Italian Journal of Freshwater Ichthyology, 2019 vol. 5(1) 2019(5.1): 325-332
Atti XVII Congresso Nazionale Associazione Italiana Ittiologi Acque Dolci – Roma

RICOSTRUZIONE STORICA DELLE CATTURE DELLA PESCA NEL LAGO DI GARDA

HISTORICAL RECONSTRUCTION OF FISHERY CATCHES FOR THE LAKE GARDA

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Parole chiave: Lago di Garda; Pesca professionale; serie storica delle catture; comunità ittica
Keywords: Lake Garda; professional fishery; catches time series; fish assemblage

Riassunto

Storicamente, nel lago di Garda l'attività di pesca ha ricoperto un ruolo molto importante per gli abitanti delle zone costiere. In questo lavoro sono presentati i dati aggiornati sulle serie storiche delle catture della pesca professionale, che possono rappresentare un importante elemento per descrivere l'evoluzione della pesca e metterla in relazione con i cambiamenti delle condizioni ambientali e delle comunità biologiche riportate nella letteratura scientifica. Le catture totali hanno raggiunto un picco a metà degli anni '60 (circa 700 tonnellate) e sono successivamente diminuite in maniera graduale fino agli anni '90, quando hanno cominciato ad oscillare attorno ad una produzione totale di circa 400 tonnellate, in analogia con quanto osservato nel periodo antecedente agli anni 50. La composizione dello sbarcato, invece, mostra dinamiche più complesse, con la scomparsa di specie molto importanti sia per l'ecosistema lacustre che per la pesca stessa (per la loro entità o per il loro valore economico), come ad esempio l'alborella *Alburnus alborella* o il carpione del Garda *Salmo carpio*. Anche se alcune delle specie plantivore hanno mostrato un forte declino, questa categoria trofica rimane molto importante per la pesca, rappresentando almeno il 50% della biomassa catturata durante tutto il periodo analizzato e rappresentando più dell'80% dagli anni '80. Questo è dovuto, soprattutto, al contributo dell'agone *Alosa agone*, importante durante tutto il periodo, e del coregone lavarello *Coregonus lavaretus*, il cui contributo è cambiato nel tempo, ma che è aumentato nell'ultimo periodo, tanto da diventare la specie più importante nell'ultima decade.

Abstract

Fishery activities in the Garda lake had historically played a very important role for the people living along the coasts of the lake. In this work we present updated time series of catches, that could be useful to describe the evolution of the fishery, linking landings with the changes of environmental conditions and biological communities reported in the literature. Total catches peaked in the mid '60s (ca. 700 metric tons) and then smoothly decreased until the '90s, when they started oscillating around a total production of about 400 metric tonnes, similarly to the situation observed before the '50s. However, catches composition shows more complex dynamics over time, with the disappearance over the years of species very important for the lake ecosystem and for the fishery itself, both in terms of catches or economic value (e.g. the Common bleak *Alburnus alborella* or the Carpione del Garda *Salmo carpio*). Even if some of the zooplankivourous species showed strong declines over time, this feeding category has always been very important for the lake fishery, representing at least 50% of the total caught biomass and reaching more than 80% of total catches since 1980. This is due to the large

contribution of the Agone *Alosa agone*, that has been very important in the whole history of the fishery of the lake, and of the European whitefish *Coregonus lavaretus*, whose contribution changed over the decades, but that is characterized by an increase in the last period, becoming the most important species during the last decade.

Introduction

Fishery activities in the lake Garda had historically played a very important role for the people living along the coasts of the lake (Malfer, 1897, 1908, 1927). Even if fishery statistics cannot be considered a direct indication of fish abundance in the ecosystem, they still represent a key element of the management of fish exploitation (Pauly et al., 2013). In the lake Garda, fish assemblages and fishery were well studied in the past (e.g. Malfer, 1897, 1908; Novello and Oppi, 1985; Giarola and Oppi, 1986; Melotto and Oppi, 1987), but updated publicly available information became rarer in these days (but see Confortini, 2005; Lugoboni et al., 2017; Volta et al., 2018), suggesting that an information gap is present, limiting the possibility of promoting an ecosystem based management (Salmaso et al., 2018). For these reasons, in this work we present updated time series of catches for the most important species for the lake Garda.

Material and methods

Historical production data were obtained from Malfer (1897, 1908, 1927) for the period 1897-1906, 1920-1925 and for the period 1907-1916 regarding *Alosa agone*. Other Authors (Giarola and Oppi, 1986) provided information for the time window 1926-1985. Total production for the period 1988-2016 was estimated from landings data provided by the Provinces of Brescia and Verona.

Stocking data were obtained from Melotto and Oppi (1987) for the *S. carpio* and integrating data from Giarola and Oppi (1986) with recent statistics gathered by the Provinces of Brescia and Verona for *Coregonus lavaretus*. Fishing effort was quantified considering the number of fishermen operating in the lake obtaining data from the literature (Malfer, 1908, 1927; Maggi, 2002) integrated with recent information provided by the Provinces of Brescia and Verona.

Number of licenses over time and stocking of *S. carpio* and *C. lavaretus* are visualized with a loess smoother (Chambers et al., 1990) fitted to the data. The correlation among stocked fish and the landings were explored with Spearman correlations by considering a 0-, 1-, 2-, 3-year time lag.

The landings time series of the main species (z-score transformed data) were studied by means of Dynamic Factor Analysis, that can be considered as a Principal Component Analysis for time series (Zuur et al., 2003a, 2003b, 2007). Different models were fitted, considering alternative formulations with 1 to 3 common trends and different model structures for the errors of the processes, in particular taking into account the following alternatives: there is only one process variance value (diagonal and equal); there is a variance for each process (diagonal and unequal); there are values on the diagonal and off-diagonals (unconstrained); there is one process variance and one covariance (equalvarcov) (Holmes and Ward, 2012; Holmes et al., 2012). The best model was selected among the candidate considering the Akaike Information Criterion corrected for small samples (Burnham and Anderson, 2002; Zuur et al., 2003b; Holmes et al., 2012).

Results

The total catches do not show a clear linear trend, but they seem to be characterized by different patterns in separate time windows (Figure 1): oscillating values (between 300 and 500 Tonnes / year) reaching a minimum in the early '50s of the XX century (below 250 Tonnes); a sharp increase reaching the maximum in the early '60s (almost 700 Tonnes); a subsequent decrease in total catches until the late '80s (300 Tonnes); a moderate increase in the last 25 years. Among the most important species (in volume), the European whitefish *Coregonus lavaretus* is the one that showed the strongest increase, not being present in catches at the beginning of the time series (first record in the statistics: 1926) and representing the most important catch in the last few years (Figure 1b). The common bleak *Alburnus alburnus* was the most important catch in the 1887-1896 decade and it is almost disappeared in the early 2000s. The shad *Alosa agone* showed large oscillations in the studied period, with a sharp peak in the late '60s, then stabilizing around an average value of 170 Tonnes / year. In the very last years the catches show a negative trend. The European perch *Perca fluviatilis* shows two periods, 1975-1980 and from 2000 to 2016, with relative high values of landings. The lake trout *Salmo trutta*, the endemic *carpione Salmo carpio* and the European eel *Anguilla anguilla* were characterized by relative high levels of catches at the end of the XIX century (at least 20 Tonnes/year) and are not fished at all nowadays for different reasons (for protecting the endangered *carpione* or for sanitary reasons as for the eel) or are caught in small quantities, as for the Lake trout, that used to be one of the most relevant species for the fishery in the XIX century. For the eel the time trend shows a peak in the '80s with 70 Tonnes, followed by a steep decline before the fishing ban established in 2011. The pike, *Esox cisalpinus*, while floating around lower average value with respect of the first part of the time series, still represents a relevant catch for the professional fishery, while the tench *Tinca tinca,* after a reduction of the catches with the minimum values recorded around the 1990, started to increase in the landings. The other species, grouped under the category "Other", show in the last few decades a total amount of catches of the same order of magnitude (average 39 Tonnes) than in the first part of the series (average 44 Tonnes), while being much more relevant in the central period (1965-1980: ca. 100 Tonnes) with a peak of about 300 Tonnes in 1929-1930s. Also the composition of this category changed over time with the burbot *Lota lota* and the wels catfish *Silurus glanis* that were not present in the lake at the beginning of the time series.

In the period 1897 – 2016 the number of professional fishermen decreased drastically (Figure 2a), from about 500 fishermen to ca. 100, but with a more stable situation after the beginning of the 2000s.

The number of whitefish larvae stocked in the lake oscillated widely, and in the last 15 years stabilized around 40 millions fish fry. The number of fish stocked each year is not correlated with the total catches, but the whitefish landings are positively correlated with the number of fish fry stocked two years before ($r = 0.284$; $p < 0.05$). The number of *carpione* larvae stocked increased up to the 1930s, and then decreased, and stocking ceased in the '70s. In the last decade an experimental activity of restocking have been started, but the data are not available. The catches of *carpione* is not correlated with the number of fry stocked.

The selected DFA model includes three temporal trends, with an "unconstrained" process variance-covariance structure (Table 1). The fitted trends, along with the associated loadings – which represent how important a trend is for each species – are presented in Figure 3: trend 1 describes a peak in catches before 1960, followed by a sharp decrease and then a slower decrease; trend 2 is characterized by a positive tendency from the '80s; trend 3 shows a quick catch increase until the late '60s, followed by a slower decline that tend to accelerate after 2010. Some species are associated with one of these trends: *S. carpio* and *S. trutta* follow the decreasing pattern described by trend 1 (Fig. 3), and the evolutions of *C. lavaretus* and *E.*

cisalpinus are explained by two common trends: the second and first ones for the whitefish and the first and the third ones for the pike. For the other species, the association with the trends is more complex (i.e. not negligible loadings on three trends), resulting in a less straightforward interpretation.

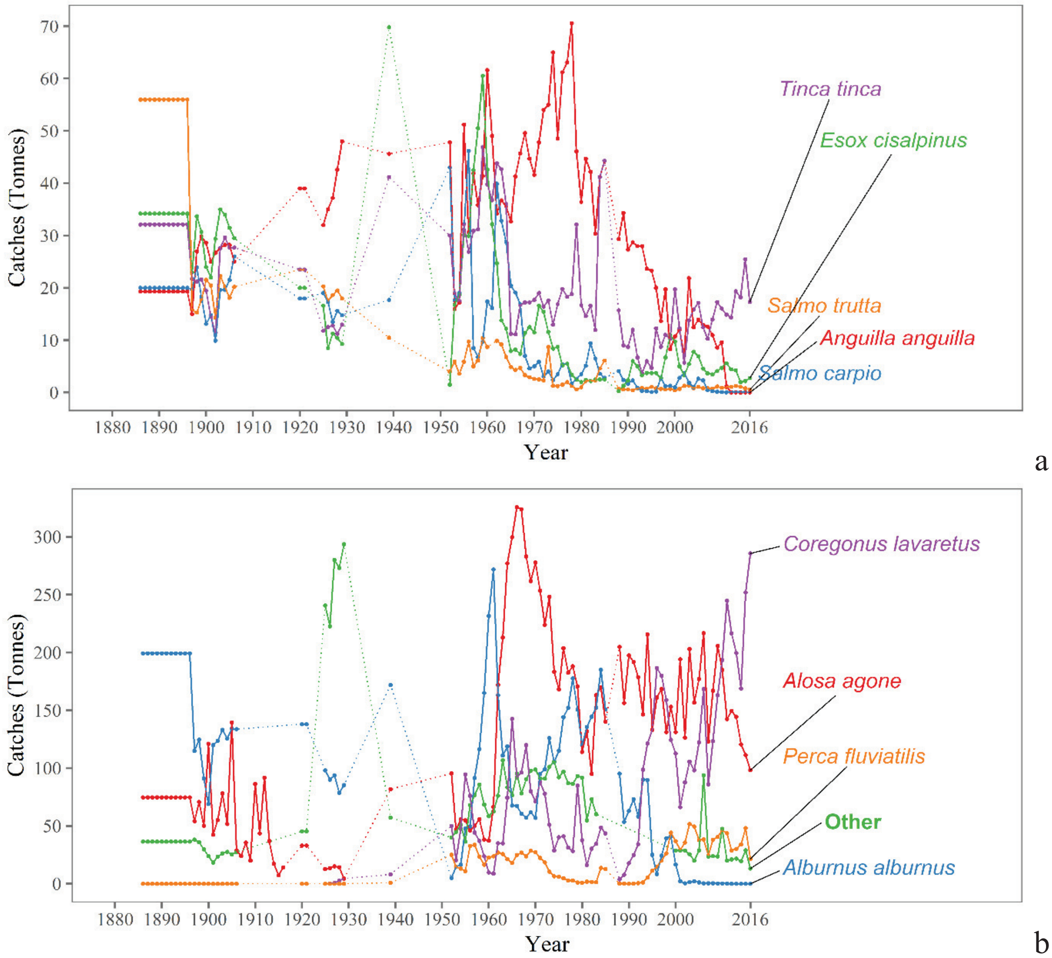

Figura 1. Serie temporali delle catture per le specie decrescenti (a) o crescenti (b). Le line punteggiate rappresentano periodi in cui i dati sono mancanti.
Figure 1. Time series of catches of the low volume or decreasing species (a) and high volume or increasing species (b).Dotted lines represent missing data.

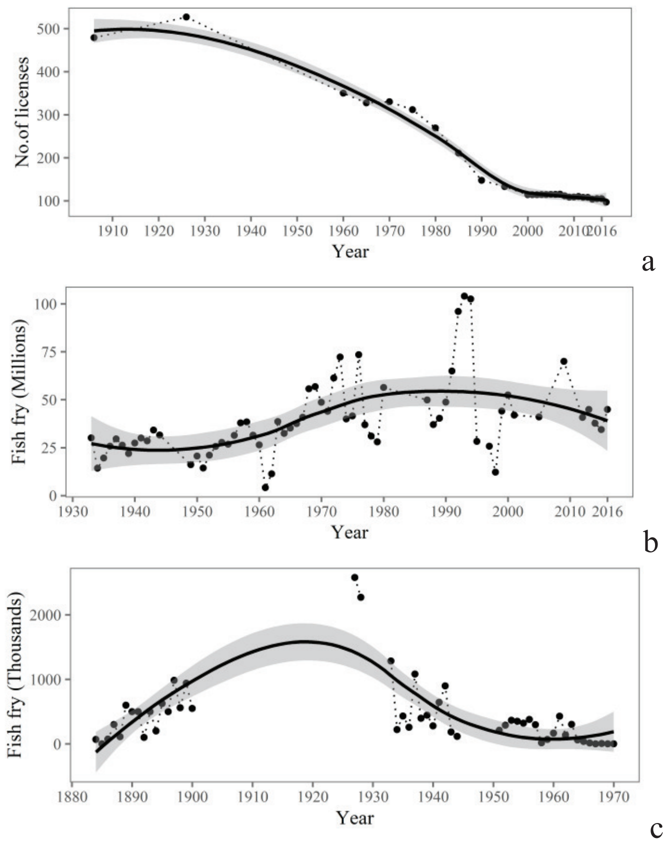

Figura 2. Numero di licenze per la pesca professionale (a); numero di avannotti di C. lavaretus *(a)* and S. carpio *(b) immessi nel lago.*
Figure 2. Number of licences for professional fishing (a); C. lavaretus *fry (b) and* S. carpio *fry (c) stocked in the lake.*

Tabella I. Tabella di selezione dei modelli DFA. R: struttura della varianza-covarianza associata ai processi; m: numero di processi inclusi; logLik: verosimiglianza; deltaAICc differenza di AICc rispetto al modello migliore; Ak_wt: pesi di Akaike.
Table I. DFA model selection table. R: process variance-covariance structure; m: number of processes included in the model; logLik: loglikelihood; deltaAICc difference of AICc with respect to the best model; Ak_wt: Akaike weight.

R	**m**	**logLik**	**deltaAICc**	**Ak_wt**
unconstrained	3	-417.64	0.00	1.00E+00
unconstrained	2	-464.32	75.42	4.20E-17
diagonal and unequal	3	-499.52	76.51	2.43E-17
equalvarcov	3	-508.94	79.74	4.84E-18
diagonal and equal	3	-511.20	82.06	1.52E-18
diagonal and unequal	2	-541.31	144.48	4.24E-32
equalvarcov	2	-553.06	152.76	6.73E-34

diagonal and equal	2	-566.14	176.78	4.10E-39
unconstrained	1	-529.72	186.33	3.47E-41
equalvarcov	1	-663.90	357.54	2.30E-78
diagonal and unequal	1	-656.89	358.29	1.58E-78
diagonal and equal	1	-670.14	367.93	1.27E-80

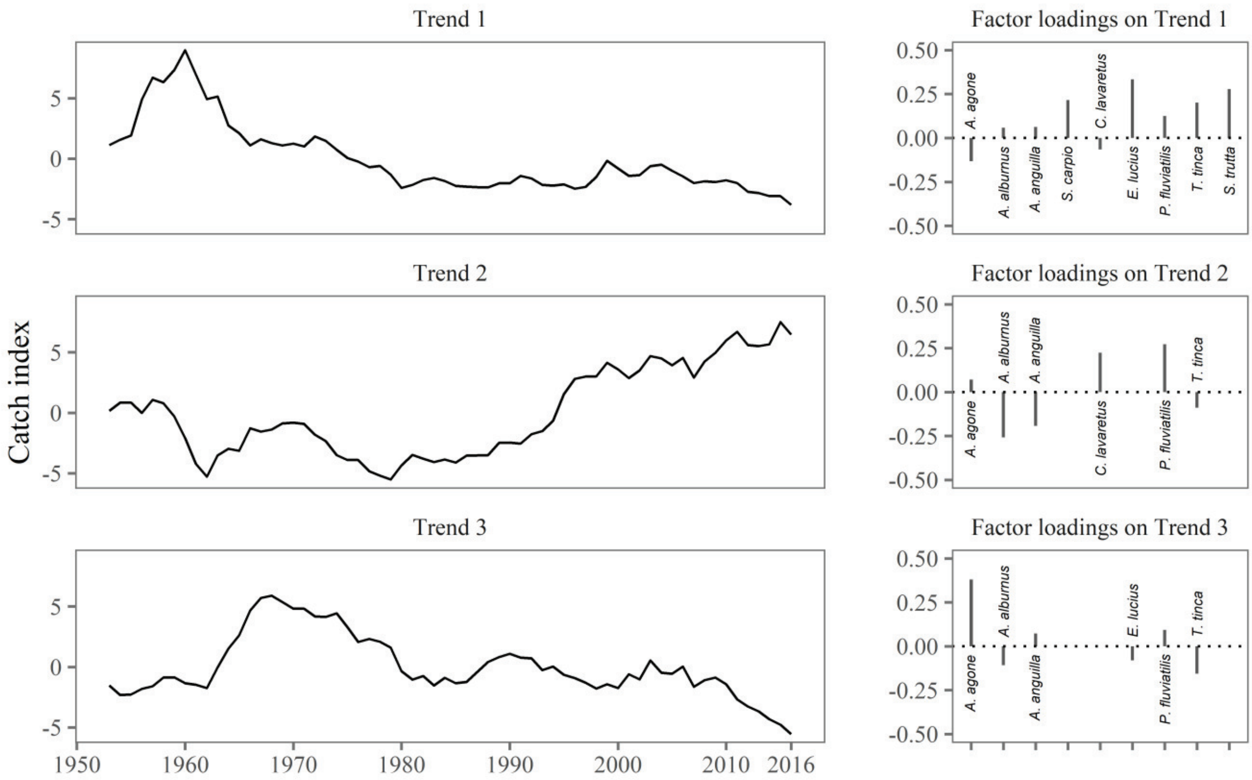

Figura 3. Trend stimati nel modello DFA selezionato e loading *delle specie, associati a ciascun trend.*
Figure 3. Estimated trends by the selected DFA model and species loading for each trend.

Discussion and Conclusions

We reconstructed the temporal dynamics of the landings in the lake Garda over a period ranging from 1887 to 2016, and explored the trends dynamic by using Dynamic Factor Analysis, a method useful to estimate common trends in multivariate datasets (Zuur et al., 2007).

This work confirms the negative trend previously reported for some species, such as the *carpione*, the lake trout, the bleak and the European eel (Melotto and Oppi, 1987; Confortini, 1998, 2005; Ciutti et al., 2010; Volta et al., 2018); the stability of the catches of the shad *Alosa agone* (Confortini, 2005), but showed increased landings for the European whitefish. The overall production, after the peak recorded in the mid '60s (ca. 700 metric tons), smoothly decreased until the '90s, when they started oscillating around a total production of about 420 metric tonnes (11.39±1.89 kg·ha^{-1}·year^{-1}), similarly to the situation observed before the '50s. Also the composition of the less important species changed, mostly due to the emergence of introduced species (e.g. *L. lota* and *S. glanis*) and local extinction of autochthon species (Confortini, 2005; Volta et al., 2018).

Even if the debate on the usefulness of fishery data to infer on the conditions of fish stocks is still open (Pauly et al., 2013), the utility of catch data to understand the effects of anthropogenic pressures has been showed for different ecosystem types (e.g. Zucchetta et al., 2016), and catch statistics and productivity have been used as an ecosystems indicator also for lakes (e.g. Thomas and Eckmann, 2007; Anneville et al., 2017).
In this light the update presented in this work represents an important contribution, not only for describing the evolution of the fishery and, indirectly, of fish assemblage, but also for being the base for exploring the role of the long term changes of climatic and environmental conditions in influencing fish assemblage dynamics and landings evolutions in the lake Garda (Rogora et al., 2017; Salmaso et al., 2017).

Acknowledgements
We thank Dr. Maria Pia Viglione (Settore Pesca - Ufficio Territoriale Regionale di Brescia) and Dr. Ivano Confortini (Servizio tutela faunistica e ambientale della Provincia di Verona) for providing part of the data used in this work. This study has been funded by the project EU H2020 project ClimeFish (EU 677039)

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