# LA FAUNA ITTICA IN LAGUNA DI VENEZIA: AGGIORNAMENTO DELLA LISTA TASSONOMICA E REVISIONE DELLA CLASSIFICAZIONE IN GRUPPI FUNZIONALI

# FISH FAUNA IN THE VENICE LAGOON: UPDATING THE SPECIES LIST AND REVIEWING THE FUNCTIONAL CLASSIFICATION

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**Keywords:** Fish assemblage, diversity, functional classification, ecological guilds, seasonality, lagoon

## Riassunto
Il presente lavoro effettua una revisione della classificazione in gruppi funzionali della fauna ittica della laguna di Venezia, e aggiorna la lista tassonomica sulla base di oltre 15 anni di ricerca in questo ecosistema. La lista comprende tutti gli stadi vitali incluso l'ittioplancton e consta di 94 taxa, di cui 14 riscontrati solo dopo il 2010. La nuova classificazione in gruppi funzionali, che consta di otto guild, comprese due guild distinte di residenti lagunari e due di migratori marini, evidenzia le differenze nell'uso degli habitat lagunari da parte delle specie in stagioni diverse.

## Abstract
This work aims at reviewing the existing ecological classification of fish fauna in the Venice lagoon, and updating the list of species found during 15+ years of research in this ecosystem. The checklist encompass all fish life stages including ichthyoplankton, and contains 94 taxa, with 14 recorded only after 2010. The new functional classification, made of eight guilds including two guilds of lagoon residents and two of marine migrants, highlights the differences in species' use of lagoon habitats in different seasons.

## Introduction
Ecological guilds are widely used to categorise fish species according to the way in which they use an ecosystem and provide an useful tool to understand spatial and temporal dynamics in fish distribution, habitat functionality and connectivity between ecosystems (Elliott *et al.*, 2007; Franco *et al.*, 2008). The most recent synthesis on fish diversity and distribution in the Venice lagoon (Franzoi *et al.*, 2010) allocated 80 taxa into five broad ecological guilds: lagoon residents (*LR*), spending their whole life cycle within the lagoon; marine migrants (*MM*), spawning at sea but penetrating regularly into the lagoon; anadromous migrants (*MA*), spawning in freshwaters and entering the lagoon while migrating to marine adult habitats; marine stragglers (*MO*), marine stenohaline species irregularly found within the lagoon in areas most influenced by the sea; freshwater stragglers (*FW*), freshwater stenohaline species occurring occasionally in the lagoon in low salinity waters near river mouths. Such classification was based on literature and specific knowledge of species life cycles in the Venice lagoon (Franzoi *et al.*, 2010). The present work takes advantage of the many research and

monitoring surveys carried out in the Venice lagoon, including those made since the review by Franzoi *et al.* (2010) (Zucchetta *et al.*, 2016; Cavraro *et al.*, 2017; Scapin *et al.*, 2018). This work aims to update the fish species list of the Venice lagoon and, with an extensive and diverse dataset available, to propose a revised functional classification, taking into account species frequency of occurrence and habitat use.

**Material and methods**

Fish data from 2001 to 2017 were used in this study. The dataset integrated spring, summer and autumn observations made in different lagoon habitats including both shallow waters and deeper channels, and were carried out using either beach seine or fyke nets (together accounting for 95% of total observations). The dataset was also integrated with a small number of observations made with trawl and bongo nets. Using different gears with different selectivity (e.g. seine net for juveniles of marine and resident species, and adults of small sized resident species; fyke net for sub-adults and adults; bongo net for ichthyoplankton) allowed to target all fish life stages. The functional classification scheme proposed here, based on the work of Potter *et al.* (2013), was then used to allocate each taxon included in the updated checklist into one ecological guild, according to the specific use of the Venice lagoon ecosystem made by that taxon (Franco *et al.*, 2006, 2008; Zucchetta *et al.*, 2016). The relative frequency of occurrence of each taxon in the dataset was calculated separately for spring, summer and autumn observations, considering only the two main sampling gears (i.e. seine and fyke net) and treating them separately.

**Results**

The new fish checklist contains 94 taxa (Table I). Among them, 91 are classified at the species level, with two additional taxa classified at the genus level and one at the family level. Overall, 64 genera and 37 families were recorded. The checklist includes 14 new taxa: *Atherina hepsetus* (Atherinidae), *Arnoglossus kessleri* and *A. laterna* (Bothidae), *Trachinotus ovatus* (Carangidae), *Symphodus doderleini*, *S. melops* and *S. ocellatus* (Labridae), the family Lotidae (only found as ichthyoplankton), *Pomatomus saltatrix* (Pomatomidae), *Serranus hepatus* (Serranidae), *Buglossidium luteum*, *Microchirus* sp. and *Monochirus hispidus* (Soleidae) and *Sarpa salpa* (Sparidae). The new classification scheme distinguishes lagoon resident taxa with also marine or freshwater populations (ES, 12% of the current total number of taxa) from solely estuarine ones (ESs, 4%). Similarly, the previous guild of marine migrants is now split into marine estuarine-dependents (ME-D, 5%), whose juvenile stages require lagoon habitats, marine estuarine-opportunists (ME-O, 12%), which regularly enter the lagoon but can alternatively use other coastal habitats, and catadromous (C, only *Anguilla anguilla*). The majority of taxa belong to the guild of marine stragglers (MS, 59%). Freshwater stragglers (FS) account for 6% of the total number of taxa, while anadromous (A) include only *Alosa fallax*. All new taxa are included in the MS guild. Most ES and ESs occur in the dataset with high frequency from spring to autumn, with ESs being overall more common in the seine net samples than in fyke net ones (Figure 1). Among seine net samples, spring observations feature a higher diversity of relatively common migrant species (10 to 25% of occurrence) compared to other seasons, with ME-D being overall more frequent than ME-O in spring. Conversely, fyke net samples show higher frequencies of some ME-D (namely Mugilidae) during autumn. On the whole, MS, A and C show very low frequencies of occurrence.

*Tabella I. Lista tassonomica del popolamento ittico della laguna di Venezia. Per ciascun taxon è indicata la guild ecologica di appartenenza secondo Franzoi et al. (2010) e la nuova classificazione proposta. I taxa inclusi per la prima volta nella lista sono sottolineati. Si veda il testo per la definizione delle guild*

*Table I. Species list of fish assemblage in the Venice lagoon. For each taxon, the ecological guild according to Franzoi et al. (2010) and the proposed new classification is indicated. New taxa are underlined. See text for guild definitions*

| | | | **Ecological guilds** | |
|---|---|---|---|---|
| **Family** | **Species** | **Label** | **Franzoi *et al.*, 2010** | **Proposed new classification (Potter *et al.*, 2013)** |
| Anguillidae | *Anguilla anguilla* | AAN | MM | **C** |
| Atherinidae | *Atherina boyeri* | ABO | LR | **ES** |
| Atherinidae | *Atherina hepsetus* | AHE | | **MS** |
| Belonidae | *Belone belone* | BBE | MM | **ME-O** |
| Blennidae | *Parablennius gattorugine* | PGA | MO | **MS** |
| Blennidae | *Parablennius sanguinolentus* | PSAN | MO | **MS** |
| Blennidae | *Parablennius tentacularis* | PTE | MO | **MS** |
| Blennidae | *Parablennius zvonimiri* | PZV | MO | **MS** |
| Blennidae | *Salaria pavo* | SPA | LR | **ES** |
| Bothidae | *Arnoglossus kessleri* | AKE | | **MS** |
| Bothidae | *Arnoglossus laterna* | ALA | | **MS** |
| Callionymidae | *Callionymus risso* | CRI | MO | **MS** |
| Carangidae | *Trachinotus ovatus* | TOV | | **MS** |
| Carangidae | *Trachurus trachurus* | TTR | MO | **MS** |
| Centrarchidae | *Lepomis gibbosus* | LGI | FW | **FS** |
| Clupeidae | *Alosa fallax* | ALFA | MA | **A** |
| Clupeidae | *Sardina pilchardus* | SPI | MM | **ME-O** |
| Clupeidae | *Sprattus sprattus* | SSP | MM | **ME-O** |
| Congridae | *Conger conger* | CCO | MO | **MS** |
| Cyprinidae | *Carassius carassius* | CCA | FW | **FS** |
| Cyprinidae | *Pseudorasbora parva* | PPA | FW | **FS** |
| Cyprinidae | *Rhodeus amarus* | RAM | FW | **FS** |
| Cyprinodontidae | *Aphanius fasciatus* | APFA | LR | **ESs** |
| Engraulidae | *Engraulis encrasicolus* | EEN | MM | **ME-O** |
| Gadidae | *Merlangius merlangus* | MME | MO | **MS** |
| Gobiidae | *Gobius cobitis* | GCO | MO | **MS** |
| Gobiidae | *Gobius niger* | GNI | LR | **ES** |
| Gobiidae | *Gobius paganellus* | GPA | LR | **ES** |
| Gobiidae | *Knipowitschia panizzae* | KPA | LR | **ESs** |
| Gobiidae | *Pomatoschistus canestrinii* | PCA | LR | **ESs** |
| Gobiidae | *Pomatoschistus marmoratus* | PMA | LR | **ES** |
| Gobiidae | *Pomatoschistus minutus* | PMI | MM | **ME-O** |
| Gobiidae | *Zebrus zebrus* | ZZE | MO | **MS** |
| Gobiidae | *Zosterisessor ophiocephalus* | ZOP | LR | **ES** |
| Labridae | *Labrus viridis* | LVI | MO | **MS** |
| Labridae | *Symphodus cinereus* | SCI | MO | **MS** |
| Labridae | *Symphodus doderleini* | SDO | | **MS** |
| Labridae | *Symphodus mediterraneus* | SMED | MO | **MS** |
| Labridae | *Symphodus melops* | SME | | **MS** |
| Labridae | *Symphodus ocellatus* | SOC | | **MS** |
| Labridae | *Symphodus roissali* | SRO | LR | **MS** |
| Labridae | *Symphodus tinca* | STI | MO | **MS** |
| Lotidae | Lotidae sp.* | | | **MS** |
| Moronidae | *Dicentrarchus labrax* | DLA | MM | **ME-O** |
| Mugilidae | *Chelon auratus* | CLA | MM | **ME-D** |
| Mugilidae | *Chelon labrosus* | LAU | MM | **ME-O** |
| Mugilidae | *Chelon ramada* | LRA | MM | **ME-D** |
| Mugilidae | *Chelon saliens* | LSA | MM | **ME-D** |
| Mugilidae | *Mugil cephalus* | MCE | MM | **ME-O** |
| Mullidae | *Mullus surmuletus* | MSU | MM | **ME-O** |
| Myliobatidae | *Aetomylaeus bovinus* | PBO | MO | **MS** |
| Phycidae | *Phycis phycis* | PPH | MO | **MS** |
| Pleuronectidae | *Platichthys flesus* | PFL | MM | **ME-D** |
| Poeciliidae | *Gambusia holbrooki* | GHO | FW | **FS** |
| Pomatomidae | *Pomatomus saltatrix* | PSAL | | **MS** |
| Salmonidae | *Salmo trutta* | STR | FW | **FS** |

| | | | | |
|---|---|---|---|---|
| Sciaenidae | *Sciaena umbra* | SUM | MO | **MS** |
| Sciaenidae | *Umbrina cirrosa* | UCI | MM | **MS** |
| Scombridae | *Scomber scombrus* | SSC | MO | **MS** |
| Scophthalmidae | *Scophthalmus maximus* | SMAX | MM | **MS** |
| Scophthalmidae | *Scophthalmus rhombus* | SRH | MO | **MS** |
| Scorpaenidae | *Scorpaena porcus* | SPO | LR | **MS** |
| Serranidae | *Serranus hepatus* | SHE | | **MS** |
| Soleidae | *Buglossidium luteum* | BLU | | **MS** |
| Soleidae | *Microchirus* sp. | | | **MS** |
| Soleidae | *Monochirus hispidus* | MHI | | **MS** |
| Soleidae | *Pegusa impar* | PIM | MM | **MS** |
| Soleidae | *Solea solea* | SSO | MM | **ME-O** |
| Sparidae | *Boops boops* | BBO | MO | **MS** |
| Sparidae | *Diplodus annularis* | DAN | MM | **MS** |
| Sparidae | *Diplodus puntazzo* | DPU | MO | **MS** |
| Sparidae | *Diplodus sargus* | DSA | MO | **MS** |
| Sparidae | *Diplodus vulgaris* | DVU | MO | **MS** |
| Sparidae | *Lithognathus mormyrus* | LMO | MM | **MS** |
| Sparidae | *Oblada melanura* | OME | MO | **MS** |
| Sparidae | *Pagellus erythrinus* | PER | MO | **MS** |
| Sparidae | *Pagrus major* | PMAJ | MO | **MS** |
| Sparidae | *Pagrus pagrus* | PPAG | MO | **MS** |
| Sparidae | *Sarpa salpa* | SSA | | **MS** |
| Sparidae | *Sparus aurata* | SAU | MM | **ME-D** |
| Sparidae | *Spicara* sp. | | MO | **MS** |
| Sparidae | *Spondyliosoma cantharus* | SCA | MO | **MS** |
| Sphyraenidae | *Sphyraena sphyraena* | SPSP | MO | **MS** |
| Syngnathidae | *Hippocampus guttulatus* | HGU | LR | **ES** |
| Syngnathidae | *Hippocampus hippocampus* | HHI | LR | **ES** |
| Syngnathidae | *Nerophis maculatus* | NMA | MO | **MS** |
| Syngnathidae | *Nerophis ophidion* | NOP | LR | **ES** |
| Syngnathidae | *Syngnathus abaster* | SAB | LR | **ESs** |
| Syngnathidae | *Syngnathus acus* | SAC | MM | **MS** |
| Syngnathidae | *Syngnathus taenionotus* | STA | LR | **ES** |
| Syngnathidae | *Syngnathus tenuirostris* | STE | MM | **MS** |
| Syngnathidae | *Syngnathus typhle* | STY | LR | **ES** |
| Trachinidae | *Echiichthys vipera* | EVI | MO | **MS** |
| Triglidae | *Chelidonichthys lucerna* | CLU | MM | **ME-O** |

*taxon exclusively found as ichthyoplankton.

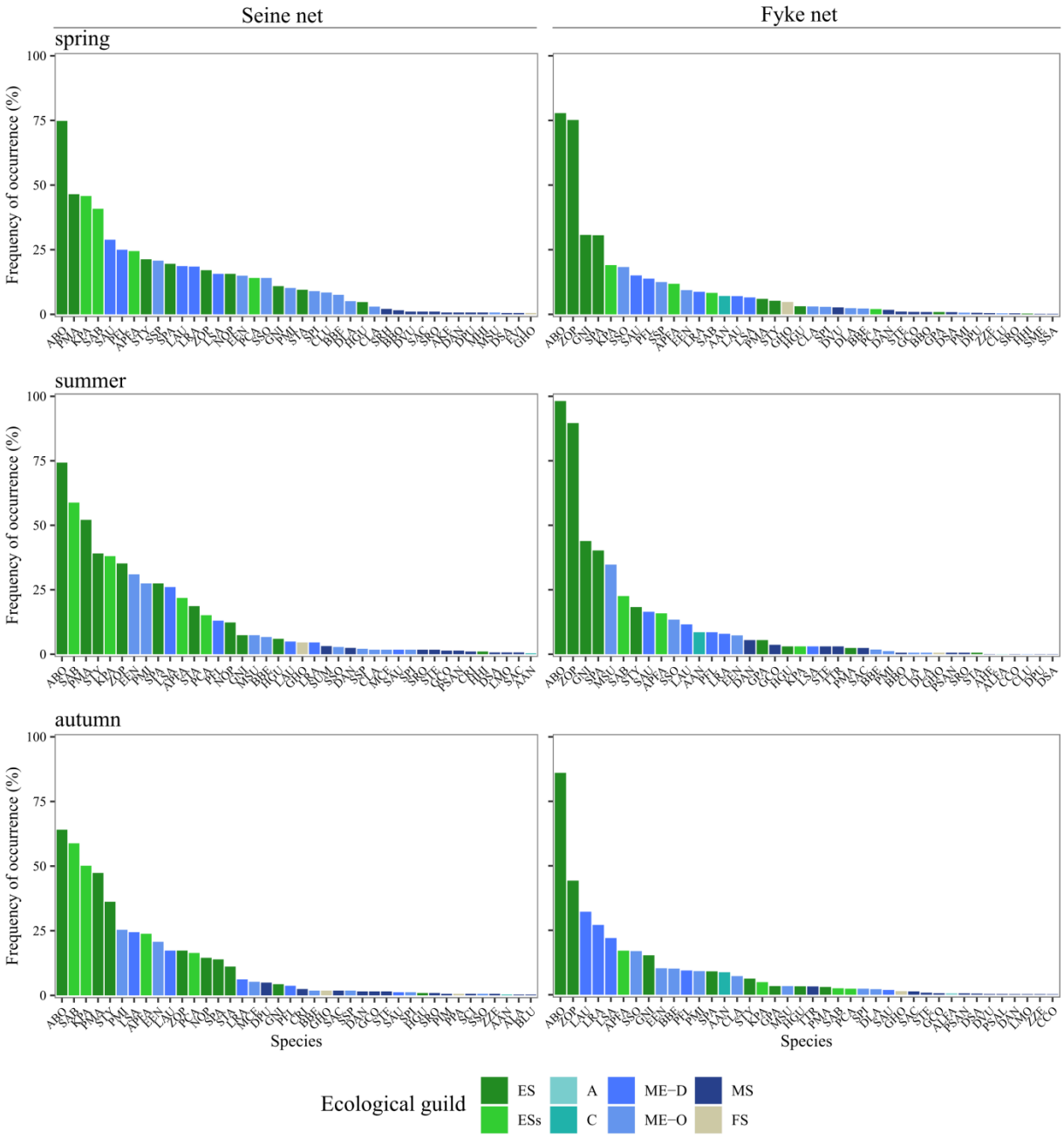


*Figura 1. Frequenza relativa delle specie ittiche in primavera (riquadri in alto), estate (in centro) e autunno (in basso) riscontrati nei campioni di sciabica (sinistra) e bertovello (destra). Sono illustrate solo le 40 specie più comuni in ciascun subset. Le abbreviazioni di specie e gruppi funzionali sono indicate in Tabella I*

*Figure 1. Relative frequency of occurrence of fish species during spring (above panels), summer (central) and autumn (bottom) in seine net (left) and fyke net samples (right). Only the 40 more common species in each subset are shown. Species and guild labels are reported in Table I*

**Discussion and Conclusions**

Fish distribution in the Venice lagoon is non-homogeneous, being affected by the high heterogeneity that is typical of most transitional water ecosystems (Elliott & Hemingway, 2002; Elliott *et al.*, 2007). ES and ESs are the most common ecological guilds in the lagoon, although including a limited number of species, and are mostly associated with specific habitats (Franco *et al.*, 2006). The higher frequencies of ESs in seine net observations suggest that they are less motile and more strongly linked to shallower, less dynamic lagoon areas compared to ES, which in turn are found with high frequencies also in fyke nets, hence being overall more motile and using also more dynamic environments (e.g. those in proximity of lagoon channels). Major seasonal differences can be detected in the distribution of marine migrants. Both ME-D and ME-O are mostly found in seine net samples during spring, hence as postlarvae and juveniles gathering in shallower and sheltered habitats after entering the lagoon (Franco *et al.*, 2006; Franzoi *et al.*, 2010). In autumn, some species (namely ME-D mugilids belonging to the genus *Chelon*) become more common in fyke nets, this highlighting their increase in size and motility before reproductive migrations to sea. ME-D are overall more common than ME-O, hence confirming that not all migrants exploit the lagoon in the same way, and suggesting that the nursery function of lagoon habitats is exploited mainly by ME-D species (Potter *et al.*, 2013). Finally, the marine-like nature of areas closer to sea inlets and along the main lagoon channels explains the high diversity of MS in the lagoon.

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