frontiers in Marine Science

ORIGINAL RESEARCH
published: 02 March 2017
doi: 10.3389/fmars.2017.00053

The Marine Fisheries in Bulgaria's Exclusive Economic Zone, 1950–2013

Çetin Keskin[1]*, Aylin Ulman[2,3], Kyrstn Zylich[2], Violin Raykov[4], Georgi M. Daskalov[5], Daniel Pauly[2] and Dirk Zeller[2]

[1] Fisheries Faculty, University of Istanbul, Istanbul, Turkey, [2] Sea Around Us, Global Fisheries Cluster, University of British Columbia, Vancouver, BC, Canada, [3] Department of Earth and Environmental Sciences, University of Pavia, Pavia, Italy, [4] Institute of Oceanology of Bulgarian Academy of Science, Varna, Bulgaria, [5] Laboratory of Marine Ecology, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria

This study presents a reconstruction of the total catch of Bulgarian marine fisheries in the Bulgarian Exclusive Economic Zone for the time period 1950–2013, including previously unreported landings, discards, recreational and subsistence catches. The landings data officially reported by Bulgaria to the Food and Agriculture Organization of the United Nations for the Mediterranean and Black Seas (FAO Area 37) were revised in line with all available information. The reconstructed total catch for 1950–2013 was 1.7 times the (adjusted) baseline data reported by Bulgaria to FAO and 1.5 times the unadjusted data as reported by FAO. This study revealed major deficiencies in the officially reported Bulgarian catch data, foremost the large amount of unreported industrial catches, especially for the last two decades. The exclusion of some fisheries sectors, notably the absence of data on the subsistence and recreational fisheries in reported data are also noteworthy.

Keywords: Black Sea, invasive species, landing, overfishing, small pelagics, unreported catches

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Correspondence:
Çetin Keskin
seahorse@istanbul.edu.tr

Specialty section:
This article was submitted to Marine Fisheries, Aquaculture and Living Resources, a section of the journal Frontiers in Marine Science

Received: *15 December 2016*
Accepted: *15 February 2017*
Published: *02 March 2017*

Citation:
Keskin Ç, Ulman A, Zylich K, Raykov V, Daskalov GM, Pauly D and Zeller D (2017) The Marine Fisheries in Bulgaria's Exclusive Economic Zone, 1950–2013. Front. Mar. Sci. 4:53. doi: 10.3389/fmars.2017.00053

INTRODUCTION

Global fisheries catches have been decreasing in recent decades (Pauly and Zeller, 2016), which has not only impacted the populations of target species (i.e., population size, demographic and genetic characteristics), but has also changed community structure (biodiversity) and the function of the other components of ecosystems (i.e., trophic levels, Pauly et al., 1998, 2002; Daskalov, 2002; Tsikliras et al., 2015).

The impact fishing has on marine ecosystems can be demonstrated at the broadest scale by initially examining the data documenting extractions of the marine resources. Based on this concept, reconstructing the national fisheries catch data set can provide insights into the historical catch time-series and create a more detailed, comprehensive regional dataset (Pauly and Zeller, 2016 and references therein). The aim of this study is to assemble the total reconstructed catch of Bulgaria in the Black Sea, and to provide a comprehensive dataset which includes all marine fisheries removals, such as landings and unreported catches (discards, subsistence and recreational catches) from the Bulgarian component of the Black Sea ecosystem as a baseline for future studies.

Study Area

The Black Sea has a surface area of 422,100 km^2 (excluding the Sea of Azov), and a mean and maximum depths of approximately 1,300 and 2,210 m, respectively. The Black Sea is connected to the Aegean and hence Mediterranean Sea through the Bosphorus and the Dardanelles, which themselves are connected by the Sea of Marmara.

The upper layer of the Black Sea has low salinity (averaging around 17–18 psu) and warmer average summer temperatures (up to 30°C), both of which inhibit the surface layer from mixing with the deeper layer, which has a salinity averaging 22–24 psu and temperatures of approximately 8.5°C. The majority of the Black Sea water column (about 90%), is deeper than 150–200 m and is anoxic and devoid of multicellular life (Oguz et al., 1998). The contrast between the river runoff (mainly from the Danube, Dniester and Dnieper rivers), and high-salinity waters (from the Mediterranean Sea, entering the Black Sea via the Bosphorus Strait) enhance the stratification, and prevent any mixing between surface and deeper layers. Although the lower 90% of the Black Sea basin is devoid of oxygen and contaminated with hydrogen sulfide, the upper layer is productive and provides suitable habitats for numerous epipelagic and neritic species (Zaitsev, 2008).

The Black Sea ecosystem has suffered from several anthropogenic disturbances, such as eutrophication, the introduction of alien species (*Mnemiopsis leidyi*) and the overexploitation of large pelagic predators in the mid- to late twentieth century (Prodanov et al., 1997; Zaitsev and Mamaev, 1997; Caddy, 2008). Eutrophication has dramatically altered the base of the marine food web; additionally, the overexploitation and decline of some fish populations, such as large pelagic fishes, contributed to providing the necessary conditions for successful alien species invasions (Daskalov, 2002).

In 1946, a large sea snail, the invasive rapa whelk (*Rapana venosa*), was first seen in the Black Sea. The rapa whelk was successful in its new environment and became widespread (except in very low salinity areas). It is a notorious predator which feeds on oysters, mussels and other bivalves, and thus exerts a major influence on local populations of malacofauna. In the 1980s, in response to an international demand for sea snails, a massive fishery for the rapa whelk emerged in Turkish waters. Along the Bulgarian coast, a rapa whelk fishery commenced in 1994 (Daskalov and Rätz, 2010), which helped reduce the rapa whelk's impact on its prey species. This may possibly be the only example of a human-induced decline in an introduced species in the Black Sea.

Despite the entire Black Sea ecosystem being affected by these and similar issues, they are all treated as "national" issues, as there is no ecosystem-wide management authority or agreement.

Fishing History

The Bulgarian Exclusive Economic Zone (EEZ) is around 35,000 km^2 (**Figure 1**, http://www.seaaroundus.org), which corresponds to just under 7% of the total Black Sea area (Popescu, 2011). The Black Sea corresponds to Major Fishing Area 37 of the General Fisheries Commission for the Mediterranean (GFCM), Sub-area 37.4; Division 37.4.2, and Bulgaria's fisheries occur within Geographical Sub-area 29.

Bulgaria's continental shelf (to 100 m depth) along the Bulgarian coast is about 40 km wide; the relatively shallow fishing grounds (down to depth of 100–120 m) range from Cape Kartalburun (near the Romanian border) to the Rezevo River (near the Turkish border). The exploitation of fisheries resources is limited to the upper shelf, since depths below 100–150 m are anoxic.

Bulgarian marine fish catches have exhibited trends similar to other Black Sea countries. In the mid-1960s, Atlantic mackerel (*Scomber scombrus*), Atlantic bonito (*Sarda sarda*) and bluefish (*Pomatomus saltatrix*) were the commercially most important species (Ivanov and Beverton, 1985). In the late 1960s and early 1970s, Atlantic mackerel, Atlantic bonito and bluefish catches dramatically decreased in the Bulgarian Black Sea fisheries. Among demersal species, turbot (*Scophthalmus maximus*) was one of the most important commercial species, and catches averaged around 330 $t \cdot year^{-1}$ in the 1960s, but dropped to 12 $t \cdot year^{-1}$ by the 1980s (Zaitsev and Mamaev, 1997). In the 1970s, the over-exploitation of larger pelagic predators, combined with the increased eutrophication of the north-western Black Sea led to a dramatic increase in the catches of small pelagics such as sprat (*Sprattus sprattus*), anchovy (*Engraulis encrasicolus*) and Mediterranean horse *mackerel* (*Trachurus mediterraneus*). The sprat population saw a massive increase in biomass from the mid-1970s and 1980s, and its maximum catch was recorded in 1989, after which the stock collapsed, but later rebounded (Radu et al., 2010). In the late 1980s, an alien invasive ctenophore, the warty comb jelly (*Mnemiopsis leidyi*) reached its maximum abundance in the Black Sea, and thus became a powerful food competitor of adult planktivorous fish, and a significant predator of their eggs and larvae. As a consequence of this and other changes in this Large Marine Ecosystem (LME, Pauly et al., 2008), the rapa whelk has become, since 1995, the most commercially important taxon, followed by sprat.

Modernization of the Bulgarian fishing fleet began just before the 1950s. Industrial or large-scale purse seine and trawl vessels developed in the 1950s. In the 1960s, however, Bulgaria began to buy high-seas fishing and support vessels from the Soviet Union, Poland and East Germany, and began to build infrastructure for fish processing. From 1965 to 1990, Bulgaria owned a large high-seas distant-water fleet (consisting of 30 high-capacity trawlers and 6 transport vessels) that was actively engaged in the Atlantic and in the south-eastern Pacific. This fleet was liquidated in the early 1990s after the collapse of the former USSR, and the Bulgarian fishing fleet refocused their efforts on the Black Sea coastal zone (Popescu, 2011). In the 1970s, approximately 80% of marine catches came from the industrial fisheries, and the remainder came from the artisanal sector, which used mainly passive gears (Kumantsov and Raykov, 2012). In 2008, the Bulgarian fleet consisted of 2,547 vessels with a total gross tonnage (GT) of 8,378 and total kilowatts (kW) of 63,860 (**Table 1**). The small-scale sector represented 96% of the fishing fleet in term of vessel numbers, i.e., 2,440 vessels under 12 m in length, and was responsible for landing around 57% of the Black Sea catch (Radu et al., 2010). Throughout this study, we use the term "industrial" to refer to the large-scale commercial sector, and "artisanal" to refer to the small-scale commercial sector.

Bulgarian fisheries policy is shaped by several international fisheries agreements (i.e., UNCLOS, UNCLOS, CITES) and the European Union Common Fisheries Policy (since its entry into the European Union in 2007). The country is also a member of General Fisheries Commission for the Mediterranean

FIGURE 1 | Exclusive Economic Zone (EEZ) and continental shelf (to 100 m depth) of Bulgaria in the Black Sea.

(GFCM) and the FAO. The National Agency for Fisheries and Aquaculture within the Ministry of Aquaculture and Food is the executive body responsible for national policy on fisheries and aquaculture and implements the Fisheries Legislation in Bulgaria. In this context, Total Allowable Catches (TACs) for sprat and turbot were set in the mid-late 2000s. Some other management implementations include a licensing system for fishers, effort control via limiting fishing gear, engine power and vessels; seasonal closures are imposed to protect some stocks during their reproductive periods; and closed areas and bans of bottom trawling and dredging are imposed. Since 2012, beam trawling is allowed only in selected areas. No permit or licenses are required to participate in the marine recreational fishery.

"Industrial" (Large-Scale) Fishery

In 2008, the industrial fleet consisted of 108 vessels >12 m in length. Sprat is to this day targeted mainly by large-scale pelagic trawlers seasonally from February to November. Whiting (*Merlangius merlangus*), turbot, anchovy, shad (*Alosa* spp.), Mediterranean horse mackerel and red mullet (*Mullus barbatus*) are incidentally caught as by-catch (Radu et al., 2010), but sold commercially. The bottom trawl fishery began to develop for turbot in the 1950s, but was banned in 1994 to protect declining turbot stocks and beds of Mediterranean mussel, *Mytilus galloprovincialis* (Konsulova et al., 2001).

Dredges and beam trawlers were used in the rapa whelk fishery, but were also banned in 2001 to protect vulnerable benthic biotic communities such as mussel beds. Note that dredge and beam trawl fisheries may be classified as small-scale fisheries in Bulgaria, as domestic classification is based on vessel size only. However, for the purposes of the *Sea Around Us* (www.seaaroundus.org), any fishing gears that are actively dragged across the sea-floor or through the water column using engine power are considered "industrial" (i.e., large-scale), following Martín (2012).

TABLE 1 | Composition of the Bulgarian fishing fleet in 2008 (Radu et al., 2010).

		Length (m)				
		<6 m	6–12	12–18	18–24	24–40
Registered vessels		842	1598	68	27	12
Active vessels		213	434	45	13	11
Active gear	Pelagic trawlers	0	3	8	2	11
	Other gear	22	115	17	4	0
Passive gear	Hook and line	14	23	2	0	0
	Drift/fixed netters	166	224	8	1	0
	Pots/traps	3	33	1	0	0
	Other passive gear	2	11	0	0	0
Variable gear	Active and passive gear	6	25	9	6	0

"Artisanal" (Small-scale Commercial) Fishery

The coastal fishery has traditionally been carried out by small vessels (<12 m) which use mainly passive fishing gear, such as trap nets (uncovered pound nets), and beach seines in the inshore area. Here, these vessels/gears are considered "artisanal." Pound nets are deployed in 9 to 12 m depth in coastal inshore waters (Radu et al., 2010) from March to November, and target species vary according to season: sprat is targeted during spring and the beginning of summer, and anchovy and Mediterranean horse mackerel are targeted in summer and autumn. Whiting, turbot, red mullet and other demersal species are incidentally caught as by-catch, but retained for commercial sale (Radu et al., 2010). The set gillnet fishery operates in the coastal and offshore waters of Bulgaria and targets primarily turbot, while dogfish (*Squalus acanthias*), thornback ray (*Raja clavata*), common stingray (*Dasyatis pastinaca*) and sturgeons (Acipenseridae) are often incidentally caught as by-catch (Radu et al., 2010). The number of vessels operating by LOA (length overall) in 2008 is given in **Table 1**.

METHODS

Reported Catch Data

The baseline data used for the work presented here are the catch statistics submitted annually by Bulgaria to FAO which are incorporated into the global database (FishStat; www.fao.org/fishery/statistics/software/fishstatj/en), complemented by national Bulgarian data published by Prodanov et al. (1997); Mikhailov and Prodanov (2003), and Panayotova et al. (2012). Tunas and other large, highly migratory pelagic fishes (e.g., swordfish), which were originally abundant in the Black Sea, are not considered here.

According to the data reported by FAO on behalf of Bulgaria in the Mediterranean and Black Seas (FAO Area 37, release date March 2015), total catches appeared very high for the years between 1964 and 1969 (driven by high values for "marine fishes nei," i.e., "marine fish not elsewhere identified"). On closer inspection of Bulgarian FAO data for areas other than 37, it was found that duplicate "marine fishes nei" (or Miscellaneous Marine Fishes, MMF) values had been reported for Bulgaria fishing in three other areas (the central-eastern Atlantic, south-eastern Atlantic and north-western Atlantic), i.e., the exact same values were present in all three areas. By comparing FAO data with Northwest Atlantic Fisheries Organization (NAFO) data, it was found that these MMF values were indeed incorrect. It was therefore assumed that the reported catch for FAO Area 37 (Mediterranean and Black Seas) also had these values mistakenly added on to the real reported MMF catch. We therefore subtracted the duplicated MMF tonnage reported in the other areas from the MMF in FAO Area 37 for the years 1964–1969. This resulted in an adjusted FAO baseline, which was used for the rest of the reconstruction as reported baseline data. We suggest Bulgaria formally request a retrospective data correction of FAO data.

Since all taxa were reported as "marine fishes nei" from 1950 to 1963, we disaggregated this category taxonomically by using reports of national data to assign most of the tonnage to specific species or families (Prodanov et al., 1997; Mikhailov and Prodanov, 2003; Panayotova et al., 2012). Any remaining tonnage was kept as "marine fishes nei." These national reports were also used to improve the catch data from 1964 to 1969, as much of these data still remained as MMF and many species/families had rounded, estimated values listed.

Unreported Catches

Unreported catches as defined here include unreported commercial, subsistence and recreational catches, as well as discarded catch.

Commercial Catches

Sprat has been the main catch for Bulgaria since 1970. However, published reports on Bulgarian fisheries have clearly documented that some commercial sprat catches have gone unreported (Mikhailov and Prodanov, 2003; Daskalov and Rätz, 2010). On average, Daskalov and Rätz (2010) estimated of actual catches for 1992 and 1993 were 55% higher than the reported sprat catches in 1990 and 1991. From 1994 to 1999 sprat catches were assumed to have been under-reported by the same ratio and averaged 1.79 times higher than reported data (Daskalov and Rätz, 2010), and were used to estimated unreported sprat component for 2000 and 2001. The ratio was not applied to the years 2002–2003, as the reported data exhibited a spike in these years and it was assumed that reporting coverage was more complete in this time period. Therefore, in order to remain conservative, we linearly interpolated the unreported tonnage from 2001 to 2004. There was also an expert assessment in 2007 which estimated catches to be 2,985 t as opposed to 2,559 t (EU, 2008), with FAO using the former value. Thus, we assume that catches were fully reported in 2007 and use the ratio (unreported = 0.17*reported) between the two 2007 estimates in Daskalov and Rätz (2010) to obtain a conservative estimate of unreported catches in 2008–2013. We also assumed there to be a much lower likelihood of under-reporting from 1950 to 1989 (during communist rule), and therefore added a conservative 10% of landings to account for under-reporting of sprat during that period.

In Bulgaria, marine bivalve catches include the striped Venus clam (*Chamelea gallina*), bean clam (*Donax* spp.) and mussel. According to information available at the FAO (http://www.fao.org/fi/oldsite/FCP/en/bgr/body.htm), the 2000 FAO reported data for rapa whelk equated to 90% of the total shellfish catch. We considered the remaining 10% to be comprised equally of *C. gallina*, *Donax* spp. and miscellaneous marine molluscs ("marine molluscs nei") for the 1994 to 2013 period.

Some sturgeons are anadromous or potamodromous, as in the case of the sterlet sturgeon (*Acipenser ruthenus*) (Mikhailov and Prodanov, 2003); thus, *A. ruthenus* was excluded from consideration in the present study. While the fringebarbel sturgeon (*Acipenser nudiventris*) is commercially extinct, the beluga sturgeon (*Huso huso*) and the Russian sturgeon (*Acipenser guldenstaedti*) are still commercially important in the Bulgarian fishery. Wild caviar export data were used to estimate unreported sturgeon catches from 1998 to 2006 (Kecse-Nagy, 2011; **Table 2**). We converted caviar weight to fresh fish weight for *H. huso*, *A. gueldenstaedti* and *Acipenser stellatus*, using gonado-somatic coefficients from Jivkov et al. (2003), and then estimated catches by using the sex ratio of the same three species (**Tables 2, 3**).

Bulgaria became a member of the European Union (EU) in 2007, and intra-EU trade no longer appears in the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) data for caviar exports. It is likely that caviar export to other EU countries have continued after 2007 without being recorded in CITES data, and the estimated unreported catch in 2006 was thus used as estimate for the years 2007 to 2013.

TABLE 2 | Wild origin caviar exports used to estimate sturgeon catches (wet weight) in Bulgaria (from the CITES Trade Database; Kecse-Nagy, 2011).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Exported caviar (kg)	2,392	2,025	2,788	992	2,337	1,563	920	1,421	667	–	–	–	–
Estimated female (t)	13	11	15	6	13	9	5	8	4	–	–	–	–
Estimated male (t)	40	34	46	17	39	26	15	24	11	–	–	–	–
Estimated total (t)	53	45	62	22	52	35	20	32	15	–	–	–	–
Unreported catch (t)	39	33	59	22	45	31	16	30	15	15	15	15	15

Rapa whelk has become a commercially valuable resource with high demand on the international market. In Bulgaria, this fishery commenced in 1994 and rapa whelk were originally caught by scuba divers. However, shortly thereafter, there was illegal rapa whelk fishing by bottom trawlers, beam trawlers and dredgers (Daskalov and Rätz, 2010). For the period from 2000 to 2010, the bulk of rapa whelk catches were illegally taken by dredges and beam trawls (V. Raykov, pers. obs.). We estimated an unreported catch component for rapa whelk based on export data for the period from 2002 to 2010 (**Table 4**). The same percentage rates for the select processing types of rapa whelk in 2009 (Daskalov and Rätz, 2010) were used and applied to the 2002–2010 period to disaggregate the unreported catch component. Since rapa whelk is exported without its shell, the exported amounts first had to be converted to equivalent weights with shell on, to account for total fishery removals. A rate of 85.8% of total weight was added to both the frozen meat and sweetbread rapa whelk exported amounts to account for this (Düzgüneş et al., 1988). Unreported rapa whelk catches were interpolated from zero in 1993 to the estimate of 12,313 t in 2002 that came from the export data. Finally, the ratio of reported to unreported rapa whelk catches in 2010 was applied to the 2011–2013 reported data.

An unreported catch of turbot (*Scophthalmus maximus*) taken by Bulgaria was estimated from sources stating that Bulgarian fishers also have under-reported their own turbot catches from the Bulgarian EEZ in recent years (total estimated at 300 t·year^{-1}; EU, 2009). The total turbot catch was accepted as 250 t·year^{-1} to avoid over-estimation, and this was used as an anchor point in 2007 (last year of data in the EU, 2009 report). To remain conservative, the unreported catch was then interpolated from zero in 1994 (year before turbot catches started again) to 183 t in 2007 (difference between 250 t and the reported amount). The ratio of reported to unreported data in 2007 was then applied to the reported data from 2008 to 2013. We also assumed some turbot catches to have been unreported throughout the 1950–1989 period, but to a much lesser extent. Thus, from 1950 to 1989, an additional 10% of the reported turbot catch amount was estimated to have been unreported, and added to the reported component.

Lastly, there were also data in the national reports used above (Prodanov et al., 1997) from an expert assessment of whiting (*Merlangius merlangus*) that we incorporated, and which indicated that catches were severely under-reported from 1975 to 1993.

Discards

To estimate discards, published reported discard rates by select fisheries from the Black Sea and eastern Mediterranean were sought, which included both industrial (mid-water trawl, bottom trawl, purse seine, dredge) and artisanal fisheries (gill and trammel nets, hand line, long line, fish pound net, beach seine net). These discard rates were then applied to the reported data for each of the target species for each fishery with the help of expert advice (**Table 5**). Given that discard rates were only applied to reported catches (and thus represent minimum estimates of discards), the discards of the rapa whelk fishery are likely considerably underestimated as there was a substantial unreported landings component to that fishery.

Whiting contribute greatly to the trawl catches in the Black Sea, but are not a targeted fishery and are mostly discarded by Bulgarian fishers (Raykov et al., 2008). In neighboring

TABLE 3 | Gonado-somatic coefficients (G) and sex ratio (female: male) for sturgeons in Bulgaria (adapted from Jivkov et al., 2003).

Species	G (%)	Sex ratio	Species contribution (%)
Huso huso	18	3:1	83
Acipenser gueldenstaedti	16	1:1	10
Acipenser stellatus	16	2:1	7

TABLE 5 | Discard rates applied to select fisheries in Bulgaria.

Ecosystem	Fishing gear	Discards (%)
Marmara Sea[a]	Bottom trawl	16.2
Black Sea[b]	Sea snail dredge	11.5
Global[b]	Bottom long line	8.2
Global[b]	Beam trawl	7.5
Black Sea[b]	Mid-water trawler	5.1
Global[b]	Beach seine	4.4
Global[b]	Hand line	1.8
Black Sea[c]	Purse seine	1.0
Global[b]	Gill net and trammel net	0.5
Global[b]	Pound nets, weirs	0.5

[a]*Zengin and Akyol (2009).*
[b]*Kelleher (2005).*
[c]*Şahin et al. (2008).*

TABLE 4 | Exported rapa whelk tonnages (NAFA, Bulgaria for the purposes of National report of Focal point of Bulgaria to AG FOMLR, BCS).

Type of Rapa whelk	2002	2003	2004	2005	2006	2007	2008	2009 (%)	2010
Frozen	284	343	302	269	351	436	324	146 (13)	167
Frozen sweetbread	656	792	698	620	811	1,005	747	326 (30)	386
Frozen meat	1,136	1,373	1,209	1,075	1,405	1,743	1,295	572 (52)	668
Frozen meat with shell	109	132	116	103	135	168	125	59 (5)	64
Exported	2,185	2,641	2,325	2,067	2,702	3,351	2,491	1,104 (–)	1,285

In 2009, the processed category percentage is given in brackets (adapted from Daskalov and Rätz, 2010, Table 4.7.3.1).

Romania, the whiting portion of reported demersal catches was 42% from 2000 to 2006 (Maximov and Staicu, 2008). To account for discarded whiting in Bulgaria, an additional 20% was conservatively assumed to account for this component and was applied to the reported catches of demersal taxa by industrial bottom trawls from 1950 to 1994 (as bottom trawling was banned after 1994).

Recreational and Subsistence Catches

Recreational fishing is understood here to mean fishing primarily for leisure or enjoyment, while subsistence fishing is understood to mean fishing for the primary purpose of providing protein for self- or family-consumption (recreational and subsistence fisheries are here assumed not to generate discards) While the two sectors are difficult to separate, it is generally understood that subsistence fishing over time evolved into recreational fishing, as incomes increased and food security was no longer a primary concern.

In Bulgaria, recreational fishing is most popular from April to June, and from September to November. It occurs in inshore waters and targets gobies (Gobiidae), grey mullets (Mugilidae), horse mackerel, bluefish, Atlantic bonito, turbot, Mediterranean horse mackerel and garfish (*Belone belone*). However, no data on the number of recreational fishers and/or their catch rates or amounts have been collected in Bulgaria.

There has been both recreational and subsistence fishing in Bulgaria for the 1950 to 2010 period. Since no data on this topic exists, estimated catch rates from the Black Sea coast of Turkey were used as a starting point (Ulman et al., 2013) to estimate recreational and subsistence catches, i.e., 0.258 $t \cdot fisher^{-1} \cdot year^{-1}$ in 1950 and 0.129 $t \cdot fisher^{-1} \cdot year^{-1}$ in 2010. To derive the number of recreational/subsistence fishers for Bulgaria, we assumed that in 1950, 2% of the coastal population fished either recreationally and/or for subsistence purposes, and this rate was linearly decreased to 0.95% of the coastal population by 2013 due to the declining availability of larger fish. To derive the coastal population, we started with total population data from Populstat (1950–1959; http://www.populstat.info) and The World Bank (1960–2013; www.data.worldbank.org) and then assumed that only people living within 20 km from the coast were involved in these fisheries. The coastal population data, however, was only available for 100 km from the coastline (CIESIN, 2012); therefore, we conservatively assumed 25% of the population within 100 km of the coast were actually living within 20 km of the coast. The coastal population data was also only available for the years 1990, 2000, and 2010. Therefore, we used the proportion of total population living 100 km from the coastline in 1990 and applied this from 1950 to 1989 and the proportion for 2010 was applied to 2011–2013. We then also interpolated the proportion between the 1990 and 2000 anchor point, as well as the 2000 and 2010 anchor point and applied this to the total population. We then reduced the catch rates used for Bulgaria by 50% from that used for Turkey in 1950, i.e., 0.129 $t \cdot fisher^{-1} \cdot year^{-1}$, and 20% in 2010, i.e., 0.103 t $fisher^{-1} \cdot year^{-1}$, since recreational fishing appeared to be less intensive than in Turkey (V. Raykov, pers. obs.); the interpolation was carried forward to 2013. We also made an adjustment to the catch in the early 1990s, as all fisheries were affected by a massive invasion of ctenophore in the Black Sea, which was deemed a "fisheries crisis" and resulted in a temporarily collapse of the pelagic fisheries (Daskalov, 2002). In light of this crisis, from 1989 to 1991, we decreased the recreational/subsistence catch rates by a further 75%. The newly adjusted 1991 value and the 1993 catch amount were then interpolated as there was a quick recovery period for small pelagics. In order to assign the estimated recreational/subsistence catches to the two sectors, we assumed that in 1950, 70% of these catches were taken for subsistence purposes, which was linearly decreased to 30% by 2010 (with decline carried forward to 2013), and the remaining catches were assigned to the recreational fishery (i.e., increasing from 30 to 70%). Sturgeon, Atlantic bonito, Atlantic mackerel, bluefish, turbot, Mediterranean horse mackerel, grey mullet and gobies were the main recreational/subsistence taxa for the 1950–2013 period (**Table 6**). We assumed that the overwhelming majority recreational/subsistence fishers operate from shore.

RESULTS

The reconstructed total catch for the marine fisheries of Bulgaria for 1950–2013 was estimated to be 1.7 times the (adjusted) data reported by FAO for the Black Sea fisheries of Bulgaria (**Figure 2A**). Total catches were only slightly higher than those reported by the FAO (after adjustment for likely over-reporting) on behalf of Bulgaria up until 1993 (just before the rapa whelk fishery commenced). Total catches increased from an annual average of around 5,800 $t \cdot year^{-1}$ in the 1950s (only slightly

TABLE 6 | Catch composition (%) for recreational and subsistence catches in Bulgaria from 1950 to 2013 (based on V. Raykov unpublished data).

Taxon	1950–1959	1960–1969	1970–1979	1980–1989	1990–1999	2000–2013
Atlantic bonito	35	30	5	1	1	2
Atlantic mackerel	25	22	5	2	–	–
Bluefish	15	20	10	2	1	2
Horse mackerel	3	3	50	60	50	35
Grey mullet	5	5	15	20	23	30
Goby	2	2	13	15	25	30
Turbot	10	15	1	–	–	1
Sturgeon	5	3	1	–	–	–

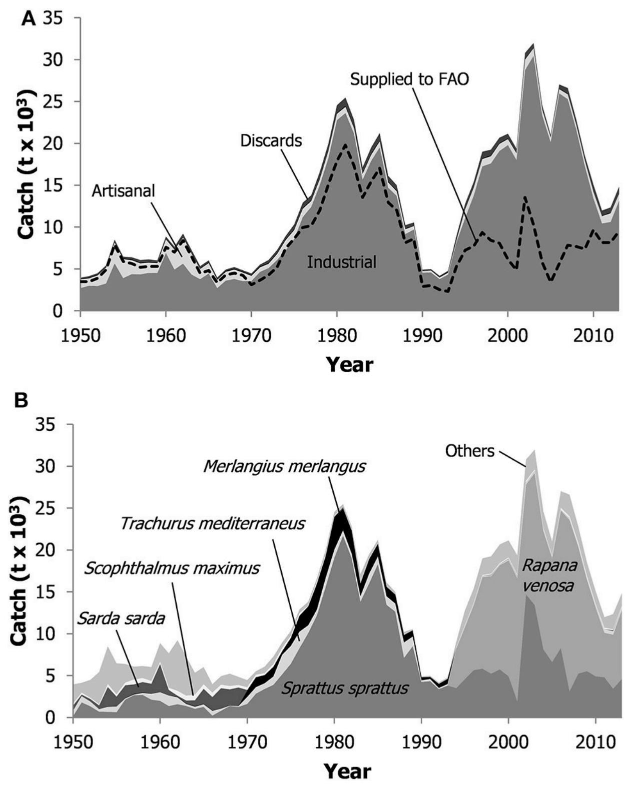

FIGURE 2 | Reconstructed total catches for Bulgaria in the Black Sea, 1959–2013. (A) Landings by fisheries sector + discards; officially reported data as reported by FAO (adjusted for duplicate reporting between 1964 and 1969) on behalf of Bulgaria are overlaid as line graph. Subsistence and recreational catches are included, but too small to be visible; **(B)** by major taxa. The category "others" consists of 38 additional, minor taxa. The significant reduction in fishing around 1990 resulted from the privatization of the fishing fleet from a state-owned industry.

higher than the 5,100 t·year^{-1} reported by the FAO on behalf of Bulgaria) to a peak of 25,500 t in 1981 (of which 19,800 t were reported; **Figure 2A**). Catches declined to a low in the early 1990s with an estimated 4,700 t·year^{-1} and then increased to a second peak of 32,000 t in 2003, before declining to an average of 13,600 t·year^{-1} at the end of the time period (2010–2013). Total reconstructed catch was on average only 1.2 times the adjusted reported data from 1950 to 1989, and increased to 1.9 times in the 1990s (**Figure 2A**), and were then, on average, 3.1 times for the rest of the time period (**Figure 2A**; Appendix Table 1 in Supplementary Material). The reconstructed total catch consisted of reported industrial landings (54%), unreported industrial landings (34%), industrial discards (3.3%), reported artisanal landings (6.1%), unreported artisanal landings (0.6%), artisanal discards (0.1%), subsistence catches (0.9%), and recreational catches (0.8%).

Total industrial catches increased from 4,100 t·year^{-1} in the 1950s, to a peak of 24,600 t in 1981. Catches then declined to a low of 3,900 t in 1992. Catches increased in 1994, due to the opening of the rapa whelk fishery, to a second peak of 31,000 t in 2003, before declining to an average of 12,600 t·year^{-1} at the end of the time period (2010–2013, **Figure 2A**). Industrial unreported catches were 41% of the reconstructed total industrial catch (37.5% unreported landings and 3.6% discards). Unreported industrial landings increased throughout the time period, from 3% of the industrial catch in the 1950s to an average of 20% and 17% in the 1970s and 1980s, respectively. Unreported industrial landings increased rapidly in the mid-1990s due to the rapa whelk fishery and averaged 58% in the 2000s.

The discards from the industrial and artisanal fisheries amounted to 3.3 and 0.1%, respectively, of the reconstructed total catches (**Figure 2A**). Discards increased from 210 t·year^{-1} in the 1950s to 780 t·year^{-1} from the late 1970s to late 1980s. Discards then decreased to 130 t·year^{-1} in the early 1990s but increased again to an average of 570 t·year^{-1} for the rest of the time period. The main discarded species were sprat (55%), rapa whelk (26%), whiting (8%), turbot (4%) and Mediterranean horse mackerel (1%).

Reconstructed total catches were mostly composed of sprat (47%), rapa whelk (28%), Mediterranean horse mackerel (4%), whiting (4%), Atlantic bonito (3%) and turbot (2%; **Figure 2B**, Appendix Table 2 in Supplementary Material).

DISCUSSION

The prospects for the marine fisheries in the Bulgarian EEZ are limited by the specific characteristics and production potential of the Black Sea ecosystem, especially by its limited shelf area. Another constraint is the limited biodiversity, which is under constant threat. There are only 134 fish species recorded in the Bulgarian section of the Black Sea (Stefanov, 2007). During 1960–1970, 26 of these fish species were commercially targeted, which decreased to 5 major target species by the 1980s (Zaitsev and Mamaev, 1997). Our results show three separate periods revealing distinctive catch compositions for the Bulgarian coastal waters: (1) from 1950 to 1969, the major species caught were sprat and Atlantic bonito; (2) from 1970 to the mid-1990s, catches were dominated by sprat; and (3) and from the mid-1990s onwards, catches were dominated by rapa whelk, still with a large contribution of sprat (**Figure 2B**).

The contribution of Bulgarian fisheries catches to total Black Sea catches is low, only slightly over 2% of Turkey's reconstructed total catch from 1950 to 2010 (Ulman et al., 2013). On the other hand, the reconstructed total catch for 1950 to 2013 was 67% higher than the data submitted by Bulgaria to the FAO. Most of the unreported catches were deemed to have occurred after 1990, since reporting and control measures were much stricter in the planned economy of the earlier period, as was the case for neighboring Ukraine (Ulman et al., 2015). Total commercial catches in the Black Sea significantly decreased after the collapse of the Black Sea pelagic fisheries at the end of the 1980s due to overfishing, a trophic cascade and the ctenophore invasion (Daskalov, 2002; Daskalov et al., 2007). The catch dynamics of the most important species in the Bulgarian Black Sea shelf zone illustrate a prominent decreasing trend beginning in the 1990s.

On a sectoral basis, the reconstructed total catch of Bulgaria was similar to that of the Turkish Black Sea (Ulman et al., 2013), both having a small artisanal catch component (7–15%) and a much higher industrial component (75–90%), although, as stated above, the catches of Turkey slightly under of Bulgaria. Bulgaria's reconstructed total catches differed from that of Romania, in terms of its much lower artisanal catch contribution (7% for Bulgaria compared with 66% for Romania) due to the highly popular traditional Romanian fishing method "crawling" (a stationary inshore net deployed in shallow waters) which was the main fishing technique used in Romania until the 1980s (Ulman et al., 2015). The reconstruction for Ukraine demonstrated that the national catch statistics included only commercial large-scale landings and failed to include small-scale, recreational or artisanal catches (Ulman et al., 2015), and at present are just over 6 times that of Bulgaria's marine fisheries.

The three distinct periods of catch, characterized by three distinct ecological shifts, can be distinguished in the catch composition of Bulgarian fisheries: during the first and second periods, the catch composition was similar to that of other Black Sea countries in terms of dominance by pelagic fishes, i.e., larger pelagics in the first period and small pelagics in the second. The third period differed from the trends in other Black Sea countries owing to a high rate of rapa whelk catches in Bulgaria. During this third period, targeted species were small pelagic fish (i.e., sprat, Mediterranean horse mackerel, anchovy) and demersal fishes (turbot, gobies, dogfish and most recently red mullet), while the rapa whelk gained the prominent role in the commercial fisheries. Although the introduction of the rapa whelk contributed to the fisheries economy after 1993, high disturbance to the benthic ecosystem from destructive fishing practices (dredging and beam trawling) resulted in negative ecological effects on benthic communities, especially on the Mediterranean mussel beds (Konsulova et al., 2001; Daskalov and Rätz, 2010), as also noticed in neighboring Ukrainian waters where macrobenthos biomass was reduced 20-fold due to intense trawling (Ulman et al., 2015). Taking into consideration the amount of illegal unreported rapa whelk taken from Bulgarian, Ukrainian (Ulman et al., 2015) and Turkish waters (Ulman et al., 2013), habitats and biodiversity are likely much more under threat from illegal mobile bottom-fishing gear than previously assumed.

Russia, Ukraine, Bulgaria, Romania, Turkey and Georgia all share the stocks of migratory Black Sea species. Cold-water small pelagics complete their entire life cycle in the Black Sea, seasonally migrate to reach wintering areas in the south and return to feeding and spawning areas in the following spring in the north (Ivanov and Beverton, 1985). In contrast, larger warm-water pelagics, such as bluefish, Atlantic mackerel and Atlantic bonito are highly migratory, i.e., move from the Sea of Marmara or to the Eastern Aegean Sea through the Bosphorus, then swim westwards and northward along the Bulgarian and Romanian coasts to reach their summer feeding grounds in the western and northwestern Black Sea (Demir, 1957; Türgan, 1959).

The northwest and western region of the Black Sea, with its large shallow continental shelf areas and high nutrient inputs by rivers provide highly productive waters, which are suitable for spawning and feeding. Sprat, a cold-water species, prefers the coldest habitable portions of the Black Sea, as the shoals move toward coastal waters in the northwest in winter and offshore in autumn (Ivanov and Beverton, 1985). Mediterranean horse mackerel are a warm-water migratory species which pass from south to north to spawn along the Bulgarian coast in spring, and from north to south for feeding in autumn. These two species also provide seasonal catches in the Bulgarian EEZ.

Turbot is the main commercial demersal fish species and is mainly found in the western and northwestern shelf of the Black Sea along the coasts of Bulgaria, Romania and Ukraine. Its migration along the shelf links shallow waters (in spring, for spawning) and deeper waters (in winter, for feeding). The previously discussed illegal turbot catch (by Turkish fishers) from Bulgarian and Romanian waters (Ulman et al., 2013; Banaru et al., 2015), points to a need of a common policy between member countries (Bulgaria and Romania), and cooperation with the remaining four non-EU bordering countries to recover turbot stocks to a previous larger-size and population levels.

In the Black Sea, the status of turbot and anchovy stocks were reported as "overexploited" and "in overexploitation," respectively, the Mediterranean horse mackerel stock was reported as "overexploited" and the dogfish population was considered "depleted" at the Black Sea scale. In contrast, Black Sea sprat stocks were deemed as sustainably exploited (GFCM, 2014).

This study illustrates some major deficiencies in the nationally (and hence internationally) reported fisheries data, such as the exclusion of some fisheries sectors, notably the absence of any catches stemming from subsistence and recreational fisheries. We feel that our estimates of total marine fisheries catch for Bulgaria provide a more accurate and comprehensive baseline, which should be further improved through targeted studies of the previously omitted sectors.

The European Union's Marine Strategy Framework Directive, 2008/56/EC (MSFD), the first legislative instrument dedicated to protecting biodiversity for all of Europe's regional seas by 2020, seeks to achieve a Good Environmental Status (GES) in European Seas by protecting the resource base. Although the MSFD seeks to foster the ecosystem approach, environmental protection and sustainable use, if all resource users are not made to fish sustainably, it is highly unlikely that the directive will work. In the Mediterranean and Black Sea basins, the regions in most peril from overexploitation are the Black Sea and the Eastern Mediterranean (Tsikliras et al., 2015). The main driver for the high rate of exploitation is likely the overcapacity of the Turkish large-scale commercial fishery. As long as rebuilding stocks to some optimal former level is not prioritized by all shared users of the Black Sea (Ulman, 2014), it will remain at its current degraded state yielding mainly low value species such as sprat and anchovy, and the future of the fisheries will remain questionable.

This reconstruction of marine fisheries catches for Bulgaria provides an improved baseline for its marine fisheries, to help understand the impact fisheries have had, and to help the implementation of management rules of the MSFD. Because of the many assumptions that were made, some parts of this reconstruction will be very uncertain, however. Thus, readers are welcome to send suggestions for corrections, updates and/or other improvements via www.seaaroundus.org, from which the detailed data underlying this reconstruction can also be downloaded.

AUTHOR CONTRIBUTIONS

The original methodology was decided upon by DZ. VR and GD provided some of the background data. ÇK, AU, KZ, and DZ helped calculate the methodology. ÇK, AU, KZ, VR, GD, DP, and DZ contributed to both the writing and editing of the paper.

ACKNOWLEDGMENTS

ÇK wishes to thank The Scientific and Technological Research Council of Turkey (TÜBİTAK) (2219 International Post-Doctoral Research Fellowship Programme); AU, KZ, DP, and DZ acknowledge support from the *Sea Around Us*, a scientific initiative funded by The Paul G. Allen Family Foundation.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fmars.2017.00053/full#supplementary-material

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.