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## CROATIAN MARINE FISHERIES (ADRIATIC SEA): 1950-2010

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### ABSTRACT

We estimated the total Croatian marine fisheries catches from the eastern part of the Adriatic Sea, from 1950-2010. Using the official catch database reported in national statistical yearbooks as the reported data baseline, we added the following unreported catch components: unreported commercial landings, discards, and subsistence and recreational catches. The reconstructed total catch from 1950-2010 was approximately 115% higher than the data officially reported by the Directorate of Fisheries for the same time period. For the 1990-2010 post-Yugoslavia time period, this difference was 137% on average. Our reconstruction is likely an underestimate, as we used minimum values based on conservative assumptions. However, a conservative estimate is still preferable to the current default assumption of zero catch in the absence of officially-reported IUU data.

### INTRODUCTION

Croatian marine fisheries take place along most parts of the eastern Adriatic coast (almost 40% of the total Adriatic Sea). Since ancient times, fishing has played an important role in shaping the life of local people that live in coastal areas, and the first known written document about Croatian fisheries dates back to 995 AD (Margetić 1997).

The Adriatic Sea (Figure 1) is a small, semi-enclosed sea of the Mediterranean (4.6% of its total area) connected to the Eastern Mediterranean via the Otranto Strait (width 40 nm and maximum depth 741 m; Buljan and Zore-Armanda 1971). The Adriatic is a shallow sea, with continental

shelves covering 73.9%. The depth gradually increases from the northwest (max. 50 m) to the southeast (max. 1,330 m). Depths greater than 200 m are only found in the central and southern parts. The Adriatic Sea is a relatively warm sea (summer sea surface temperatures are usually between 22-25° C) and its basin is distinguished by a relatively high salinity of about 38.3 psu (Buljan and Zore-Armanda 1971). A strong connection between the Adriatic and the eastern Mediterranean is supported by water masses flowing into the Adriatic from the Eastern Mediterranean along the east coast of the Adriatic and flow out along the west coast.



Figure 1. The Exclusive Economic Zone (EEZ) and shelf areas less than 200 m depth for Croatia in the Adriatic Sea.

The Adriatic Sea, like the Eastern Mediterranean, is a highly oligotrophic area and the primary production is low and phosphorous limited (Siokou-Frangou *et al.* 2010). The only exceptions are the northernmost Adriatic, where high river nutrient loads are responsible for phytoplankton blooms and high levels of eutrophication (Degobbis *et al.* 2000) and narrow coastal zones which include channel areas and estuaries (Buljan 1964). Thus, fish abundances and, as a consequence, fishery catches are highest in these areas. The deeper, open waters of the southern Adriatic are less productive, and more typical of the Mediterranean as a whole (Fonda Umani *et al.* 1990).

Up until 1990, the Adriatic Sea was second in fishing and economic importance among the 10 fishing areas in the Mediterranean. Several countries fish in the Adriatic Sea: Italy (79% of reported catches), Croatia (16%), Slovenia (2%), Albania (2.6%) and Montenegro (0.3%; Jardas 1996). Croatia is the most important coastal fishing country of the former Yugoslavia, and is second only to Italy in terms of landings of marine capture fisheries in the Adriatic Sea. Marine capture fisheries dominate the fisheries sector in Croatia and are more important than the smaller, freshwater/inland fisheries sector (Fredotović and Mišura 2003). Traditionally, Croatian marine resources have been distinguished as pelagic, demersal, and coastal although there are little clear natural distinctions among them (Jardas and Pallaoro 1997). Around 90% of the catch consists of fish (71.1-79.4% small pelagic fish) and 10% consists of invertebrates. Small pelagic catches are mostly comprised of *Sardina pilchardus*, *Engraulis encrasicolus*, *Sprattus sprattus* and *Trachurus trachurus*. *Sardina pilchardus* comprises 63.9-70.1% of catches within this group (Sinovčić 2000). Since the majority of the catch consists of small pelagic fish, Croatia has a well-developed and well-equipped commercial fleet for this type of fishing.

The bottom trawl fishery for demersal resources takes place over the entire Adriatic continental shelf and on some parts of the continental slope in the southern Adriatic. It mostly targets *Mullus barbatus*, *Merluccius merluccius* and *Nephrops norvegicus* (Vrgoč *et al.* 2004).

Coastal fisheries have been described as taking place in a relatively small area - on average, about 300 m offshore with a maximum depth of about 80 m, which corresponds to about 6% of the total Croatian Adriatic fishing grounds (Jardas and Pallaoro 1997). Here, however, we consider artisanal fisheries to utilise all coastal and territorial waters, and the *Sea Around Us* project defines 'artisanal' or 'small-scale' fishing area as the *Inshore Fishing Area*, which is defined as 50 km from shore or 200 m depth, whichever comes first (Chuenpagdee *et al.* 2006). It is a typical Mediterranean multi-species, multi-gear fishery employing more than 50 different types of fishing gears to catch about 150 species of commercial interest from almost 440 fish species that have been listed as the Adriatic ichthyofauna (Dulčić and Dragičević 2011). The rich Mediterranean tradition of fishing techniques is fully reflected in the Adriatic coastal fisheries.

Croatia and its fisheries persisted under two different political regimes. The first was a socialist period with a state controlled economy that was established after World War II during which Croatia was a constituent entity of the former Yugoslavia. The second regime came after an armed conflict during 1991 - 1996 which brought Croatia independence and a transition to a market-based economy. However, fisheries were little influenced by country-level political issues, as most fishing vessels have always been small (< 12 m length, < 15 GRT) and have generally been privately owned over the entire time period

In the former Yugoslavia, large-scale industrial pelagic fishing under state control was common, while other types of fishing (small-scale, artisanal), although extensive and ongoing, were not a major political focus. To illustrate this, almost 30 fish processing factories were active during the 1960s (Basioli 1985), while nowadays there are only a few. In the early 1990s, socio-political interruptions (i.e., the change from state to private ownership and the transition from a socialist to a market economy) and the armed conflict led to the collapse of the purse seining industry (both fishing and processing), while the trawling sector dramatically increased (~10 fold increase) (Matić-Skoko *et al.* 2011a). This was driven largely by the disappearance of the regional market for canned small pelagic fishes due to trade interruptions caused by the conflicts. In particular, the restructuring encompassed a redirection of the fishery from small pelagic resources towards demersal resources, which were considered to be underexploited (Fredotović and Mišura 2003).

This led to the construction of more bottom-trawlers, until a ban was issued in 2000 (Mišura 2002). More recently, with renewed opening of regional trade infrastructures, an increasing number of trawlers are converting back to purse seiners.

The artisanal fisheries have always been represented by large numbers of both professional and subsistence fishers, and reflect the rich fishing tradition that is similar to the rest of the Mediterranean. However, a sharp upward trend of new entrants to the subsistence sector was observed in the early 1990s during the war period when socio-economic reasons led to a high number of people engaging in fishing (Stagličić *et al.* 2011).

The regulation governing fisheries issues in Croatia is the Fisheries Act (Official Gazette No. 56/10). Together with its subordinate acts (Code of Conduct for Professional Fishing, Code of Use of Fishing Gear for Professional Fishing, Fish and Other Sea Organisms Protection Decree; Official Gazette No., 63/10a, 148/10, 63/10b), it regulates spatial and temporal fishing restrictions, minimal landing size of commercial fish species, and technical details of fishing gear and fishing techniques. Four main sectors of fisheries that are of interest here can be identified from the Croatia's Marine Fisheries Act: commercial (large-scale, industrial; and small-scale, artisanal), subsistence, recreational and sport fishing. Commercial fishing is a profit-making activity encompassing large-scale industrial fishing (purse seine and trawl fisheries) and small-scale artisanal fishing (high diversification of fishing gears and techniques, targeting a large variety of species). Fish and other marine organisms caught in the course of subsistence, recreational or sport fishing are not to be sold and are intended solely for fishers' and their families' own consumption. Additionally, the Fisheries Act (Official Gazette No. 56/10) further distinguishes fishing for scientific purposes and tourism. For a more detailed review of Croatian marine fisheries see Cetinić and Soldo (1999) and (Matić-Skoko *et al.* 2011a).

For an accurate assessment of fishing effort, reliable data on the type, dimension, and quantity of fishing gear are required. Although some data exist for Croatia's fisheries, they are not monitored and recorded systematically, thus making them practically unusable for any serious analysis. Fishing effort is complex to measure, especially given the diversity of gears and vessel types characterizing artisanal fisheries, so management assessment has been based mainly on the number of boats and/or number of fishers, limiting the evaluation of actual fishing pressure on resources. Approximately 2,200 licenses have been issued to professional fishers by the late 1990s (Cetinić and Soldo 1999). According to the Central Bureau of Statistics, by 2005, Croatia had 3,720 registered professional fishers and 3,692 fishing vessels. The 'professional' category is made up of 2,729 registered trawlers, seiners, and smaller vessels that operate in the coastal and open waters of the Adriatic (Mišura 2002). Issuing of new licenses stopped in 2008, and the official statistics of the Directorate of Fisheries (DF) for the period 2009-2010 counted around 4,000 vessels (the number of vessels approximates the number of licenses) in the professional fishery sector. Of these 4,000 vessels, 3,360 vessels are less than 12 m in length, and could be considered artisanal in nature, depending on gear types used.<sup>1</sup> In addition, there are around 12,000 vessels registered as subsistence vessels.

Marine fisheries landings in the eastern Adriatic ranged from 17,000-30,000 t·year<sup>-1</sup> during the 1950-1980 time period (Basioli 1985), while from 1983-1993 landings were around 24,000-54,000

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<sup>1</sup> For the global data purposes of the *Sea Around Us* project, all catches taken by fishing gears that are dragged through the water (e.g., pelagic trawls) or across the seafloor (bottom trawls) are deemed industrial, irrespective of vessel size (see also Martín 2012).

t·year<sup>-1</sup> according to national Croatian statistics (Dulčić *et al.* 2007). During the dissolution of the former Yugoslavia and the ensuing armed conflict, there was a substantial decline in the fisheries sector and total landings. Jardas and Pallaoro (1997) suggested that the Adriatic artisanal fisheries alone could be catching more than the pelagic and trawl fisheries (total landings about 30,000 t·year<sup>-1</sup>). However, official statistics of the Directorate of Fisheries (DF) for the 2008-2010 period shows that annual landings are stable at about 50,000 t·year<sup>-1</sup>, of which 90% are landings of small pelagic, while artisanal landings comprise only 1%. Thus, this assessment is certainly an underestimate, since the majority of industrial trawl and artisanal landings go unreported. Landings by both trawl and artisanal sectors may be substantial, given the large number of fishers involved and the high productivity of the coastal zone. Recreational fishing is another fisheries sector that has been completely unaccounted for in officially reported landings statistics. Data dealing with recreational fishing are generally rare, despite this having been a very popular activity for decades, and much of the resident population as well as a growing number of visiting tourists engage in it. Therefore, recreational catch may have a significant impact on near-shore marine resources.

The objective of the present study is to provide an estimate of total marine fisheries catches in the eastern Adriatic by Croatia during the time period from 1950-2010. Although several studies and reports have been published previously, there has been no comprehensive review of potential historical catches or any apparent effort to fully represent total catches. Our approach utilizes assumption-based estimations to cover all aspects of the various components of unreported fisheries catches for all years between 1950 and 2010.

## METHODS

A reconstruction of Croatia's total marine fisheries catches was undertaken for the time period of 1950-2010 following the general principles outlined in Zeller *et al.* (2007). Annual database records derived from different reports by the responsible national authority, currently called the Directorate of Fisheries (previously under different names and different ministries), were used as the baseline for our reconstruction. National sources were used in place of the FAO commercial landings data as they present the data disaggregated by each country entity of the former Yugoslavia and were deemed more reliable. The officially reported fisheries data account exclusively for commercial landings and not total catches. Therefore, to fully account for all removals, we supplemented reported landings with estimates of catches generated by unreported and unregulated fisheries. Sources of unreported catches considered here include: (i) *unreported landings* – i.e., landed catches not reported to authorities; (ii) *discards* - i.e., fish caught by fishing operations, but not retained; (iii) *subsistence*; and (iv) *recreational* catches. The resulting reconstructed time series of total catch is derived by summing all these components (officially reported landings statistics + estimated unreported catches), and represents the best estimate of total catches for Croatia from 1950-2010.

The basic methodological approach used to shape our assumptions regarding unreported catches, and retroactively estimate total catches, consisted of utilizing as wide a range of information and data sources as possible, including academic and grey literature, media sources, and personal information based on interviews and collaborations with fisheries experts. Whenever information

and data that were considered usable for each of the catch components were found, they were transformed to create so-called 'anchor points' (sensu Zeller *et al.* 2007). From these anchor points, a complete time series of data from 1950-2010 was constructed using expansion methods (e.g., linear interpolations and extrapolations) for years when data were not available (Zeller *et al.* 2006; Zeller *et al.* 2007; Zeller and Pauly 2007).

Underreporting and discarding was estimated separately for each of the fisheries sectors, to account for known differences in their reporting and discarding practices. Differences in discard rates are largely driven by differences in the construction and operation of fishing gears, while the proportion of reported catches has been significantly influenced by political and economic circumstances. Following the dissolution of Yugoslavia and transition to a market-based economy, unreported catches became much more widespread. All unreported and discarded catches were accounted for as percentage rates, which were applied to landings data. Specifically, rates of unreported landings were applied to landings statistics, while discard rates were applied to the sum of landings statistics and unreported landings.

## INDUSTRIAL PURSE SEINE FISHERY

Catches of pelagics have always been considered relatively well documented (Jardas and Pallaoro 1997). In the former Yugoslavia, the accuracy of reporting purse seine fishery landings was ensured by state control. During this time period (1950-1990), the vast majority of purse seine vessels were owned by the state, and all vessels were obliged to deliver landed catch directly to national authorities, and all fish were sold for similar prices. Even after Croatia gained independence and transitioned to a market-based economy, the purse seine fishery remained strongly linked to a small number of coastal landing centers, thus making the marketed fish relatively easy to monitor. However, in 2003, the Croatian government began providing direct financial subsidies (per kg of fish reported) with the intent of strengthening the purse seine fishery (Anon. 2005; Par *et al.* 2006). This provided a very strong incentive to over-report actual catches, and has primarily been exploited by tuna farmers, due to the low traceability of fish caught by their own purse seiners to feed the farmed tuna. Information derived from correspondence with fishers and fishery experts led us to use a rate of 15% from 2004 onwards to account for over-reporting in the landings of small pelagics. Clearly, this over-reporting of catches (and taxonomic miss-reporting) needs to be urgently addressed, although some opinions suggest that the rate is lower at around 5%. Furthermore, we assumed a discard rate of 0% for the purse seine fishery during the entire study period, based on reports that indicate that discarding in this type of fishery is almost non-existent (Vassilopoulou 2011, and references therein).

## INDUSTRIAL FISHERY

Landings of the trawl fishery have likely always been underreported and data on discards are entirely absent from the officially reported statistics (Jardas and Pallaoro 1997; Krstulović Šifner *et al.* 2009). Underreporting by the trawl fishery has been an issue even when Croatia was a part of the former Yugoslavia, owing to the opportunity and profitability of selling the catch directly to the market. As there are no published reports documenting unreported landings by this fishery, we

used an assumption-based approach to derive anchor points. For the time period of 1950-1980, it was assumed that unreported trawl landings were twice the reported landings, while for the last decade of the former Yugoslavia (1980-1990), when noncompliance became much more widespread, unreported landings were assumed to have been three times that of reported landings, as was suggested by Jardas and Pallaoro (1997). From 1991 onwards, reflecting the transition from a state-controlled economy to a market-based economy, this rate was carried forward unaltered.

The estimation of discards is based on studies by Krstulović Šifner *et al.* (2009) and Vrgoč *et al.* (2009) who found discarding to be on average 30% of the total catch. This rate was applied to the sum of trawling landings statistics and unreported landings to produce a time series of trawling discards. Only in the early years (1950-1960), when the trawl fishery in the eastern Adriatic was in the development phase (Basioli, 1986), did we assume a much higher discard rate of 50% of total catches (A. Soldo, unpubl. data).

## ARTISANAL FISHERY

The magnitude of artisanal fishing is underestimated in the official statistics, due to the widespread and scattered nature of these fisheries and the associated difficulties and cost of obtaining reliable catch data (Matić-Skoko *et al.* 2011a; Matić-Skoko *et al.* 2011b). Since the market for artisanal fisheries is largely decentralized, it has always been feasible for these fishers to sell some or all of their catch for a respectable price without recording it. Nowadays, for example, the vast majority of artisanal fishers (up to 90%) are thought to report less than a quarter of their catch. To fully account for all likely artisanal catches from 1950-2010, we applied an adjustment factor of 4 to the reported artisanal catches from 1950-2010 (A. Soldo, unpubl. data). As a wide variety of fishing gears with different selectivity properties is used in artisanal fisheries, recent studies (Dulčić *et al.* 2009; Dulčić *et al.* 2010) examining artisanal fisheries catches of several dominant artisanal fishing gears were used to derive discard rates. Discards for each of the studied fishing gear was calculated as a proportion of unmarketable, unpalatable or inedible species to the total catch, and an average discard rate of 20% (A. Soldo, unpubl. data) was applied for the entire time period of this study (1950-2010).

## SUBSISTENCE FISHERY

Subsistence catches have never been accounted for in Croatia's reported landings and are generally very scarce in the literature. Therefore, we based the reconstruction of subsistence catches on the number of subsistence fishers. The number of subsistence fishers for the time period of interest (1950-2010) was extracted from studies and reports by (Basioli 1978, 1979, 1985), Jardas (1980) and Mišura *et al.* (2008). Additionally, Mišura *et al.* (2008) gave an estimate of catches of 6,000 t·year<sup>-1</sup> by about 13,000 currently registered subsistence fishers. Assuming proportionality, we derived a complete time series of subsistence catches by following the changes in the reported number of fishers.

## RECREATIONAL FISHERY



No requirements exist for the reporting of recreational fishing in Croatia, despite the substantial proportion of the resident population (and visiting tourists) who engage actively in recreational fishing (Fredotović *et al.* 2007). As with the subsistence sector, the reconstruction of recreational catches was done indirectly using the available information on the number of fishers. The number of recreational fishers in Croatia was reported to be 25,000 from 1979 to the early 2000s (Basioli 1979; Vodopija 1997; Par *et al.* 2006; Fredotović *et al.* 2007), thus we assumed 25,000 for 1979 to 2000. For 2010, expert opinion suggests that the number of recreational fishers has increased to around 80,000 (A. Soldo, unpubl. data). Grubišić (1968) reported a number of 15,338 recreational fishers for the corresponding year. Thus, we assumed that in 1950 there were 10,000 recreational fishers, and for years when data were unavailable, we estimated the number of fishers using a linear interpolation between the anchor points in 1968 (15,338), 1979 (25,000), 2000 (25,000) and 2010 (80,000). Only Basioli (1979) gave an estimate of total possible recreational catch at about 1,500 t·year<sup>-1</sup>. For years between 1950 and 1978, estimated catch was reduced in accordance with the trend of fishers during that time. From 1980 to 1990, we assumed proportionality with the trend in the number of recreational fishers, and estimated catch was carried forward as a fixed rate. During Croatia's armed conflict for independence between 1991 and 1996, we assumed a decrease in recreational fishing. From 1991 to 1993, we assumed a 25% decrease in recreational catch compared to 1990, and a 75% decrease from 1993 to 1995. Recreational catches for 1996 were increased to 50% of catches made in 1990. The trend from 1980 to 1990 was then carried forward again from 1997 to 2010.

## TAXONOMIC BREAKDOWN

Data concerning the species composition of catches are very limited and pertain only to landings. The taxonomic breakdown of landings was obtained from annual fisheries reports. For the 1950-1990 period, landings were disaggregated to species level for most of the pelagic fishes (*Sardina pilchardus*, *Engraulis encrasicolus*, *Sprattus sprattus*, *Scomber scombrus*, *Scomber japonicus*, *Thunnus thynnus*, *Euthynnus alletteratus*, *Sarda sarda*, *Auxis rochei*, *Belone belone* and *Trachurus* spp.), while the landings of demersal and coastal taxa are presented discontinuously and separately only for *Merluccius merluccius*, *Mullus* spp., *Spicara* spp., *Boops boops*, Mugilidae, Soleidae, *Palinurus elephas*, *Nephrhops norvegicus* and Cephalopoda. While many more taxa are caught by these sectors, they are all reported as 'miscellaneous marine fishes'. More detailed taxonomic accounting of landings can be found only for the last few years (2008-2010). Taxonomic breakdown presented here comprises 22 taxa – 20 fish species, 2 crustacean species and cephalopoda as an aggregated category – for which landings were rather continuously reported, plus a miscellaneous category. The composition of catches for the missing years was interpolated.

Using the species composition given in reported national landings data, we assigned catches to taxa with as much resolution as possible. Catches from the recreational and subsistence sectors were assigned to families, using the same taxonomic information as the industrial and artisanal sectors.

The estimated demersal discards were assigned taxonomically to demersal taxa with an assumed resolution at the family level

## RESULTS AND DISCUSSION

We present data accounting for Croatia's total marine fisheries catches in the eastern Adriatic Sea for the period 1950-2010. The total catch for Croatia, as reconstructed here, used reported landings statistics as baseline data and estimated various forms of unreported catches. Our added estimates of unreported catches were comprised of *unreported landings*, *discards*, *subsistence*, and *recreational* catches. The total reconstructed catch over the 1950-2010 time period was about 115% higher than the officially reported landings (Figure 2a). Catches showed a steady increase from an average of around 41,000 t·year<sup>-1</sup> in the 1950s to a peak of almost 103,000 t·year<sup>-1</sup> in 1987 (Figure 2a). This peak was followed by a decrease in total catches (particularly pronounced in the 1990s) to a low of around 39,000 t·year<sup>-1</sup> in 2001. Another increase was observed near the end of the study period and reached 81,000 t in 2010 (Figure 2a).

The scale of underreporting increased from around 50% in the early 1950s to a peak of around 220% in the mid-1990s, before declining to around 78% by 2010 (Figure 2a, Table 1, see Appendix Table A1 for complete time series data). The largest discrepancies between officially reported landings and estimated total catches in the early-mid 1990s occurred during, and immediately after, the period of armed conflict leading to Croatian independence. This was a result of exposure to severe socio-economic uncertainty connected to the violent conflict going on at the time. In such conditions, many people opted not to report the catches so as to void the taxes and earn a little bit more by selling the catch directly. On the other hand, in early post war years, relevant fisheries services were just being established and were unable to effectively enforce the regulations (Vodopija 1997). Even nowadays, fisheries services are still being restructured in an attempt to optimize the system of fisheries monitoring and data collection. The trend of increasing catches between 1950 and the 1990s can be attributed to the increase in fishing effort resulting from developments and the advancement of technology and construction of fishing gears following WW II (Basioli 1986). Particularly, industrial fisheries expanded in the 1950s from about 50 vessels to over 200 vessels by the early 1980s (Basioli 1985; Figure 2a).

Overall, unreported landings (commercial, subsistence and recreational) accounted for the largest share of total unreported catches, with over 1.4 million t over the 1950-2010 time period, compared to 430,000 t of discards (Figure 2a, Table 1). Estimated unreported landings in the commercial fisheries from 1950-2010 totalled approximately 1,000,000 t, of which 54% were underreporting in the industrial sector, specifically trawl fishery, and the remaining 46% were artisanal unreported catches (Figure 2b, Appendix Table A1). Unreported trawl landings were low from 1950 to the beginning of the 1980s, averaging 2,900 t·year<sup>-1</sup>. After this period, a dramatic increase occurred during which unreported landings averaged over 13,000 t·year<sup>-1</sup>. This is a consequence of re-orientation of the industrial sector from the pelagic fishery to the trawl fishery (Fredotović and Mišura 2003). Moreover, trawl vessels had become bigger and more powerful (Basioli 1986), and thus attained larger catches. On the other hand, underreporting in artisanal fisheries fluctuates between several orders of magnitude in tonnage; in 2002 an estimated 2,000 t of catch were unreported whereas in 1993 there was more than 21,000 t of unreported catch.

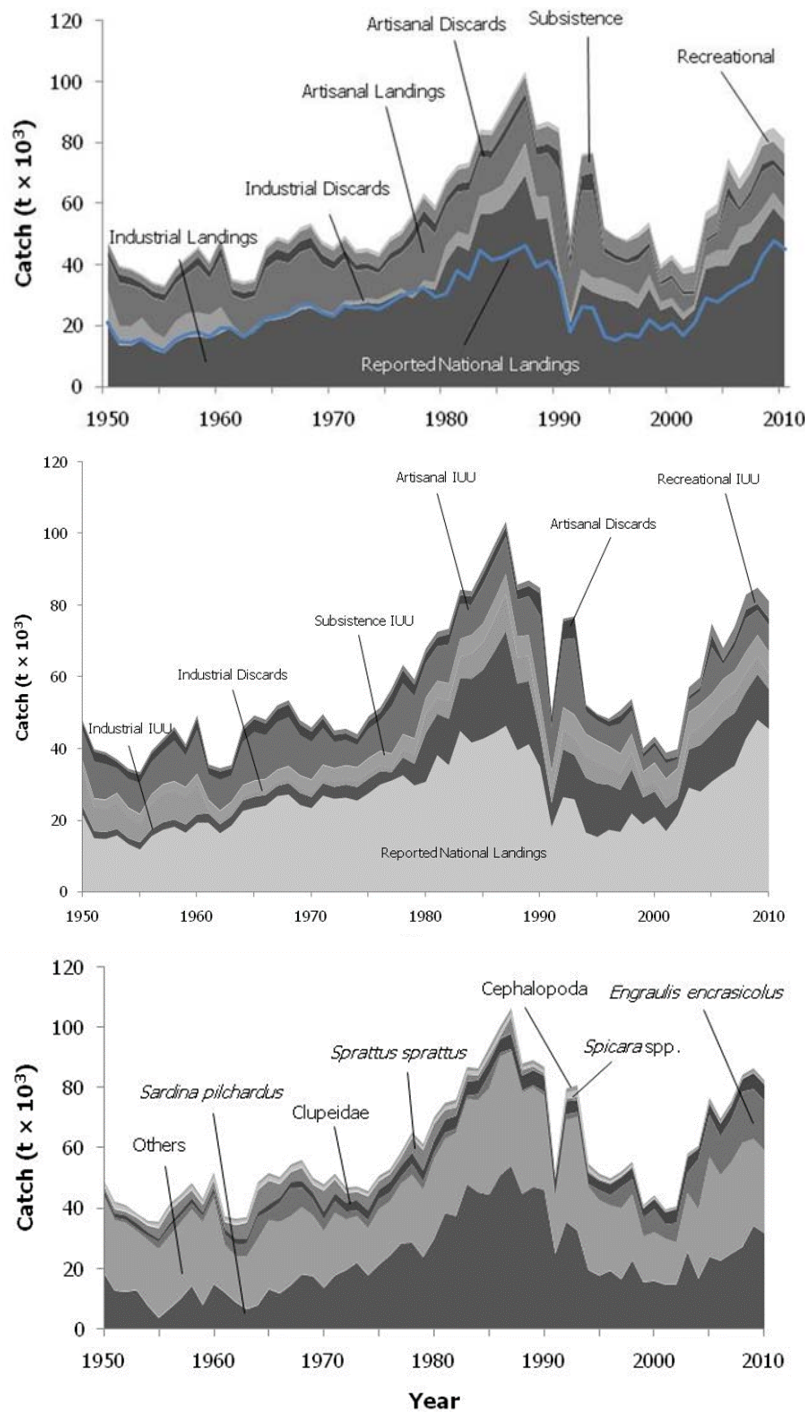


Figure 2. Croatia's fisheries removals in the eastern Adriatic Sea for the 1950-2010 time period: (a) total reconstructed catches by sectors in comparison to total reported national landings; industrial and artisanal 'landings' are a sum of unreported landings and reported landings; (b) total reconstructed catch by component, including reported and unreported landings, discards, subsistence, and recreational catches; and (c) total reconstructed catch by taxa with 'others' representing 31 additional taxa with lesser contributions and marine fishes nei.

**Table 1.** Croatia's catch averaged by decade (t·year<sup>-1</sup>) by catch component. 'Adjustments' represent over-reported landings.

<b>Component</b>	<b>1950-1959</b>	<b>1960-1969</b>	<b>1970-1979</b>	<b>1980-1989</b>	<b>1990-1999</b>	<b>2000-2010</b>
Reported landings	15,984	22,183	27,885	40,493	21,217	31,965
Adjustments	0	0	0	0	0	-5,437
Industrial	12,946	18,465	24,643	37,133	17,491	29,974
Artisanal	3,038	3,718	3,242	3,360	3,726	1,991
Discards	9,900	5,027	4,324	9,697	7,605	6,010
Subsistence	2,398	2,990	3,927	5,234	5,788	5,977
Recreational	726	1,016	1,330	1,500	975	3,150
<b>Total</b>	<b>44,993</b>	<b>53,399</b>	<b>65,351</b>	<b>97,417</b>	<b>56,802</b>	<b>73,631</b>

Discards totalled just over 430,000 t over the 1950-2010 time period. Again, discards of the industrial trawl fishery were the most substantial, representing about 64% of our total discard estimate. Trawl discards were lower during the first three decades (1950-1980), increasing dramatically with the expansion of trawl fishery in the mid-1980s and remaining substantial throughout the remaining period (1990-2010). Artisanal discards ranged from 680 to 6,000 t·year<sup>-1</sup> over the study period. Lower discard rates in the artisanal sector, compared to the industrial sector, stem from high selectivity of most fishing gears used in the artisanal fishery. Furthermore, artisanal fishers typically retain all fish or marine invertebrates that have a lower market price for personal consumption. Therefore, actual discarding in the artisanal fishery is quite small.

Subsistence catches accounted for slightly over 269,000 t from 1950-2010 and are shown to be a significant addition of unreported landings (Figure 2b, Appendix Table A1). Subsistence catches increased steadily over the years. In the 1950s, catches of the subsistence fishery were on average 2,400 t·year<sup>-1</sup>, increasing in 1960s to around 3,000 t·year<sup>-1</sup>, and to 4,000 t·year<sup>-1</sup> in the 1970s. In the 1980s, subsistence catches increased substantially to 5,000 t·year<sup>-1</sup> and from then on continued to rise, albeit at a slower rate, with an average catch of 5,800 t·year<sup>-1</sup> in the 1990s. During the last decade (2000-2010), catches stabilized around an average of approximately 6,000 t·year<sup>-1</sup>.

The number of subsistence fishers generally increases when political or socio-economic conditions are difficult, e.g., during and immediately after the armed conflict or in times of economic recession such as at the end of the 2000s. Fishers obtain certain social benefits by entry in this category (e.g., no obligation to pay taxes for their catches), but also have limitations in terms of type and quantity of fishing gear they may use and daily catch limit. Unfortunately, compliance of this category of fishers is rather low. Not only do they violate regulations regarding restrictions on quantities of allowed fishing gear, thus leading also to violation of the daily catch limit of 5 kg, but they are not insignificant catches are often sold on the informal or black markets, hindering the sales of commercial fishers. Such behaviour leads to increased tensions between both sides (Matić-Skoko *et al.* 2011b).

Estimates of recreational catches between 1950 and 2010 totalled approximately 90,000 (Figure 2b, Appendix Table A1). Recreational catches increased steadily from approximately 600 t·year<sup>-1</sup> in 1950 to an estimated 1,500 t·year<sup>-1</sup> from 1980 onward, with a temporal decline to less than 400 t·year<sup>-1</sup> during the armed conflict in the early 1990s. Thereafter, catches increased from 1,820 t·year<sup>-1</sup> in 2001 to 4,800 t·year<sup>-1</sup> in 2010.

Based on the taxonomic breakdown available to us, fisheries landings of Croatia have been dominated by small pelagics, particularly *Sardina pilchardus*, which on average represents more than 40% of total landings (Figure 2c). In the 1980s, exceptionally large catches of Clupeidae, including *S. Pilchardus*, were recorded and comprised an average of more than 57% of the total landings. At the same time, catches of *Engraulis encrasicolus* declined to less than 3%. This change in catch composition has been attributed to climate oscillation (Grbec *et al.* 2002). From the time series of taxonomic breakdown, it is also evident that landings of *Trachurus* spp. and *Spicara* spp. have continuously been declining from 4-7% in the early years (1950-1970) to below 1% in the last two decades (1990-2010, Figure 3). These species have traditionally been used as main food resources of coastal and island inhabitants, but due to their low commercial value nowadays they are in general not recorded in landings as they are treated as bycatch or discard (Dulčić *et al.* 2010). Among demersal species, the largest contributions to total landings are made by *Merluccius merluccius* and *Mullus* spp. (which together represent an average of about 3% of total landings).

## CONCLUSION

This study illustrates explicitly what has long been suspected – Croatia's officially reported landings considerably underestimate true catches in the fishery. Our estimates turned out to be very close to the presumptions of total catches reaching up to 70,000 t expressed by Jardas and Pallaoro (1997) and Vodopija (1997). The current method of fisheries catch reporting is inadequate and incomplete, and more comprehensive reporting which includes all fishing sectors is necessary to account for total catches.

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APPENDIX

year	landings	adjustments	unreported	discards	subsistence	recreational	total
1950	21,477	0	13,545	12,705	2,290	600	50,617
1951	14,981	0	15,371	9,532	2,318	640	42,842
1952	14,776	0	14,888	9,352	2,346	660	42,022
1953	15,789	0	11,792	9,488	2,373	680	40,123
1954	13,351	0	12,796	8,288	2,387	720	37,543
1955	11,840	0	13,898	7,796	2,401	740	36,675
1956	15,551	0	14,177	9,662	2,429	760	42,580
1957	17,320	0	14,792	10,654	2,457	800	46,022
1958	18,205	0	16,663	11,238	2,485	820	49,411
1959	16,550	0	14,395	10,285	2,498	840	44,568
1960	19,297	0	17,969	12,057	2,512	880	52,715
1961	19,297	0	13,268	3,075	2,622	900	39,162
1962	16,401	0	14,778	3,416	2,732	920	38,248
1963	18,507	0	13,797	3,151	2,842	957	39,253
1964	22,613	0	18,993	4,547	2,952	993	50,098
1965	23,434	0	20,829	5,040	3,062	1,029	53,393
1966	24,080	0	19,435	4,596	3,172	1,065	52,348
1967	26,754	0	20,514	4,814	3,282	1,101	56,466
1968	27,180	0	21,270	5,062	3,337	1,138	57,987
1969	24,267	0	19,168	4,508	3,392	1,174	52,509
1970	23,375	0	18,355	4,211	3,502	1,192	50,634
1971	26,899	0	18,495	4,277	3,612	1,210	54,492
1972	25,981	0	15,655	3,460	3,721	1,246	50,064
1973	26,307	0	15,748	3,518	3,776	1,283	50,632
1974	25,477	0	15,214	3,378	3,831	1,319	49,220
1975	27,543	0	17,555	4,016	3,941	1,355	54,410
1976	29,957	0	17,590	3,917	4,051	1,391	56,907
1977	31,066	0	21,117	4,578	4,161	1,409	62,332
1978	32,533	0	24,821	6,019	4,271	1,428	69,071
1979	29,710	0	23,739	5,869	4,405	1,464	65,186
1980	30,730	0	29,232	7,997	4,539	1,500	73,997
1981	38,168	0	27,262	7,156	4,672	1,500	78,759
1982	35,368	0	30,018	8,045	4,806	1,500	79,737
1983	44,909	0	30,952	8,471	5,074	1,500	90,906
1984	41,646	0	32,928	9,368	5,208	1,500	90,649
1985	42,716	0	36,877	10,574	5,341	1,500	97,009
1986	44,335	0	40,554	11,992	5,475	1,500	103,856
1987	46,324	0	43,706	13,279	5,609	1,500	110,418
1988	39,523	0	36,049	10,162	5,743	1,500	92,977
1989	41,210	0	35,784	9,923	5,877	1,500	94,293
1990	34,920	0	40,048	9,841	6,145	1,500	92,453
1991	18,118	0	26,075	5,869	6,278	1,125	57,466
1992	26,469	0	39,406	10,378	6,412	750	83,415
1993	25,862	0	40,405	10,607	6,412	375	83,662
1994	16,560	0	28,053	7,768	6,183	375	58,939
1995	15,364	0	26,849	7,462	5,954	375	56,004
1996	17,347	0	24,550	6,496	5,725	750	54,868
1997	16,752	0	27,039	6,905	5,496	1,500	57,693
1998	21,915	0	25,306	6,645	5,038	1,500	60,405
1999	18,866	0	17,270	4,076	4,232	1,500	45,944
2000	20,971	0	18,353	4,057	5,186	1,500	50,067
2001	16,969	0	17,893	3,737	5,602	1,830	46,030
2002	21,204	0	15,417	2,626	6,504	2,160	47,911
2003	29,091	0	21,849	5,200	6,183	2,490	64,813
2004	27,980	-3,957	24,443	6,175	6,275	2,820	63,735
2005	30,772	-3,889	33,705	8,763	6,000	3,150	78,501
2006	33,109	-4,747	26,130	6,908	6,000	3,480	70,880
2007	35,206	-4,956	28,863	7,653	6,000	3,810	76,576
2008	42,821	-6,243	29,823	7,696	6,000	4,140	84,237
2009	48,038	-7,329	27,012	6,896	6,000	4,470	85,086
2010	45,458	-6,937	25,953	6,404	6,000	4,800	81,678