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MULTIMETRIC INDICES BASED ON VEGETATION DATA FOR ASSESSING ECOLOGICAL AND HYDROMORPHOLOGICAL QUALITY OF A MAN-REGULATED LAKE

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ABSTRACT – A functional characterization of the littoral and shore vegetation was performed in the Lake Idro to assess its ecological quality and hydromorphological alteration. A detailed survey of hydro-hygrophilous vegetation was carried out in 2010-2012. Three multimetric indices were calculated: the *MacroIMMI* (the Italian macrophytic index for mid-size subalpine lakes with a maximum depth < 125 m), the SFI (Shorezone Functional Index), and the LHS (Lake Habitat Survey). The *MacroIMMI* (0.76) classified the lake in a good ecological status, although the dominant aquatic species were exotic (*Elodea nuttallii* and *Lagarosiphon major*). The SFI pointed out that the 50% of total shorelines displayed a very good or excellent conservation status; conversely, the LHS revealed high levels of morphological alteration coupled with rather good levels of habitat diversity, likely due to the high colonization rates of macrophytes along the lake shore. The lacustrine multimetric indices seem suitable for assessing the conservation status of mid-size lakes. However, for the present case-study, the metrics used require further implementation to suit the peculiarities of Italian subalpine lakes.

KEYWORDS: MACROPHYTES, MULTIMETRIC INDICES, *MACROIMMI*, SFI, LHS, WFD, ECOLOGICAL ASSESSMENT, MID-SIZE SUBALPINE LAKES, LAKE IDRO

INTRODUCTION

Hydro-hygrophilous vegetation contributes actively to the protection and improvement of water quality of lakes, also providing suitable habitats for a variety of animal and microbial species (Wetzel, 1990; Verhoven et al., 2006). The extent and composition of riparian plant communities and submerged aquatic vegetation (SAV) control nutrient availability and the food chains, thus buffering nutrient loading from the catchment and protecting shorelines from erosion (Scheffer & Carpenter, 2003; Scheffer & Jeppesen, 2007).

Despite the important ecological functions and services provided by hydro-hygrophilous vegetation, since the last century a major portion of lacustrine plant belts have been altered by human pressures (e.g., shore reinforcements, navigation facilities, water pollution and level decrease, and alien species invasions). Overall, these alterations have resulted in a dramatic reduction in the representativeness and distribution of macrophyte and amphibian vegetations in aquatic habitats (Hicks & Frost, 2011; Chappuis et al., 2012; Bolpagni et al., 2013). Anthropogenic impacts mostly affected the vertical distribution and the maximum growing depth of aquatic plants. Simplified submerged vegetation also reflects the non-ideal conservation status of a water body (Azzella et al., 2011, 2013; Bolpagni, 2013).

In response to the loss of hydro-hygrophilous vegetations and land-water ecotones and the lack of data on the conservation status of macrophytes in inland waters, in the last decade several surveys were carried out to obtain valuable data on poorly investigated taxonomic groups (e.g., macrophytes in deep lakes, benthic diatoms in large rivers). Furthermore, since the enactment of the European Water Framework Directive (WFD, 2000/60/EC) several methods were developed in order to assess the role of macrophytes and hydromorphology in determining the ecological status (Oggioni et al., 2011; Ciampittiello et al., 2012). At the national scale, the criteria and methods for evaluating

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the ecological quality of lakes using macrophytes and morphological parameters were enforced with the Decree n. 260/2010. Specifically, the hydromorphological approach is essential to evaluate the relationships existing between the ecological status and human impacts, in the light of the central role of human activities in the evolutionary processes of catchments and watersheds (Ciampittiello, 2011; Ciampittiello et al., 2012).
In this framework, two multimetric indices were developed and implemented in Italy as tools to assess the shores functionality and the hydromorphological conservation status of lakes: the SFI (Shorezone Functional Index) (Siligardi et al., 2011) and the LHS (Lake Habitat Survey) (Ciampittiello et al., 2012). These two indices and the lacustrine Italian macrophytic index (*MacroIMMI*, Oggioni et al., 2011) were poorly applied and tested so far.
A comprehensive study of littoral and riparian habitats of the Lake Idro was conducted in the years 2010-2011 with the aim to assess the effectiveness of these tools. This lake was chosen as a case study due to its expected critical ecological status. A complete overview of littoral vegetation of the studied site is reported by Bolpagni (2013). In this paper the results of: *i*) the ecological quality assessment of the macrophyte contingent of littoral zones using the *MacroIMMI* index; and *ii*) a specific functional characterization of the shore zones of the lake applying the SFI and the LHS indices are reported.

Material and Methods

Study area

Lake Idro is located in the Southern Pre-Alps at an altitude of 368 m a.s.l. between Lombardy and Trentino-Alto Adige Regions (Bolpagni, 2013; see Fig. 1). The basin is ~ 12 km long and ~1 km wide with a surface of ~ 11 km^2, the maximum depth is 124 m and the water volume is ~ 8.5 10^8 m^3; its average inflow is ~ 30 m^3 s^{-1} with a water residence time of ~ 1 year (Nizzoli et al., 2012). The lake is meromict, with a mesotrophic to eutrophic status. The oxygenated surface water layer is restricted to the upper 40 - 50 m, while about 60% of the entire water volume is persistently anoxic (Nizzoli et al., 2012). There are many causes for this condition, in particular the intensification of agriculture and zoo-technical activities and the quick development of aquaculture and industries in the lake catchment since the 1960s which resulted in a progressive accumulation of nutrients delivered from the catchment in waters and sediments. A more detailed description of the study area is given in Bolpagni (2013).

Ecological and functional indexing procedure

From July 2010 to October 2011, a complete analysis of the hydro-hygrophilous vegetation of the Lake Idro was carried out. Three multimetric indices were chosen to describe the ecological and functional status of littoral and riparian zones of the basin: *MacroIMMI* (Oggioni & Bolpagni, 2010; Oggioni et al., 2011), SFI (Siligardi et al., 2011) and LHS (Rowan et al., 2006).
According to the WFD, the Lake Idro is included in the category AL-6, it being a southern-Alpine basin with an altitude lower than 800 m a.s.l., a maximum depth < 125 m, and a mean depth > 15 m. The *MacroIMMI* is the macrophytic index to be used for the ecological evaluation of the macroscopic primary producer communities of AL6 lakes (Oggioni et al., 2011):

$$MacroIMMI = \frac{som + exot + S_d + s_k + z_{c\text{-}max}}{5} \quad (1)$$

where *som* is the frequency of submerged plant species; *exot* is the frequency of the exotic species; S_d and s_k are the lake macrophyte diversity and trophic status, respectively; $z_{c\text{-}max}$ is the maximum depth of macrophyte colonization.
The SFI index provides information about the ecological functionality of the shores of a lake (Siligardi et al., 2011). Its application requires the evaluation of both biotic and abiotic factors able to describe: *i*) the buffering capacity of the riparian vegetation, *ii*) the complexity and artificiality of the shoreline, *iii*) the anthropogenic use of the riparian sectors, and *iv*) the morphological structure of watershed. These data have to be collected within shore stretches with similar ecological, morphological and functional characteristics (Siligardi et al., 2011). Data matrix is then processed using the SFINX02 software that generates a classification tree and leads to the evaluation of shorezone functionality.
The LHS index provides information about the morphological alterations and the hydro-morphological quality of a lake. For basins with an area ranging from 0.3 to 14 km^2 as the Lake Idro, LHS requires data from 10 Habitat Plot Observation Stations (Hab Plot), including three different sectors: riparian, littoral and beach zones. Specifically, the method requires the characterization of: *i*) the structural features, *ii*) the composition of vegetation, *iii*) the human-induced alteration of each plot, and *iv*) a general evaluation of the alterations at the basin scale. The data processing generated two different indices: LHMS (= Lake Habitat Modification Score) and LHQA (= Lake Habitat Quality Assessment) describing the morphological alterations and the habitats quality of the basin, respectively.

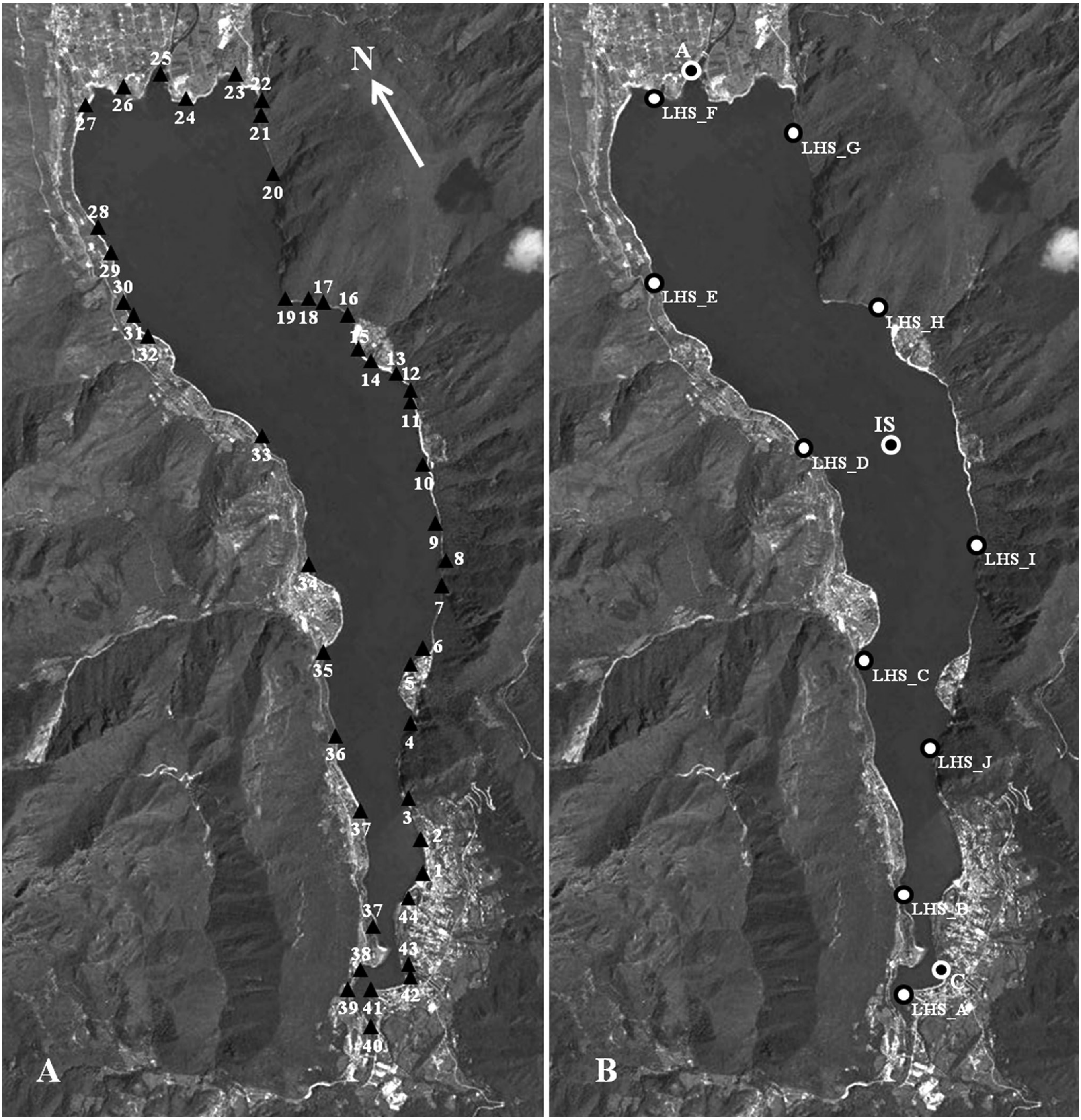

Fig. 1. - Spatial localization of the 44 shore stretches for the SFI calculation (**A**), and of the 10 Hab-Plot (LHS_x) and the IS = Index, A = tributary and C = outlet sampling sites for the LHS calculation (**B**).

Sampling procedures

The macropyhte data for the calculation of the *MacroIMMI* were collected along 46 transects, identified on the basis of information gathered in the recent past by Galanti (from 1997 to 1999; data unpublished) and Roberti (2004). During the first year of investigation (2010), the field surveys were limited to the southern portion of the basin and a total of 18 vegetation transects (June 30^{th}, August 4^{th}-5^{th} and 23^{th}-25^{th}) (Fig. 1b) were considered. In 2011, the aquatic plants characterization was concluded setting up further 28 transects (August 17^{th}-26^{th}).

In 2010, also 4 sampling campaigns were carried out for the application of SFI (6 - 7, 10, 20 - 21, and 23 - 25 August) and the preliminary evaluation of LHS applicability. In 2012 the collection of data for the calculation of SFI (30 June - 3 July) and the application of LHS protocol (28 August) was completed following the procedure reported in Ciampittiello (2011) and Siligardi et al. (2011). The localization of the lake stretches used for the calculation of the SFI is reported in Fig. 1A; while the localization of the 10 Hab-Plot and the *IS* site chosen for the calculation of the LHS is reported in Fig. 1B.

Table 1. Basic macrophytic data for *MacroIMMI* computation; for each transect (TR) performed are reported slope (Sl), length (L TR), maximum growing depth (Z_c), and the average percentage cover of macrophytes detected (*Cer_dem* = *Ceratophyllum demersum*; *Cha_glo* = *Chara globularis*; *Cha_vul* = *Chara vulgaris*; *Cla_aeg* = *Cladophora aegagrophila*; *Elo_nut* = *Elodea nuttallii*; *Fon_ant* = *Fontinalis antipyretica*; *Lag_maj* = *Lagorosiphon major*; *Myr_spi* = *Myriophyllum spicatum*; *Pot_luc* = *Potamogeton lucens*; *Pot_per* = *Potamogeton perfoliatus*; *Pot_pus* = *Potamogeton pusillus*; *Ran_tri* = *Ranunculus trichiphyllus* subsp. *trichophyllus*; *Spi* = *Spirogyra* sp.; *Zan_pal* = *Zannichellia palustris* subsp. *polycarpa*).

TR	Sl	Z_c	L TR	*Cer_dem*	*Cha_glo*	*Cha_vul*	*Cla_aeg*	*Elo_nut*	*Fon_ant*	*Lag_maj*	*Myr_spi*	*Pot_luc*	*Pot_per*	*Pot_pus-*	*Ran_tri*	*Spi*	*Zan_pal*
9’’’	0.2	9.0	38	-	2.3	-	-	-	0.1	-	-	-	-	-	-	-	-
8.0	0.0	9.0	218	-	1.4	0.5	-	0.3	-	0.4	0.1	-	-	0.1	-	-	-
7.0	0.0	9.0	228	-	1.3	-	-	0.3	-	0.9	0.4	-	0.3	-	-	-	-
3.0	0.2	6.0	40	-	-	-	-	0.7	0.3	2.3	0.5	0.2	-	0.2	-	-	-
5.0	0.1	9.0	121	-	2.5	1.0	-	0.4	-	0.1	-	-	0.6	-	-	-	-
6.0	0.2	9.0	47	-	1.3	0.7	-	0.8	-	0.2	-	-	0.2	-	-	-	-
F1	0.4	10.0	27	-	0.3	-	-	1.6	-	1.5	0.6	-	-	0.5	-	-	-
F	0.2	9.0	37	-	0.4	-	-	2.7	-	-	1.0	-	-	1.0	-	-	-
E	0.6	9.0	16	-	0.3	-	-	2.1	-	0.7	1.1	-	-	0.7	-	-	-
E1	0.1	9.0	90	-	0.7	0.1	-	2.2	-	0.2	0.9	-	-	0.7	-	-	-
D	0.2	8.0	43	-	1.0	-	-	2.3	-	-	0.9	-	-	0.6	-	-	-
D1	0.4	9.0	24	-	0.8	-	-	2.2	-	-	0.9	-	-	0.2	-	-	-
A	0.3	9.0	27	-	0.9	-	-	0.6	-	1.9	1.0	-	-	-	-	-	-
A1	0.4	9.0	25	-	0.5	-	-	0.8	-	2.0	0.8	-	-	0.1	-	-	-
B	0.4	9.0	21	-	0.6	-	-	1.1	-	2.0	0.3	-	-	0.4	-	-	-
B1	0.4	9.0	24	-	0.7	-	-	2.0	-	0.3	0.7	-	-	0.7	-	-	-
C	0.4	9.0	22	-	0.6	-	-	-	-	2.7	0.9	-	-	0.1	-	-	-
C1	0.4	9.0	23	-	0.7	0.1	-	2.1	-	0.3	1.0	-	-	0.3	0.1	-	-
AN1	0.7	8.0	12	-	0.7	-	-	0.6	-	2.0	0.4	-	-	-	-	-	-
AN2	0.6	8.0	14	-	0.6	-	-	0.7	-	2.0	0.6	-	-	-	-	-	-
AN3	0.3	8.0	24	-	0.3	-	-	1.0	-	2.0	0.3	-	-	-	-	-	-
AN4	0.6	9.0	15	-	0.3	-	-	0.8	-	2.2	0.3	-	-	-	-	-	-
4B	0.4	9.0	21	-	0.8	0.1	-	0.6	-	1.3	0.1	-	-	0.2	-	-	-
4C	0.5	9.0	18	0.1	0.9	0.1	0.1	0.7	-	1.3	0.4	-	-	0.2	-	-	-
4D	0.5	9.0	19	-	0.4	-	-	1.6	-	1.2	0.3	-	-	0.1	-	-	-
7A	0.4	8.0	21	-	0.3	-	0.1	0.6	-	2.0	0.4	-	-	-	-	-	-
7B	0.5	9.0	18	-	-	-	0.1	1.8	-	1.0	0.3	-	-	-	-	-	-
7C	0.5	9.0	20	-	0.4	-	-	0.7	-	1.3	0.6	-	-	0.1	-	-	-
10A	0.4	9.0	21	-	0.3	-	-	0.9	-	1.8	0.3	-	-	0.1	-	-	-
10B	0.3	5.0	16	-	-	-	-	-	-	0.5	-	-	-	-	-	-	0.5
10C	0.2	4.0	18	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-
10D	0.6	9.0	16	-	-	-	0.6	-	-	0.3	0.2	-	-	-	-	-	-
14A	0.1	6.0	55	-	-	-	-	-	-	0.5	0.7	-	-	-	-	0.5	-
14B	0.2	8.0	35	-	0.9	-	-	0.4	-	1.4	0.3	-	-	-	-	-	-
14C	0.1	5.0	87	-	-	-	1.0	-	-	-	-	-	-	-	-	-	-
14D	0.2	8.0	40	-	0.5	-	-	-	-	1.4	0.3	-	-	-	-	-	-
18A	0.9	8.0	9	-	0.3	-	-	0.5	-	1.4	0.3	-	-	-	-	-	-
18B	0.5	6.0	13	-	-	-	-	0.5	-	2.7	0.5	-	-	0.2	-	-	-
20.0	0.4	6.0	14	-	-	-	-	0.3	-	2.0	0.5	-	-	0.2	-	-	-
21.0	0.3	8.0	25	-	0.6	-	-	0.6	-	1.1	0.4	-	-	0.1	-	-	-
22.0	0.3	8.0	24	-	0.3	-	0.1	0.6	-	1.3	-	-	-	-	-	-	-
23.0	0.3	9.0	36	-	0.9	-	-	0.8	-	1.1	0.4	-	-	0.1	-	-	-
24.0	0.5	8.0	15	-	1.0	0.1	-	0.8	-	0.4	-	-	-	0.4	-	-	-
25.0	0.4	6.0	16	-	-	0.2	-	1.2	-	0.7	-	-	-	0.3	-	-	-
26.0	0.4	8.0	20	-	0.3	-	-	1.4	-	1.1	-	-	-	0.1	-	-	-
27.0	0.5	6.0	12	-	-	-	-	1.2	-	2.4	0.4	-	0.2	-	-	-	-

Results

A total of 14 macrophytes were identified during the two years of investigation, including two Chlorophyta (*Cladophora aegagrophila* and *Spirogyra* sp.), two Charophyta (*Chara globularis* and *C. vulgaris*), one Bryophyta (*Fontinalis antipyretica*), and nine Spermatophyta (*Ceratophyllum demersum*, *Elodea nuttallii*, *Lagarosiphon major*, *Myriophyllum spicatum*, *Potamogeton lucens*, *P. perfoliatus*, *P. pusillus*, *Ranunculus trichophyllus* subsp. *trichophyllus*, and *Zannichellia palustris* subsp. *palustris*). *L. major*, *E. nuttallii*, and *M. spicatum* were present in at least 80% of transects performed; *Chara globularis* and *Potamogeton pusillus* exhibited lower percentage values equal to 76% (35 transects) and 54% (25 transects), respectively. A summary of the macrophyte average percentage values is shown in Table 1.
The values of metrics needed for the calculation of the *MacroIMMI* index are reported in Table 2. On the basis of these metrics, the water body was classified in a "good ecological status" (*MacroIMMI* = 0.76), a result that was largely affected by the high value obtained by the metric "frequency of the submerged species" (= *som*).

Table 2. Metrics for *MacroIMMI* computation; Class limits of ecological quality (Vmin and Vmax) are in agreement with the Italian Ministrerial Decree n. 260/2010 (s_k = trophic score; *som* = relative frequency of submerged plant species; *exot* = relative frequency of exotic species; S_d = macrophyte diversity; $z_{c\text{-}max}$ = maximum depth of growth); V normal = normalized values.

metrics	Vm	V min	V max	V normal		V normal
s_k	0.35	*0.2*	*0.7*	0.30		
som	100.00	*43*	*72*	1.97	57.49*	0.50
exot	57.49	*55*	*99*	0.06		
S_d	83.36	*70*	*90*	0.67		
$z_{c\text{-}max}$	10.00	*2*	*12*	0.80		
MacroIMMI				**0.76**		**0.47**

*value of *som* excluding the alien species contribution.

For estimating the SFI index, the shorelines (26.7 km) was divided into 44 distinct shore stretches, only a few of which were affected to intense anthropogenic perturbations that resulted in a localized alteration of the lake shore and beaches (Tables 2, and 3). The "Bad" SFI value (5) was exclusively associated to the 16% of the total length of the shoreline (about 4.3 km) that comprised eight littoral sectors (Fig. 2). The urban contexts were included in this category, especially in the southern and northern sectors of the basin. Natural vegetation was scarcely represented and these sectors were frequently characterized by beaches that were periodically replenished by allochthonous materials. No shoreline sectors resulted to have a "Poor" evaluation (SFI = 4). 15 stretches showed a "Moderate" level of shorezone functionality (SFI = 3) with a total length of about 9.2 km (Fig. 2). These latter sectors were characterized by the presence of slight levels of human pressure (e.g., periodical cutting of riparian vegetations, installation of quays or buoys) that resulted into a moderate alteration of littoral and hydro-hygrophilous vegetations. The remnant 21 lake sectors with a total length of ~ 13.2 km equivalent to the 50% of total shoreline extension displayed an optimal conservation status with natural and near-natural conditions. Areas within category 2 ("Good" functionality level) were characterised by the irregular presence of paths and not-paved sidewalks used as approaches to the lake shore, sparse residential settlements or not-intensive agricultural areas. Generally, these stretches displayed a near-natural condition with good conservation status, mainly characterized by continuous riparian and littoral vegetation stands and only sporadic presence of artificial substrates. Finally, four sectors, isolated and not easily accessible were assigned to the "Excellent" functionality level (SFI = 1). These sectors were characterized by well-developed fringes of hydro-hygrophilous vegetation, even though the water-terrestrial ecotones were mostly reduced to a thin belt of about 5-10 m (Fig. 2, above).
The results obtained by the application of the LHS method highlighted high levels of morphological alteration, expressed by a low value of LHMS (14), and strong habitat diversity, showed by a high LHQA value (66). Overall, these outputs were consistent with the high conservation level of the riparian zones that were mainly dominated by broadleaf/mixed woodlands. The shore zones and littorals exhibited moderate levels of vegetation cover from 40% to about 60% of the total available area. No beach alterations were observed with the exception of the Hab-Plot LHS_F (Fig. 1) where the bank was strengthened and the lakeside was protected by a barrier to contain the erosive action of waves. Within all the investigated Hab-Plot it was not possible to detect the presence of any type of direct human pressures (e.g., commercial activities, residential areas, roads or railways, tracks and footpaths, parks and garden).
A relative good agreement was found comparing the results obtained with different indices. In particular, with the exception of LHMS, all other indicators taken into account pointed out that the lake is in a general good ecological status.

Discussion

On the basis of *MacroIMMI*, the Lake Idro can be considered in a "good ecological status", however its littoral zone was almost all colonized by alien species, largely represented by

Table 3. SFI results for the Lake Idro; PS = Personal evaluation, GF = Functional assessment: 1 = Bad, 2 = Poor, 3 = Moderate, 4 = Good, and 5 = Excellent (in pale gray we reported the stretches in Bad conditions).

Stretch			PS	GF	Score
ERID01	**-**	**(Ponte Neco - Loc. Lombard)**	**4**	**5**	**4.73**
ERID02	-	(Loc. Lombard - Loc. Calchere)	2	3	3.15
ERID03	-	(Loc. Calchere – Vantone)	1	1	1.15
ERID04	-	(Vantone 1)	2	3	3.15
ERID05	-	(Vantone 2)	2	3	3.21
ERID06	-	(Vantone – 1st tunnel)	4	2	2.14
ERID07	-	(two tunnels)	1	2	2.00
ERID08	-	(2nd tunnel)	2	2	2.14
ERID09	-	(tunnels – Loc. Parole)	3	1	1.15
ERID10	-	(Loc. Parole – Massicciata)	3	3	3.15
ERID11	-	(Massicciata)	1	3	3.21
ERID12	-	(Massicciata – Vesta)	3	1	1.15
ERID13	-	Vesta (1st sector)	1	3	3.21
ERID14	-	Vesta (2nd sector)	3	3	3.15
ERID15	**-**	**Vesta (3rd sector)**	**1**	**5**	**4.73**
ERID16	-	(Vesta – Loc. Corna di Faner)	2	2	2.00
ERID17	-	(Corna di Faner)	3	2	2.00
ERID18	-	(Corna di Faner - Pra della Fame)	4	1	1.15
ERID19	-	(Pra della Fame - falesie di Baitoni)	2	2	2.00
ERID20	-	(falesie di Baitoni - passerella di Baitoni)	5	2	2.00
ERID21	-	(falesia - porto Baitoni)	2	2	2.00
ERID22	**-**	**(Lido di Baitoni)**	**4**	**5**	**4.73**
ERID23	-	(SIC di Baitoni)	4	2	2.21
ERID24	-	(SIC di Baitoni - foce Chiese-Caffaro)	4	2	2.14
ERID25	-	(foce Chiese-Caffaro)	2	3	3.21
ERID26	**-**	**(Lido Porto Ponte Caffaro)**	**4**	**5**	**4.73**
ERID27	-	(Lido Porto di Ponte Caffaro - Loc. villaggio S. Antonio)	5	2	2.00
ERID28	-	(Loc. villaggio S. Antonio)	2	3	3.21
ERID29	-	(Loc. villaggio S. Antonio - Loc. villaggio Liperone)	1	2	2.00
ERID30	-	(Loc. villaggio Liperone)	2	3	3.21
ERID31	-	(Loc. primo - Loc. villaggio Delta Liperone)	1	2	2.00
ERID32	-	(Loc. villaggio Delta Liperone - Rocca d’Anfo)	2	3	2.78
ERID33	-	(Rocca d’Anfo)	2	2	2.00
ERID34	-	(Delta di Anfo)	4	3	3.21
ERID35	-	(Delta di Anfo - Loc. villaggio Tre Capitelli)	1	2	2.00
ERID36	**-**	**tratto in sponda destra Loc. villaggio Tre Capitelli**	**2**	**5**	**4.73**
ERID37	-	(Loc. villaggio Tre Capitelli - Loc. Grotta)	3	3	2.78
ERID38	**-**	**(Loc. Grotta)**	**3**	**5**	**4.73**
ERID39	**-**	**(Loc. Grotta - Galleria di fondo)**	**1**	**5**	**4.73**
ERID40	-	(Galleria di fondo - incile fiume Chiese)	3	3	3.21
ERID41	-	(Ponte di Pieve Vecchia - Loc. Coren)	1	3	2.78
ERID42	-	(Loc. Lido Porto di Lemprato)	3	2	2.14
ERID43	**-**	**(Loc. Canale Enel)**	**1**	**5**	**4.73**
ERID44	-	(Loc. Canale Enel - Ponte Neco)	2	2	2.00

Summary of the SFI results.

SFI value	Shore stretches identified	Total km	Percentage
1 - Excellent	4	2.4	9%
2 - Good	17	10. 8	40%
3 - Moderate	15	9.2	34%
4 - Poor	0	0.0	0%
5 - Bad	8	4.3	16%
Total	**44**	**26.7**	**100%**

E. nuttallii and *L. major* (Roberti 2004; Bolpagni & Tomaselli, 2005; Bolpagni, 2013). As reported above, *MacroIMMI* was applied to the macrophyte analysis of the Lake Idro because the lake belongs to the AL-6 lake-type (Oggioni et al., 2011). The $MTI_{species}$ index has to be used for vegetation analysis in deeper lakes, with maximum depths greater then 125 m and thus belonging to AL-3 type (Oggioni et al., 2011). Differently from *MacroIMMI*, that considers also the frequency of the submerged and exotic plant species (*som* and *exot*), the macrophyte diversity (S_d), and the

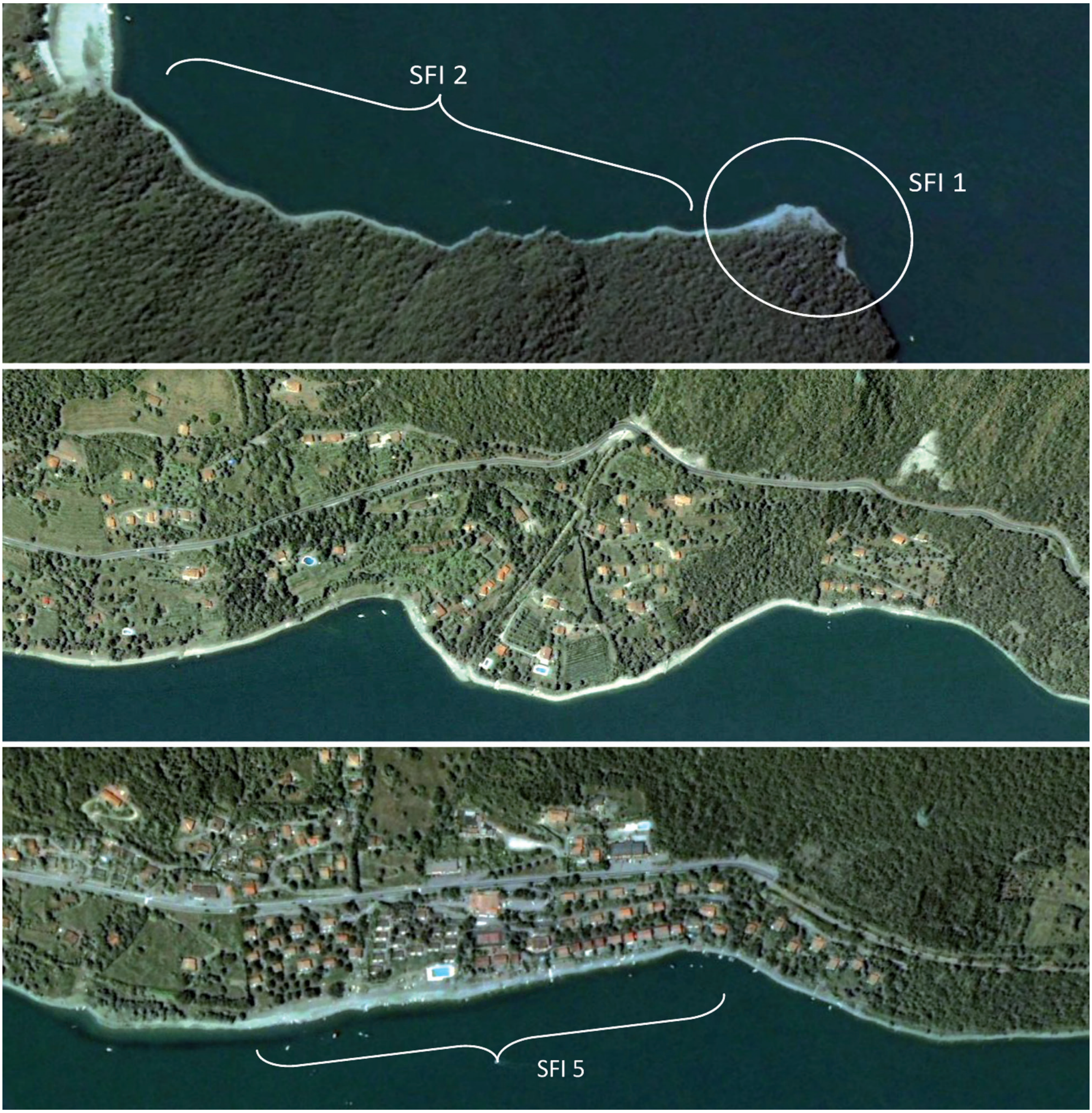

Fig. 2. - Examples of SFI categories 1 and 2 (upper panel), 3 (middle panel) and 5 (lower panel).

maximum depth of macrophyte colonization ($z_{c\text{-}max}$), the $MTI_{species}$ index considers exclusively the lake trophic score values. Accordingly, if we calculated the $MTI_{species}$ for the Lake Idro, the low value of $MTI_{species}$ (0.35) will classify the lake in a "scarce" ecological status. This condition is also proved by the taxonomic analysis performed during this study and exhaustively reported in Bolpagni (2013) that revealed the dominance of extremely opportunistic species as alien elodeids (*E. nuttallii* and *L. major*) and *M. spicatum*, and the absence of well-developed submerged meadows of charophytes. The discrepancy between the *MacroIMMI* value and the evidences gathered by the floristic analysis suggests reconsidering the weight of the different metrics used in the index calculation, for example lowering the contribution of alien species in the "*som*" metric computation. For instance, the exclusion of the contribution of *E. nuttallii* and *L. major* from the calculation of *som* determines a notable reduction in the value of *MacroIMMI* from "good" to "scarce ecological status" (from 0.76 to 0.47). This result seems to be more consistent with the current physico-chemical conservation status of the basin (Nizzoli et al., 2012) and with the output of $MTI_{species}$ application.

With respect to the outputs of the SFI indexing procedures, the half of the total perimeter of the lake exhibited a "good" or an "excellent functionality" level; and only about 9% of the lake shorezones displayed "bad" values. Overall, the SFI index appeared sufficiently suited to describe the conservation status of riparian habitats but it also resulted to be scarcely suitable for detecting the ecological functionality of aquatic communities for different reasons. First of all, the SFI calculation method considers the presence and heterogeneity of vegetation as indicators of good ecological status thus failing to notice the ecological importance of some habitats such as native shorezone typologies that are naturally scarcely colonised by grasses or other forms of plants (Bolpagni, 2013). Furthermore, the SFI method tends to overestimate the metabolic activities of herbaceous plant species not distinguishing, for example, between annual or perennial grass vegetation. Moreover, the species list reported by the user manual (Siligardi et al., 2011) is extremely poor and requires additions to evaluate correctly the Italian lacustrine habitats. Even though the results of this study highlight that SFI illustrates rather efficiently the structural conservation of the investigated shorezones, it appears clear the necessity of revising several methodological aspects of the SFI calculation.

The LHS index results suggest that the studied lake was characterized by a considerable level of hydromorphological alteration and a rather high level of habitat diversity, probably due to the diffuse colonization of littoral belts by macrophytes, due to the high nutrient availability and the great lake-level variability during last years (Nizzoli et al., 2012; Bolpagni, submitted). Based on these evidences, the LHS index seems to get appropriately the status of alteration of the lake morphology, though as SFI also LHS tends to overestimate the role of ecotonal and littorals habitats diversity and structural complexity in describing the lake hydro-morphological quality.

The present study suggests how the local relative high floristic-vegetation diversity supported by the high nutrient availability coupled with a moderate hydrological disturbance can resulting in a positive evaluation of the lake's ecological status. Both vegetation and functional approaches appear to disguise the hydro-morphological impacts due to human activities.

On the whole, despite the use of indices as ecological functionality descriptor can be convenient, the disagreement observed between morphological and vegetational/habitat assessments stresses the need to update, wide and adapt several descriptors to the peculiarities of the Italian lakes and their surrounding areas (e.g., in terms of land covers, alien species, etc). Similarly, the lists of species selected to evaluate the ecological functionality of littorals and lacustrine ecotones are often incomplete and need to be carefully revised and updated for Italian water bodies.

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