Temporal variations in Lake Maggiore (Italy) and its fish community: trophic status, water temperature and fishery with emphasis on the coregonid *C. macrophthalmus* N.

Volta Pietro[1], Sala Paolo[1], Rogora Michela[1], Morabito Giuseppe[1], Cerutti Igorio[1] & Alcide Calderoni[2]
1 - CNR-ISE, Institute of Ecosystem Study, Largo Tonolli 50, 28922 Verbania Pallanza, Italy
2 - CIPAIS Commissione Internazionale per la Protezione delle Acque Italo-Svizzere
E-mail: p.volta@ise.cnr.it

Introduction

Lake Maggiore (North Italy) is one of the largest and deepest lakes in the perialpine region. A long series of limnological, biological and fishery informations exists, gathered by the International Commission for the Protection of Italian-Swiss waters (CIPAIS), the Italian-Swiss Fishery Commission (CISPP) and the CNR-Institute of Ecosystem Study.

Here **we describe the changes** in the **fish assemblages** and **commercial harvest of Lake Maggiore. CPUE data (1979-2010)** are **analysed** in the light of the **anthropogenic** and **environmental pressures**.

We also **focuse** on the **body growth** and **age structure** of the **catch** of the **coregonid *C. macrophthalmus*** (Nusslin, 1882) the most important fish species in the commercial harvest and for whom a body growth data series has been collected by CNR-Institute of Ecosystem Study from 1960 to 2010.

Data and analyses

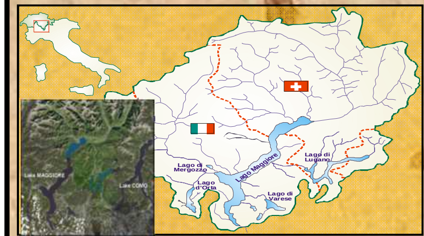
Commercial harvest data (annual catch) were recorded in different years since the first world war. However, the registration remained scattered until 1979 when the International Commission for the Protection of Italian Swiss Waters (CIPAIS) was established.

Total CPUE, CPUE of each species (tons $ind^{-1}y^{-1}$) and length-at-age of *C. macrophthalmus* were tested against TP_{mix}, TP_{mean}, Chl *a*, $T°_{epi}$ (0-25m) $T°_{hypo}$ (25-360m), $T°_{mix}$ at a different time lags (0 years to -9 years) by means of a stepwise forward Ridge regression. Data were Log_{10} transformed if necessary.

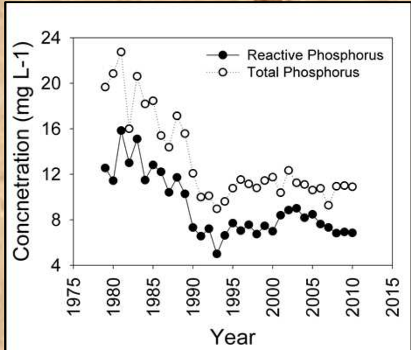
Temporal variations in limnological parameters

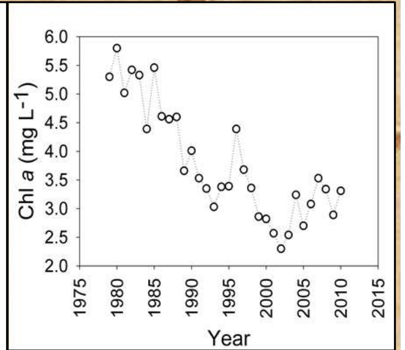
Eutrophication started in the 1950s and peaked at the end of 1970s. Then, the lake recovered.

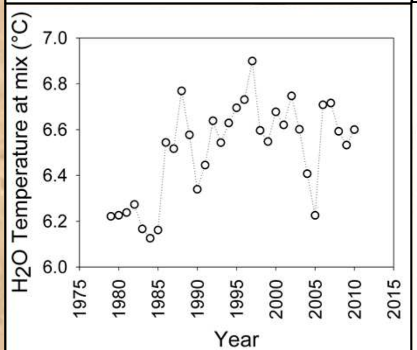
Besides changes in trophic status, the effects of climate warming on Lake Maggiore have become particularly evident during the last decades, with an increase in the caloric content of the waters (Ambrosetti & Barbanti, 1999). From 1978 the water temperature rose significantly in the whole water column (adjR^2=0.55, $F_{1,47}$=58.53, p<0.001) and both in the hypo- (R^2=0.49, $F_{1,31}$=, p<0.001) and epilimnion (R^2=0.33, $F_{1,31}$=, p<0.009).

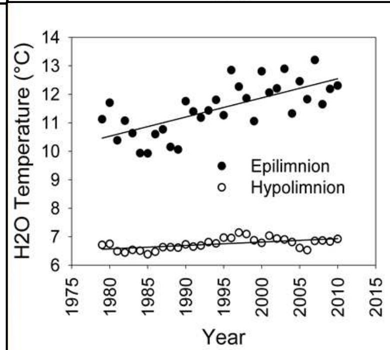


Lake Maggiore	
Altitude (m a.s.l.)	194
Max depth (m)	376
Mean depth (m)	176.5
Area (km²)	212
Volume (km³)	37.5









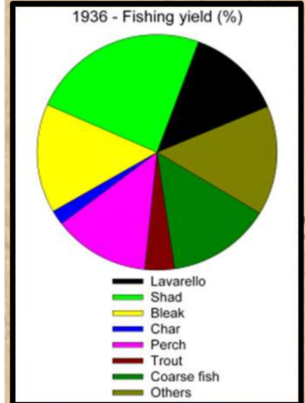
Fish community and fishing yield composition

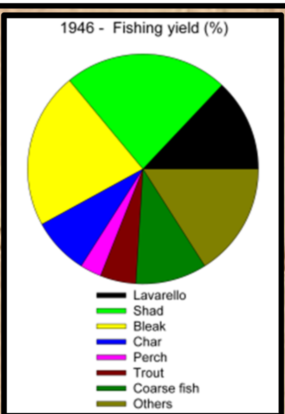
Fish species richness increased in the last two centuries. Among the native species, only the anadromous twaite shad disappeared. Eel is mantained by stocking.

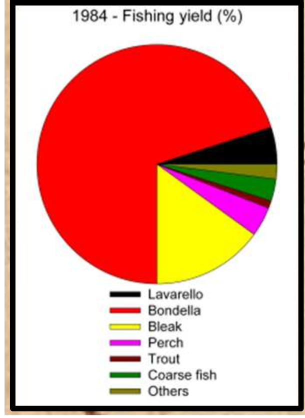
Commercial fishing in the 1800s was targeted on all available eatable fish species. The total fish production was ca. 15 kg ha^{-1}. Later, before the 1950s, the fish production increased to an average of ca. 18 kg ha^{-1}. The harvest composition was stable untill the 1950.

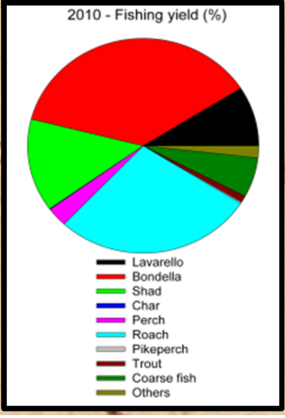
However, after the introduction of the "*bondella"* whitefish (1950) the commercial fishing was mostly addressed to this species. The fish production peaked at the end of 1980s increasing up to ca 50 kg ha^{-1}.

Eurithermal species such as the native shad and the non native roach increased in the catch during the 1990s whilst coregonids, trout and perch declined. At present, the total production fell down to 8 kg ha^{-1} as consequence of the dramatic decrease of the number of fishers (from 100 in the 1980s to 25 units) and the decrease of the lake productivity due to the oligotrophication.





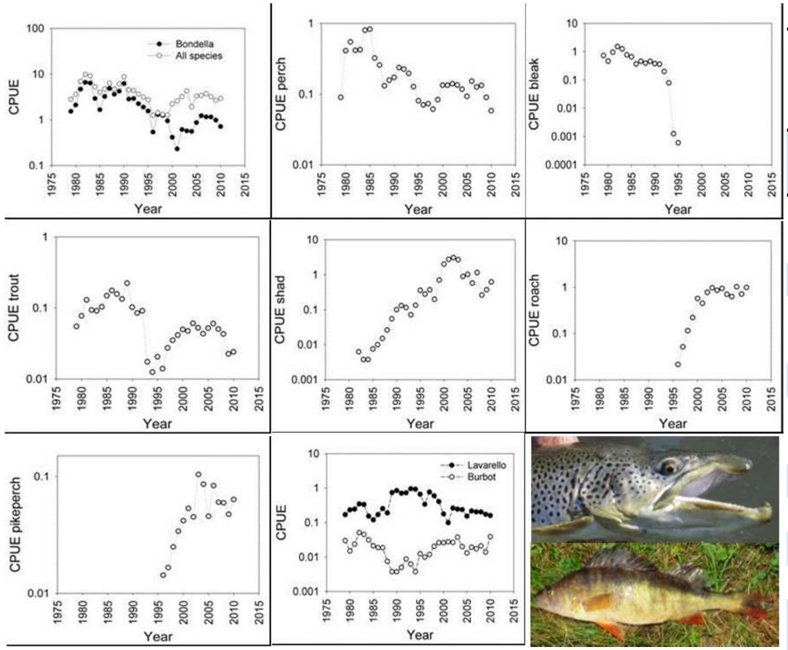




Species composition of the L. Maggiore fish assemblages in different periods. "x" denotes presence, "-" absence, "*" presence due only to stocking practices. The year or decade of the first introduction is indicated

Fish species	<1850	<1900	<1950	<2000	<2010
Barbel (*Barbus plebejus*)	x	x	x	x	x
Bleak (*Alburnus arborella*)	x	x	x	x	x
Blenny (*Salaria fluviatilis*)	x	x	x	x	x
Bullhead (*Cottus gobio*)	x	x	x	x	x
Burbot (*Lota lota*)	x	x	x	x	x
Carp (*Cyprinus carpio*)	x	x	x	x	x
Chub (*Squalius cephalus*)	x	x	x	x	x
Danube roach "pigo" (*Rutilus pigus*)	x	x	x	x	x
Eel (*Anguilla anguilla*)	x	x	x	*	*
Gudgeon (*Gobio gobio*)	x	x	x	x	x
Italian roach "triotto" (*Rutilus aula*)	x	x	x	x	x
Italian nase (*Chondrostoma soetta*)	x	x	x	x	x
Minnow (*Phoxinus phoxinus*)	x	x	x	x	x
Padanian goby (*Padogobius martensii*)	x	x	x	x	x
Perch (*Perca fluviatilis*)	x	x	x	x	x
Pike (*Esox lucius*)	x	x	x	x	x
Rudd (*Scardinius erythrophthalmus*)	x	x	x	x	x
Shad (*Alosa agone*)	x	x	x	x	x
Stoneloach (*Cobitis taenia*)	x	x	x	x	x
Tench (*Tinca tinca*)	x	x	x	x	x
Trout (*Salmo trutta lacustris*)	x	x	x	x	x
Twaite shad (*Alosa fallax*)	x	x	-	-	-
NON NATIVE					
Whitefish "lavarello" (*C. lavaretus*)		(1861)	x	x	x
Char (*Salvelinus alpinus*)			(1910)	x	x
Black bullhead (*Ameiurus melas*)			(1930s)	x	x
Largemouth bass (*Micropterus salmoides*)			(1930s)	x	x
Pumpkinseed (*Lepomis gibbosus*)			(1930s)	x	x
Whitefish "bondella" (*C. macrophthalmus*)				(1950)	x
Wels catfish (*Silurus glanis*)				(1990s)	x
Crucian carp (*Carassius carassius*)				(1990s)	x
Pikeperch (*Sander lucioperca*)				(1990s)	x
Roach (*Rutilus rutilus*)				(1990s)	x
Ruffe (*Gymnocephalus cernua*)				(1990s)	x

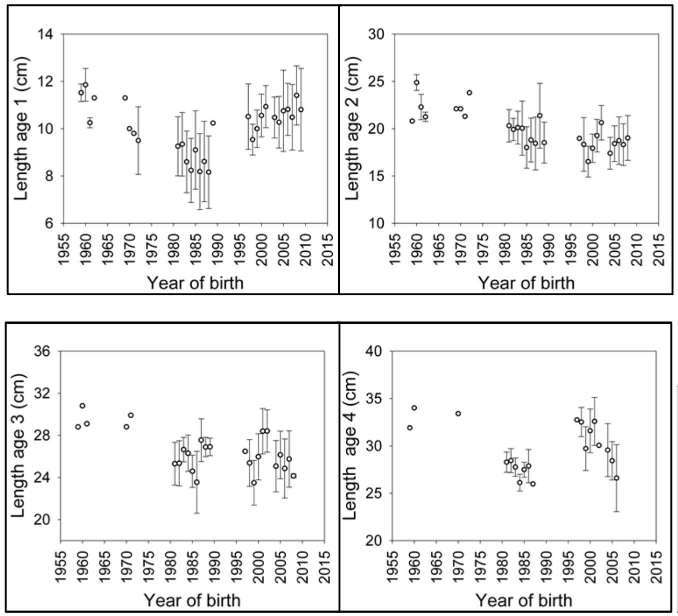
CPUE, trophic status and water temperature: significant links



Variables retained by the Ridge regression. Significant variables are in bold. ↑=positive effect; ↓=negative effect, number=time lag. The order of the different time lags corresponds to the magnitude of the β value.

	TP_{mix}	TP_{mean}	Chl a	T_{epi}	T_{hypo}	T_{mix}
$CPUE_{tot}$	↑-3, -4, -2, -1 ↓-8	↑-3	↓-7	↑0	↑-7, ↓-1	↑-2
$CPUE_{bondella}$	↑**-6**	↑-6, -2				↓**-8**, -5
$CPUE_{lavarello}$	↑**-5** ↓0	↑-1 ↓0			↓-8	↑**-2** ↓-8, 0
$CPUE_{trout}$	↑**-1**, -3	↑-1, -3		↓0		
$CPUE_{burbot}$	↑1	↑0, ↓-5, -8	↑0, ↓-2, -5	↑**-5**, -3, -7 ↓-4		
$CPUE_{perch}$		↑**-4**, **-6**, -3			↓-1	↑**-5**, -4
$CPUE_{bleak}$		↑**-3**, **-1**, **-2**, -4, -6			↓-3	↓-6, -8
$CPUE_{shad}$	↓-7, -4		↑-2, -4, -5	↓-7	↑**-5**, -3, -4	
$CPUE_{roach}$	↑-1			↑**-5**, -3,	↑**-6**, **-7**, -8	
$CPUE_{pikeperch}$	↑0,-1,-2 ↓-8		↓0	↑**-3**	↑**-6**, ↑-8	

Length of "bondella", trophic status and water temperature: changes in the age structure of the catch



Variables retained in the Ridge regression. Significant variables are in bold. ↑=positive effect; ↓=negative effect, number=time lag. The order of the different time lags corresponds to the magnitude of the β value.

	TP_{mix}	TP_{mean}	Chl a	T_{epi}	T_{hypo}	T_{mix}	Lt2
Length at age 1		↓-1	↓-5, -6	↑**0** ↓-1		↑**-7** ↓-1	
Length at age 2	↓**-6**		↓-3	↓**-1**	↓**-1**, -3		
Length at age 3			↑**-1**, -8	↑**-1**			↑**-1**
Length at age 4	↓-1	↓-3		↓**-6**, -3 ↑-1