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CAVIAR AND POLITICS: A RECONSTRUCTION OF RUSSIA'S MARINE FISHERIES IN THE BLACK SEA AND SEA OF AZOV FROM 1950 TO 2010

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ABSTRACT

The aim of the present study was to reconstruct total Russian fisheries catch in the Black Sea and Sea of Azov for the period 1950 to 2010. Using catches presented by FAO on behalf of the USSR and Russian Federation as a baseline, total removals were estimated by adding estimates of unreported commercial catches, discards at sea, and unreported recreational and subsistence catches. Estimates for 'ghost fishing' were also made, but not included in the final reconstructed catch. Total removals by Russia were estimated to be 1.57 times the landings presented by FAO (taking into account USSR-disaggregation), with unreported commercial catches, discards, recreational, and subsistence fisheries representing an additional 30.6 %, 24.7 %, 1.0%, and 0.7 %, respectively. Discards reached their peak in the 1970s and 1980s during a period of intense bottom trawling for sprat that partially contributed to the large-scale fisheries collapse in the 1990s. Since the dissolution of the former Soviet Union, unreported catches, including from recreational and subsistence fisheries, are on the rise as a result of poverty, lack of consistent fisheries policies, and the lucrative gains from poaching, especially for sturgeon.

INTRODUCTION

From the 16th to the 19th century, Russia aimed to expand over the steppes and secure control over the coasts of the Black Sea and Sea of Azov. Russia needed access to a warm water port, such as those of the Black Sea, for development of year-round trade and a strong navy that was not hampered by ice as occurs in its other territories, e.g. Murmansk in winter (Figes 2010). After numerous raids and conflicts over the territory with the stagnating Ottoman empire, Russia secured access to the seas, which was a factor enabling its rise as a major political power.

Due to the location of the Black Sea and Sea of Azov between the south of Eastern Europe and Asia Minor (see Figure 1), their coasts are a melting pot of different cultures, religions, and ethnicities, as numerous great empires and civilizations have occupied its coasts, e.g., Scythian nomads, Vikings, Mongols, Cossacks, etc. The first European civilization to inhabit the coasts were the Ancient Greeks, who colonized the land between 750 and 500 BC, building settlements that are now modern day cities, e.g. Kerch, Novorossiysk, Sochi, etc. (Vershinin 2014).

The legacy of the Greeks is also seen, allegedly at least, in the etymology of the 'Black Sea'. Prior to settlement, the Greeks named it *pontos axeinos*, or 'hostile, inhospitable place' either because it was difficult of navigate or its shores were inhabited by savage tribes (King 2004). The root word *axeinos*, meaning dark or unlit could have been the origin of the name, although upon settlement the Greeks changed its name to *pontos euxinos*, or kindly, hospitable sea (King 2004). Several other hypotheses exist. One is simply that the name referred to the dark appearance of the water during a storm, likely contributed by the high microalgae concentration in the sea. Another is that any metallic object submerged below 200m becomes completely black, as 87% of its water, or anything between 200m and 2000m is anoxic, meaning its deeper layers contain no oxygen, rather dissolved sulfuric acid (Vershinin 2014). This can also be seen by the presence of black sea shells, which over time made it to the beaches (Vershinin 2014).

Both the Black Sea and the Sea of Azov are highly unique bodies of water. The Black Sea, in addition to being the words largest stratified body of water (in reference to its large anoxic layer), is also the largest

landlocked basin in the world, with an area of 436,400 km^2 and a maximum depth of 2,212 m. In contrast to the depth of the Black Sea, the Sea of Azov is the shallowest sea in the world, which a maximum depth of only 14 m (Encyclopaedia Britannica 2005), and thus a vacation favorite for families with small children (O. Nikolenko[1], pers comm.).

As a result of the freshwater flowing into both seas from numerous rivers, along with their limited connection to the salty waters of the Mediterranean sea (via the Bosphorus Strait to the Sea of Marmara, which further connects to the Aegean Sea region of the Mediterranean via the strait of the Dardanelles), the waters have a low salinity. Furthermore, the Sea of Azov has an even lower salinity than the Black Sea, as it has no access of its own to the Mediterranean Sea; rather it is connected by the Strait of Kerch directly to the Black Sea. Appropriately, the seas resemble that of the Baltic Sea (Zeller et al. 2011), with many of the otherwise ubiquitous marine taxa – such as the cephalopods being absent, while other, freshwater and/or brackish water species tolerant of such conditions are endemic to the region (Lleonart 2008; Yankova *et al.* 2011). In addition to lowering the salinity of the Black Sea and Sea of Azov, rivers carry with them an exceptionally high content of biological matter, so that the low biodiversity is offset by high productivity and biomass of the species present (Vershinin 2014).

Figure 1. Map of the Exclusive Economic Zone (EEZ) and shelf waters (to 200 m depth) of the Russian Federation and neighboring countries in the Black Sea and Sea of Azov.

This abundance was what originally attracted the Ancient Greeks, who gave numerous accounts of the prolific stocks of sturgeon, mullet, salmon, and tuna in the Black Sea, noting that the waters of the Black Sea were more plentiful than those of their origin, the Eastern Mediterranean (Vershinin 2014). For centuries the Black Sea and Sea of Azov continued to be rich fishing grounds for the people who settled on their coasts.

[1] Personal communication: Oksana Nikolenko was born in the USSR and often travelled as a tourist to the Black Sea and Sea of Azov between the 1970s to the present day.

Fisheries

The Black Sea, jointly with the Azov Sea, has been a traditionally important fishing ground for the Russian Federation and former Soviet Union (Makoedov and Kožemяko 2007; Knudsen and Toje 2008), as its fishery supported thousands of families along its coast since the end of the Crimean war in 1856, when the Ottoman Empire signed a peace treaty which allowed Russian commerce and activities in the Black Sea. Prior to 1917, the Black Sea and Sea of Azov fisheries in Tsarist Russia were coastal and employed simple fishing methods (Knudsen and Toje 2008). With the Russian Revolution, fisheries technology and organization were likewise 'revolutionized', e.g. seiners were introduced in 1931, trawlers entered in the 1950s, and large factories were built along the coast of the Black Sea to process these catches (Knudsen and Toje 2008). The Black Sea began to serve as a base for the Soviet Union's large distant-water fleet, while simultaneously, state-organized fishing cooperatives (*rybkolkhozes*) fished within the Black Sea and Sea of Azov (Knudsen and Toje 2008).

Both the Black Sea and Sea of Azov were once highly productive ecosystems, with representative species at all trophic levels, and had especially large stocks of large pelagic predator species (Matishov *et al.* 2004; GFCM Secretariat 2012). However, as a result of overfishing top predators, starting in the 19th century through the 1950s and 1960s, the ecosystem shifted to one dominated by small pelagic fishes in the early 1970s (GFCM Secretariat 2012), and later, from 1989 on, to one dominated by gelatinous plankton (Shiganova 1998; Shiganova and Bulgakova 2000). In a typical case of fishing down the food web (Pauly *et al.* 1998), this trophic cascade was intertwined with the general decline in the health of the ecosystem as a result of a large-scale eutrophication from runoff from rivers that drain into the seas, carrying with them increased nutrient loads and oil pollution. Moreover, the introduction of the comb jelly (*Mnemiopsis leidi*) in the late 1980s devastated the fish stocks as the invasive species feeds on fish eggs and competed with small pelagic species for food (Knudsen and Toje 2008).

Although the fisheries did recover from the jelly comb invasion in the early 1990s, the fishery is still in a precarious state, as of the total of 184 fish species inhabiting the Black Sea and Sea of Azov, dozens appear currently on the IUCN list as endangered species (Yankova *et al.* 2011), while the number of commercially targeted fish species in the fisheries is less than 10 (STECF 2011). The final blow to the Russian fishery in the Black Sea was delivered by the collapse of the Soviet Union, manifested by the immediate cessation of state subsidies for the maintenance and investments in new vessels and technology. These factors resulted in most of the fleet being disbanded; effort declined to approximately one third of its previous level and the fishery has not recovered since (Knudsen and Toje 2008).

The role of fisheries in providing food security in Russia is potentially very important. However, Russian fisheries are currently unable to meet domestic demand for fish and seafood due to the decreasing catch and the growing export to the East Asia markets (which remain much more attractive for the fishing enterprises than delivery to the domestic market). The lack of balance between demand and actual supply has negative consequences for the future (the deficiency in healthy protein food). The negative balance is compensated by increasing imports (in big cities), and, where possible, by increased recreational and subsistence fishing or the unreported (black) catch market (FAO 2007).

The aim of this study was to reconstruct total Russian fisheries catch in the Black Sea for the period 1950 to 2010 (and excluding Ukrainian and Georgian catches, previously included in 'Soviet' catches). As total fisheries removals are often considerably larger than the officially reported data (Wielgus *et al.* 2010; Zeller *et al.* 2011), we hope that this study will highlight the magnitude of unaccounted fisheries removals, assist policy makers in setting more sustainable catch quotas, and inform the public on actual levels of fisheries extraction in the region.

METHODS

The Food and Agriculture Organization of the United Nations (FAO) maintains a publicly accessible database describing reported landings by country, species, major fishing area, and year for the period 1950-2010 (www.fao.org/fishery/statistics/en). We refer to these landings as the 'baseline catch' on top of which we estimated unreported portions of catch for the Black Sea and Sea of Azov. As the aim of this

study was to determine the total removals (as opposed to baseline catch), several components were added to the baseline catch: i) unreported commercial catch; ii) discards; iii) recreational and subsistence catches; and iv) escape mortality (or 'ghost fishing'). Note that item (iv) is presented here only for its own sake, i.e., it is not part of the other catch reconstructions performed by the *Sea Around Us* (see e.g., Zeller et al. 2011), and hence is not taken into account in data comparisons or the global database maintained by the *Sea Around Us*.

For this analysis, we reconstructed catches for the present day EEZ boundaries of the Russian Federation, assuming these boundaries trace back to 1950. As the reconstruction covers only data to 2010, we did not adjust for the 2014 annexation of the Crimea by Russia, although we comment on some of its implications near the end of this contribution.

Baseline landings

The former Soviet Union and Russian Federation reported landings for the Black Sea and Sea of Azov (Major Fishing Area 37, subarea 4.2 and 4.3) to FAO from 1950 – 2010. The former Soviet Union stopped reporting in 1987 (on behalf of modern day Ukraine, Georgia, and the Russian Federation), after which the Russian Federation took over as the reporting entity. Thus, FAO landings for the 1950 to 1988 period are aggregate and do not differentiate between the three former USSR-republics, such that it was necessary to extract only Russian catches from this aggregate sum. Since the catch reconstructions for Ukraine (Ulman *et al.* 2014) and Georgia (Ulman and Zeller 2014) have already been completed, we subtracted their reported baseline catches from the USSR FAO data for 1950 to 1987 to generate the approximated Russian reported baseline data.

The landings for Ukraine and Georgia were totalled by year and taxon, and then the appropriate links were created by year to standard FAO taxonomic names, including the 'marine fishes nei' category, which denotes miscellaneous marine fishes (MMF). This category grew smaller over time, and since landings for Georgia and Ukraine were taken from national, independent sources, for some years predominantly in the later time period, MMF was negative. For those years, this category was compensated by re-allocating catches from a species with high landings, most often from Black and Caspian Sea sprat (*Clupeonella cultriventris*). From 1988 to 2010, FAO landings for the Russian Federation were used (Figure 2).

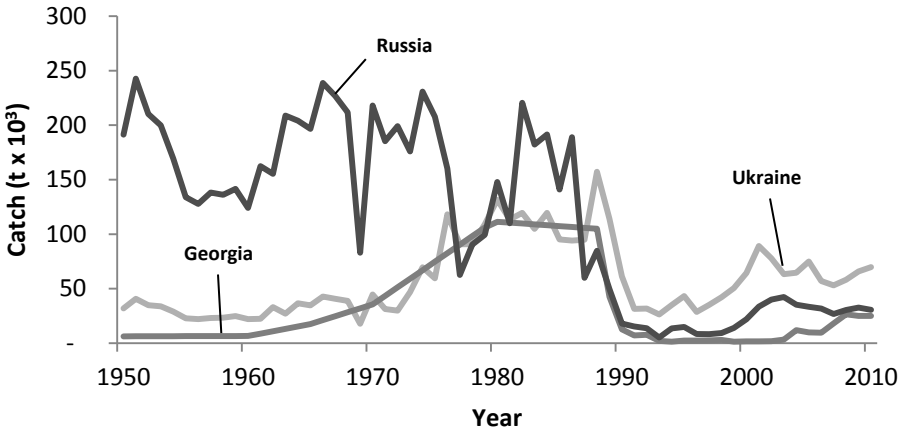

Figure 2. Re-allocated 'baseline catch' of former Soviet Union countries that reported landings to FAO for the Black Sea and Sea of Azov

Miscellaneous marine fishes (MMF) disaggregation

Within the baseline landings attributed to Russia, some years had a large proportion of catch with no designation into what species were caught, i.e., miscellaneous marine fishes (MMF). Thus, we disaggregated these catches based on best-guess estimates of what species were likely included in this

lump sum. The species designation was derived from (Ulman *et al.* 2014), as during this time Ukraine and Russia were not only neighbors, but also governed within the same system, and thus assumed to have similar reporting dynamics. Furthermore, minor changes were made to reflect country specific differences (Table 1).

Table 1. Species disaggregation of FAO's 'marine fishes nei' category (1950 – 1987).

Common name	Scientific name	%
Big-scale sand smelt	*Atherina boyeri*	63
Turbot	*Scophthalmus maximus*	13
Shi drum	*Umbrina cirrosa*	9
Gurnards	*Trigla*	6
Garfish	*Belone belone*	5
Chub mackerel	*Scomber japonicus*	1
Common shrimp	*Crangon crangon*	1
Swordfish	*Xiphias gladius*	1
Bluefish	*Pomatomus saltatrix*	1

These changes included adjusting the taxonomic names of silversides and decapoda as was presented in (Ulman *et al.* 2014). We changed the designation of silversides to big-scale sand smelt (*Atherina boyeri*), as it appears to be the most commonly caught silverside by Russia. Similarly, we adjusted decapoda to common shrimp (*Crangon crangon*) for the same reason. The only change made with respect to the composition of catch was the addition of 1% catches of bluefish (*Pomatomus saltatrix*) as there were no landings for this species in the early years, while it is known that this was a species commonly landed. This increase in 1% for bluefish was offset by a decline from 7% to 6% allocation for gurnard (*Trigla*). For the years after the dissolution of the Soviet Union between 1988 and 2010 we disaggregated catch as a proportion of landed catch for that year.

Commercial fisheries, industrial and artisanal

Two distinctive gears were employed for fishing within the Black Sea and Sea of Azov: middle-sized vessels (25 to 30 m) working with active gear, i.e., purse seine and trawl, and coastal brigades, typically belonging to cooperatives, that fished in small boats (4 to 5 m) using passive gears, e.g., weirs (Knudsen and Toje 2008). Based on the general definitions of small-scale (artisanal) versus large-scale (industrial) gears (Martín 2012), the former would be considered industrial, while the latter would be defined as artisanal. However, the Russian concept of artisanal fisheries was never well established, and in fact to this day "there is no legally adopted term for artisanal fishery" (FAO 2007). Additionally, while in most countries the infrastructure and level of catch reporting by the artisanal fleet is usually minimal, cooperatives were largely linked with the government, regulated and managed centrally as well as given certain production quotas to fulfill (A. Zanevsky[2], pers. comm.). Thus, we believe that the reported commercial catch encompassed landings by both the industrial and artisanal fleet, although the extent to which each fleet contributes to landings is not well-documented.

In order to separate the catch of the artisanal fleet from the industrial fleet, we used the species caught as a guideline (Appendix 1). We obtained a list of commonly targeted species by the artisanal fleet along with common by-catch species from the artisanal fishery by decade (Ulman *et al.* 2014), which was compiled from expert assessments of the region. This list included those species caught by the coastal gillnet gear, which is a common artisanal gear used by all Black Sea countries, both to catch demersal fish species, e.g., turbot, flounder (*Platichthys flesus*), dogfish (*Squalus acanthias*), gobies (Gobiidae), sturgeon (Acipenseriformes), etc., and pelagic fish, e.g. Danube shad (*Alosa pontica*), mullet (*Mugilidae)*, bonito

[2] Personal communication: Andrew Zanevsky was born in the USSR and resided there until 1991.

(*Sarda sarda*), bluefish, etc. (Birkun Jr 2002; GFCM 2012). We considered those species targeted by the artisanal fleet and those caught as bycatch separately.

The most common industrial target species are few in variety, i.e., sprat and anchovy (*Engraulis encrasicolus).* Additionally, we included rapa whelk (*Rapana venosa*) as a specie commonly caught by the industrial fleet, despite the fact that it is mostly reputed to be a target species for artisanal operations. This is because rapa whelk is generally caught by bottom dredge, which, as gear that is actively dragged or moved across the seafloor, is defined as an industrial gear (Martín 2012). Hence, many species fell into three basic categories: Artisanal target, artisanal by-catch, and industrial target. All other species were placed in a separate fourth category, labelled 'Other'.

Finally, we applied these categories to the FAO reported landings in an effort to allocate what can be considered industrial and artisanal catch. More specifically, artisanal catch included 100% of the catch of artisanal target species, 75% of the catch of common by-catch in the artisanal fishery, and 10% of the landings of 'other' species. The remainder of what was not considered artisanal was labelled industrial, notably, 100% of catch of industrial target species, 25% of catch of common by-catch species in the artisanal fishery, and 90% of catch of 'other' species.

Unreported commercial catches

The nature of unreported catches from the Black Sea and Sea of Azov differed depending on the context within which it took place, i.e. the socialist USSR or the liberalized Russian Federation.

Soviet Era

For many years, the planned Soviet economy was considered all-encompassing, mostly aided by mass propaganda and lack of information exchange. However, in the later years of the Soviet Union, as its economy was weakening, information about the Soviet 'second economy,' or shadow (black market) economy, was brought to the surface. This economy included everything that was unplanned, unregulated, unreported, privatized, and/or illegal, and was widespread in nearly all sectors, especially food, construction, repairs, transport, medical services, among others (Sampson 1987). In truth, the government was not blind to this economy, and as a Soviet official expressed, "the government knows exactly who is dealing in what – arrests are made only when there is some larger political reason" (O'Hearn 1980).

According to a public opinion survey in 1992, the main reason given for the wide presence of illegal incomes was the pervasive shortages of goods and services and the need to break the law in order to obtain them (31%), followed by loose administrative controls and record-keeping (16%), dishonesty of officials (14%), ineffective law enforcement (11%), and imperfect laws and lenient punishment for black-marketeering (11%) (Rutgaizer 1992). Indeed, officials were often complicit, as bribe expenses usually averaged 15 – 20% of illicit earnings (Sampson 1987). Collective attitudes such as "everyone is doing it," and that the elite are getting their own special fringe benefits, contributed to making such activities natural and commonplace in Soviet culture (Sampson 1987).

With respect to food, Soviet émigré interviews indicate that 30% of all home food was purchased via the private or second market (Sampson 1987), which corresponds to unreported food at 43% of reported amounts. This offers a rough guideline as to the extent of this secondary market, complemented by poaching statistics that O'Hearn (1980) obtained from the Soviet press, which generally reported such data for the sake of exemplifying an environmental problem, rather an economic one. In the case of fishing, by 1980 there was, according to a Soviet observer, a "painfully large number" of poachers who supplement the parallel market for personal gain (O'Hearn 1980), mostly due to black market prices ranging from four to 10 times higher than official state purchasing prices as well as small fines for poaching (O'Hearn 1980).

The number of poachers increased dramatically from the 1960s to the 1970s, and was on the rise during the writing of the report in 1980 (O'Hearn 1980). In the first eight months of 1975, there were 2,550 apprehensions in the Volga area, Saratov oblast (a region not far from the Black Sea and Sea of Azov), mostly from six fishing collectives, where fishers would take their catches home to allocate some for

private sale and then hand in the rest (O'Hearn 1980). Apparently, private boats used for poaching numbered 1.8 million in the entire Soviet Union (O'Hearn 1980).

Annual private catch was assessed at 33% of total commercial catch by O'Hearn (1980); although, it was estimated in some regions about ten times higher, as is seen by an official report from the Kuibyshev reservoir (central region) that estimated unregulated catch at 267% of reported catch. Specific data for the Black Sea and Sea of Azov were not available, but it is known that the shadow economy was more developed in the periphery of the country, rather than the central regions of the USSR (Sampson 1987). Since the Black Sea and Sea of Azov are on the periphery and since higher food prices on the private market are consistent across the entire Soviet Union, we extended the estimate of 33% of unreported catches as a percentage of reported catch, or 25% of total catch, to our region of study during the Soviet years. We consider this estimate to be conservative, especially in the later years of the Soviet period.

Post-Soviet Era

With the dissolution of the Soviet Union, under-reporting magnified for the Russian Federation (FAO 2007; Knudsen and Toje 2008; Raykov *et al.* 2011; GFCM Secretariat 2012) as well as other former Soviet Union countries (Ulman *et al.* 2014; Ulman and Zeller 2014). Both legal fishers and poachers were involved in unregulated activities. According to a deputy director, "state enterprises bring less than 15 – 16% of their catch to legal landings sites, and reportedly sell the rest to illegal processing and trade channels" (Vaisman and Raymakers 2001). This corresponds to unreported catch at 84 – 85% of total catch, or 525 – 567% of landings. It was unclear whether this referred to sturgeon catches, or all catches, so as a conservative representation we assumed unreported catches doubled from 25% of catch in 1986 to 50% of catch by 1991 , or 100% of landings.

Furthermore, there is evidence that under-reporting increased even more in the 2000s. Of all the countries fishing in the Black Sea, the quality of reporting was considered poorest for the Russian Federation and Georgia, especially from 2001 to 2008 (Raykov *et al.* 2011). Specifically for the Russian Federation, data have been missing since 2005 (Raykov *et al.* 2011).

There are several reasons for this. First, less investment was directed towards an already ageing fishing fleet, whereby capital investment, qualified specialists in navigation, and fishing and processing technologies all declined by over 30% in 2000 compared to 1990 (FAO 2007). As the fleet continued to age, this corresponded to a strong decline in CPUE, e.g., three to four times lower than the CPUE for the most modern vessels, which "leads to their involvement in IUU catch" (FAO 2007).

Second, several experiments of the federal government in quota allocation via auctions in 2001 to 2003 caused high quota prices and thus "enormously stimulated the IUU catch used by companies to compensate for the high prices of quotas at the auctions" (FAO 2007). With low CPUE, and higher prices, many fishers are forced to engage in illicit activities.

In summary, we assumed unreported catches were zero from 1950 – 1953, covering the end of Stalin's rule, increasing to 33% by 1972, which corresponds to when the number of poachers increased dramatically from previous levels (O'Hearn 1980). We maintained unreported catch at 33% of landings until 1986, interpolated to 100% for the period 1991 – 2000, thereafter increasing once more to 150% of landings for the 2005 – 2010 time period. Species were assumed to have the same proportion of unregulated catch as landings, as well as additional unreported quantities for turbot and sturgeon, two commercially valuable species, whose catches were estimated in the following section.

<u>Poaching of commercially valuable species</u>

In addition to unreported catches by legal fishers, "uncontrolled large-scale poaching in the Russian part of the Black and Azov Seas has reached unprecedented levels" (Öztürk 2013). In particular, this will be considered separately for two commercially valuable species, i.e., sturgeon and turbot.

Sturgeon

Black caviar, the unfertilized roe of sturgeon, is considered a gourmet delicacy by the Russian people, highly sought after in worldwide markets (Catarci 2004). The Caspian Sea and the Sea of Azov contain more than 90% of the world's stock of sturgeon as of 1997, and, in 1993, to protect these stocks from

exploitation, the President of Russia adopted measures to protect the stocks from poachers, decreeing high fines in the order of several hundred times the minimum monthly salary (Vaĭsman 1997). However, these measures were not effective. According to the number of illegal fishing nets observed by helicopter surveys, estimates of illegal catch in the Sea of Azov are 18.8 to 29.4 times higher than official 1998 catch, and this is only considering illegal nets, while other gears used by poachers were not considered, such as bottom lines and hooks (Vaisman and Raymakers 2001). Discrepancies between scientific and fisheries data in the 1970s and 1990s are likely caused by underestimation of catches due to unreported illegal sturgeon fishing (Vaisman and Raymakers 2001).

In the 1950s, we assumed unreported catch was 20% of reported landings, (as caviar may have been reported, but perhaps the weight of sturgeon itself was not), then unreported catch increased gradually to reach 100% in 1985 and thereafter grew to 500% in 1994 as the market becomes liberalized and sturgeon became more rare and prices increased. Unreported catch was then increased to the lower bound of our 1998 anchor point, or 1880% of reported landings, and thereafter assumed to remain constant until 2010. Additionally, reported catches by 2007 and 2008 declined to 1 tonne, and in 2009 and 2010 there were no catches reported. In order to account for unreported catches in the late 2000s, we very conservatively added 0.5 t of 'reported' catches in 2009 and 0.25 t of 'reported' catches in 2010 (which were counted as unreported in the data), and then applied the percentage of unreported catch as outlined above.

Turbot

Turbot is also a highly prized species and can be illegally targeted using bottom (turbot) gillnets or can be unlawfully kept as by-catch in gears such as trawls, longlines and purse seines (Radu *et al.* 2011). Furthermore, "in all countries of the region, the non-reported catch of turbot exceeds many times the official catch," (Radu *et al.* 2011). In order to estimate unreported catch we first observed the level of reported catches.

There were no 'turbot' landings in the FAO data for the USSR or the Russian Federation, although turbot was a common target species. We already corrected for this between 1950 – 1987 when the miscellaneous marine fishes category was disaggregated, although in the years 1962, 1973, and 1978 – 1987 the MMF category was zero and thus, there were also no turbot catches allocated using this process. We did not make adjustments for 1962 and 1973, as these may simply have been years with small catches of turbot. However for the years 1978 – 1987, there was direct evidence of turbot fishing. Specifically, there was overfishing of turbot in the early 1980s which led to a sharp decline in turbot stock and a prohibition on turbot fishing from 1986 to 1996 (Parliamentary Assembly 2002).

Hence, from 1950 to 1977 when some turbot catches were present, we used the same method to estimate unreported catch previously described for all the other species. By 1977, reported catches were at 478 t and the additional unreported catch was 159 t (or 33% of reported catch) resulting in total catch of 637 t. We assumed this 1977 level of catch remained constant at 637 t until 1983, which would represent the overfishing of the early 1980s. To depict the decline in stock, we assumed the catch declining by half from 1983 to 1985.

While there was a prohibition on turbot fishing in the Russian Federation from 1986 to 1996, there is evidence that unregulated catch was still being taken. Specifically, (Radu *et al.* 2011) indicated that unreported catches of turbot for all Black Sea countries (except Turkey) were equivalent to the reported catches of Turkey from 1995 to 2008, as turbot fishing was legal in Turkey. Thus, we divided the equivalent of Turkish reported landings among the five other maritime countries of the region, i.e. Ukraine, Russian Federation, Georgia, Bulgaria, and Romania, in proportion to their reported landings of all species from 1950 – 2010. We interpolated catch from its 1985 level to 624.5 t in 1995, calculated as a proportion of Turkish reported landings and thereafter followed the trend of Turkish reported catch from 1996 to 2010.

Discards

Discards are catches that are dumped at sea, usually dead, rather than retained and landed. Since discards are not reported in the fisheries of the Black Sea and Sea of Azov, we estimated these catches by (i) first, obtaining representative discard rates by fishing gear, (ii) determining commonly discarded species by

fishing gear, and (iii) linking fishing gear utilized from 1950 to 2010 with species caught in artisanal and industrial operations.

(i) Discard rates by fishing gear

Common gears in industrial operations of the Black Sea and Sea of Azov are purse seine, mid-water trawl, bottom-trawl, and bottom dredge, while a common gear for artisanal coastal fishers is the coastal encircling net (gillnet), a passive gear.

According to global studies on discards, the average discard rates for the Mediterranean and Black Sea trawls were between 45 to 50% (Kelleher 2005). We assumed the lower bound of 45% for this analysis. The discard rate for mid-water trawlers is 5.1% (Kelleher 2005). For purse-seine, Kelleher (2005) stated that the anchovy purse-seine fishery had negligible to zero discards since most fish are used as fishmeal, while Ulman *et al.* (2014) presented evidence that the discard rate is approximately 5%, mostly of small-sized sprat. Thus, for this paper, we assumed an average of Kelleher and Ulman's estimates of discards for the purse seine at 2.5% of catch. The sea snail dredge fishery has a discard rate of 11.5% and the coastal encircling net (gillnet) has a discard rate of 7.4% (Kelleher 2005). For a summary of common gears utilized in the Black Sea region and their associated discard rates, please refer to Table 2.

Table 2. Discard rates by gear in the Black Sea and Sea of Azov

Gear	**Discard rate (%)[1]**	**Discard rate (%)[2]**	**Source**
Bottom trawl	45 - 50	81.8	Kelleher 2005
Mid-water trawl	5.1	5.4	Kelleher 2005
Purse seine	2.5	2.6	Ulman et al 2014
Snail dredge	11.5	13.0	Kelleher 2005
Coastal encircling gillnets	7.4	8.0	Kelleher 2005

[1] *Discard rate as a percentage of total catch*
[2] *Discard rate as a percentage of retained catch*

(ii) Discarded taxon by fishing gear

While there are very few studies of discarded species in the Black Sea and Sea of Azov, various sources state that whiting (*Merlangius merlangus*) is a by-caught species that is commonly discarded in the Black Sea (Birkun Jr 2002; STECF 2011). According to (Radu *et al.* 2011), whiting is rarely targeted by industrial operations, but is a very common by-catch in trawl fisheries for other species or non-selective fixed-nets in coastal sea areas. Thus, we assumed that whiting was a discarded species in all fisheries. As an aside, note that there are numerous studies on the by-catch and discards of cetaceans (e.g., Birkun Jr 2002), however the *Sea Around Us* does not include marine mammals in their catch estimates and thus we did not consider these studies.

Piked dogfish, rays (Dasyatidae) and horse mackerel (*Trachurus* spp.) are common taxa caught in purse seine gears and a certain proportion of these are assumed to be discarded (STECF 2011). Additionally, sprat is often caught with anchovy and discarded due to its low economic value (Ulman *et al.* 2014). Thus, we assumed half of the tonnage of discarded catch is sprat, as it is often found mixed with anchovy (Ulman and Zeller 2014). Sprat discards were divided in proportion to the total landings of Black and Caspian Sea sprat (*Clupeonella cultriventris*) and European sprat (*Sprattus sprattus*), i.e., 85% and 15%. The remaining 50% of the discards were divided evenly between dogfish, rays, horse mackerel, and whiting.

We assumed that the discards for the mid-water trawl have a similar taxonomic composition to purse seine. However, due to lack of more specific knowledge, we assumed the 5.1% was divided equally among

piked dogfish, rays, horse mackerel, whiting, and sprat. Of the 20% of discarded catch designated as sprat, we further divided it into Black and Caspian Sea sprat and European sprat based on proportionality to total landings as for the purse seine gear. During the bottom-trawl period, we assumed a similar taxonomic composition of discards to that used in (Ulman *et al.* 2014): 20% spiny dogfish, 20% rays, 20% skates (Rajidae), 10% damaged or juvenile sprat, 10% whiting, 5% gurnards (*Trigla*), 5% scorpionfishes (*Scorpaena* spp.), 5% miscellaneous marine crustaceans, and 5% marine fishes nei.

For the snail dredge, we assumed an equal distribution between five taxonomic groups including miscellaneous marine crustaceans, miscellaneous marine fishes, and whiting, along with the demersal gurnards and scorpionfishes. For other industrial species, we applied an identical taxonomic distribution as for gears targeting sprat, while for artisanal catch an equal proportion of whiting, 'marine fishes nei', and 'miscellaneous marine crustaceans' was assumed.

(iii) Target species of various fishing gear

Major target species of industrial operations are anchovy, rapa whelk, and sprat. Anchovy is typically targeted via purse seine and mid-water trawl (GFCM Secretariat 2012), and we assumed an equal proportion of anchovy catch was caught with purse seine as with mid-water trawl. Therefore, we averaged the discard rate for purse seine (2.5% of catch) and mid-water trawl (5.1% of catch) to estimate the discard rate for all operations targeting anchovy at 3.8% of catch for all years of the present study. Rapa whelk is targeted with bottom dredges (GFCM Secretariat 2012) so we assumed a discard rate of 11.5% of catch, or discarded species at 13% the tonnage of rapa whelk landed. Sprat is targeted with mid-water and bottom trawls (GFCM Secretariat 2012), yet we did not assume a constant discard rate from 1950 to 2010 due to the historical evolution of gear utilized to target sprat.

Bottom trawling was outlawed as far back as the beginning of the 20th century because of its negative impact on the environment; however in the mid-1970s all Black Sea states resumed this type of fishing, re-labelled as 'near-bottom trawling', in order to target concentrations of sprat residing on the bottom layers of the shelf (Zaitsev and Mamaev 1997). Indeed, the volume of sprat catch increased as much as 15 – 20 times in the 1980s compared to the 1960s (Eremeev and Zuyev 2007), but the negative consequences of this far outweighed the increased catch (Zaitsev and Mamaev 1997).

Sprat fishing operations changed in the 1990s from bottom to pelagic trawling. However, the situation did not change much "since sprat formed benthic assemblages in the near bottom" and effective fishing control was lacking (Eremeev and Zuyev 2007). By 1997, the use of bottom trawls was prohibited (Zaitsev and Mamaev 1997) and has remained so except for Turkey, which uses bottom trawls to target turbot (GFCM Secretariat 2012).

Therefore, for sprat we assumed a discard rate of 5.1% of catch from 1950 to 1974 when vessels were employing mid-water trawls. This dramatically increased to 45% when the fleet began using bottom-trawling in 1975 and remained at this level until 1992. Thereafter, we interpolated the discard rate back to 5.1% by 1994, as there was evidence of this gear being phased out less swiftly than it was adopted. From 1994 to 2010 the discard rate remained constant at 5.1%.

Lastly, we considered all other industrial catch of other species beyond the major target species. This included the 25% of catch of species commonly caught as by-catch in the artisanal fishery along with the 90% of 'other' species not defined as major target species (Appendix 1). To obtain a discard rate for catch of the latter species, we took the weighted average of the discard rate for all other target species by year.

For all artisanal catches we assumed a discard rate of 7.4% of catch, which is consistent with the fact that on the Mediterranean and Black sea most artisanal fisheries discard less than 15% of catch (Kelleher 2005). Table 3 gives a summary of target species, gear used, and commonly discarded species.

Table 3. Gear utilized to target industrial and artisanal species in the Black and Azov Sea fisheries; commonly discarded species during operations

Fishery	Target species	Gear used	Discarded species
Industrial	Anchovy	Mid-water trawl and purse seine	Sprat, whiting, piked dogfish, rays, horse mackerel
	Sprat	Mid-water trawl; bottom trawl from 1970s to 1990s	Sprat, whiting, piked dogfish, rays, skates, miscellaneous marine crustaceans, gurnard, scorpionfishes, horse mackerel, marine fishes not identified
	Sea snail	Dredge	Miscellaneous marine crustaceans, gurnards, scorpionfishes, miscellaneous marine fishes, whiting
	Other industrial catch	Purse seine, mid-water trawl, bottom trawl, snail dredge	Same as for sprat
Artisanal	All artisanal catch	Coastal encircling gillnets and other passive gears	Whiting, marine fishes not identified, miscellaneous marine crustaceans

Subsistence and recreational fisheries

Subsistence and recreational fisheries are "difficult to distinguish... particularly as the two are governed by the same fishing rules" in Russia (FAO 2007). Both are independent activities, employing simple gears, such as handline, hand trawl, or fishing by hand. None of the catches taken by either of these two sectors are included in officially reported data.

Human population

The Black Sea coastal zone is densely populated; in 1997 there were 1,159,000 people living on the Russian Federation coastal zone, 48% of whom lived in the big cities of Sochi, Anapa, Novorissisk, Gelendgik, and Tuapse (Zaitsev and Mamaev 1997). In 1997, the total population living on the Russian coast of the Black Sea was 0.8% of the total Russian population. We compiled the population figures from 1950 to 2001 using Populstat (www.populstat.info/Europe/russiac.htm) and from 2002 to 2010 using Russtat (www.gks.ru/bgd/regl/b13_12/IssWWW.exe/stg/d01/5-01.htm), interpolating between any missing years, and assumed the proportion of people living on the Black Sea remained constant over the entire time period. We also assumed the proportion of urban residents, 48%, and rural residents, 52%, remained constant.

Further, we included the high number of tourists that visit the Black Sea since Soviet times; Zaitsev and Mamaev (1997) stated that in the Black Sea as a whole, there was a permanent population of 16 million residents with 4 million visitors during the summer tourist season, corresponding to a tourist population of 25% of permanent population, albeit for only part of the year. We assumed this figure was representative of the post-Soviet times, when tourism greatly increased. Prior to this, the Black Sea also had its fair share of tourists, as it was a common destination for Soviet workers who were allocated tourist trips (*putevka*) by their employers (Knudsen and Toje 2008). We assumed the representative tourist population was 10% during Soviet times, as people were poorer and only a lucky few were given the chance to go on vacation. We interpolated between 10% in 1987 and 25% in 1992 for the years in transition (Figure 3).

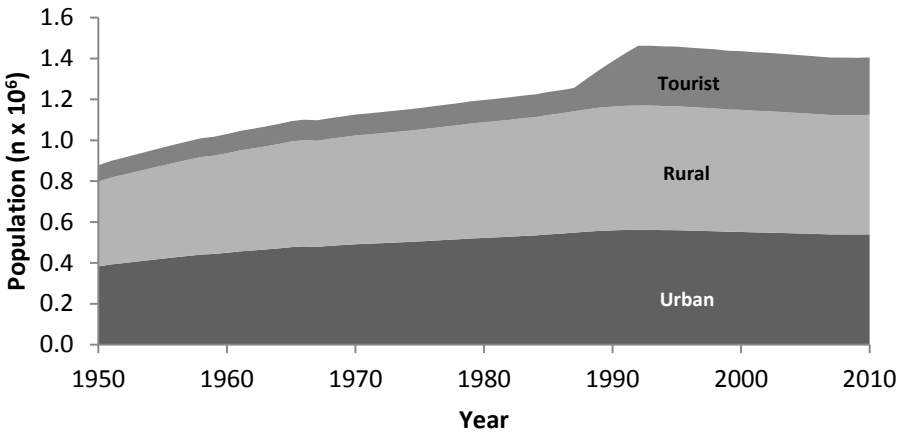

Figure 3. Russian coastal population on the Black Sea and Sea of Azov

Recreational catches

Recreational fishing is very well developed in Russia (FAO 2007) and a common activity in both the Sea of Azov and the Black Sea (O. Nikolenko, pers. comm.). As was seen in an episode about the Sea of Azov on a Russian recreational fishing show, *Подсекай, Семёныч!* (www.good-fishing.net) on a landstrip of 20 meters, about 20 fishers could be seen; men and women from very young to very old. According to the narrator, "everyone does it, both residents and tourists" and that "regardless of how sophisticated the gear is, everyone comes home with a catch" (translated from Russian). The same show for the Black Sea describes how fishing could be done year-round and was common, as a sports fishery exists there. We assumed, therefore, that 3% of both tourists and urban residents participated in the recreational fisheries. For simplicity's sake, we excluded residents from 'rural' areas, assuming they may be more likely to participate in subsistence activities. Thus, our differentiation between recreational and subsistence fishing is simple and based on residence location only.

Since limited estimates of catch were available on the recreational fishery in the Russian Federation, we assumed a similar CPUE and species disaggregation as that for the recreational fisheries of the Ukraine (Ulman *et al.* 2014) where expert assessment indicated a CPUE of 49 kg·fisher^{-1}·year^{-1} in the 2000s. We utilized this rate from 1994 to 2010, assumed a rate 50% higher for the years 1950 to 1975 (73.5 kg·fisher^{-1}·year^{-1}), and interpolated in between. An adjustment was made to account for the comb jelly invasion by estimating the adjusted catch rate at 75% of the calculated rate from 1988 to 1991, and then interpolated to its 1994 catch rate of 49 kg·fisher^{-1}·year^{-1}.

We believe that this CPUE time series is rather conservative, as is evidenced in other sources. For example, on the recreational fishing show (Sea of Azov), it was stated that in two hours one can catch nearly one full bucket of gobies (*Gobius melanostomus*) during the goby season using a simple baited line, which corresponds to a CPUE of 2.5 kg·hour^{-1}. Another simple fishing method used is catching by hand; a fisher caught nearly one goby every couple of minutes, and in 20 minutes there was nearly a full bucket, which corresponds to a CPUE of 15 kg·hour^{-1}. Thus, the CPUE of 49 kg·fisher^{-1}·year^{-1} would imply a total fishing time of about 20 hours·fisher^{-1}·year^{-1} for baited hand line or 3 hrs·fisher^{-1}·year^{-1} by hand, which is conservative.

Likewise, all species mentioned in personal communications and YouTube videos were consistent with the detailed species distribution in Ulman *et al.* (2014). Notably, one of the major recreational target species on the Black Sea was the horse mackerel (*Trachurus mediterraneus*). Finally, Oksana Nikolenko (pers. comm.), who visited the Black Sea as a tourist often from the 1970s to the 2000s mentioned diving for mussels, a common target species for recreational fishers cited in (Ulman *et al.* 2014).

Subsistence catches

In the former Soviet Union, although there were major food shortages, there was a certain level of food security such that no one was ever truly hungry (O. Nikolenko, pers. comm.). Along the coast of the Black Sea, much like everywhere else in the country, large cafeterias were set up to ensure this (Nelson and Silva 2014). However, the quality of food in such cafeterias was considered "terrible" (Nelson and Silva 2014), so many people still cooked, after having waited in lines for hours to purchase vegetables and other foods at exorbitant prices (A. Zanevsky, pers. comm.).

Thus, it can be assumed that in rural communities or small villages, subsistence fishing complemented the rations for the very poor, rather than being an alternative food source. The official per capita consumption of fish in the Soviet Union was 23.5 kg per capita (FAO 2007). With the dismantling of the Soviet Union, per capita consumption dropped to 15 kg per person in 1990 from 23.5 kg in 1987 and then to 10 kg per capita in 2002 (Matishov *et al.* 2004). While this is the consumption pattern for Russia as a whole, we assumed this trend was reasonable.

Since subsistence fishing was likely limited during the Soviet years, we assumed that 5% of the annual consumption of fish by the rural population was derived from personal subsistence fishing. Although the proportion of fish consumption caught within the Black Sea by the rural population would be expected to increase after the dissolution of the Soviet Union, we kept the amount constant at 5% until 1992 due to the jelly bloom, which limited the availability of fish. After the jelly bloom, we interpolated the proportion of total per capita consumption from 5% in 1992 to 20% in 1995 to represent that residents in more rural communities could no longer rely on the government, and had to fish for themselves. Until 2002, as the per capita consumption of fish in Russia as a whole declined to 10 kg per capita, we assumed subsistence remained relatively constant to its 1995 levels, such that the proportion of consumption increased to 26% by 2002 and thereafter remained constant. The species disaggregation was the same as that for recreational fisheries, as both employ simple fishing methods.

Escape mortality (or 'ghost fishing')

Ghost fishing is "the mortality of fish and other species that takes place after all control of fishing gear is lost by a fisher" (Brown and Macfadyen 2007). Specifically in the Black Sea, ghost fishing is a very common phenomenon as nets are not only 'lost,' but also purposefully abandoned when fishers try to escape the detection of patrol guards or other authorities while engaging in illegal fishing (Öztürk 2013). While no data are available on the extent of ghost fishing in the Black Sea or Sea of Azov for Russia, the figures for other countries are staggering. In one small fishing village in Turkey, 1,200 nets were lost in 2008, while in Bulgaria, an estimated span of 31,210 meters of abandoned nets are reported to be 'fishing' by entangling various species in their mesh (Öztürk 2013).

Although we did not include these figures in our reconstructed catches for the sake of consistency, as no other catch reconstruction has done so, we modelled the mortality from ghost fishing for small pelagic fish species.

For European anchovy and European sprat, we assumed a mortality rate of 91% for fish shorter than 12 cm and 62% for those longer than 12 cm that have escaped from fishing gear (Suuronen *et al.* 1996). The mean length of European anchovy in the Russian Black Sea catch is 12 cm (STECF 2011) with equal distribution on each side. Therefore the same distribution was assumed for the specimens that have escaped (50% < 12 cm; 50% > 12 cm). In the case of the European sprat, all specimens in the catch are less than 12 cm in length (STECF 2011), therefore it was assumed that 100% of specimens that have escaped the gear are < 12 cm. The escape rate of European anchovy and European sprat were set at 25% according to the Atlantic herring model (Skúvadal *et al.* 2011). Jack and horse mackerel escape mortality was estimated using a 35% escape rate and 40% mortality rate, assuming a similar escape and mortality rate due to similarity in morphology and behavior with the Atlantic mackerel *Scomber scombrus* (Misund and Beltestad 2000; Huse and Vold 2010). For gobies, a 20% escape rate was assumed with an 8.2% escape mortality (Duzbastilar *et al.* 2010). For whiting, an escape rate of 86.3% from 100 mm mesh nets was used (Madsen *et al.* 2008), with a 28% escape mortality from 100 mm mesh nets (Sangster *et al.* 1996). Escape mortality was not calculated for the cartilaginous fishes, mullets (Mugilidae), marine invertebrates, and other species, due to a lack of reliable data; it is believed to be negligible.

Reported commercial catch

The reported baseline catch was composed of commercial industrial and artisanal landings. Industrial landings averaged approximately 172,000 t·year^{-1} in the early-1950s and declined to 51,000 t·year^{-1} in the late-1950s; this pattern continued throughout the 1960s, 1970s, and 1980s as catches increased and decreased abruptly, peaking in 1982 with 199,000 t of catch and averaging 134,000 t·year^{-1} until 1987, which marked the dissolution of the Soviet Union. Thereafter, catches declined dramatically to a minimum of 4,300 t in 1993, a value over forty times less than the 1986 level of catches, and then recovered slightly in the 2000s with 29,000 t·year^{-1} (Figure 4).

Artisanal landings began at 31,000 t in 1950 and climbed to a double peak of 96,600 t in 1958 and 97,800 t in 1964, due to high catches of gobies. Thereafter, catches declined to 15,300 t in 1970 and stayed at this level, averaging 19,400 t·year^{-1} throughout the 1970s until 1985, after which catches dropped to a minimum of 940 t in 1992. Catches increased slightly in the late-1990s, to approximately 3,600 t·year^{-1} in the 2000s (Figure 4).

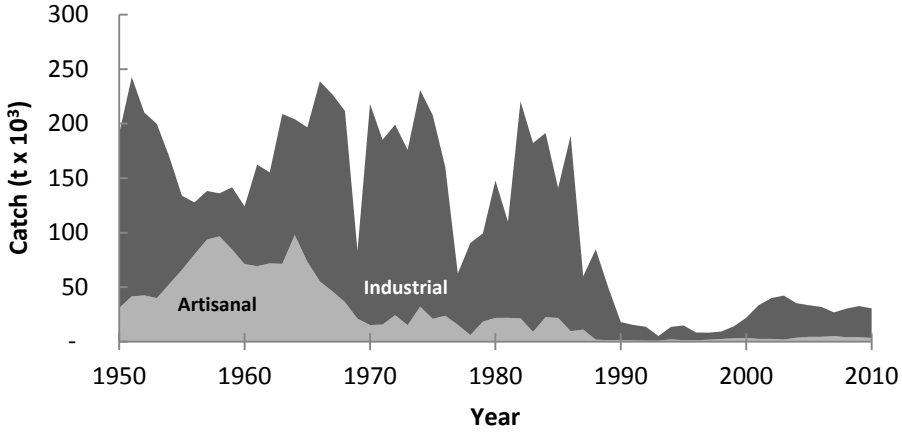

Figure 4. Industrial landings as reported or assigned (from Soviet data) to the Russian Federation for the Black Sea and Sea of Azov.

Unreported commercial catch

Unreported commercial catches increased from 530 t in 1950 to an average of 47,800 t·year^{-1} from 1960 to 1987, which oscillated frequently, peaking in 1974 with 77,200 t and falling to a minimum of 21,300 t in 1977. After the dissolution of the Soviet Union in 1987, unreported commercial catch also declined to a minimum of 9,000 t in 1993, but then increased to a level just below the unreported catch during the Soviet period, peaking in 2003 with 55,300 t of catch and averaging 45,000 t·year^{-1} throughout the 2000s (Figure 5).

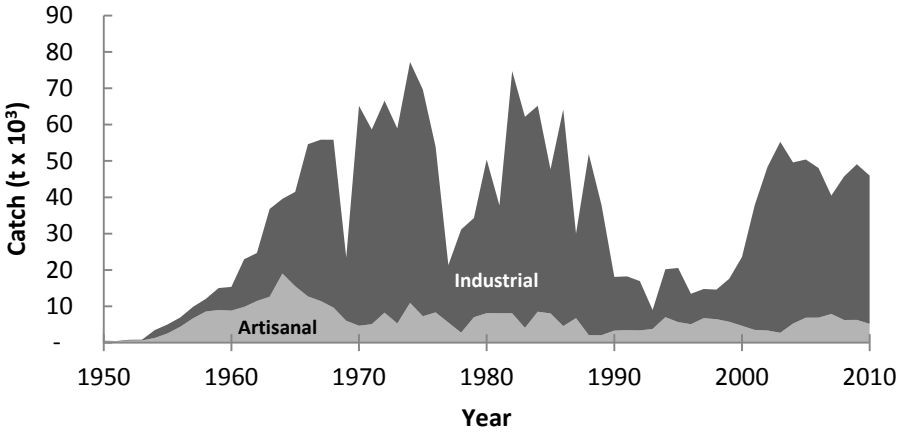

Figure 5. Unreported commercial catches as estimated for the Russian Federation for the Black Sea and Sea of Azov.

Discards

Discards averaged 11,800 t·year^{-1} from 1950 to 1974 and dramatically increased to 112,000 t in 1975, the year bottom trawlers were introduced to target sprat assemblages on the shelf. Discarded catch grew to 156,000 t in 1982, and then declined substantially to 15,600 t in the early 1990s as bottom trawlers were outlawed and phased out. By the mid-1990s discards averaged 1,500 t·year^{-1} due to small catches overall, and increased slightly in the 2000s to 4,100 t·year^{-1} (Figure 6).

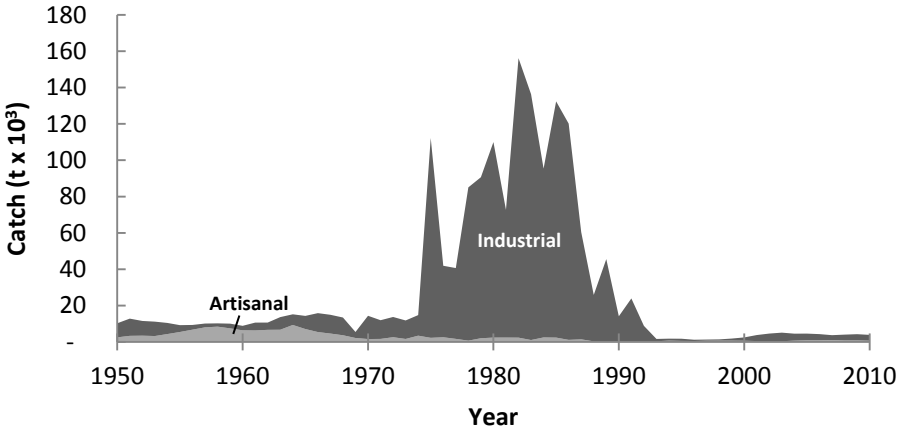

Figure 6. Discards as estimated for the Russian Federation for the Black Sea and Sea of Azov.

Recreational and subsistence catches

Recreational catches began at approximately 1,000 t in 1950 and slowly increased to 1,300 t in 1975 as a result of a growing population. Although population continued to grow, catches after 1975 slightly declined as a result of the declining CPUE and available biomass offsetting this trend, reaching 1,150 t of catch in 1987. With the comb jelly invasion from 1989 – 1992 catches averaged 940 t and recovered in the mid-1990s. Thereafter, recreational catches remained fairly stable at about 1,200 t·year^{-1} in the 2000s (Figure 7).

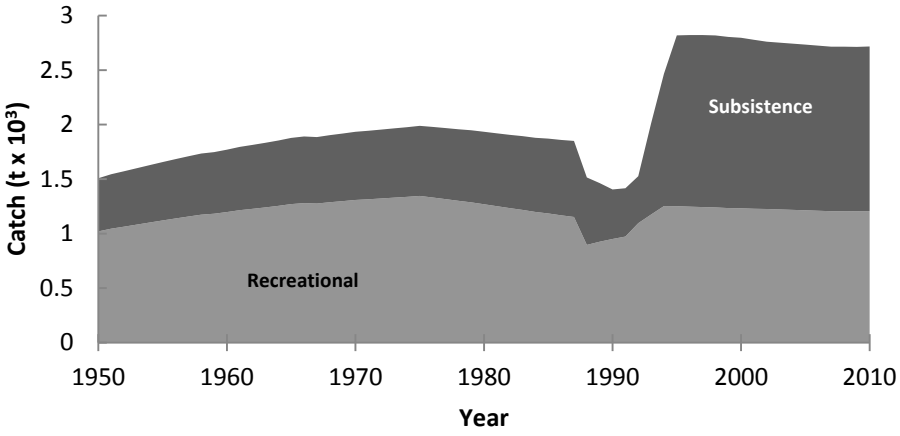

Figure 7. Recreational and subsistence catches as estimated for the Russian Federation for the Black Sea and Sea of Azov.

Subsistence catch began at 490 t in 1950 and slowly increased to 700 t in 1987. Following the dissolution of the Soviet Union, subsistence catches declined to 430 t in 1992 due to the comb jelly invasion which severely limited fishing followed by a large spike in subsistence fishing to 1,600 t in 1997 and 1998 as fishing became an important livelihood to those living near the coast, remaining at 1,500 t·year^{-1} throughout the 2000s (Figure 7).

Total reconstructed catch

Total removals began at 204,000 t in 1950, initially declined in the late 1950s to approximately 157,000 t·year^{-1}, but then steadily increased, although in a rather unstable pattern, to reach 453,000 t of catch in 1982, predominantly due to high discards in the bottom trawling fishery for sprat. Thereafter, catches declined sharply to 18,000 t in 1993 before increasing in the late 1990s and early 2000s to approximately 89,000 t of catch in the mid to late 2000s (Figure 8a). Total removals by sector are given in Appendix 2.

Total removals over the time period 1950 to 2010 were dominated by Black and Caspian Sea sprat (*Clupeonella cultriventris*) along with European anchovy (*Engraulis encrasicolus*) as can be seen in Figure 8b. In the 1950s, big-scale sand smelt (*Atherina boyeri*) and gobies (Gobidae) were also common. European sprat (*Sprattus sprattus*) had a smaller proportion of catch than Black and Caspian Sea sprat but was still important, while catches of whiting (*Merlangius merlangus*) were predominantly discarded. 54 other taxonomic groups were present in the category of 'other species' and although each taxon was a small component of catch, together they were significant in their contribution. Total removals by taxon are presented in tabular form in Appendix 3.

Total removals of the Russian fishing fleet in the FAO subarea 37.2 and 37.4.3 for the period 1950 to 2010 were estimated to be 1.57 times the total landings reported by FAO on behalf of the Russian Federation (or the assumed Russian fraction of Soviet Union reported data) (Figure 8a). For each sector except discards, the unreported portions increased over time. Industrial fisheries accounted for 79.1% of total catches (including discards), artisanal for 19.8%, and subsistence and recreational for 0.5% and 0.7%, respectively. Although escape mortality is not considered in the present analysis, it would have contributed an additional 4.5%.

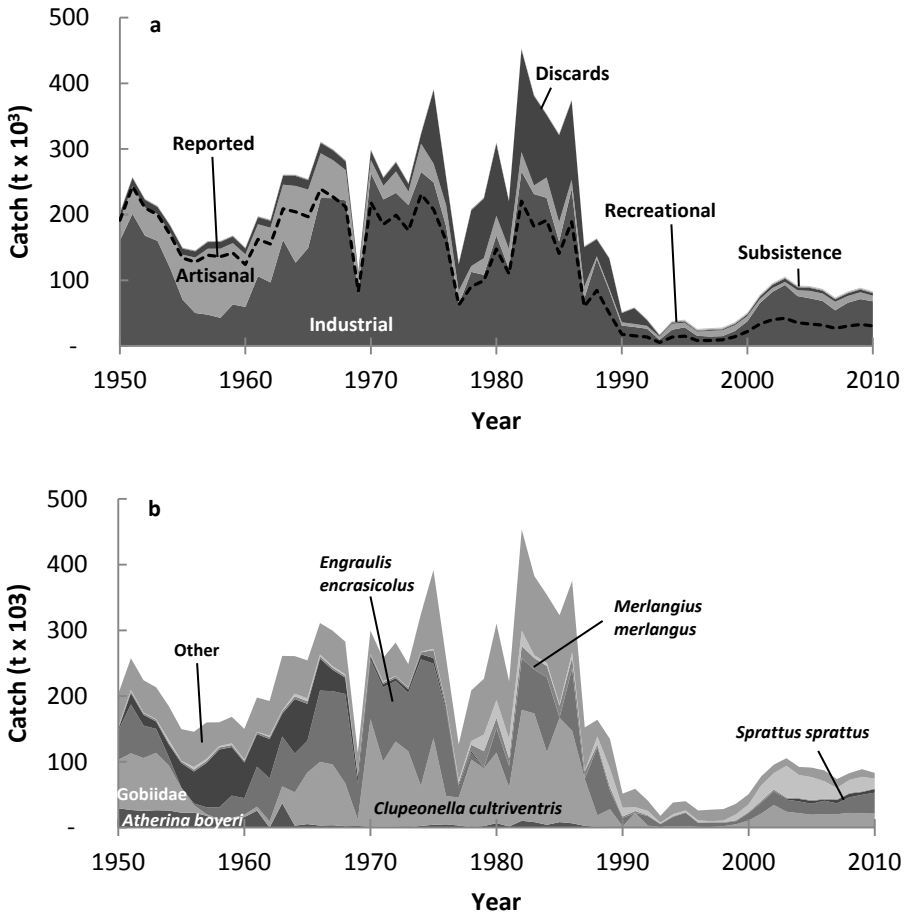

Figure 8. Total reconstructed catch in Russian waters of the Black Sea and Sea of Azov, 1950-2010, a) by sector (subsistence and recreational catches are too small to show clearly, and b) by species. 'Other' represents 55 additional taxonomic categories.

DISCUSSION

The once rich ecosystem which attracted the Ancient Greeks to settle the coast of the Black Sea and Sea of Azov has drastically changed over time. While the present reconstruction only extends back to 1950, there is ample evidence of 'shifting baselines' (Pauly 1995) prior to the 1950s. Particularly, between the 1830s and 1950s, annual catch in the Sea of Azov exceeded 300,000 t, composed mainly of high value species such as sturgeon, sander, and vimba (Matishov *et al.* 2004). In the Black Sea, catches in the first half of the 20th century reached 200,000 to 250,000 t for the USSR (Knudsen and Toje 2008). These early estimates of at least 500,000 t·year^{-1} by Russia and Ukraine are significantly higher than the reconstructed catch, which numbers under 280,000 t·year^{-1} (225,000 t·year^{-1} for Russia) in the 1950s, illustrating that stocks of large predator species had already been depleted at the starting year of the present study.

The situation worsened in the second half of the 20th century. The dramatic decline in total catches with the demise of the Soviet Union in the late 1980s and early 1990s, and the lack of substantive recovery since, was largely a result of overfishing and excess fishing capacity, which clearly illustrates the immense role centralized planning and excessive state subsidies (Sumaila *et al.* 2010) had on Russian (Soviet) fisheries. Lack of responsible fisheries legislation was also to blame, especially during the 1970s and 1980s when bottom trawling for sprat assemblages was permitted on the continental shelf.

Total removals of the Russian fishing fleet for the period 1950 to 2010 were estimated to be 57% greater than total landings presented by FAO, of which discards contributed 24.7%. Trawling was responsible in part for the collapse in fisheries in the late 1980s as it:

1. Destroyed the benthic organisms and communities;
2. Swirled large masses of peltic fractions (finely dispersed sediment filled with minerals, organic and toxic substances) into the pelagic zone, thus reducing transparency and furthering eutrophication; and
3. Silted vast parts of the continental shelf, which dramatic declined the biodiversity of species, e.g. mussels, as well as ruined the reproductive and feeding grounds of valuable commercial species such as sturgeon, turbot, and gobies (Zaitsev and Mamaev 1997; Eremeev and Zuyev 2007).

Other environmental factors contributed to the collapse of fisheries, including eutrophication furthered by the high nutrient loads and oil pollution carried by major rivers into the seas and the introduction of the invasive comb jelly.

Besides discards, which were at their peak during the Soviet regime, other unreported components of catch increased after its dissolution, notably unreported commercial catches, which contributed 30.6% of the 57% total unreported catch, along with recreational fishing (1%) and subsistence catches (0.7%). After 1987, all subsidies and funding to fisheries ceased, and so many fishers, plagued by poverty and increasingly high costs of fishing, turned to illegal fishing (FAO 2007). This was magnified by a lack of consistent fishery policy, and various government actions that increased the costs of operation for fishers (FAO 2007). While there is still no legally defined term for artisanal fishers in Russian fishery policy, small–scale fisheries, which represent roughly 80 percent of the fisheries in the Mediterranean and the Black Sea in terms of fishing vessels, appear to be particularly affected (GFCM Secretariat 2013).

With regards to unreported commercial catch, the culture of bribery and corruption seen during the Soviet years (Sampson 1987) has lingered in the post-USSR era, as Russia's corruption index is remarkably poor for a relatively wealthy country; indeed, its rating is on par with most African countries (The Guardian 2011). This is seen clearly in fisheries of the Black Sea where "fishing inspectors may be controllers and poachers at the same time" (Knudsen and Toje 2008). Increased unreported catches are linked with the extinction of the most valuable species (Губанов 2006). Sturgeon is a clear example of this with unregulated catches many times higher than reported catches, especially during the 1990s when prices for caviar skyrocketed (Catarci 2004). While in the late 1990s the sturgeon population in the Azov Sea was estimated at 17 million; by 2008 there were only 100 female sturgeons in the Azov Sea capable of reproducing (TheFishSite 2008).

Similar to unreported commercial fishing, subsistence fishing increased as the government no longer provided the relative support network it once did. Recreational fishing also slightly increased, mostly due to the surge in tourism, which in many ways replaced the commercial fishery as the main source of livelihood in the Russian Black Sea coast (Knudsen and Toje 2008). A transformation also took place in the tourist industry itself. Whereas during Soviet times tourists would rent a small wooden cabin for themselves and their family, the 1990s saw a wave of hotels and luxurious resorts came into being (O. Nikolenko, pers. comm.). Thus, while the number of tourists has increased, there is still a need to understand the extent to which tourists are interested in recreational fishing or if they prefer to "keep their back to the sea" (Knudsen and Toje 2008).

The former Soviet Union was extremely active in fisheries research and maintained an extensive system of research institutes, most of which have been maintained to this day (FAO 2007). While there are many scientist and studies that focus on the biological aspects of the fishery, there are an extremely limited amount of studies done on illegal or small-scale fishers, especially in the Black Sea region (Öztürk 2013). In fact, of all countries bordering the Black Sea and Sea of Azov, Russia has the least representation and concrete data on the level of illegal fishing in the region, as Russia is usually not well represented at GFCM conferences (GFCM Secretariat 2012; Öztürk 2013). There is a growing need for such research if the fisheries are to recover.

Politics to this day continue to be deeply intertwined with the destiny of fisheries in the Black Sea and Sea of Azov. In the 2014 conflict in which the Russian Federation unilaterally annexed the Crimean peninsula, Russia's EEZ increased nearly threefold, from approximately one sixth of the Black Sea and Sea of Azov (Figure 9a) to nearly one third of it (Figure 9b), as Crimea added approximately 36,000 square miles (i.e., 93,000km²) to Russia's existing waters (Broad 2014).

Figure 9a. Russian EEZ before annexation.

Figure 9b. Russian EEZ after annexation.

While many reasons were given by Russia for this action, oil was an issue that slipped under the radar. The Black Sea, and in particular the regions recently annexed by Russia, have been found in geological studies to contain a substantial amount of oil, considered by some to be the next 'North Sea,' which boosted the economies of all countries in the region (Broad 2014). Besides the prospects of drilling, the annexation enabled the re-routing of a pipeline, aimed to deliver Russian gas to Europe, so that it was more direct and cost-efficient (Broad 2014).

Although the present reconstruction does not consider the newly annexed territory as part of the Russian Federation, unfolding political events will inform how to consider this for the future. In any case, this politically tumultuous region will continue to have impacts well beyond its borders.

ACKNOWLEDGEMENTS

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Appendix Table A1. Artisanal and industrial target species and bycatch for the Russian Federation in the Black Sea and Sea of Azov.

Category	Taxon	Common name
Artisanal target species	*Crangon crangon*	Common shrimp
	Gobiidae	Gobies
	Merlangius merlangus	Whiting
	Mugilidae	Mullets
	Mullus barbatus barbatus	Red mullet
	Mytilus galloprovincialis	Mediterranean mussel
	Perciformes	Perch-likes
	Pleuronectiformes	Flatfishes
	Scomber japonicus	Chub mackerel
	Scomber scombrus	Atlantic mackerel
	Shrimps and prawns	Shrimps and prawns
	Trachurus	Jack and horse mackerels
	Umbrina cirrosa	Shi drum
	Xiphias gladius	Swordfish
Artisanal by-catch species	Acipenseridae	Sturgeons
	Belone belone	Garfish
	Brachyura	Marine crabs
	Miscellaneous marine crustaceans	Marine crustaceans
	Pomatomus saltatrix	Bluefish
	Rajiformes	Skates and rays
	Sarda sarda	Atlantic bonito
	Scophthalmus maximus	Turbot
	Sharks or rays and chimaeras	Sharks rays and skates etc
Industrial target species	*Clupeonella cultriventris*	Black and Caspian Sea sprat
	Engraulis encrasicolus	European anchovy
	Rapana spp.	Sea snails
	Sprattus sprattus	European sprat
Other species	*Alosa immaculata*	Pontic shad
	Aspius aspius	Asp
	Atherina boyeri	Big-scale sand smelt
	Carangidae	Jacks and pompanos
	Carps or barbels and other cyprinids	Carps and barbels other cyprinids
	Gadiformes	Cods
	Cyprinus carpio carpio	Common carp
	Diplodus spp.	Seabreams and porgies
	Esox lucius	Northern pike
	Gasterosteus aculeatus aculeatus	Three-spined stickleback
	Osmerus mordax mordax	Rainbow smelt
	Pelecus cultratus	Sichel
	Perca fluviatilis	European perch
	Rutilus rutilus	Roach
	Sander lucioperca	Pike-perch
	Sardina pilchardus	European pilchard
	Scorpaena spp.	Scorpionfishes
	Silurus glanis	Wels catfish
	Spicara maena	Blotched picarel
	Trigla spp.	Gurnards

Appendix Table A2. FAO reported landings versus total reconstructed catch (t) as well as catch by sector for the Russian Federation in the Black Sea and Sea of Azov, 1950 – 2010.

Year	FAO landings[1]	Total reconstructed catch	Industrial	Artisanal	Subsistence	Recreational	Discards
1950	191,308	203,600	160,400	31,400	488	1,020	10,260
1951	242,664	257,500	201,200	41,900	500	1,050	12,830
1952	210,193	224,100	167,900	43,100	508	1,060	11,550
1953	199,784	213,400	160,000	40,600	517	1,080	11,160
1954	169,380	184,900	118,600	54,200	527	1,100	10,450
1955	133,875	149,800	70,500	68,400	536	1,120	9,230
1956	127,756	145,700	50,200	84,500	544	1,140	9,340
1957	138,218	159,900	47,700	100,400	553	1,160	10,120
1958	136,080	160,100	42,900	105,200	561	1,170	10,220
1959	141,628	168,500	63,200	93,500	565	1,180	10,060
1960	124,102	150,100	59,500	80,000	572	1,200	8,860
1961	162,410	197,800	106,300	79,100	581	1,220	10,630
1962	155,351	192,500	96,800	83,300	586	1,230	10,660
1963	208,810	261,100	161,600	84,000	593	1,240	13,660
1964	204,133	260,800	126,900	116,800	599	1,260	15,200
1965	196,614	254,300	149,200	88,900	607	1,270	14,330
1966	238,792	311,100	225,400	68,000	611	1,280	15,850
1967	226,819	299,500	225,000	57,600	610	1,280	14,930
1968	211,709	282,900	221,600	45,900	615	1,290	13,440
1969	83,027	113,800	79,300	27,100	620	1,300	5,470
1970	218,037	299,500	263,300	19,900	625	1,310	14,390
1971	185,276	257,800	223,100	20,800	628	1,320	11,950
1972	199,093	281,400	233,200	32,500	632	1,320	13,730
1973	175,969	248,700	214,500	20,400	635	1,330	11,820
1974	230,758	324,700	264,900	43,100	639	1,340	14,770
1975	207,781	391,700	249,200	28,200	643	1,350	112,240
1976	160,188	258,000	182,000	32,100	647	1,330	41,910
1977	62,558	126,500	62,900	21,000	652	1,320	40,650
1978	90,500	208,700	112,800	8,800	656	1,300	85,060
1979	99,393	226,300	108,300	25,400	661	1,290	90,650
1980	147,817	310,100	168,300	29,900	665	1,270	109,990
1981	110,050	222,400	117,800	30,000	668	1,250	72,670
1982	220,522	453,400	265,700	29,500	672	1,230	156,190
1983	182,201	382,600	231,300	13,100	677	1,220	136,370
1984	191,453	353,900	225,700	31,000	680	1,200	95,390
1985	141,005	323,000	158,900	29,800	687	1,190	132,390
1986	189,037	375,200	239,000	14,200	691	1,170	120,150
1987	59,982	152,300	72,200	17,800	698	1,150	60,460
1988	84,715	164,000	132,700	3,900	619	900	25,880
1989	49,742	134,600	84,100	3,400	538	930	45,580
1990	17,946	51,500	31,100	5,000	454	950	14,120
1991	15,324	58,900	28,900	4,700	443	970	23,930
1992	13,694	41,000	26,300	4,300	431	1,100	8,850
1993	5,222	17,900	9,500	4,700	836	1,180	1,640
1994	13,592	38,100	24,700	9,100	1,214	1,250	1,800
1995	14,913	40,000	28,400	7,100	1,567	1,250	1,760
1996	8,421	25,900	15,500	6,400	1,574	1,250	1,210
1997	8,281	27,200	14,400	8,600	1,578	1,240	1,310
1998	9,286	28,100	15,000	8,900	1,578	1,240	1,400
1999	14,013	36,200	22,800	8,800	1,570	1,230	1,850
2000	21,966	50,800	37,500	8,100	1,564	1,230	2,480
2001	33,543	77,900	65,300	6,000	1,550	1,230	3,780
2002	39,957	95,700	82,400	5,900	1,535	1,230	4,600
2003	42,322	105,400	92,900	4,600	1,530	1,220	5,110
2004	35,308	92,200	76,000	8,900	1,525	1,220	4,550
2005	33,460	91,200	72,500	11,300	1,520	1,210	4,580
2006	31,847	86,900	68,600	11,300	1,515	1,210	4,300
2007	26,843	73,800	54,300	13,000	1,509	1,210	3,720
2008	30,394	82,900	65,800	10,300	1,509	1,210	4,020
2009	32,659	88,700	71,400	10,400	1,508	1,210	4,260
2010	30,607	83,200	68,000	8,600	1,510	1,210	3,880

[1] *Amounts from 1950 – 1988 are those estimated to represent the Russian Federation portion of reported USSR catch.*

Appendix Table A3. Total reconstructed catch (t) by taxon for the Russian Federation in the Black Sea and Sea of Azov, 1950-2010. 'Other' represents 55 additional taxonomic groups.

Year	*Atherina boyeri*	*Clupeonella cultriventris*	*Engraulis encrasicolus*	Gobiidae	*Merlangius merlangus*	*Sprattus sprattus*	Other
1950	29,270	73,710	44,650	2,210	2,330	1,330	50,120
1951	26,700	86,240	74,330	17,210	2,870	1,860	48,270
1952	25,230	80,470	49,380	16,270	2,700	920	49,120
1953	26,300	87,210	36,540	11,250	2,640	900	48,530
1954	25,880	68,740	12,830	19,250	2,710	4,020	51,490
1955	22,590	37,270	900	37,400	2,660	820	48,130
1956	22,670	11,410	2,560	48,630	2,850	3,940	53,670
1957	17,860	2,290	10,560	67,590	3,150	3,000	55,470
1958	9,960	2,620	17,990	88,070	3,200	2,030	36,200
1959	12,310	2,480	33,760	73,950	3,000	2,590	40,390
1960	15,810	3,640	25,230	54,450	2,640	1,270	47,050
1961	25,770	6,010	60,800	49,570	2,880	530	52,240
1962	0	9,340	65,450	59,980	2,920	2,010	52,800
1963	37,060	25,600	75,900	34,660	3,490	1,340	83,050
1964	2,810	50,710	59,040	82,870	4,200	4,040	57,090
1965	5,220	78,380	48,340	56,330	3,760	4,430	57,860
1966	2,930	96,970	108,410	48,770	3,670	2,590	47,790
1967	3,490	92,390	111,530	32,580	3,370	1,880	54,250
1968	1,980	65,380	135,860	24,750	2,870	2,360	49,700
1969	2,460	9,830	53,340	11,590	1,350	850	34,410
1970	1,000	164,050	90,710	4,870	2,980	600	35,310
1971	1,190	99,240	112,640	5,280	2,430	1,560	35,490
1972	1,090	129,740	92,110	4,070	2,980	510	50,850
1973	0	115,950	88,860	5,470	2,480	490	35,460
1974	2,480	61,050	192,310	7,680	3,000	700	57,520
1975	4,150	131,730	113,400	8,650	12,020	1,950	119,750
1976	4,780	43,170	129,760	4,560	5,080	910	69,760
1977	3,090	42,610	14,420	3,560	4,630	3,750	54,460
1978	350	103,020	9,980	3,030	9,550	5,700	77,030
1979	2,260	87,610	0	1,440	24,880	25,220	84,880
1980	6,640	107,290	36,740	830	15,370	27,360	115,900
1981	1,660	59,360	32,440	460	11,030	29,630	87,830
1982	10,270	168,750	77,780	1,000	18,450	23,170	153,930
1983	8,240	165,270	66,240	750	17,310	4,340	120,470
1984	4,150	110,460	113,430	920	16,730	4,500	103,720
1985	8,230	158,700	0	850	17,510	2,370	135,310
1986	6,480	140,680	94,260	1,340	16,090	7,630	108,770
1987	2,550	71,160	0	1,070	10,610	880	66,010
1988	1,060	17,510	103,630	160	4,090	12,060	25,520
1989	640	27,230	28,450	190	4,810	28,530	44,760
1990	100	1,860	12,650	150	2,100	13,210	21,490
1991	70	22,160	90	160	2,620	5,850	27,970
1992	20	2,840	14,590	160	1,130	6,600	15,670
1993	20	820	4,270	210	550	1,430	10,570
1994	20	2,300	13,680	250	1,030	3,070	17,710
1995	30	2,050	20,140	280	830	2,600	14,110
1996	60	920	5,910	290	600	3,110	15,030
1997	30	720	6,590	280	640	1,450	17,470
1998	50	1,990	4,930	290	880	2,520	17,450
1999	40	4,940	4,540	500	1,030	8,990	16,220
2000	130	10,550	10,950	720	1,390	11,540	15,530
2001	200	21,050	16,310	750	2,260	23,480	13,900
2002	220	34,050	20,400	790	2,500	24,840	12,880
2003	420	23,650	18,400	1,600	1,370	48,410	11,600
2004	130	21,670	17,900	3,840	1,220	35,160	12,270
2005	50	19,410	16,770	4,230	1,320	34,870	14,530
2006	20	20,470	20,240	1,870	1,210	26,680	16,430
2007	20	20,320	16,600	4,870	1,220	17,160	13,580
2008	20	22,220	23,740	5,620	1,220	19,680	10,360
2009	90	21,510	28,190	4,200	1,140	22,010	11,600
2010	50	21,040	31,970	5,480	980	14,930	8,740