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RESEARCH ARTICLE

A reconstruction of the Ukraine's marine fisheries catches, 1950-2010

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Abstract

Ukraine's marine fisheries catches were re-estimated for the 1950-2010 time period using a reconstruction approach which estimated all unreported fisheries removals, i.e., catches from the industrial, artisanal, recreational, and subsistence sectors, as well as discards from major fisheries. The reconstructed total catch for the 1950-2010 time period is 1.4 times the data we deemed officially reported on behalf of Ukraine to the FAO, which included only industrial landings. Reconstructed catches consisted to 71% of industrial, 11% artisanal, 8% recreational and 7% subsistence landings, while discards accounted for 3%. Total catches increased from about 50,000 t in 1950 to a peak of about 175,000 t in 1988, then declined with the collapse of the Soviet Union to about 55,000 t in 1991, also due to an invasion of ctenophores in the Black Sea. In 2010, total reported marine landings for Ukraine were about 70,000 t, while the reconstructed total catch was just over 110,000 t. Major unreported species were Mediterranean horse mackerel (*Trachurus mediterraneus*), gobies (Gobiidae), whiting (*Merlangius merlangus*), and bluefish (*Pomatomus saltatrix*). Accounting for all fisheries removals should help to establish a reliable baseline, better understand the fisheries, and thus assist management.

Keywords: Black Sea, unreported catches, policy, industrial, artisanal, recreational

Introduction

The Ukraine shares the Black Sea basin and its biological resources with five countries: Russia, Georgia, Turkey, Bulgaria and Romania (Figure 1). The catchment area of the Black Sea is over 2 million km^2, five times the area of the

sea itself (Zaitsev *et al.* 2002). The Sea of Azov basin, which the Ukraine shares with Russia, is 38,000 km^2, and averages just 7 m in depth. The Ukraine is also a very important catchment area involving the Danube, Dnieper, Dniester, Southern Bug and Siverskyi Donets Rivers jointly draining much of Europe.

The Fisheries

In the Black Sea, as the rest of the world, catch capacity dramatically increased with industrialization. Seiners were introduced to the Ukraine in 1931, which enabled catches to double and bottom trawlers were introduced in the 1950s (Knudsen and Toje 2008). These two industrial fishing methods gave the coastal fleet the power to expand offshore, and later to distant-waters.

The governments of the former Soviet Union modernized the fisheries of the various Soviet Republics, including the Ukraine, by supplying trained fishers to the industrial fishery sector, which enabled industrial vessels to fulfil the successive plans involving higher catch quotas (Knudsen and Toje 2008). However, while the catch of the Ukraine and other Black Sea countries increased until 1983, the ecosystem began showing signs of stress in the mid-1970s.

Fishing pressure first caused sturgeon (Acipenseridae) and turbot (*Scophthalmus maximus*) stocks to show signs of over-exploitation, while many other larger predatory fish populations crashed, notably Atlantic mackerel (*Scomber scombrus*), bluefish, and chub mackerel (*Scomber japonicus*). Later, red mullet (*Mullus barbatus*), and spiny dogfish (*Squalus acanthias*) (GFCM 2012) followed suit, although the red mullet stock somewhat recovered in the 2000s. At first, increase in effort, and the geographical and taxonomic expansion of the fisheries masked the declining trend in local catches (Eremeev and Zuyev 2007; Pauly 2009); thus the disappearance of the large predators went almost unnoticed. Subsequently, no management actions were taken to reverse the losses, a typical case of 'Fishing Down Marine Food Webs' (Pauly *et al.* 1998) triggering a 'trophic cascade' (Daskalov 2002).

After the near-complete removal of large predators, their former prey, the small pelagics (anchovy *Engraulis encrasicolus*, sprat *Sprattus sprattus*, Mediterranean horse mackerel and whiting) increased their biomass, resulting in their contribution to the total Black Sea landings increasing from 70% in the 1960s-1970s to 93% in 1988 (Eremeev and Zuyev 2007).

The Ukrainian coastal fisheries consist of two main commercial sectors: artisanal (small-scale) and industrial (large-scale). The artisanal sector is characterized by small boats averaging 4-5 m in length using passive fishing gear such as set traps ('*stavniki*') and fixed nets (Mikhailov and Papaconstantinou 2006).

Figure 1. The Ukrainian Exclusive Economic Zone (EEZ) and shelf waters to 200 m depth in the Black Sea, and Sea of Azov waters which were under the jurisdiction of Ukraine

The inshore artisanal fishery used to mainly target valuable species such as sturgeons, a fishery was prohibited in 2000; thereafter, the main target-species switched to *so-iuy* mullet (*Liza haematocheila*), an introduced species.

Other target species include European anchovy, silversides (Atherinidae) and flatfish (Pleuronectiformes). Only non-motorized vessels are permitted to target inshore shad (*Alosa immaculata*), and silversides in the Sea of Azov. Longlines and gillnets are used to catch the newly targeted dogfish (Squalidae), skates (Rajidae) and rays (Dasyatidae) (V. Shlyakhov, unpubl. data) in coastal waters. The main invertebrates caught are Mediterranean mussel (*Mytilus galloprovincialis*) and Rapa whelk (*Rapana venosa*), both collected by hand and via bottom dredges (Shlyakhov and Charova 2003).

The industrial sector operates mainly trawler-seiner vessels averaging 18-24 m in length (V. Shlyakhov, pers. obs.), as well as multi-purpose type vessels using other net-types and longlines. In 2000, there were 95 operational industrial fishing vessels in the Black and Azov Seas (Pramod and Pitcher 2006), which decreased to about 80 by 2004. These vessels target mainly anchovy, sprat, goby, and *so-iuy* mullet. The sprat bottom-trawl fishery began in the mid-1970s and was at first very intensive, with over 120,000 bottom-trawl hauls conducted in the north-west portion of the Black Sea from 1979 until 1986 (Eremeev and Zuyev 2007) (see Discards section for more details).

Pre-independence, the Ukraine followed strict Soviet standards for fish product marketing, processing, and storage, and had heavily-guarded waters, which contributed to few accounts of illegal and unreported fishing. During the 1980s, when Ukraine was still a component of the Soviet Union, reported marine catches averaged 115,000 $t \cdot year^{-1}$. However, after Ukraine gained independence (July 16, 1990), most fisheries subsidies were cancelled, and soon after, the national Monitoring, Control and Surveillance (MCS) system almost entirely collapsed (Knudsen and Toje 2008).

From 1992 onwards, the fisheries became privatized, and lacking state fiscal help, were unable to maintain fishing vessels and their associated infrastructures (Knudsen and Toje 2008). In 2002, a state-licensing system for commercial fisheries was established which introduced Total Allowable Catch (TAC) quotas for some rare and valuable species (Knudsen and Toje 2008). With the introduction of such quotas, some companies have been leasing out vessels and crew to help reach quota limits. From the mid-1990s, the Ukraine has been establishing new standards aimed to satisfy EU trade requirements (Sağlam and Duzguneş 2010).

While the Ukraine also has an important distant-water fleet (Zeller and Rizzo 2007), this paper deals only with Ukraine's marine catches taken exclusively from their own Exclusive Economic Zone (EEZ), and other waters under its jurisdiction, which covers about 144,000 km^2 (Figure 1). Also, this assessment of total marine removals only deals with catches of marine and brackish-water fish and invertebrates, and does not include seaweeds, marine mammals or freshwater fisheries. The United Nation's FAO Fishstat database includes Ukraine's fisheries in FAO statistical area 37 (Mediterranean and Black Seas), and the Black Sea is then divided into sub-areas 37.4.1 (Marmara Sea, not discussed here), 37.4.2, the 'Black Sea proper', and 37.4.3, the 'Sea of Azov'. The marine resources of the Sea of Azov (Figure 1) are shared by Russia and the Ukraine, and the annual catch is decided upon by a bilateral Ukrainian-Russian Commission.

Over the last 20 years, total catches from the Sea of Azov declined substantially, from about 100,000 $t \cdot year^{-1}$in the 1980s (Popovych 2011) to just over 30,000 $t \cdot year^{-1}$ in 2010. The deterioration of this sea is largely attributable to industrial wastewater contamination and increased salinity levels from the diversion of natural freshwater (www.ukraineatpresent.com), but may also be due to increased illegal, unreported and unregulated fishing (Popovych 2011).

In 2002, Ukrainian state funds for conducting fisheries research (of which monitoring and control are a large part) changed from a line item of the budget devoted to the "Conservation, selection and reproduction of fish stocks" to a line item on devoted "Fundamental Research" and "Applied Developments";

the associated funds were also drastically reduced, from US $1 million in 1996 to US $250,000 by 2006, thus drastically shrinking research capabilities.

Following the economic recession, which affected all ex-Soviet republics in the early 1990s, marine fisheries became more attractive, if only because of a lack of other opportunities. Thus, annual reported catches increased from a low of 26,000 t in 1993 to about 90,000 t in 2001, partly due to some success in rebuilding the economy and also because a sizeable increase in both anchovy and sprat stocks. In 2003, Russia prohibited Ukrainian vessels from fishing anchovy in Russian waters, thus reducing Ukraine's share of catches from the Sea of Azov. By 2010, reported Ukrainian marine catches were less than 70,000 t (Appendix Table 1).

There are four large fishing ports in the Ukraine: Sevastopol, Ill'ichevsk, Kerch and Mariupol (Figure 1), and close to 40% of Ukraine's continental shelf and 12-mile coastal zone are made-up of no-take protected areas (Shlyakhov, unpubl. data, www.mpaglobal.org).

Distant-water fisheries

Approximately 9,000 people are employed in distant water fisheries, with total annual catches averaging 150,000 $t \cdot year^{-1}$ (Pramod and Pitcher 2006). Since independence, the vessels in this fleet have been in an increasing state of disrepair (Knudsen and Toje 2008), but this may not apply to their fish finding and navigational electronics, as the former are crucial to commercial success and the latter must meet the minimum requirements of the International Maritime Organization.

The Ukraine inherited over 330 fishing vessels from the former Soviet Union, most of which were resold to other countries, rebuilt to cargo vessels, or scrapped. Most of the fishing fleet was between 29-32 years old (as of 2010), suggesting that they vessels will need to be scrapped between 2010 and 2015 (FAO 2004).

As of 2002, there were 47 oceanic large-capacity industrial vessels ranging in length from 82-128 m, 14 carrier vessels ranging in length from 124-172 m, 31 smaller carrier vessels ranging in length from 27-55 m, and 39 medium-capacity trawlers ranging in length from 55-62 m (Pramod and Pitcher 2006). The catches of the Ukraine's distant-water fleet are not included in this report.

Illegal fishing accounts

The only country known to commonly fish illegally in Ukrainian waters is Turkey, which has, by far the largest fishing capacity in the Black Sea. There are many accounts of such illegal activity, for example: In April 2007, a Turkish fishing vessel was detained by the Ukrainian Coast Guard with about 380 individual turbot, each weighing up to 6 kg; (www.redorbit.com/news/

international/897084/turkish_boat_detained_in_ukrainian_waters_for_illegal_fishing/); and in 2008, a Turkish fishing vessel, the '*Ozgur*' was caught in the Ukrainian EEZ with fishing nets in the ship holds and fined close to US $10,000 (www.illegal-fishing.info/). Also, in Ozturk (2013), there are 30 accounts of Turkish fisheries getting detained in Ukraine for illegal fishing activities. In 2007, Ukrainian and Turkish experts negotiated a system to help prevent Turkish fishers from poaching in Ukrainian waters. One solution they identified was that Turkish vessels were to implement a vessel monitoring system (VMS) onboard their Ukrainian-bound vessels, to alert Ukrainians of the number and location of vessels if they entered Ukrainian waters.

Governance

A Scientific Fisheries Council advises the central executive body - the State Committee for Fisheries or '*Derzhcomrybhosp*', tasked with monitoring and enforcement. In 2002, a fisheries license system was initiated, and in 2011, a new law was established for commercial fisheries, issuing five-year permits, but not restricting capacity (GFCM 2012). Most commercial species have non-transferable catch quotas and have Minimum Legal Landing Size (MLLS) regulations in place.

In November 2011, the Ukraine ramped up its fines for illegal fishing by 23 times, from 34 to 800 *hryvnias* (i.e., from about US $4 to about $100) for each illegally caught specimen. In a 10-month period, the department registered over 1,000 violations, detaining hundreds of offenders and confiscating thousands of pieces of illegal fishing equipment (http://en.forua.com/news/2011/11/24/130321.html).

This paper aims to reconstruct total marine fishery removals for the Ukraine from 1950-2010 using the approach of Zeller *et al*. (2007), which will help establish a more comprehensive baseline, and inform future fisheries management efforts.

Materials and Methods

Baseline reported data

Three data sources were used to establish a time-series of 'reported' marine catches for the Ukraine for the entire 1950-2010 period: 1) the re-allocation of former Soviet Union reported landings data to the constituent republics of the U.S.S.R. completed by Zeller and Rizzo (2007); Ukrainian landings calculated by expert assessment from the official statistics of the former USSR (V. Shlyakhov, unpubl. data); and FAO reported data.

Zeller and Rizzo (2007) disaggregated the marine landings reported by FAO for the former Soviet Union and re-allocated these landings to the six maritime former Soviet Republics, based on each of the newly independent Republics'

initial five-year average reported catch from 1988-1992. Three of these former Soviet Republics fished in FAO Area 37 (Mediterranean and Black Sea): Georgia, the Russian Federation and Ukraine. The three year averages were re-calculated (based on expert assessment provided below in from 1970-1972) and the difference between the average of the first 3-years of national data and the re-allocation provided by Zeller and Rizzo (2007) was 26.8%. Therefore we assumed that 26.8% of the disaggregated Ukrainian catches from 1950 to 1969 were caught in Ukrainian waters, while the remaining 73.2% were caught elsewhere in the Mediterranean Sea; for 1970 to 1987, we used Ukrainian landings calculated by expert assessment from the official statistics (V. Shlyakhov, unpubl. data); and 3) for 1988 to 2010, data reported by the Ukraine to FAO were used.

These three data sources were used to create our 'reported baseline' to which unreported industrial, artisanal, recreational, and subsistence landings, as well as major discards were added. All reported data as derived here from 1950-2010 were assumed to be industrial catches. Since fisheries under Soviet rule were highly regulated, the reported statistics for 1950 to the late 1980s are assumed to be inclusive of all industrial catches.

To improve on the taxonomic composition of reported data, the first three years of the dataset derived from the expert assessment (item 2 above) were averaged (1970-1972), and each taxon's percentile contribution to the total was applied to the newly derived annual total catch for Ukraine, and applied to the years from 1950 to 1969.

The 'marine fishes nei' category was disaggregated for the 1950-1969 period into eight taxonomic groups commonly caught and reported at this time (Table 1). Local expert consultation (V. Shlyakhov, pers. obs.) was used in combination with the first three years of available Turkish catch statistics from the western Black Sea (1967-1969) to improve on the poor taxonomic allocation during this time. Expert opinion (V. Shlyakhov, pers. obs.) suggested most of the catches then pertained to silversides; thus nearly two-thirds (63%) of catches were allocated to silversides. For the 1970-1987 period, the 'marine fishes nei' category was disaggregated into 10 taxonomic groups, most of which were not included in the Ukrainian statistics, but were commonly caught in the Ukrainian waters based on local expert advice (V. Shlyakhov, pers. obs.; Table 2). The 1988-2010 period had the 'marine fishes nei' accepted as the amounts were low.

Estimating unreported catches

Number of commercial fishers

To derive a time-series of commercial fishers, published accounts of total Ukrainian fishers (when available) were used in combination with actual population trends. The Ukrainian population was 37.3 million in 1950 (www.un.org/esa/population), rose to nearly 52 million by 1990

(www.populstat.info), peaked at 52.2 million in 1992 and has since declined to approximately 46 million people in 2010 (www.tradingeconomics.com).

Table 1. Allocation to taxa for the 'marine fishes nei' category from 1950-1969

Taxon or group	Scientific name	%
Silversides	*Atherina boyeri*	63
Turbot	*Scophthalmus maeoticus*	13
Shi drum	*Umbrina cirrosa*	9
Gurnard	*Trigla lyra*	7
Garfish	*Belone belone*	5
Chub mackerel	*Scomber japonicus*	1
Decapods	Decapoda	1
Swordfish	*Xiphias gladius*	1

Table 2. National 'marine fishes nei' taxonomic allocation from 1970-1987. Source: TURKSTAT Turkish western Black Sea fisheries statistics (1977-1979)

Taxon or group	Scientific name	%
Atlantic horse mackerel	*Trachurus trachurus*	35
Bonito	*Sarda sarda*	35
Garfish	*Belone belone*	5
Shi drum	*Umbrina cirrosa*	5
Scorpionfish	Scorpaenidae	5
Brown meagre	*Sciaena umbra*	3
Seabreams and porgies	Sparidae	3
Lobsters and crabs	Decapoda	3
Chub mackerel	*Scomber japonicus*	3
Gurnard	*Trigla lyra*	3

Prior to independence, there were 80,000 fishers working in all sectors (http://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_083074/lang--en/index.htm) (i.e., freshwater, distant water, and coastal marine fisheries), which was reduced to approximately 45,000 fishers employed in all sectors in 2001 (FAO 2004), representing, a 56% reduction in the number of fishers during this period (these ratios were used to account for the industry trend). In 2000, there were 5,600 commercial fishers in the coastal marine fleet (i.e., fishing in Ukraine's EEZ), which decreased to 4,200 by 2010 (V. Shlyakhov, pers. obs.). Therefore, the 5,600 fishers in 2000 was increased by 56% (the same ratio as used above to account for the industry trend) to obtain a number of commercial fishers for 1990 of 8,736 fishers.

To derive the number of fishers for 1950, national Ukrainian population trends were used, i.e., the number of coastal marine commercial fishers derived for 1990 (i.e., 8,736) was multiplied by 0.72 to derive an assumed number of

fishers in 1950 (i.e., 6,290). Thereafter, we interpolated the number of fishers between our anchor points in 1950, 1990, 2000 and 2010.

To remain conservative, after the total number of commercial fishers was estimated, 40% of the total commercial fishers were assumed to have belonged to the industrial commercial sector (whose catches were all deemed to have been reported up to 1990), while the remaining 60% of fishers were assumed to belong to the artisanal commercial sector (whose catches have not been previously estimated). It is understood that there is no legal distinction in the Ukraine between industrial (large-scale commercial) and artisanal (small-scale commercial) operations, and in fact, many commercial fishers are engaged in both (V. Shlyakhov, pers. obs.).

Unreported industrial catches

When the Soviet Union collapsed, regulatory agencies became incapable of performing Monitoring, Control and Surveillance (MCS) procedures, leading to essentially 'open access' fisheries in the ex-Soviet Republics bordering the Black Sea. It has been suggested that the decrease in reported catches in the 1990s represents a decrease in the 'reporting' of catches, but not in 'actual' catches or effort (Knudsen and Toje 2008). In addition, due to possible corruption since independence, only about 20% of actual catches are thought to have been reported (S. Jatsenko, pers. obs.).

However, the Soviet-era subsidization of the fleets declined abruptly, and fleets would have been required to resume operations based on a completely different business model. Thus, in light of the above anecdotal evidence that under-reporting had indeed been occurring and likely been increasing since independence, an unreported industrial component was estimated. To remain conservative, it was assumed that there was zero industrial under-reporting in 1990 which was linearly increased to 20% industrial under-reporting by 2010. This was calculated by multiplying each annual percentage (from 1991-2010) by the industrial reported catch amounts for each year. The taxonomic allocation used was the same as for the reported catches.

Artisanal catches

In the Ukraine, artisanal (i.e., small-scale-commercial) fisheries have not yet been described quantitatively, nor properly assessed. From 1950-2010, artisanal landings were estimated using the derived time-series of number of coastal commercial fishers, 40% of which were assumed to use industrial fishing gear, thus the remaining 60% were assumed to use artisanal commercial gear. We assumed an annual artisanal catch rate of 1.5 $t \cdot fisher^{-1} \cdot year^{-1}$ which was held constant from 1990-2010, and the catch rate was doubled to 3 $t\ fisher^{-1} \cdot year^{-1}$ for 1950-1970 to account for an ecosystem which included larger, higher trophic-level fish. The catch rate was then linearly decreased from 1971 to

1989. The number of fishers·year^{-1} were multiplied by the assumed catch rates to determine artisanal catches.

Since the most important fish stocks in the Black Sea crashed from 1990-1992, due to a carnivorous comb jelly invasion (Daskalov 2002; Gücü 2002; GFCM 2011), the artisanal catch estimated in this fashion was reduced by 75% during 1990-1992; this was then linearly increased to our 2000 anchor point. The species allocated to these catches varied annually, reflecting the natural changes in the Black Sea ecosystem and were derived using a combination of expert advice, fisheries statistics, and the recreational catch composition.

Unreported sturgeon catches
All sturgeon (Acipenseridae) species have been included in the Convention of International Trade of Endangered Species since 1998 (Black Sea Commission 2008). According to the IUCN Red List (www.iucnredlist.org/), the six species of sturgeons native to the Danube River basin are globally classified as either 'Vulnerable', 'Endangered' or as 'Critically Endangered'.

Sturgeon abundances increased in the region in the latter half of the 20th century, from 0.2 million individuals in 1966 to somewhere between 5.3-6.2 million individuals by 1992-1993, due to efficient protection combined with restocking efforts for Russian sturgeon. These numbers, however, decreased to about 2 million individuals by 1998 and 1.5 million individuals by 2002 (Black Sea Commission 2008). One major hindrance to sturgeon population recovery is that juveniles are still caught in the (illegal) net fisheries targeting pike-perch and *so-uiy* mullet.

With the dissolution of the Soviet Union, poaching has increased in the Sea of Azov (Demyanenko and Diripasko 2003). The estimated abundance of the Azov sturgeon stock for 2004-2005 was only 5% of the early 1990s (FAO 2005). Experts suggest that these declines are due to a reduction of spawning grounds, illegal fishing, and the alteration of river flow regimes. Fisheries scientists in the Ukraine annually derive the Total Allowable Catch (TAC) by estimating current fishing mortality in combination with estimating unreported catches (V. Shlyakhov, unpubl. data). Their results suggest that the populations of Russian sturgeon and starry sturgeon are depleted because catch limits are not respected, which is not surprising, given that these two species are the most valued on the black market. Indeed, while unreported and illegal catches occur in all sectors, they tend to be mainly associated with the most valuable fish species (Prodanov *et al.* 1997; Shlyakhov *et al.* 2005), For example, juvenile sturgeon with total lengths between 50-70 cm are common in Ukrainian fish markets, although illegal to catch, and thus are unreported (Shlyakhov 2003). Many sturgeon are also caught as incidental by-catch (Suciu 2008).

Unreported sturgeon catches were estimated from 1964 to 1992 for the north-western part of the Black Sea and the Danube (Prodanov *et al.* 1997) and for the Sea of Azov from 1988 to 2005 (Black Sea Commission 2008). We present these data in Table 3, if only to encourage further research on this topic. However, to avoid the possibility of double-counting, we have assumed that these unreported sturgeon catches were accounted for in our reconstructed catch estimate for artisanal, subsistence, and recreational subsectors.

Recreational and subsistence catches

Recreational and subsistence fisheries share a common feature: their catch is not sold, or at least is not supposed to be. Here, they are initially estimated as one item, then later disaggregated into fish caught primarily for pleasure (i.e., recreational fishing) and fish caught primarily for household consumption (i.e., subsistence fishing).

An estimated 1 to 3 million people were engaged in either full-time or part-time recreational/subsistence fishing, including freshwater fishing (FAO 2004). Subsistence fishing dominates rural areas, and recreational and sports fishing dominates urban areas with > 1 million inhabitants. The catch of recreational fisheries is partly collected and involve 15 taxa, but these data are incomplete due to monitoring limitations, and represent less than 5% of the fishery.

Table 3. Unreported sturgeon catch estimates in the Ukraine, 1964-2005

Black Sea[1]				**Sea of Azov[2]**	
Year	Catches (t)	Year	Catches (t)	Year	Catches (t)
1964	60	1982	41	1988	4,814
1965	45	1983	41	1989	4,814
1966	31	1984	39	1990	4,814
1967	25	1985	64	1991	-
1968	1	1986	36	1992	3,213
1969	15	1987	55	1993	3,213
1970	14	1988	61	1994	3,213
1971	15	1989	45	1995	2,040
1972	10	1990	47	1996	2,040
1973	14	1991	55	1997	2,040
1974	30	1992	78	1998	984
1975	14			1999	984
1976	12			2000	984
1977	40			2001	109
1978	45			2002	109
1979	21			2003	109
1980	53			2004	54
1981	43			2005	54

Sources: [1] Prodanov (1997); [2] Black Sea Commission (2008)

However, the results showed that in 2006, 54,000 recreational fishers landed a total of 509 t of fish of the 15 taxa monitored, equating to 9.4 kg·fisher^{-1}·year^{-1} (V. Shlyakhov, unpubl. data).

The Ukraine has the highest coastal population living along the Black Sea coast, estimated at 6.8 million people (Zaitsev and Mamaev 1997), or 15% of the total population. Given the economic situation of the country, the high national unemployment rate and Ukraine's extensive coastline, we assumed that the number of coastal marine recreational/subsistence fishers was 1% of the total population after independence, and 0.25% of the total population from 1950-1989. The lower proportion of marine recreational/subsistence fishers pre-independence was due to the strict control of the coastal zone by the Soviet regime, thus making access and fishing more difficult (V. Shlyakhov, pers. obs.). The 0.25% rate was linearly increased to 1% from 1990-1992.

This leads to an estimate of about 450,000 recreational/subsistence fishers in 2010, which is much lower than the FAO estimate of 1-3 million (which, however, includes freshwater anglers). We used this estimate of marine recreational/subsistence fishers in conjunction with the only published recreational catch rate per fisher of 49 $kg \cdot fisher^{-1} \cdot year^{-1}$ for the early 2000s (FAO 2004) to derive a catch estimate. Given the changes in taxonomic assemblages over time in the Black Sea, in which most of the large predatory fish had been removed from the Black Sea ecosystem, the catch rate was increased by 50% for 1950-1970, i.e., to 73.5 $kg \cdot fisher^{-1} \cdot year^{-1}$, and was linearly decreased to 49 $kg \cdot fisher^{-1} \cdot year^{-1}$ by 2000.

To differentiate between recreational and subsistence sectors, it was assumed that for the entire 1950-2010 period, 70% of all estimated recreational/subsistence catches were caught for subsistence purposes (i.e., primarily as a protein source), and 30% of catches were caught for recreational purposes (i.e., primarily for fun or enjoyment).

The catch composition of the recreational and subsistence catches were modified from our artisanal catch composition (V. Shyakhov, pers. obs.), in combination with Turkish western Black Sea catch data to understand when the absence of certain species began. As the Black Sea species composition changed strongly over time, a different taxonomic breakdown was applied for each year (see Table 4), and the amounts were interpolated between 1950 and 2010. Although sturgeon catches were prohibited for the recreational sector, they were still allotted 1% of total recreational/subsistence catches from 1950-1990 due to the existence of a 'Black market' for prohibited species.

Industrial discards

Discards are defined as that part of "the catch that is thrown away, or dumped at sea" (Kelleher 2005), and may include both commercial and non-commercial species. Reasons for discarding include damaged or spoiled catch, catch smaller than legal landing sizes, or having little or no market or commercial value (Rousou 2009).

Table 4. Recreational and subsistence catch allocation for 1950 and 2010, percentages mostly interpolated and adjusted based on expert advice

		1950	2010
Common name of species	**Scientific name**	**%**	**%**
Bluefish	*Pomatomus saltatrix*	13	4
Atlantic mackerel	*Scomber scombrus*	1	0
Mediterranean horse mackerel	*Trachurus mediterraneus*	15	10
Mediterranean mussel	*Mytilus galloprovincicalis*	14	10
Shrimps	Penaeidae	5	5
European flounder	*Platichthys flesus*	5	0
Grey mullets	Mugilidae	5	5
Red mullets	Mullidae	5	2
Gobies	Gobiidae	5	20
Whiting	*Merlangius merlangus*	10	10
Groupers and seabream	Epinephelinae and Sparidae	4	0
Shi drum	*Umbrina cirrosa*	4	0
Bonito	*Sarda sarda*	3	1
Garfish	*Belone belone*	3	0
Dogfish	*Squalus acanthias*	2	2
Rays/skates	Rajidae	2	2
Turbot	*Scophthalmus maetocis*	2	2
Sturgeons	Acipenseridae	1	0
Crabs/lobsters	Decapoda	1	0
Sea snail	*Rapana venosa*	0	7
Pacific mullet	*Mugil soiuy*	0	20

A small bottom trawl fishery existed briefly in the early 1950s targeting sturgeon and turbot. However, intensive bottom trawling for sprat began in the mid-1970s, and from 1979-1986, over 120,000 trawl hauls were performed in the northwest section of the Black Sea, which either damaged or completely destroyed benthic communities from the scouring of the heavy bottom-trawl boards (Eremeev and Zuyev 2007). The number of macrobenthos species in these silted areas declined 3.5-fold, their abundance 2.5-fold and their biomass more than 20-fold (Zaitsev *et al.* 1999).

Since no bottom trawling discard rate specific to the Ukraine could be located, a weighted bottom trawl discard rate from the Turkish Black Sea of 42% (Ceylan *et al.* 2014) provided the first anchor point used here. To remain conservative, the percentage was decreased to 30% and was applied only to the reported sprat catches for the intensive 1975-1986 trawling period discussed above. Of these 30% discards, 5% were allocated as damaged and juvenile sprat and whiting, while the remaining 25% were allocated as non-target (i.e., non-commercial) fish and invertebrates, to account for the disappearing macrobenthos species during the period of heavy trawling. Of the 25% discard of non-target species, the taxonomic composition allocated was dogfish (*Squalus acanthias*,20%), skates (Rajidae, 20%), rays (Dasyatidae, 20%), scorpionfish (Scorpaenidae,

5%), echinoderms (Echinodermata, 10%), miscellaneous marine crustaceans (Crustacea, 10%), marine molluscs (5%), conger eels (Congridae, 2.5%), and moray eels (Muraenidae, 2.5%). Some of these taxa are no longer present in Ukrainian waters in substantial quantities, but they represent the best estimates for what was initially removed by the intensive trawling period, as no data exist on the topic. Other commonly occurring benthic species had commercial value and thus would have been retained as bycatch, and not discarded.

For all other industrial catches, in the absence of any information on discards, a conservative 1% of total reported catches was applied to account for some industrial discards, which undoubtedly have occurred throughout time. Furthermore, in winter months during the bottom trawling period (1975-1986), anchovy and sprat were often landed together, and since anchovy have more-value, sprat was often discarded and not accounted for (V. Shlyakhov, unpubl. data). Thus, an additional 5% of sprat discards was assumed for reported anchovy catches during the 1975-1986 period.

During 1987-2005, the sprat fishery switched from bottom trawling to mid-water trawling, and only a 5% total discard rate (as juvenile and damaged sprat and whiting) was used for this time period, which apparently has since increased due to a higher concentration of juveniles in the catch in subsequent years (V. Shlyakhov, pers. obs.). Thus, we linearly increased the rate from 5% in 2006 to 8% by 2010.

Artisanal discards
Due to a total lack of information regarding the artisanal sector, a conservative 1% of artisanal catches was assumed to account for discards from this sector, composed of the juveniles of retained species and/or species with no market value.

Results

Ukraine as a whole
The reconstructed total catch for the Ukraine averaged about 50,000 $t \cdot year^{-1}$ in the 1950s and 1960s, after which it began increasing and peaked in 1984 with about 147,000 $t \cdot year^{-1}$, and then decreased to about 55,000 t in 1991 due to the Black Sea fisheries crisis, and dissolution of the U.S.S.R., after which the catches partially recovered to average about 100,000 $t \cdot year^{-1}$ in the late 2000s (Figure 2a, Appendix Table 1). Thus, the reconstructed total catch was 1.4 times the reported data from 1950-2010. Our reconstruction of Ukraine's total catch from 1950 to 2010 combines the reported landings submitted to the FAO with our best estimates of unreported industrial, artisanal, recreational, and subsistence landings, as well as major discards (Figure 2a).

From the reconstructed total catches (inclusive of the reported data) for the 1950-2010 period (Figure 2b), European anchovy (28%), European sprat (20%), and Black and Caspian Sea sprat (8%) were the major contributors to the catches, followed by gobies, whiting, Mediterranean horse mackerel and Mediterranean mussel.

Industrial landings
Reported industrial landings for the Ukraine averaged just over 30,000 t·year^{-1} in the 1950s, peaked in 1988 at over 155,000 t, declined substantially during 1991-1993 to just under 30,000 t·year^{-1}, and have since somewhat recovered to an average of about 60,000 t·year^{-1} in the late 2000s. In 1991, unreported industrial catches contributed 300 t which increased annually to about 14,000 t by 2010 (Figure 2a, Appendix Table 1). The major species caught by the industrial sector from 1950-2010 were European anchovy (40%), European sprat (27%), Black and Caspian Sea sprat (11%), gobies (6%), and Mediterranean mussel (4%). Note that small pelagics account for over 90% of total catches during this period.

Artisanal landings
Artisanal landings (all deemed unreported) averaged nearly 11,500 t·year^{-1} in the 1950s, peaked in 1970 at 13,500 t, then declined during 1990-1992 to just less than 2,000 t·year^{-1}, recovered to 7,000 t in 1993 and has since decreased to average less than 4,000 t·year^{-1} in the late 2000s (Figure 2a, Appendix Table 1). The major taxa caught by the artisanal sector from 1950-2010 were whiting (10%), sturgeon (8%), bluefish (8%), gobies (8%), European mussel (6%), Mediterranean horse mackerel (6%), decapod (6%), grey mullet (6%), and European anchovy (5%), with 15 other taxa making up the remaining 37% of catches.

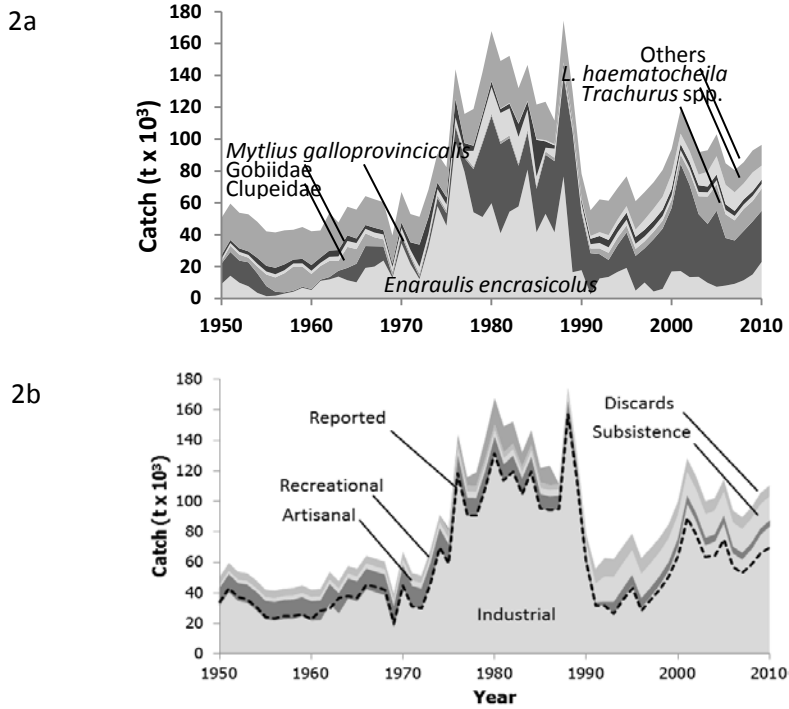
Recreational landings
Previously unreported recreational landings averaged just over 2,000 t·year^{-1} in the early 1950s, peaked in 1992 at 16,500 t, and then decreased slightly, averaging nearly 16,000 t·year^{-1} in the late 2000s (Figure 2a, Appendix Table 1). The major species caught by the recreational sector for the 1950-2010 period were Mediterranean horse mackerel (14%), gobies (12%), Mediterranean mussel (11%), *so-iuy* mullet, bluefish, and whiting (each at 10%), and sea snail (6%), with 14 other taxa making up the remaining 27%.

Subsistence fisheries
Previously unreported subsistence landings were likely relatively stable from 1950-1970, averaging 4,700 t·year^{-1}, declined to a low of 3,300 t in 1988, increased to over 11,000 t·year^{-1} immediately after independence and has since declined to average 7,000 t·year^{-1} in the late 2000s. The major species we assume caught for subsistence purposes from 1950-2010 were Mediterranean horse mackerel (14%), Mediterranean mussel (12%), bluefish (11%), gobies

(10%), whiting (10%), *so-iuy* mullet (7%), other grey mullets (5%), with 13 other taxa making up the remaining 31% of catches.

Discards

Discards were assumed to be relatively low throughout the 1950s and 1960s, averaging 430 t·year^{-1} for those decades. They increased significantly in the mid-1970s, peaking in 1980 at 17,000 t, and then declining to a low of 80 t in 1996, before increasing slightly to again average 430 t ·year^{-1} in the late 2000s. The taxa thought to be mainly discarded were sprat (27%), skates, rays and dogfish (13% each), crustaceans and echinoderms (6% each), and anchovy (5%), with 57 'other' taxa making up the remaining 19%.



Figures 2. Reconstructed total marine catches for Ukraine 1950-2010 by **(a)** taxon, with the 'others' group includes 56 additional taxa; and **(b)** fisheries sector plus discards, with reported data overlaid as dotted line

Discussion

The catch reconstruction of the Ukraine illustrated some key points about the country's fisheries and its reporting practices. Firstly, it is apparent that only the larger-scale industrial fisheries are accounted for in the data reported by FAO on Ukraine's behalf. This study is a first attempt to estimate/reconstruct the

unreported landings of the industrial, artisanal, recreational and subsistence sectors as well as major discards in order to establish a more comprehensive time-series for total fisheries removals. Assessing and understanding the scale of unreported fisheries can aid management by improving stock assessment, thus enabling the sustainability of stocks, and securing a future for these renewable resources, resulting in strengthened food security.

For the Ukraine as a whole from 1950-2010, the sectors which had the highest contributions to the total reconstructed catch were the industrial sector (70%), followed by the artisanal sector (11%), the subsistence sector (7%), the recreational sector (9%), and discards of both the industrial (2%) and artisanal sectors (1%).

Considering the time-series of total reconstructed catches both by sector (Figure 2a), and by taxonomic group (Figure 2b), it is apparent that the industrial sector more than doubled its catches from 1970 to 1980 due to a vast increase in the abundance of small pelagics. The estimates of unreported industrial catches post-independence are likely conservative and may in fact be much higher.

Commercial fisheries have been operating in the Black Sea for well-over two millennia (Bekker-Nielsen 2005), but in the last 50 years the system has been dramatically altered and transformed to an alternative state, one which is devoid of large predators, leading now to a race to catch the remainder of the small pelagics.

Since the Black Sea is a nearly isolated marine ecosystem, it provides a natural example of what can happen when the ecosystem approach is not fostered: the combined effects of pollution, eutrophication, and overfishing have resulted in a runaway trophic cascade (Daskalov 2002), one that will likely never return to resemble its former environment. The Black Sea, with respect to its shared resources, urgently needs to be managed within an ecosystem-based framework by all its shared users by reducing total fishing capacity and rebuilding current stocks if there is to be any fishing in this sea in the future (Ulman 2014). Or else, the Black Sea will only known as a case-study of what *not to do*, for fishery managers worldwide to learn from.

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Appendix Table 1. Reported marine fisheries landings (t) for Ukraine in the Black Sea, and reconstructed total industrial, artisanal, recreational, and subsistence landings and discards.

Year	Reported	Industrial	Artisanal	Recreational	Subsistence	Discards	Total
1950	34,120	31,974	11,322	2,056	4,798	320	50,470
1951	43,015	40,787	11,432	2,122	4,797	408	59,546
1952	37,311	34,927	11,542	2,188	4,795	349	53,801
1953	35,597	33,805	11,652	2,255	4,792	338	52,842
1954	30,352	28,978	11,762	2,323	4,788	290	48,141
1955	24,204	22,852	11,872	2,392	4,784	229	42,128
1956	23,170	22,040	11,982	2,462	4,778	220	41,482
1957	24,869	23,147	12,092	2,532	4,772	231	42,775
1958	24,574	23,353	12,203	2,604	4,765	234	43,158
1959	25,608	24,874	12,313	2,676	4,757	249	44,868
1960	22,623	22,069	12,423	2,749	4,748	221	42,210
1961	28,652	22,379	12,533	2,823	4,738	224	42,697
1962	29,509	33,156	12,643	2,898	4,728	332	53,756
1963	36,824	27,015	12,753	2,973	4,716	270	47,728
1964	37,991	36,610	12,863	3,050	4,704	366	57,593
1965	36,898	34,647	12,973	3,127	4,691	346	55,785
1966	45,173	42,854	13,083	3,206	4,677	429	64,249
1967	44,123	40,714	13,193	3,285	4,662	407	62,261
1968	41,877	38,809	13,303	3,365	4,647	388	60,512
1969	20,303	17,878	13,413	3,446	4,630	179	39,545
1970	44,753	44,753	13,523	3,527	4,613	448	66,864
1971	31,287	31,287	13,293	3,570	4,543	313	53,006
1972	29,842	29,842	13,056	3,611	4,474	298	51,282
1973	46,939	46,939	12,815	3,652	4,404	469	68,278
1974	69,721	69,721	12,567	3,691	4,333	697	91,010
1975	59,502	59,502	12,315	3,729	4,262	2,626	82,434
1976	118,302	118,302	12,056	3,767	4,191	5,551	143,867
1977	90,794	90,794	11,792	3,803	4,119	5,322	115,831
1978	90,822	90,822	11,523	3,838	4,048	8,697	118,928
1979	109,191	109,191	11,248	3,871	3,976	13,770	142,057
1980	131,531	131,531	10,968	3,904	3,904	17,495	167,802
1981	113,606	113,606	10,682	3,935	3,831	17,008	149,063
1982	119,624	119,624	10,391	3,965	3,759	14,546	152,285
1983	104,875	104,875	10,094	3,993	3,686	9,351	131,999
1984	119,544	119,544	9,792	4,021	3,613	9,628	146,598
1985	95,220	95,220	9,484	4,047	3,541	9,446	121,737
1986	94,107	94,107	9,171	4,071	3,468	12,650	123,467
1987	94,833	94,833	8,852	4,094	3,395	517	111,691
1988	157,256	157,256	8,528	4,116	3,322	1,175	174,396
1989	114,122	114,122	8,198	4,136	3,250	509	130,214
1990	61,241	61,241	1,966	8,390	6,416	281	78,293
1991	31,527	31,842	1,895	12,483	9,289	204	55,713
1992	31,728	32,362	1,824	16,501	11,949	202	62,839
1993	26,286	27,074	7,016	16,354	11,521	171	62,137
1994	34,987	36,387	6,733	16,202	11,104	224	70,650
1995	43,212	45,372	6,451	16,045	10,696	280	78,844
1996	28,635	30,353	6,169	15,883	10,297	79	62,782
1997	35,136	37,595	5,887	15,717	9,908	149	69,256
1998	42,132	45,503	5,604	15,546	9,528	119	76,299
1999	50,582	55,134	5,322	15,371	9,156	213	85,197
2000	64,378	70,815	5,040	15,191	8,794	317	100,158
2001	89,203	99,016	4,914	15,262	8,584	402	128,177
2002	77,910	87,259	4,788	15,330	8,376	324	116,077
2003	63,297	71,525	4,662	15,397	8,169	319	100,073
2004	64,732	73,794	4,536	15,462	7,965	338	102,096
2005	74,995	86,244	4,410	15,525	7,762	393	114,334
2006	57,060	66,190	4,284	15,586	7,561	358	93,979
2007	53,033	62,049	4,158	15,646	7,362	350	89,565
2008	58,247	68,732	4,032	15,703	7,165	371	96,003
2009	65,870	78,386	3,906	15,759	6,970	413	105,433
2010	69,760	83,712	3,780	15,709	6,733	451	110,385