of the biodiversity of the fish populations in the Black Sea (i.e., Slastenenko, 1955-1956; Kocatas et al., 1987; Meriç, 1995; Mater and Meriç, 1996; Öztürk, 1999; Keskin, 2010; Yankova et al., 2014) and Marmara Sea (i.e., Erazi, 1942; Türkmen, 1953; Kocataş et al., 1993; Keskin et al., 2011; Gül and Demirel, 2016). These inventories, however, present only collective information on species spatial occurrences in list format. With the exception of sharks in the Marmara Sea (Kabasakal and Karhan, 2015), they all fail to note which species are threatened by extirpation (i.e., local extinction). To address these gaps in knowledge, this study documents (1) which taxa have been extirpated from these two seas, and when they disappeared from Turkish national catch statistics; (2) which taxa in 2016 can be considered commercially extinct, i.e., taxa with declines ranging from 80 to 99% over a 50-year period, from 1967 to 2016, and still missing in 2017 and 2018 catch data; (3) which species declined substantially in catch sizes from the past to present signaling overfishing pressure; and (4) other keystone species not captured by the statistics yet are also likely in vulnerable states.

MATERIALS AND METHODS

Turkey's fishery products statistical data were compiled by the Ministry of Commerce until 1967, based on correspondence with the provinces and fisheries records. Starting from 1967, data on marine fishing started to be collected by TURKSTAT (formerly SIS). Until 1991, only information on catches and fishing fleet characteristics were published, and as of 2020, consumption, import-export and average price data were also published. Data

are compiled using a bi-annual catch report survey, which is applied to large commercial fishers by full census and small-scale fishers by a sub-sampling census. The surveys are completed each January and May.

As of 2014, marine fisheries data started to be collected in cooperation with TUIK and Ministry of Food, Agriculture and Livestock (MFAL). Also, since 2014, information on fisheries production was collected through a Small-Scale Fisheries Survey Questionnaire which is distributed monthly (and every 6 months for cross checking). Information on vessel characteristics and economic data (income-expenditure) are compiled through the annual catch survey. For the monthly surveys, the information of the previous month and the information of the previous calendar year in the annual survey are compiled through face-to-face interviews in 28 provinces along the Turkish coastline. As of 2016, surveys began being conducted electronically using a tablet instead of paper. Confidence intervals and/or error margins are factored in per different *métier*. Aquaculture production and fisheries data in marine and inland waters are directly obtained from the MFAL.

Although Turkey's fisheries statistics began to be reported to the United Nations Food and Agriculture Organization of the United Nations (FAO) in 1950, from 1950 to 1966, these data were spatially aggregated for Turkey as a whole. The year 1967 was the first year Turkish catches were spatially disaggregated by sea, i.e., the 'Western Black Sea,' 'Eastern Black Sea,' 'Marmara Sea,' 'Aegean Sea,' and the open 'Mediterranean Sea.'

If a species was present in 1967, but no longer present in 2016, this was defined as an extirpation from the sea in question, as statistics generally improved with time. Additionally, to ensure these species were still absent from the catch data in subsequent years, the TUIK 2017 and 2018 catch data were examined in detail. If the species was reported in 2017 or 2018, it was excluded from the extirpated timeline. For example, in the Black Sea, a catch of silverside (*Atherina boyeri*) was reported in 2013; this fish went missing from 2014 to 2017, but then 400 kg were reported for 2018; thus, it was removed from the timeline. In the Sea of Marmara, saddled seabream (*Oblada melanura*) was excluded from the extirpated lists as it had 6.4 t of catches in 2016, as was large eye dentex (*Dentex macrophthalmus*), which had a catch of 100 kg in 2017. The number of reported taxa in the 1967 and 2016 national catch data are presented for both fish and invertebrates in **Table 1**.

To document the declines, the reported catches of 2016 by species (or genus in a few cases) were divided by the reported catches of 1967 to determine the total decline over half a century. If a species was first included in the statistics only after 1967, it was excluded from this analysis, as were species of uncertain taxonomic status, and non-fish taxa which gained protection such as turtles, sponges and dolphins. Finally, sturgeons, which came under national protection in 1997 are included here for the Sea of Marmara as their decline was noted before they became protected, and they are still considered species at risk of disappearing.

While extirpation is usually defined as the complete disappearance of species from an area, it refers here to a disappearance from the detailed catch assembled from fisheries

collectively catching a wide range of species; thus our definition allows for a few fish to still occur in the area in question. All our findings were validated by local Black Sea and Marmara Sea fisheries experts.

Commercial extinction is defined here as a reduction of catch, over the 50 years period, of more than 80% of their original values. Such reduction, in most cases, implies that a species is no longer targeted, but may still contribute to mixed-species catches which dominate the small-scale fisheries. These species cease to support economically viable fisheries on their own, hence their decline may also be termed 'economic extinction' (Dulvy et al., 2003).

Commercial extinction precedes local extinctions for target species, but not necessarily for non-target species in mixed-species fisheries or species of high-commercial value (Dulvy et al., 2003). The definition of commercially extinct species used here is that catches reported on behalf of Turkey by the FAO have decreased by 80% or greater over a 50-year period, i.e., from 1967 to 2016. When the decrease is 100%, the species is considered extirpated.

While past perspectives are certainly necessary in understanding the degree of change in marine fisheries, scientific data dating back to the early 20th century are a rarity (Saenz-Arroyo et al., 2005). Anecdotes are able to provide rich insights into historical ecosystem structure and function (Paxton, 2009), and research has shown that fishers historical perceptions of fish abundances and sizes are generally correct (Al-Abdulrazzak et al., 2012; Tesfamichael et al., 2014). Thus, here, some anecdotal evidence for historical fish sizes are provided from personal interviews with older fishers, gathered in 2013 (see Ulman and Pauly, 2016 for a related study).

To document size reduction of commercial species over time, publications of various type were extensively searched. It is common for older documents to mention maximum sizes, but common sizes (i.e., average sizes in catches) are mentioned much less frequently. The early common size that could be found were compared to current common sizes of the same taxa, as maximum sizes would not have changed much over the last half century.

Finally, short summaries of knowledge on the major commercial species, then of other fished taxa, are presented based on peer-reviewed publications, gray literature, anecdotal information and traditional ecological knowledge (TEK) from fishers and experts. We also included two such species summaries for species that were hunted rather than fished, i.e., for common dolphin (*Delphinus delphi*) and Mediterranean monk seal (*Monachus monachus*), as they were and still are strongly impacted by fisheries.

Taxonomic and Landing Issues

Some species had their common Turkish names changed throughout the time-series of statistics; an example is *mercan*, labeled as common pandora (*Pagellus erythrinus*) in earlier years, while its Turkish name was translated to striped sea bream (i.e., sand steenbras *Lithognathus mormyrus*) in 2015; here, we stuck to *P. erythrinus*. Similarly, red porgy (*Pagrus pagrus*) was mis-labeled as common seabream or *fangri* in Turkey. John dory

TABLE 1 | Number of reported taxa in catch statistics for 1967 and 2016 for entire Turkey, Black Sea and Marmara Sea.

Year	All Turkey		Black Sea		Marmara Sea	
	Total fish reported	Total inverts/other	Total fish reported	Total inverts/other	Total fish reported	Total inverts/other
1967	66	18	56	13	66	18
2016	66	18	35	7	53	13

(*Zeus faber*) is rare in the Black Sea, and thus it is likely that the 1967, and 2016 (200 kg) catches reported from the Black Sea were caught in the Sea of Marmara and landed in a Black Sea port, thus was excluded from the Black Sea analyses. For garfish (*Belone belone*), while we think that the Turkish name 'zargana' refers to this species, we were unsure of the Turkish name 'sargan'; thus this species was excluded from the analysis as the 'sargan' catches were questionable. Species of sturgeon (*Huso huso* and *Acipenser* spp.) became protected in 1997, but were last reported in the Black Sea in 2004, thus were included in the timeline for both seas. Very few species were aggregated to family, but this was the case for sharks (with the exception of angel sharks), grey mullets (Mugilidae), and stingrays, most of which apply to *Raja clavata*, the dominant ray in the Black and Marmara Seas.

Unfortunately, the identities of some marine invertebrates in the fisheries statistics were more difficult to assess as some headings pertained to higher taxa, and not species (Cardoso et al., 2011), or the species' identity was questionable; therefore all crab species were excluded from this analysis.

RESULTS

The Black Sea

In the Black Sea, Turkish catches increased slowly from 1962 until 1977, after which they rapidly increased to nearly 500,000 t in 1988, mainly due to huge catches of anchovy (*Engraulis encrasicolus*). Since then, catches have been falling to 223,000 t in 2016[1] (TUIK, 2015, 2016). Catch per unit effort declined in the Black Sea by over 95% since peaking in 1987; the less valuable sprat (*Sprattus spattus*) is now the second most dominant species, caught for fishmeal/oil (TUIK, 2016).

Figure 2 presents a timeline of the extirpations from the Turkish parts of the Black Sea, as reflected in Turkish fisheries statistics. **Table 2** presents a list of species that are commercially extinct in the Turkish waters of the Black and Marmara Seas with their reduction percentage over the 50 years timeframe (2016 compared to 1967).

Sea of Marmara

In the Sea of Marmara, reported commercial catches peaked in 1999 at 80,000 t and have been gradually declining, to just over 32,000 t in 2016 (TUIK, 2016). Catch per unit effort declined (by about 90%) since the mid-1970s (Ulman and Pauly, 2016). **Figure 3** presents a summary of the extirpation of taxa from the Turkish parts of the Black Sea, as reflected in Turkish fisheries statistics.

[1]www.seaaroundus.org

FIGURE 2 | A timeline of marine extirpations from Turkish waters in the Black Sea.
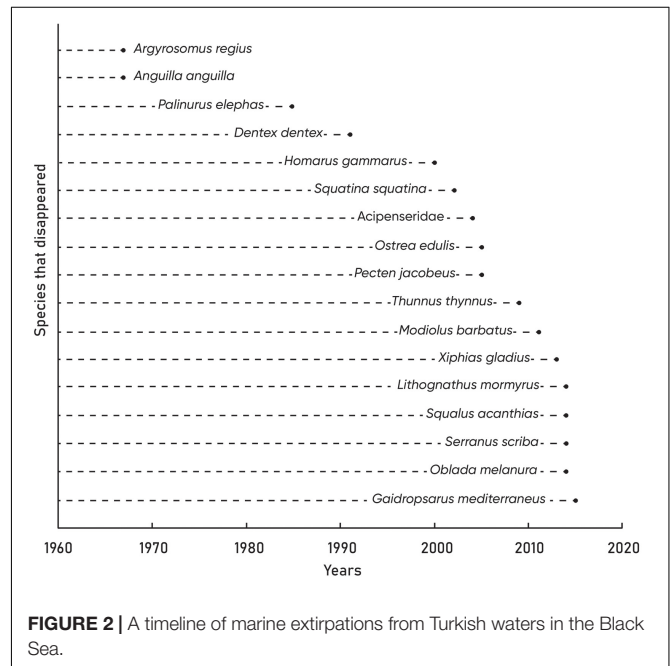
Size Reduction

Table 3 presents data on the size reduction in species exploited in Turkish waters of the Black Sea, and in the Marmara Sea. The oldest fishers among our informants validated that the current maximum sizes for many of these species used to be their common sizes before 1960. These reductions jointly represent evidence of massive overfishing in Turkish waters. Many of the species presented here have common sizes 1/2 to even 2/3 smaller than the common sizes reported in FishBase (Froese and Pauly, 2020), demonstrating that growth overfishing is likely causing these small common fish sizes in Turkish waters due to the intense levels of overexploitation.

Accounts by Taxon
Sturgeons (Family Acipenseridae)

One sturgeon family member, *Huso huso*, has a long life span lasting up to 100 years in the Black Sea. Sturgeons are very vulnerable to fishing (Cheung et al., 2005). Despite legal measures to protect sturgeons, which have now become rare, they are still caught as by-catch. This is especially due to the increasing pressure by the bottom trawl fishery, sea snail dredges and extension nets in the Samsun region (Zengin, 2011), whose operators still illegally market the sturgeons they catch. Due to the damming of the Kızılırmak and Yesilırmak Rivers,

TABLE 2 | List of commercially extinct (CE) species for Black Sea and Marmara Sea over 50 years using 1967 and 2016 catch amounts, and% decline by taxa by decreasing percentage amount.

Black Sea					Marmara Sea				
# CE	Year: 1967 (t)	Year: 2016 (t)	Decline %	Scientific name	# CE	Year: 1967 (t)	Year: 2016 (t)	Decline %	Scientific name
1	1455.1	0.5	99.97	*Umbrina cirrosa*	1	2064	0.3	99.99	*Scomber scombrus*
2	2387.2	4.2	99.82	*Chelidonichthys lucerna*	2	85.3	0.1	99.88	*Xiphias gladius*
3	463.4	0.9	99.81	*Diplodus annularis*	3	23.5	0.1	99.57	*Loligo vulgaris*
4	272.9	0.7	99.74	*Diplodus vulgaris*	4	16.8	0.1	99.40	*Gaidropsarus mediterraneus*
5	2064	6.5	99.69	*Mytilus provincialis*	5	13.64	0.1	99.27	*Serranus scriba*
6	1682	10.9	99.35	*Raja clavata*	6	193.3	1.4	99.28	*Sparus aurata*
7	1408	14.6	98.96	*Spicara smaris*	7	84.9	0.7	99.18	*Homarus gammarus*
8	507.9	6.5	98.72	*Scomber scombrus*	8	10.2	0.1	99.02	*Pagrus pagrus*
9	65.7	0.9	98.63	*Sciaena umbra*	9	73.6	0.9	98.78	*Squatina squatina*
10	168.3	5.1	96.97	Gobiidae	10	65.4	1.1	98.32	*Dentex dentex*
11	17403	685.7	96.06	*Trachurus mediterraneus*	11	365.7	7.3	98.00	*Squalus acanthias*
12	223	17.8	92.02	*Solea solea – Pleuronectes flesus*	12	185.7	3.9	97.90	*Mullus barbatus*
13	403	37.6	90.67	*Scorpaena porcus*	13	22.7	0.5	97.80	*Lichia amia*
14	1528.5	199.7	86.93	*Scophthalmus maximus*	14	51.5	1.3	97.48	*Diplodus annularis*
15	23.9	3.8	84.10	*Sparus aurata*	15	180	6.6	96.33	*Pagellus erythrinus*
16	3529	588.6	83.32	*Alosa pontica*	16	388.4	18	95.37	*Mytilus galloprovincialis*
17	3018.3	570.6	81.10	Mugilidae	17	574.3	30.2	94.74	*Boops boops*
					18	254	14.7	94.21	*Spicara smaris*
					19	34	2.3	93.24	*Umbrina cirrosa*
					20	21.4	1.6	92.52	*Octopus vulgaris*
					21	20181	1923	90.47	*Sarda sarda*
					22	946.4	133.2	85.93	Mugilidae

the fringebarbel sturgeon (*Acipenser nudiventris*) and starlet sturgeon (*Acipenser ruthenus*) disappeared from the Black Sea in the 1980s, followed by the disappearance of the Atlantic sturgeon (*Acipenser sturio*) in the 1990s (Zengin et al., 2013). The last year sturgeons were officially reported in Turkey's Black Sea

FIGURE 3 | A timeline of marine extirpations from the Sea of Marmara.

was 2004, although they became a protected species in 1997 in Turkey (Fisheries Law #1380). A special monitoring, recovery and outreach program was initiated by the Turkish Marine Research Foundation in the Sakarya and Kızılırmak-Yesilırmak estuaries following their protection (Rosenthal et al., 2015).

Six species of sturgeons (*H. huso, Acipenser gueldenstaedtii, Acipenser stellatus, A. sturio, A. nudiventris,* and *A. ruthenus*) occurred in the southern Black Sea and Azov basins in the 1950s (Tümamiral and Karapınar, 1962). Currently, all six species are listed as "Endangered" in the Black Sea (Öztürk et al., 2013), and globally, five are listed as "Critically Endangered" in the IUCN Red List, with only *A. ruthenus* listed as "Vulnerable."

Bluefish (*Pomatomus saltatrix*)

The bluefish *P. saltatrix* is a schooling, migratory, medium to large predatory fish. It is a popular game fish known for its highly aggressive behavior (Froese and Pauly, 2020), and is currently listed as "Vulnerable" in the IUCN Red List. Turkey has the second largest catch for this species after the Eastern United States. In the early 20th century, this species was caught from August to October in Istanbul, mostly from anglers on bridges using handlines spun from horse hair (Deveciyan, 1915/2006); They were abundant then, with daily Istanbul sales ranging from 50 t to 380 t per day. Bluefish have well-known local names according to their size-class, of which there are five (**Table 4**).

In 1970, one purse seine fisher (Mehmet Disçi, pers. comm.) operating near Trabzon in the Black Sea caught 40,000 t of
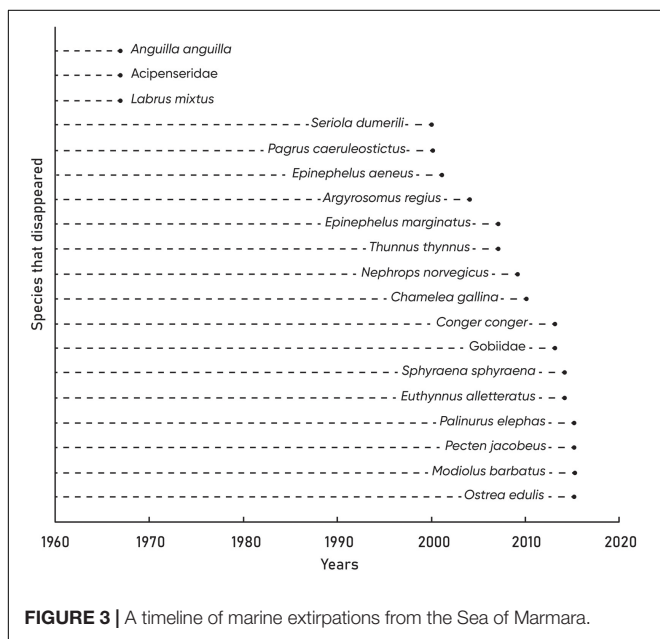
TABLE 3 | Data on size reduction of fish taxa exploited in the Turkish Black Sea and Marmara Seas by comparing their maximum length or weights (based on historical sources), to common lengths (reported in FishBase), to current common sizes in Turkish waters (using Black Sea and Marmara Sea records where possible); FL = fork length; M = Male; and F = Female.

Species	Turkish name	Max *L* (cm)	Max *W* (kg)	Common size (cm) FishBase	Common size in Turkey	References
Alosa fallax	Tirsi	60		40	27.3 cm	Turan and Basusta, 2001
Belone belone	Zargana	50		45	37 cm	Ener, 1959; Ceyhan et al., 2019
Dentex dentex	Sinagrit	100	15	50	3–5 kg; 15.9–18.4 cm	Deveciyan, 1915/2006; Gökçe et al., 2010
Dicentrarchus labrax	Levrek	103		50	25.6 cm; 28.7 cm	Ergudan and Turan, 2005; Bahtiyar, 2017
Diplodus vulgaris	Karagöz	45	3–5	22	20.5 cm	Üçal, 1975; Işmen et al., 2019
Lichia amia	Akya	200	60	100	15–20 kg	Deveciyan, 1915/2006; Bahtiyar, 2017
Lithognathus mormyrus	Mırmır	55		30	19.9 M; 20.5 F,	Sumer et al., 2014
Merlangius merlangus	Mezgit	91.5	3.1	23.5	15.7 cm	Bilgin et al., 2012
Merluccius merluccius	Berlam	140	15	45	25 cm; 22 cm/0.3–2 kg	Deveciyan, 1915/2006; Üçal, 1971; Gül et al., 2019
Mullus barbatus barbatus	Barbunya	33.2	0.68	20	20 cm; 13.3 cm	Bahtiyar, 2017; Yılmaz et al., 2019
Pagrus pagrus	Fangri mercan	91	7.7	35	18.2 cm	Işmen et al., 2013a
Pomatomus saltatrix	Lufer	130	14.4	60	16.9 cm; 18.6 cm	Akyol and Ceyhan, 2011; Ozpiçak et al., 2017
Sarda sarda	Palamut	63	12	50	35.9 cm M; 39.8 cm F	Deveciyan, 1915/2006; Nümann, 1953; Kahraman et al., 2014
Scophthalmus maximus	Kalkan	100	25	50	21.3 cm	Deveciyan, 1915/2006; Eryilmaz and Dalyan, 2015
Scorpaena porcus	Ýskorpit	25	8.7	15	11.8 cm M; 14.6 cm F	Deveciyan, 1915/2006; Bilgin and Celik, 2009
Scorpaena scrofa	Lipsöz	60	5		23.22 cm	Deveciyan, 1915/2006; Arslan and Bostanci, 2019
Sparus aurata	Çipura	70	17.2	35	15.7–21.12 cm; 20.5 cm	Aydin and Sözer, 2016; Samsun et al., 2017
Sphyraena sphyraena	Iskarmoz	165	3.6	60	27.1 cm	Ceyhan et al., 2008
Squatina squatina	Keler	183 M; 244 F		150	92 cm[2]	Akyol et al., 2015
Trachurus mediterraneus	Kraça Ýstavrit	60		30	12.3; 13.4 cm	Deveciyan, 1915/2006; Demirel and Yüksek, 2013; Kasapoglu and Duzgunes, 2014
Trachurus trachurus	Karagöz Ýstavrit	70	2	22	12–15.4 cm	Kalaycı et al., 2010
Umbrina cirrosa	Minekop	100	20	40	27.6 cm, 254.6 g	Üner, 1970; Gökçe et al., 2010
Xiphias gladius	Kılıç	455	250	300	<80 cm (LJFL)[4]	Akyol and Ceyhan, 2011
Zeus faber	Dülger	90	8	40	31 cm; 35–40 cm	Demirel and Murat-Dalkara, 2012; Işmen et al., 2013b

"*kofana*", each weighing between 6 and 7 kg, which were common then, the largest one weighing 18 kg. From November 19–21, 1984, over 2 million bluefish and larger "*kofana*" were landed

TABLE 4 | Turkish common names for bluefish (*Pomatomus saltatrix*) according to size (Türgan, 1957, 1959) and stage (Ceyhan et al., 2007).

TL (cm)	Weight (g)	Turkish name	Stage
8–10	25–50	*Defne yaprağı*	Juvenile
10–20	50–85	*Çinekop*	Juvenile – Early mature
20–25	100–250	*Sarıkanat*	Mature
25–35	250–500	*Lüfer*	Adult
>35	>1000	*Kofana*	Large adult

from the Bosphorus, which was the last sizeable catch of "*kofana*" from that region (Can, 2013).

Mature bluefish or "*lüfer*" started to noticeably decline in the beginning of 1990s, and were replaced in the markets by their juvenile counterparts: "*çinekop*" or "*sarıkanat*." Bluefish are still the most popular traditional fish species in restaurants of Istanbul; however, only the juvenile forms, i.e., mostly "*çinekop*" and sometimes "*sarıkanat*" can be had in season. Bluefish had a minimum landing size (MLS) since 1986, and this has changed several times since (**Table 5**) (Zengin et al., 2017).

The MLS for bluefish (currently 18 cm) is still about 10 cm under its size of maturity, requiring an amendment to the regulation (Yildiz and Ulman, 2020). The factors influencing changes to MLS regulations are not publicly known (Yildiz and

TABLE 5 | Changes in minimum landing size (MLS) regulations for bluefish in Turkey*.

Year	Size (cm)
1986	15
1987	17
1991	20
1995	18
2001	14
2006	14
2012	20
2016	18

*Note that in 2001, MLS began to refer to çinekop, then, in 2006, back to lüfer.

Ulman, 2020). In Turkish waters, bluefish reach sexual maturity between 26.5 cm (Atılgan et al., 2016) and 28 cm TL (Ceyhan et al., 2007; Ilkyaz, 2018).

Atlantic Bonito (*Sarda sarda*)

In spring, large schools of bonito began their migration from the Sea of Marmara to the Black Sea for spawning and in late autumn, return back to the Sea of Marmara. Historically, this migration period of large bonitos "*torik*" (**Table 6** and **Figure 4**) through the Bosphorus was a culturally important festive period in Istanbul, called the "surge in torik." In ancient times, the Golden Horn and Bosphorus were noted for their fish biodiversity, and the presence of top predators such as dolphins, swordfish, tunas, bluefish, and especially bonito (Tekin, 2010).

Based on sales records from the Istanbul fish market, 1940 had the highest peak of bonito from 1928 to 1952 with 6 million fish (Türkmen, 1953). In the 1950s, this stock was so abundant that in just 1 day, 600,000 *palamut* and 240,000 *torik* were caught (Üner, 1959). In the early 1950s, Black Sea fishers thought that the smaller "*palamut*" and the larger "*torik*" were two different species, but a study confirmed these as belonging to the same species (Nümann, 1953, 1955). Until the early 1960s, fishers would catch spawning bonito and *torik* during their spawning migration in spring to the Black Sea, and again on their return migration to the Sea of Marmara in the fall. However, from the mid-1960s onward, *torik* gradually decreased and bonito became dominant. *Torik* were last reported in Turkey in 1991 with 41 t. In the Black Sea, *Sarda sarda* catches increased from 19,440 t in
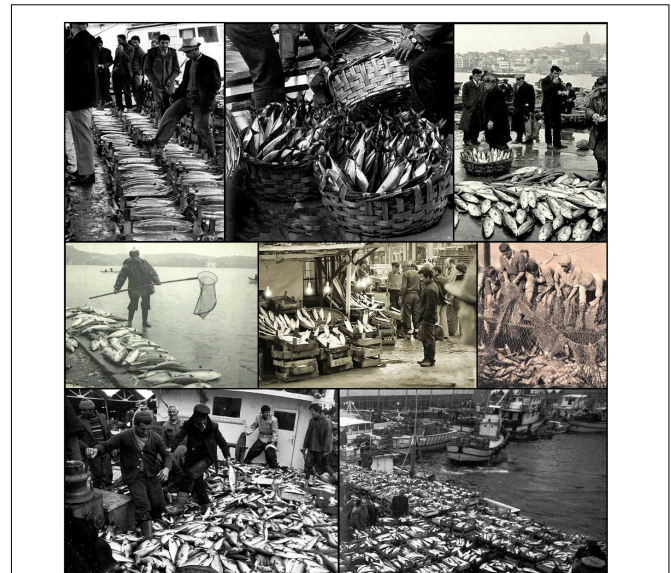

FIGURE 4 | Photos of larger bluefish '*kofana*' and bonito '*torik*' harvest in Istanbul between 1950 and 1975 (Can, 2013).

1967 to 36,273 t in 2016 whereas in the Sea of Marmara, catches declined from 20,181 t in 1967 to 1,923 t in 2016. In the last few decades, the spawning stock has not been caught during their spring northern migration to the Black Sea, and stock size has been drastically reduced (Zengin, 2019). Now they are only caught on their autumn southerly return.

Bonito have also decreased considerably in average caught size in recent decades. There are many photos from the early 20th century period in Istanbul showing individuals between 20 and 30 kg in size. About 50 years ago, their average landed weight was 3 kg, 40 years ago 1–1.5 kg, 20 years ago 1 kg and now their average weight is just between 300 and 500 g. Moreover, the perception of the size corresponding to the Turkish names has also shifted (**Table 6**), demonstrated by current fishers no longer having knowledge of the names for the larger size classes, an excellent example of shifting baselines (Pauly, 1995; Froese et al., 2008).

TABLE 6 | Fished different size classes and age for bonito (*Sarda sarda*) in the early 1900s and 1950s.

Records	Turkish name						
	Çingene palamudu	*Palamut*	*Küçük torik*	*Torik*	*Sivri*	*Altıparmak*	*Pisota*
1900s W (g)							
Summer (min.)	–	1000	1000	3000	5000	8000	10000
Winter (max.)	–	2000	4000	7000	10000	12000	<12000
1950s W (g)	>500	600–900	1500–2500	3000–4000	4500–6500	6500–8000	9000–12000
1950s TL (cm)	>40	30–35	40–50	50–60	60–65	65–75	75–85
1950s age (y)	–	–	2	3	4	–	–

Sources: 1900s – Deveciyan, 1915/2006; 1950s – Nümann, 1953; Üner, 1959. Note the shift of sizes within the named categories.

Atlantic Mackerel – *Scomber scombrus* and Atlantic Chub Mackerel – *Scomber colias*

Atlantic mackerel and Atlantic chub mackerel were both abundant in Turkey in the 1950s, when they migrated between the Aegean Sea and through the Marmara Sea to the Bosphorus, and were most abundant in the Sea of Marmara and Aegean Seas in summer months (Pauly and Keskin, 2017). Only in years with very high abundances could they also be caught in the Black Sea, notably near Şile and Zonguldak (Atlı, 1958). Both species ceased to migrate through the Bosphorus around 1970. Some commercial fishers attribute their disappearance to the introduction of the purse seine fishery in1965, and its use of high-voltage lamps.

Atlantic mackerel reappeared in the Bosphorus in 2013; however, they are still considered rare. They still associate with chub mackerel, but no longer exhibit a strong schooling behavior, as evidenced by gillnet catches, where now only 1–10 individuals can be caught at a time (B. Yalcin, pers. comm. 2013).

Larger Atlantic mackerel individuals, of 20–25 cm, were called "*lipari*", and have now disappeared from the Dardanelles. In contrast, in the 1950s, also in the Dardanelles, next to the castle, the entire slope of the hill used to be used for drying Atlantic mackerel. Istanbul fish market records from 1940 to 1952 suggest that Atlantic mackerel sales were approximately 2,000 t per year (Türkmen, 1953). In the Black Sea, the 1967 catches were 508 t, peaking in 1986 with 796 t and decreased to 6.5 t in 2016. In the Sea of Marmara, catches peaked with 2,064 in 1967 and decreased to just 300 kg by 2016. They are considered "Endangered" in the Black Sea (Öztürk et al., 2013).

Atlantic chub mackerel were abundant in the Dardanelles until the late 2000s, but are rare there now as well. In the Black Sea, catches were reported as 83.4 t in 1967 and only 20 t in 2016. In the Sea of Marmara, catches were reported as 543 t in 1967 and 207 t in 2016; thus, they are still present there, albeit in negligible amounts, but have discontinued migrating as they did before. In the Black Sea, they are considered "Endangered" (Öztürk et al., 2013).

Tuna, With Emphasis on Bluefin Tuna – *Thunnus thynnus*

Ancient bluefin tuna migrations from the Gibraltar Strait to the Black Sea were described by Aristotle and Pliny the Elder (Roberts, 2007). One fisher recalled catching 200–300 bluefin tuna, each weighing between 300 and 400 kg in one stationary trap named a "*dalyan*" in the Bosphorus in both 1956 and 1957; In this period, some weighed up to 800 kg and were up to 457 cm in TL (Nümann, 1952). However, bluefin schools ceased migrating to the Black Sea in 1985, after the entire spawning group was caught in the Sea of Marmara in just 1 day for export to Japan at high prices (Can, 2013; Ulman and Pauly, 2016). Since then, this species has only rarely been caught north of the Dardanelles (MacKenzie and Mariani, 2012). Black Sea catches peaked in 1989 with 2,687 t and were last reported in the catches in 2009 with 65 t. However, it is understood that these fish were caught in the Aegean, but landed and thus counted in a Black Sea port (TÜİK, 1967–2019).

In the Sea of Marmara, bluefin catches peaked in 2001 with 929 t and were lastly reported there in 2007 with 33 t (TUIK,

2007), also thought to be another misreporting issue. In order to clarify these and other such discrepancies, the Turkish Statistical Institute (TUIK) monitors a few vessels registered in Istanbul, but still does not inform where the catches were taken from. On February 04, 2019, six bluefin were found on a beach in Marmara Sea (Karacabey coasts; South Marmara). The individual weights of these fish were declared to be 400–500 kg by the authorities. Possible reasons for these high-value discards are probably due to illegal catches from small-scale fishers intercepted by patrol boats[2].

Listed as "Critically Endangered" in the IUCN Red List and "Endangered" for the Black Sea (Öztürk et al., 2013), due to a large reduction and nearly total disappearance of stocks.

Two other tuna species occurred in the Sea of Marmara; *Thunnus alalunga* (albacore) and *Euthynnus alletteratus* (little tunny); their maximum lengths were recorded 90 cm for albacore and 122 cm for little tunny (Nümann, 1952). However, they entered Turkish catch statistics well after 1967, and with small amounts, and thus are not further discussed here.

Turbot – *Scophthalmus maximus*

Turbot used to be very abundant in the Black Sea, in the early 1900s, between 500 and 1,000 of them, 3–10 kg each could be collected from one set of gillnets (Deveciyan, 1915/2006). Gillnets for turbot are one to two kilometers in length and are placed in the water about 10 days. Between 1928 and 1952, catch peaked in 1939, with nearly 380 t (Türkmen, 1953), and in 1951, when a record of over 520 t were sold (Türkmen, 1953). The highest reported turbot catches for the entire Black Sea region were between 1955 and 1969 (Mikhailov and Papaconstantinou, 2006), a period where the smallest caught turbot were still at least 3–4 kg, and to 12 kg specimens could be found (Üçal, 1975). Their mean size in catches declined by over 50% from 1990 to 2014 from trawl surveys (**Table 7**), disappearing altogether as a commercial species by the mid-2000s.

Fishers blame the collapse of the turbot stock on bottom trawlers, which tend to catch juveniles (Zengin, 2014). The turbot fishery was conducted by gillnet (70%) and bottom trawl (30%) when these methods are permitted in Turkish waters along the Turkish Black Sea coast (Zengin et al., 1998). The turbot fishery was especially intense between April and June, coinciding with their spawning season in May when

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[2]https://www.sabah.com.tr/galeri/yasam/yarim-tonluk-olu-orkinoslar-karaya-vurdu

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TABLE 7 | Mean length of turbot (cm) caught by trawl surveys in the Black Sea.

Year	Size (cm)
1990	41.9
1996	36.5
2000	35
2003	33
2005	34
2010	30
2012	41.3
2014	20.6

Source: Düzgüneş and Zengin, 2018.

the species moves inshore. Nearly 2/3 of their landings occur during their spawning period, likely enhancing their stock decline (Zengin and Düzgünes, 2003).

The sprat, whiting and red mullet fisheries are especially harmful for turbot stocks because they commonly use 40 mm mesh sized trawl codend and thus also catch juvenile turbot as bycatch. These impacts were directly noticed to harm turbot stocks by comparing areas open and closed to trawling along the Black Sea coast in the first half of the 1990s (Zengin and Düzgünes, 2003).

Southern Romania and Northern Bulgaria have high turbot abundances due to the sandy, gravel habitats, filled with mussel beds, and plenty of prey items for turbot (Radu et al., 2010). Turkish fishers are known to illegally fish for turbot in their waters since around 1990, when the Turkish stocks first crashed (see Keskin and Aktan, 2018). One Turkish fisher explained that in Bulgarian waters, he would catch between 2,000 and 3,000 turbots with each net, with each one weighing 5– 6 kg, until he was arrested by Bulgarian authorities in 2000 (Ulman et al., 2013). In the Black Sea, the 1967 catches were 1,529 t, peaking in 1970 with 41,182 t which gradually decreased to just 200 t in 2016. In the Sea of Marmara, turbot catches peaked in 1969 with 579 t, then decreased to 21 t by 2016. Listed as "Vulnerable" in the Black Sea due to significant population declines due to overfishing, by-catch, habitat loss and eutrophication (Öztürk et al., 2013; Demirel et al., 2020).

Swordfish (Xiphias gladius)
Swordfish occurrence in the Black Sea dates back to the early third century AD as Aelianus explained that fishers used to pray to Poseidon for swordfish not to destroy their fishing nets and freeing the tuna therein (Bursa, 2007). In the early 1900s in the Bosphorus, swordfish were caught using nets, by wooden fishing traps called "dalyans" (Deveciyan, 1915/2006), by longline, and from bluefin tuna set nets in the Sea of Marmara (Artüz, 1958). From 1935 to 1952, the Istanbul fish market processed between 100 and 350 t of swordfish per year (Türkmen, 1953). The last year a swordfish catch was reported from the Black Sea was 2013, with 200 kg. They are rare also in the Sea of Marmara, with a 99.9% reduction in reported catches from 1967 to 2016.

One very old fisher interviewed by the first author explained that when he began to fish in the early 1920s, he would harpoon between 20 and 40 swordfish a day in the Bosphorus (the maximum he could transport), each weighing over 200 kg (Ismail Kalafat, pers. comm., 2013). Another small-scale fisher explained that in the 1940s, he could catch as many swordfish from the Bosphorus as he could carry. In the late 1970s, in contrast, one small-scale fisher used to catch between 3 and 5 swordfish a year by handline in the Bosphorus and Marmara Sea, each one weighing 150– 250 kg each. Swordfish are progressively getting smaller in size in southern Turkey (**Table 3**), owing to longliners and gillnets for catching much smaller individuals than purse seines (Akyol and Ceyhan, 2011).

After swordfish commercially disappeared from the Black Sea and Sea of Marmara, the Turkish swordfish fishery relocated to the Aegean and Levantine Seas (Alıçlı, 2010; Akyol and Ceyhan, 2011). Listed as "Critically Endangered" in the Black Sea (Öztürk et al., 2013) because they seem to be nearing extinction in the basin.

Review of Accounts of Rare Taxa Not Included in Catch Statistics
Here we present a summarized review of the status of other vulnerable species. Only records from the Turkish portion of the Black Sea and Marmara Sea are presented here.

Long-Snouted Seahorse (Hippocampus guttulatus)
Seahorses are a bycatch species, collected for their peculiar shape to sell to tourists. They used to be common in the Istanbul Bosphorus in the 1950s, as a few were seen daily by the father of the first author while scuba diving. The Black Sea, until recently, had the highest seahorse abundances in Turkey. Several fishers using bottom set gillnets explained they found about 100 seahorses a day (as bycatch) specifically in September and October in the early 2010s, and only 5–10 a day in other months with an average size between 5 and 6 cm (Lawson et al., 2017). They were common until the 1960s, but have since become increasingly rarer. The Sea of Marmara had seahorses as a common species only 2–3 decades ago, but they have completely disappeared according to fishers since the mid-2000s. Listed as "Endangered" in the Black Sea (Öztürk et al., 2013) and a protected species in Turkey (Regulation #2016-35, Article 16).

Elasmobranchs
Angel shark (Squatina squatina)
This species was well-documented in historical data as a common and abundant species in the Sea of Marmara (Ninni, 1923; Tümamiral and Karapınar, 1967, 1968). However, in recent decades, only two specimens were recorded from the Sea of Marmara, one in 1994, and another in 2014. Listed as "Vulnerable" in the Black Sea due to severe population declines (Öztürk et al., 2013).

Bramble shark (Echinorhinus brucus)
Bramble shark was first reported in Turkish waters by Deveciyan (1915/2006) and Ninni (1923), with the former author stating that this was an abundant species in the Marmara Sea in the early 1900s, and commonly consumed. Bramble sharks were not mentioned again for nearly a century, but recent studies reported five females caught in Marmara Sea between 2002 and 2013, ranging from 170 to 250 cm in length (Kabasakal, 2014a). Accounts of the deep-sea fauna in the Eastern Mediterranean, Adriatic or Ionian Seas have not reported this species and it is suggested to be an extinct in the Eastern Mediterranean. Over 202 years, only 24 records for the species have been recorded for the Western and Central Mediterranean (De Maddalena and Zuffa, 2003), making the recent records from Turkey remarkable, and warranting special protection for this species. It is included by De Maddalena and Baensch (2008) in a list of the 13 most endangered species of Mediterranean sharks.

Bluntnose sixgill shark (Hexanchus griseus)
The bluntnose sixgill shark has been recorded in the Sea of Marmara on several occasions (Deveciyan, 1915/2006; Ninni, 1923; Meriç, 1994; Kabasakal, 1998), and also from the other

Turkish seas. There were 150 reported specimens from 1967 to 2013, 60% from the Sea of Marmara, 27% from the Aegean, 10% from the Mediterranean and 2% from the Black Sea, and one from the Dardanelles; the largest Turkish record is 650 cm in length, compared to the 482 cm largest length recorded elsewhere in the literature (Kabasakal, 2013). This species was neglected until the 1990s, but following the disappearance of most other species, it became more appreciated (Kabasakal, 2013). Fishmongers would often display this species to attract customers (Kabasakal, 2010).

Great white shark (Carcharodon carcharias)
The great white shark, whose global distribution was recently reviewed by Huveneers et al. (2018), was previously found in Marmara Sea (Üçal, 1976). From 1881 to 2014, 54 individuals were recorded in Turkish waters, ranging from 85–800 cm (Kabasakal, 2016b). Until 1980, great white sharks were caught in association with migrating bluefin tuna, their prey. Due to the local extinction of bluefin tuna from the Sea of Marmara in the 1980s, *C. carcharias* is also assumed to be locally extinct (Kabasakal, 2014b).

Sandbar shark (Carcharhinus plumbeus)
Sandbar sharks used to be present in all Turkish waters except for the Black Sea (Kabasakal, 2015, 2020). This implies it was once found in Marmara Sea; however, it has not been reported there since.

Blue shark (Prionace glauca)
Blue sharks were reported in Marmara Sea in the early 20th century (Deveciyan, 1915/2006; Ninni, 1923; Kabasakal, 2016b), but have not been reported there since.

Porbeagle shark (Lamna nasus)
Porbeagle sharks occurred in Marmara Sea (Deveciyan, 1915/2006; Ninni, 1923; Bilecenoğlu et al., 2002; Kabasakal, 2002), where it was fished. Most historical catches occurred in winter at the bottom of the Bosphorus near the Princes' Islands, and associated with migrating bluefin tuna and bonito. There have not been any sightings for several decades (Kabasakal, 2003), and their disappearance is likely associated with the disappearances of bluefin tuna (Kabasakal, 2016b), which last spawned in the Sea of Marmara in 1986 (Ulman and Pauly, 2016).

Tope shark (Galeorhinus galeus)
In the 1960s, in the Golden Horn (Bosphorus) fish halls, this species could always be found for sale (Türkmen, 1953). It was last reported in Marmara Sea in 1956 (Bilecenoğlu et al., 2002), but has not been sighted there in the last few decades (Kabasakal, 2003).

Marine Mammals
Common dolphin (Delphinus delphis)
The WWI to WWII period was one of economic stagnation for much of Turkey and many Black Sea fishers hunted dolphin for their livelihoods. Dolphins were targeted primarily for their blubber, to light homes, and were also used as fertilizer (Zengin, 2010). Additionally, dolphin blubber was exported to Italy and Germany as a raw material for various industries such as medicine, leather, cosmetics, food, and railways. Dolphin oil production in Turkey was 2,000 t annually until 1947, and had

doubled by 1954 (Zengin, 2010). The Turkish statistics show that in the Black Sea, dolphin catches peaked in 1971 with 4,444 t, and disappeared from catches in 1981, likely due to a population crash. In 1983, dolphins finally became protected in Turkey, much later than the other Black Sea states, which commenced dolphin protection in 1966 (Dumont, 1999). Common dolphins are listed as "Vulnerable" in the Black Sea, and it is hypothesized that their population has not been able to recover from the earlier period when they were hunted, due to incidental bycatch from various fisheries and habitat degradation (Öztürk et al., 2013).

Mediterranean monk seal (Monachus monachus)
In Turkey, 20 Mediterranean monk seals were captured from the Zonguldak and Akcakoca regions (Black Sea) for zoos, before they became protected in 1977 (Ozturk, 1996). Their population collapsed between the 1970s and 1990s, and the last reported Black Sea sighting was in 2010, although a few elusive individuals are thought to remain (Öztürk et al., 2013). Listed as "Critically Endangered" in the Black Sea (Öztürk et al., 2013), with the live captures cited as the main reason for their Black Sea disappearance.

DISCUSSION

This study presents the first timeline of disappeared fish species from the Turkish Black Sea and Sea of Marmara, and also presents other threatened commercial taxa warranting protection. The severity of biodiversity loss is certainly troubling. In the Black Sea, out of 55 commercial taxa which could be assessed, 17 are now extirpated and a further 17 taxa face commercial extinctions; thus, over half the commercial taxa are in peril. While the fisheries induced decline of the Black Sea biodiversity is somewhat documented (Gücü, 2002; Daskalov, 2003; Daskalov et al., 2008), the overfishing-induced decline of the Sea of Marmara's biodiversity is not documented. In the Sea of Marmara, the situation is even worse, with 19 extirpated taxa and 22 commercially extinct taxa, i.e., 56% of the commercial species. Many of these taxa facing commercial extinction were high-valued medium pelagics, which restricted their migratory routes and decreased in catch sizes so much that many now resemble small pelagics (e.g., Trachuridae, Mullidae, and *P. saltatrix*) due to length declines. Recovery for the extirpated stocks is unlikely as many are now rare, although a few are now under nominal protection (sturgeons, dolphins, and monk seals). The Sea of Marmara is very unfortunately located close to Istanbul, which leads to a very large number of people, including legal and illegal fishers along its northern shores.

Species diversity provides the foundation for the relative stability of ecosystems, and their resilience to minor perturbations. The scale of biodiversity loss demonstrated here, however, cracked the foundations of these ecosystems, and has reduced their connectivity (McCauley et al., 2015), as many migratory species are no longer linked to the Black Sea.

There is, on the average, a lag of approximately 50 years between the last sighting of a marine species and its reported extinction, compared to only a 4 year time-lag for terrestrial species (Dulvy, 2005). The taxa listed here as 'extirpated species' may still occur as rare species in these

waters, especially those that have recently disappeared from the catch statistics. What is mostly occurring are range restrictions: first the species disappear from the Black Sea, the connecting Bosphorus Strait, the Sea of Marmara; finally, their abundance declines in the Dardanelles as well. Since the Mediterranean is a much larger basin, the same species, albeit different stocks, are still for the most part present there.

A common theme in this study, often neglected in literature, but well understood from the TEK of fishers, is the loss of ecological connections. Many of these migratory species were well known to migrate together, and often stopped their migrations in unison once one taxon was affected. Thus, once bluefin tuna stopped its migration, it had a domino effect on other species, notably its predators (*Carcharodon carcharias* and *Lamna nasus*), and migratory companion (e.g., *Xiphias gladius*). Biotic interactions should be considered as an indicator to assess ecosystem health (Valiente-Banuet et al., 2015), and should be investigated to improve knowledge on ecological function.

Various stressors contributed to the decline of commercial fishes, but recent research attributes the majority of the losses to overfishing. Thus, in a recent stock assessment of Turkish stocks, only sprat was sustainably exploited; all other species being overfished (FAO, 2018a,b; Demirel et al., 2020). The Turkish Marmara and Black Sea fisheries have been essentially uncontrolled, practicing 'Fishing down marine food webs' (Pauly et al., 1998), moving on to the next lesser profitable species after finishing off its more valuable predecessors. The seas' nearly totally enclosed nature do not permit anywhere for fish to hide from the wide-spanning eye of sonar.

Other notable species not captured by the statistics and hence our lists, were mentioned to highlight their status. Sharks for example are one of the most endangered groups globally, particularly in the Eastern Mediterranean/Black Sea regions (Ferretti et al., 2008; Dulvy et al., 2014). As shown here, some very rare species have recently been reported from the Marmara Sea, highlighting the need for protection of such vulnerable species.

The Mediterranean and Black Seas are some of the most impacted marine ecosystems worldwide (Costello et al., 2010). The loss of diversity, complexity, and hence resilience are leading to undesirable algal blooms, dead zones, disease outbreaks and species invasions (Lotze et al., 2006). A buildup of gradual stressors (e.g., eutrophication, pollution, trophic cascades, and invasive species in addition to overfishing) have completely transformed the Black Sea (Daskalov et al., 2007), and the same is now occurring to the Sea of Marmara. Overfishing and ecological extinction of species usually precede the collapse of ecosystems (Jackson et al., 2001), highlighting a high propensity for ecosystem collapse (Sala et al., 1998), as resilience has been reduced by simplification of food webs. A gradual buildup of stressors, along with the overwhelming number of extirpated taxa and commercially extinct taxa should be a call for ecosystem rehabilitation.

There is currently a global dichotomy, where the few countries successful at rebuilding their fisheries, are advised by scientists, involve stakeholders, and have some method of effective output

controls (i.e., catches have preset limits). This is not the case for Turkey. The lack of management plan has contributed to a severe degradation of the Black Sea ecosystem, with a similar fate awaiting the Sea of Marmara. It is not obvious that recovery is not possible for the threatened species listed here (over 90%), due to range restrictions and allee effects- where too small populations negatively affect fitness and rebuilding potential (Hutchings, 2013; Burgess et al., 2017; Froese et al., 2018), but an attempt still ought to be made.

We have demonstrated how many of the previous commercial taxa have either disappeared or their catches have become so low that their fisheries have ceased. For alternative incomes, in the Black Sea, many fishers switched to target Rapa whelk (*Rapana venosa*) by beam trawl in the 1980s, and sprat in the 2000s as substitute species. However, these alternatives cause more damage to the ecosystem. For example, beam trawls are extremely destructive to benthic biodiversity and compromise ecological integrity, whereas sprat (although not consumed by humans) are extremely important to trophic structure function in their role as prey species for predatory fish. They are major prey item (39%; Işmen and Bingel, 2000) for whiting, which in turn is a major prey item (61.7%) for turbot (Zengin, 2000; Solberg et al., 2015). In fact, turbot and whiting fisheries have collapsed due to the intense sprat fisheries which recently developed in the last 25 years (Zengin and Gümüş, 2014).

The massive decline in marine biodiversity in Turkish seas has apparently largely gone unnoticed by Turkish citizens. This may be due to their disconnection from the natural world, as most people living in Turkish cities, foremost in the metropolis of Istanbul, have little connection to nature. Also, most urban dwellers have been pulled from rural areas lacking a maritime history and connections. Additionally, the shifting baselines syndrome is certainly prevalent in Turkey (Ulman and Pauly, 2016), implying that newer generations appear to accept the currently degraded state of biodiversity due to a lack of transmission of historical knowledge of what has been lost, as the relevance of these stories have no connection to the present. This study commemorates the many lost species of the Black and Marmara Seas, and may be seen as a warning call to prevent dozens of others species to join them.

Due to the gravity and severity of these losses, solutions to improve biodiversity form and function from these once highly productive seas need to be creative and adaptive. Solutions will likely involve many types of measures working synchronously. The protection of the Bosphorus and Dardanelle Straits from industrial fishing could be an effective preliminary conservation target as they are of utmost importance in delivering function to these two seas; and due to their relatively small areas, would be easy to monitor. With Turkey's very high human population growing, doubling in just the last 43 years[3], combined with their growing need for natural resources, it is of vital importance to plan for the future by protecting, sustaining and rebuilding what is left.

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[3]www.overpopulation.org

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

AUTHOR CONTRIBUTIONS

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