SCIENTIFIC DATA

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The Clodia database: a long time series of fishery data from the Adriatic Sea

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Long-term time series of species abundances can depict population declines and changes in communities in response to anthropogenic activities, climate changes, alterations of trophic relationships. Here we present a database of historical marine fishery landing data, covering a remarkably long time series (1945–2013) and referring to one of the most exploited areas of the Mediterranean Sea, the Adriatic Sea. The database includes two time series of landing data, 1945–2013 and 1997–2013, from the official statistics of the fish market of Chioggia, where the major fishing fleet of the area operates. Comparisons between the landing data of the database and landing data from other fisheries or data from scientific surveys support the reliability of the time series in depicting changes in species abundances. The database is expected to be used by fishery biologists and ecologists interested in depicting and understanding temporal variations in species abundances and community composition, in relation to environmental and anthropogenic factors.

Design Type(s)	observation design • data integration
Measurement Type(s)	fishery landing assessment
Technology Type(s)	data collection method
Factor Type(s)	
Sample Characteristic(s)	mediterranean sea biome • North Adriatic Sea and Venetian lagoon

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Background & Summary

The Clodia database includes a remarkably long, especially for the Mediterranean Sea, time series (from 1945 to 2013) of landing data from the Chioggia's fishing fleet. This fleet represents the major fishery of the Adriatic Sea and one of the most important of the entire Mediterranean Sea[1]. The traditional variability in fishing gears employed by fishermen of Chioggia makes the landings a combination of several benthic and pelagic species. The database has been named Clodia from the ancient name of the town of Chioggia.

Changes in landings can contribute to depict changes in the abundance of marine species. Historical data on species abundances are crucial to understand changes of marine communities driven by long-term anthropogenic pressures[2,3] and, therefore, to develop strategies to effectively manage marine resources. Historical quantitative data can depict the decline and recovery of exploited stocks, fluctuations in population abundance in relation to environmental factors including climate changes, changes in species distribution, variation in community composition, predator-prey cycles, etc.[4–7] Fishery-dependent data are known to present some limitations: they are usually not standardized on fishing effort, they can be affected by changes in fishing practices or exploited areas leading to misinterpretation of changes in resource abundance, they are often not species-specific and usually include only commercial species, they do not take into account discarded or illegal catches, they can be prone to misreporting, etc.[5] Despite these limitations, historical fishery data on catches can provide useful and otherwise lacking information, thus filling the gap between discontinuous scientific surveys, including species not included in such surveys and broadening the time range of scientific data[5,8,9]. Chioggia's fleet has well-defined fishing grounds (Figure 1), indeed although fishing vessels may seasonally change their fishing areas, they usually do not move further south than Ancona. Therefore in the study case, long-term changes in landings are not much affected by changes in fishery grounds.

The Clodia database is designed to be used by fishery biologists and ecologists interested in depicting and understanding temporal variations in species abundances, in relation to anthropogenic pressures such as fishery, pollution, etc., environmental factors, such as sea water temperature, salinity, etc., trophic interactions. The northern Adriatic Sea is the most exploited area of the Mediterranean Sea and is subjected to several anthropogenic pressures, among them fishery, pollution and eutrophication[1,10]. It is characterised by extremely high productivity[11], high nutrient load carried by the rivers' runoff[10,12], very shallow waters and marked seasonal and inter-annual variability in the sea surface temperature, which may span from 5 °C in winter to 27 °C in summer[13,14]. Therefore this area represents an excellent case study. Understanding the main drivers of the temporal changes in species abundance constitutes an

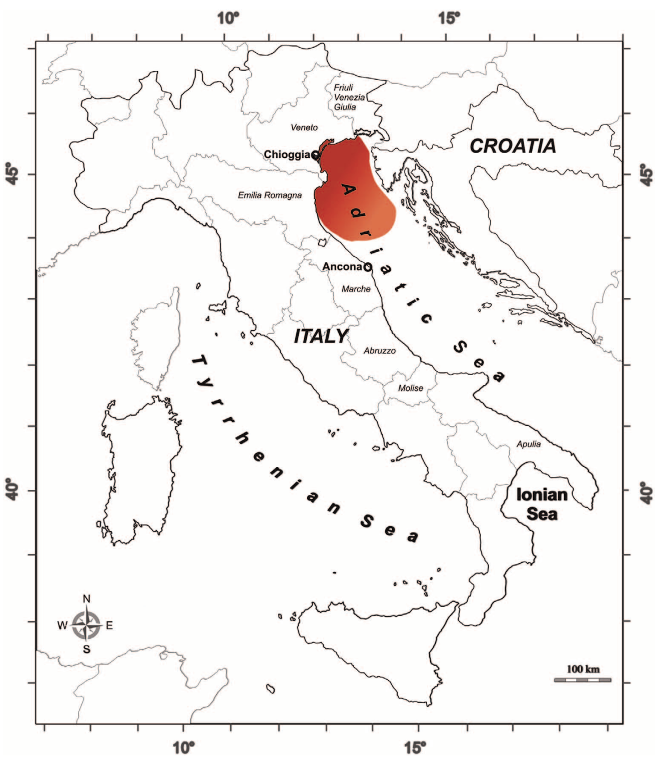

Figure 1. The Adriatic Sea. Fishing ground of the Chioggia's fleet (red area) and Italian regions are indicated.

instrument essential to develop management strategies. The Clodia database, too, can contribute to the management of marine resources.

Up to now, the data included in the database have been used for scientific researches aimed to highlight temporal changes in the composition of the landings in response to fishery pressure and environmental factors[15], the decline of exploited species, such as elasmobranchs[16], the Atlantic mackerel *Scomber scombrus*[17], and the common cuttlefish *Sepia officinalis*[18], the response of single species (*Carcinus aestuarii*) to climate changes[19].

Methods

The database includes the official monthly statistics of fish and seafood catches landed from 1945 onward at the fish market of Chioggia. Landings refer only to fish and seafood caught by local fishermen from the Chioggia's fleet, that operates in the Adriatic Sea (Figure 1), while imported products are not included. Imported products are registered separately from local catch. The trade of the fish market of Chioggia includes also small quantities of products of the local aquaculture in 'valli da pesca'. This represents a traditional aquaculture practice, exploiting, especially in the past and for nektonic species, the seasonal migrations between lagoons and open sea.

Landing data were retrieved from the registers of the fish market and were available on paper documents from 1945 to 1996 and in electronic spread sheets from 1997. The data include only landings of the fleet of Chioggia from the open sea and the Venetian lagoon, are expressed in kilograms and are grouped into categories according to the registration procedures adopted at the fish market. Categories may include one or more species. Multispecies categories usually group taxonomically similar species (e.g., species of the same genus or family). One species (*Carcinus aestuarii*) is registered into three categories, according to the life stage: ripe females, moulting individuals, and the other specimens. The different stages, indeed, have different commercial values, with moulting individuals being the most valuable ones. In the database these three categories have been kept separated. Some species, *Dicentrarchus labrax*, *Sparus aurata*, *Mullus barbatus barbatus*, *Sepia officinalis*, squids (a multispecies category including four squid species), octopuses (a multispecies category including four octopus species), and *Nephrops norvegicus*, were regularly or occasionally registered in two categories according to their size (small or large). In these cases, the categories have been merged in one, since the subdivision by size was not consistent. Elasmobranchs, the anglers *Lophius budegassa* and *L. piscatorius*, *Merlangius merlangus*, *Merluccius merluccius*, *M. barbatus barbatus* and *Mullus surmuletus* are often landed eviscerated, and sharks were occasionally landed without skin. Scallops and great scallop were sold, in particular before 1997, entire or without shell. These two weights were differently registered. Weight of scallops and great scallop without shell were converted to the equivalent weight of the animal including shells. The conversion factor was calculated from samples of *Flexopecten glaber proteus* for scallops (conversion factor: x 2.6), and samples of *Pecten maximus* for great scallop (conversion factor: x 2.9). In a few records, the weights of *M. merluccius*, *Platichthys flesus* and squids were referring to processed products (fillets or rings). In these cases, it was not possible to calculate the weight of the entire landed animals, and the values were summed to the weight of the corresponding category. Multispecies categories of fish mix and freshwater fish mix (this category occurs only before 1997) are present in the statistics accounting for extremely low values of landings. These categories may include small-sized specimens of species included in specific categories, or some species presenting low commercial value.

The trade of some species, such as *Mytilus galloprovincialis*, *Ruditapes philippinarum*, *D. labrax*, *S. aurata*, the mullets (a multispecies category including five species of Mugilidae), *Anguilla anguilla*, the prawn *Melicertus kerathurus* and *Penaeus japonicus*, include also the production of local extensive aquaculture.

Some species, *M. galloprovincialis*, *Chamelea gallina*, *Ruditapes* spp., the oysters *Ostrea edulis* and *Cassostrea gigas*, the clockles *Cardium edule* and *Cerastoderma glaucum*, the murices *Bolinus brandaris* and *Hexaplex (Trunculariopsis) trunculus*, the sea snails *Galeodea echinophora* and *Rapana venosa*, *Sipunculus nudus*, *Aporrhais pespelecani*, *Donax trunculus*, *Venus verrucosa*, *Arca noae*, *Callista chione*, *Nassarius mutabilis*, the jackknives *Ensis minor*, *E. ensis* and *Solen marginatus*, and the sea urchin *Parancentrotus lividus* are legally traded but can be sold directly from the manufacturing industries or through specialized retailers, therefore the landing is not entirely registered at the fish market of Chioggia.

Two main changes in registration procedures occurred from 1945: in 1997 some multispecies categories were divided in more specific ones; from 2012 all products are registered with the scientific name. As a consequence, the number of categories changed in 1997 and 2012. In order to allow the assessment of landing trends on a long-term scale without losing the more detailed information of recent years, two time series were constructed: a long-term time series from 1945 onward (in this time series data from 1997 were grouped in the same categories present from 1945 to 1996) and a shorter, more detailed, one from 1997 onward (Table 1). The new registration procedure, applied from 2012, will provide a more accurate registration of data. However considering that it has been launched only recently and that we noticed some misidentifications, we chose to maintain the two already existing time series. A third time series will be built when the new procedure will be fully tested and set up.

The construction of these datasets included several steps. The first step, concurrently with data digitalisation, was the identification of category composition and the tracking of changes in category names through time (for instance, from dialectal to Italian names). This phase exploited the knowledge of

FISHERY LANDING DATASET					
Time series	Type of data	Number of categories	Number of species	Number of multi-species category	Species per category
1945-2013	Monthly/annual landings in kilograms	114	185	38	1–10
1997-2013	Monthly/annual landings in kilograms	126	178	35	1–5

Table 1. Characteristics of the two time series. The lower number of species in the more recent landing time series is related to the disappearance from the landings of protected species and species that, at present, do not have commercial value: *Microcosmus vulgaris* and *Aplysia depilans*.

local fishermen and fish market employees. Moreover, surveys at the fish market at selling auctions were repeatedly performed, from 2009 onwards, to record the actual composition of landed species. The information collected from commercial employees and the composition of landings recorded during the surveys at the fish market were used to list the species included in each category and validate the taxonomic identification of species. However we cannot exclude to miss some species landed only in the past (and registered in multispecies categories) and never recorded today at the fish market. Some species were registered at the fish market only in the last decade. We cannot completely exclude that some specimens of these species have been landed in the past and registered in already existing categories, or been caught but not landed. However, at least from 1997, such biases are highly reduced, considering the new registration procedures. Therefore when we found new species in the statistics, we added a new category indicating, in the accompanying file with category details (see below), if they were likely sold in the fish mix category before 1997. When a category was not reported in the register for one or more months, we conservatively considered missing data if the category was missing for several months or even years, true zero if the category was regularly yearly landed in that period. From 1997, only data referring to the categories not entirely registered at the fish market (see above) or still sold also in the fish mix category (*Serranus hepatus*) were considered as missing data. To inform the users of all the choices made during the database construction, an accompanying file with all the details of each category has been built. The information include for each category the composition (with common, dialectal, and scientific names of the species included in that category), additional information about the data and changes in registration procedure. The second step of database construction was a careful data examination to identify latent outliers. Latent outliers were evaluated through a cross-check between monthly and annual (that are separately registered) official data, and eventually corrected.

Data Records

Landing data are represented as kilograms of fish and seafood catches landed at the Fish Market of Chioggia.

The datasets are available through an unrestricted repository at figshare (Data Citation 1), as Excel files. These datasets include the data at the time of publication. The datasets are annually updated and available, with interactive graphical representations, category explanatory details and any additional updated information, at the Clodia database website (Data Citation 2). From the same site, all data of the Clodia database can be freely retrieved.

Technical Validation

The assumption of temporal changes in landings data as proxy of changes in species relative abundances requires an evaluation of data quality and an analysis of factors influencing catch. Biases in official landing data, that may consequently affect conclusions about changes in species abundances, may originate from changes in fishing fleet, amount of unreported landing, market demands and registration procedures.

Temporal changes in fishing fleet may involve not only the number of vessels, but also gross tonnage, length and engine power of operating vessels, employed fishing gears, technological improvements. Data on the characteristics of fishing vessels are available in the Fleet Register of the European Union (http://ec.europa.eu/fisheries/fleet/index.cfm) from 1991. However these official data may present biases in vessel length, gross tonnage and engine power. In addition, since vessels may have more than one licence, and are therefore allowed to operate with different fishing gears, it is difficult to reconstruct the temporal changes in the employment of different fishing gears. From 1951, official national statistics of fishing fleet are available, however these data include only total fishing capacity (for details, see Barausse *et al.*[15,16]).

Despite the lack of reliable data on temporal changes in fishing effort, temporal changes in fishing techniques can contribute in interpreting landing statistics.

The main temporal changes in fishing techniques of the Chioggia's fleet are represented by the introduction of mid-water trawls and beam trawls ('rapido') in the early 1960s, and hydraulic dredges in the early 1970s[20]. From the 1950s new technologies were progressively introduced, such as radar and ecosounder[20]. Accordingly with the increase in fishing capacity, the improvement in technologies and the introduction of new techniques, the total landings increased from 1960s. The introduction of the mid-water trawls increased the landings of European anchovy, *Engraulis encrasicolus*, and European pilchard, *Sardina pilchardus*, from 1950s to 1960s (Figure 2).

Unreported landing is recognized to represent an important part of the catches, it has been estimated to be up to 50% of the official landing in developed countries[21], is known to be remarkable also in the Italian fish markets[22], including the fish market of Chioggia (C. Mazzoldi pers. obs.). Depending on legislation and controls, the proportion of unreported landing may change. To evaluate the occurrence of marked changes in the unreported quota, we searched for abrupt changes in landing of the different categories and interviewed the employees of the fish market. We found a marked change in the landing of sharks, a multispecies category including different species of elasmobranchs, from 1986 to 1993. Interviewing old fishermen, we were able to assess the most likely causes of that change. During that period, a law introduced a threshold of 0.7 p.p.m. of mercury allowed in the meat of sharks, compelling the analyses of all landed specimens. In 1992, the law was changed, rising the threshold to 1 p.p.m. and compelling the controls on large sharks only. Fishermen acknowledged that in the period 1986–1993 larger proportion of sharks' landing was indeed unreported. In the accompanying information of the sharks' category, this event has been highlighted. The same law applied also to tunas, however this category did not show a change in landings similar to that observed in sharks. Two categories, the oysters *Ostrea edulis* and *Crassostrea gigas*, and the European lobster *Homarus gammarus*, are considered luxury items. From 1973, these products are subjected to an increased, but variable among years, VAT tax. As a consequence, landing data may be less reliable. Besides these events, we do not have evidences of marked changes in the proportion of unreported landing up to 2013.

Changes in market demands are difficult to highlight. Interviewing the employees of the fish market we did not evidence any clear pattern, in particular for the most important commercial species of the area, excluding the ban of catch for protected species (sea turtles, dolphins, basking sharks, occasionally reported in the statistics up to 1988, 1980 and only in 1953 respectively), and the current lack of commercial value of *Microcosmus vulgaris* and *Aplysia depilans*, occasionally landed before 1990. The opportunistic behaviour of the Chioggia's fishery and the importance in the area of the fish market of Chioggia, that exports products to several countries, should buffer changes in market demand.

The availability of time series from i) other fisheries and ii) scientific surveys allows evaluating how much landing data can actually reflect changes in species abundances. Here some case studies are presented as validation of the database.

The small size of the Adriatic Sea implies that the fisheries operating in the area usually exploit the same resources[23]. Landing trends from different fisheries are expected to be similar if they reflect trends in species abundance. The Atlantic mackerel, *Scomber scombrus*, is a pelagic species represented by a single population in the northern-central Adriatic[24]. This species showed a marked decline in landing in the early 1970s[17]. Landing data from Chioggia's and Croatian statistics[25] (1950–1992) highly correlated (Pearson's correlation: $r = +0.80$, $P < 0.001$, $N = 44$), showing not only similar trends but also remarkably similar fluctuations (Figure 3).

From 1994, annual scientific surveys (MEDITS: International Bottom Trawl Survey) are performed in the Mediterranean, including the Adriatic Sea. The MEDITS program aims to collect data on the

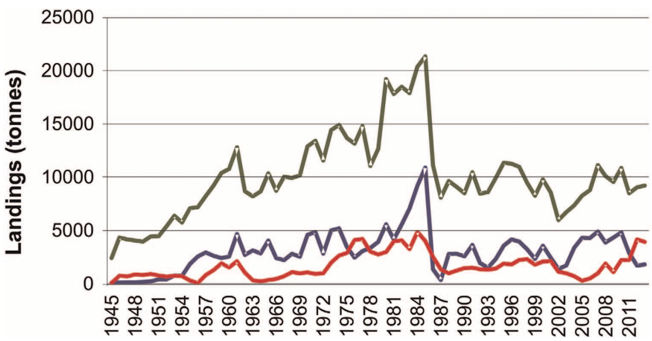

Figure 2. Annual (1945–2013) total landings (green line), landings of *E. encrasicolus* (blue line) and *S. pilchardus* (red line) of the Chioggia's fleet.

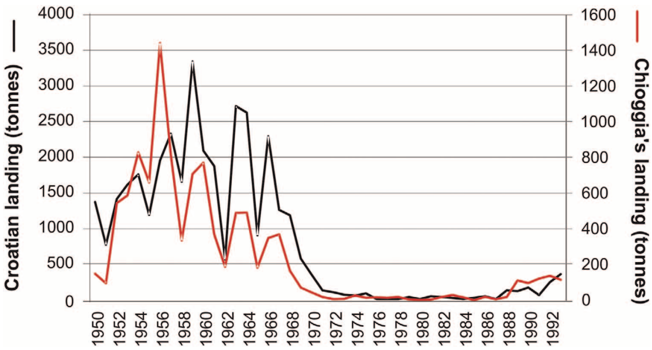

Figure 3. Annual (1950–1992) landing of *S. scombrus* of the Croatian[24] (black line) and the Chioggia's (red line) fleets.

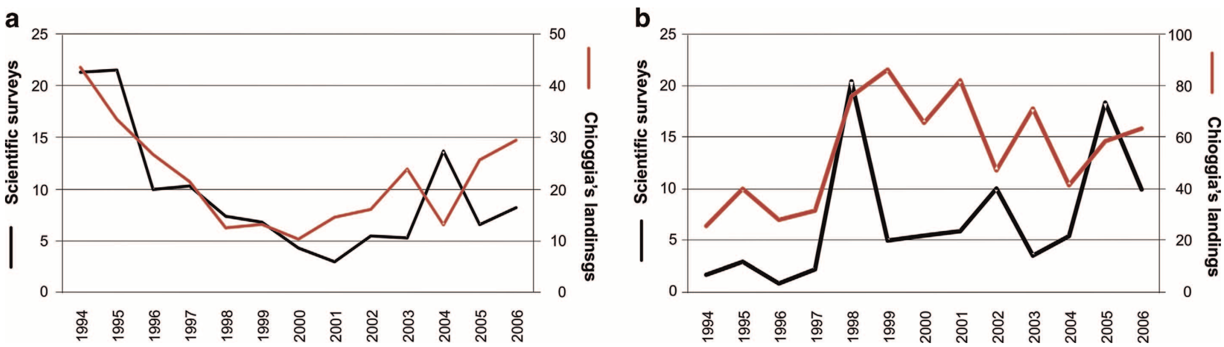

Figure 4. Annual (1994–2006) catch per unit of effort from scientific surveys (Kg/Km^2, black lines) and landings per fishing capacity (Kg/GT, gross tonnage data from Barausse *et al.*[15], red lines) of (**a**) *M. merluccius*, and (**b**) *M. merlangus*.

distribution of benthic and demersal species. The surveys are performed during spring-summer, using an otter trawl[26]. In MEDITS data, for each species, number of specimens and biomass per unit of effort are reported. Here we compare MEDITS data from 1994 to 2006, relative to the northern-central Adriatic, excluding Croatian waters (data provided by C. Piccinetti), of two commercial species, *Merluccius merluccius* and *Merlangius merlangus*. These species were chosen according to their distribution (excluding species distributed mainly in the eastern Adriatic), spawning period (excluding species spawning during the sample period, since spawning behaviour can affect catchability), coefficient of variation of MEDITS catch (excluding specie presenting coefficient of variation in MEDITS catches on average higher than 50%). Catch per unit of effort of scientific surveys and fishery data correlated positively for both species, but significantly only for *M. merluccius* (Pearson's correlation: $r = +0.72$, $P = 0.006$; Figure 4a), while for *M. merlangus* the two time series followed similar trends only before 1998 (Pearson's correlation: $r = +0.44$, $P = 0.135$; Figure 4b). The cause of the disappearance of a clear correlation after 1998 is unknown, however *M. merlangus* shows an interannual variability higher in the MEDITS data than in the landing data.

Examples for other species further support the quality of the data in the Clodia database. The categories comprising elasmobranchs showed a marked decline in landing[15], with the catch per fishing capacity declining of 89% in the last 62 years[16] (from 1951 to 2012). This value is very similar to that (94%) obtained comparing elasmobranch catch of scientific surveys performed in the Adriatic Sea in 1948 and 2005[27]. The time series of the database captured the documented collapse of the European anchovy in 1986–1987[28].

These proposed examples give evidence that the time series of landing of the database can provide reliable indication of changes in abundance, extending of many decades backward, with a yearly coverage, the results of scientific surveys. However, the validation is not an easy process, considering that only few data from scientific surveys or other Adriatic fisheries are available on such a long time scale. Therefore, the examples do not cover the entire database.

Usage Notes

Data on single species should be technically validated, if possible, with existing time series from scientific surveys and/or of landings of other Adriatic fisheries. Users are recommended to refer to the accompanying file for category information. Analysing monthly data, users should consider that from 1988 fishery with bottom and mid-water trawls is banned for approximately one month per year, usually in August.

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Data Citations

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Author Contributions

C.M., A.S. and E.R. designed the database. C.M. performed technical validations of data and wrote the paper. E.R. collected and digitalized the data. A.S. developed the database.

Additional information

Competing financial interests: The authors declare no competing financial interests.

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