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Fish and Fisheries
Skadar/Shkodra Lake

Implementing the EU Water Framework Directive in South-Eastern Europe

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Content

Acronyms

AL	Albania
CPUE	Catch per unit of effort
CSBL	Conservation and Sustainable Use of Biodiversity at Lakes Prespa, Ohrid and Skadar/Shkodra
EU	European Union
IfB	Institute of Inland Fisheries Potsdam
ind.	Individuals
FMO	Fisheries Management Organization
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
MMG	Multi-mesh gillnet
MN	Montenegro
NPUE	Number of individuals per unit of effort
PENP	Public Enterprise for National Parks
RM, RCG	Republic of Montenegro
SD	Standard deviation
SL	Skadar/Shkodra Lake
TL	Total length
TW	Total weight
WFD	Water Framework Directive

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Foreword

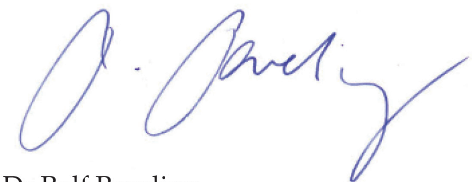
The fish fauna of the three great lakes of the Western Balkans is one of the richest and most diverse in Europe. Lake Shkodra/Skadar alone is home to more than 30 indigenous fishes, including Natura 2000 species such as marble trout and regional endemics such as Ohrid spirlin. In addition, more than a dozen non-native species are believed to have been introduced into the lake, either deliberately or through negligence. Some of these alien species, e.g. European perch, are of increasing commercial value while others impress by their sheer abundance more than by their economic potential (e.g. bitterling).

The management and sustainable use of the lake's fishes poses manifold challenges to competent authorities and small-scale fishers alike. First, vulnerable species are protected under national and EU nature conservation legislation and require special conservation efforts. Second, economic species such as carp or bleak are exploited haphazardly and sometimes illegally with little if any knowledge on the status of stocks and maximum sustainable yields. Third, fisheries regulations differ among countries and are, in any case, poorly implemented. Lastly, fishes are one of four so-called biological elements – or indicators – that determine the ecological status of lakes according to the EU Water Framework Directive. The Directive requires that good ecological status, i.e. the status of the fish fauna (and other biota) under nearly undisturbed conditions, has to be maintained or restored, and that specific measures are to be taken to fulfil this requirement.

However complex and variable these challenges may be, they have one thing in common: the need for data and up-to-date information on the status of the fish fauna of the lake. Yet sampling fish is anything but a small undertaking in terms of both effort and finance. The last comprehensive stock assessments had been made during communist times in both countries. In those days, annual catch statistics were collated by fishing authorities, providing a fairly sound basis for the management of stocks. Unfortunately, such statistics are no longer collected, let alone data from independent monitoring campaigns.

It is from this perspective that German Development Cooperation supported partner countries in conducting multi-annual fish sampling pursuant to fishing standards set by the European Committee for Standardization, of which Albania and Montenegro are affiliate members. Standardized sampling was carried out in three consecutive years jointly by Albanian, German and Montenegrin experts, yielding a prolific data base on more than 25,000 specimens of fish, and an outline of the present-day composition and abundance of fish assemblages in Lake Shkodra/Skadar. For species such as bleak data sets were sufficiently large to derive immediate management recommendations while other species of economic and/or conservation importance require further monitoring as well as employment of different fishing gear before firm conclusions on their management can be drawn. Furthermore, specific fish community traits have been identified which can be the basis for formulation of specific reference conditions and subsequent assessment of the lake according to the Water Framework Directive using fish as biological element.

In any case, the present investigation generated the most comprehensive data set since communist times. Investigators and authors are acknowledged not only for gathering and analysing this wealth of information but also for doing it collaboratively and compliant with recognized methods. Fishing authorities in turn are encouraged to make best use of the data, and to ensure that adequate resources are allocated for future monitoring, including collation of catch statistics.



Dr Ralf Peveling

Program Manager CSBL

1 SUMMARY

Lake Shkodra/Skadar[1] is the largest freshwater body on the Balkan Peninsula. It covers an area of about 370 to 600 km² and is shared between Montenegro and Albania. Because of its specific hydrological characteristics, exposure to Mediterranean climate, close connection to Adriatic Sea via Buna/Bojana River, diverse shoreline, and physico-chemical water quality it is home to myriads of animal and plant species, many of which are endemic to the lake or region. To protect these natural treasures the Montenegrin part of Lake Skadar was proclaimed National Park in 1983, while the Albanian lake area holds the status of a Managed Natural Reserve (Protected Landscape) since 2005 (Grudnik & Gajšek 2011).

The fish fauna of the lake is composed of freshwater and saltwater species as well as of coldwater and warmwater fishes. As a result, fishing has always been an important activity of local people as it secures food and income. At present, however, there is concern that fish stocks are overexploited and, due to e.g. environmental pollution, introduction of invasive species and illegal fishing activities, are under significant pressure (APAWA & CETI 2007, Talevski et al. 2009 a, Grudnik & Gajšek 2011, Milošević & Talevski 2015). While available data of annual fish catches date back several decades, there is only scarce information on the current status of fish (Palluqi et al. 2011). A systematic monitoring of fish, conducted according to standardized methods and covering both Montenegrin and Albanian waters, has never been performed.

In the course of the Technical Assistance program *Conservation and Sustainable Use of Biodiversity at Lakes Prespa, Ohrid and Skadar/Shkodra* (CSBL) which is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry of Economic Cooperation and Development, repeated fishing campaigns were undertaken on the lake. A main goal of these activities was to deliver further training to fishery scientists and practitioners of Albania and Montenegro on the European standard EN 14757 (European Committee for Standardization 2015) which is used to sample fish to assess the ecological status of lakes compliant with EU Water Framework Directive (Directive 2000/60/EC) requirements. Concurrently, however, this method also provides important information from a fisheries perspective as it enables determination of species occurrence and calculation of relative fish abundance, biomass (expressed as catch per unit of effort, CPUE) as well as identification of the size structure of fish populations (European Committee for Standardization 2015).

During fall of 2013, 2014 and 2015 a total of 312 multi-mesh gillnets (MMG) of mesh sizes (knot to knot) in the sequence of 43 mm, 19.5 mm, 6.25 mm, 10 mm, 55 mm, 8 mm, 12.5 mm, 24 mm, 15.5 mm, 5 mm, 35 mm and 29 mm were placed in Montenegrin and Albanian waters of the lake. As a result, more than 25,000 fish were caught by MMG. Catches were subsequently identified to species level, weighted, and measured (total length, TL). Further fishery data provided in this report result from electrofishing samples and analyses of commercial catches (use of "Kalimera" nets) taken at Montenegrin sites.

The total MMG catch consisted of 18 species. An additional species, Adriatic trout (*Salmo farioides)*, was caught by use of a "Kalimera" net. Bleak (*Alburnus scoranza*), roach (*Rutilus prespensis*) and Eurasian perch (*Perca fluviatilis*) were most abundant on either side of the lake, while spotted roach (*Pachychilon pictum*) and stone moroko (*Pseudorasbora parva*) were caught in significant numbers on Albanian parts of the lake as well. Differences in size structure development of fish populations over time were found between Montenegrin and Albanian sampling sites. For example, in Montenegrin waters, numbers of larger bleak (TL ≥ 14 cm) dropped constantly over the years and the share of bigger roach (TL ≥ 14 cm) of the total catch was low relative to juveniles in any one year. With regard to perch, numbers of specimens caught dropped from 2013 to 2014 but increased again in 2015. In Albanian samples, numbers of large bleak also decreased over time. Furthermore, between-year differences in size class strength were noticed. For instance, in 2013 most bleak belonged to larger size classes whereas in 2014 (and 2015) most of the sampled fish were of small size.

[1] The names Shkodra and Skadar are used together or interchangeably.

On the contrary, the number of adult roach increased from year to year in the Albanian parts of the lake and Eurasian perch appeared first in significant numbers in Albanian catches in 2015.

Taken together, the data from over 25,000 fish sampled at Lake Shkodra/Skadar during the CSBL project show that

- non-indigenous species have established stable populations. For example, on the average Eurasian perch made up about 20% of all specimens caught, and stone moroko approximately 10%. Both species have much higher abundances at selected localities,
- the fish assemblage is numerically dominated by a few species (bleak, roach, perch, stone moroko), which, on average, account for > 90% of fish individuals,
- biomass and abundance of commercially exploited bleak is dramatically dropping, especially at Montenegrin sites and, therefore, there is strong need for bleak stock recovery,
- annual monitoring of short-living species (such as bleak), in particular, needs to be conducted in order to recognize trends in size structure and to respond timely to avoid overexploitation of stocks,
- spatial differences in species assemblage occur between northern (Montenegrin) and southern (Albanian) parts of the lake, which needs to be considered when representative sampling sites are chosen in future monitoring programs,
- MMG fishing is a useful technique to obtain qualitative and quantitative information on fish assemblage. It, however, needs to be complemented by other fishing methods (such as electrofishing) to generate knowledge about species (such as European eel, *Anguilla anguilla*) that cannot be caught by gillnets, and
- it is essential to document fishing efforts (CPUE, NPUE) in order to detect and analyze temporal and spatial variations in fish population dynamics.

Fishery can be sustainable when management decisions are based on sound and comprehensive data. The present report, therefore, is complemented by references to current fishery legislation in Montenegro and Albania and includes information on lake fishery and catches. It furthermore depicts important fish habitats and provides recommendations for future fish stock monitoring. In case of Lake Shkodra/Skadar, a transboundary management of fish stocks is necessary to sustain stocks also in the future.

2 INTRODUCTION

Lake Skadar/Shkodra is a large fluvial lake shared between Albania and Montenegro on the Balkan Peninsula. For centuries, the lake has been of great importance to the people in the region, providing food, income and serving as transportation route (Hassert 1892). Nowadays it is internationally well known for, among others, its scenic attractions and diverse biota. The lake is home to myriad of animal and plant species, many of which are rare or threatened. Moreover, many taxa of the occurring flora and fauna are endemic to this area (Talevski et al. 2009 b, Sadori et al. 2015, Pešić & Glöer 2013, Sulçe et al. 2013). Due to its high importance for species conservation, the lake was included in the Ramsar list as a wetland of international importance in 1995 (Montenegro) and 2005 (Albania) (Grudnik & Gajšek 2011). Great effort is currently being made by both riparian states as well as international organisations to preserve this precious resource for present and future generations (Anonymous 2003, 2005, 2009).

Investigations on fishes of Lake Skadar/Shkodra have also been conducted in the past. These studies, however, were often of faunistic value only, focused on the biology of selected species, or were restricted to national territories of the riparian countries. In conclusion, although fishing has always been an important human activity in the lake region, almost no systematic monitoring of the lake's fish stocks has been executed during the last decades. Knowledge about the state of the fish stocks, however, is a prerequisite for their sustainable use.

The *Conservation and Sustainable Use of Biodiversity at Lakes Prespa, Ohrid and Skadar/Shkodra* (CSBL) project is a Technical Assistance program implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry of Economic Cooperation and Development. It aims, among others, at protecting endangered species and improving management of aquatic resources in the Western Balkans. Sustainable Fisheries is one of several focal areas addressed by the CSBL program. It targets fishes in their natural freshwater environment. A main task of this area is the implementation of transboundary fish monitoring compliant to the requirements of the EU Water Framework Directive (WFD). The present report results from these activities. It focuses on Lake Skadar/Shkodra.[2] The fishery data presented here provide baseline information for future stock assessments and studies on stock dynamics of different species.

In addition of being the main object of fisheries, fishes are also a biological quality element to assess the ecological status of a lake according to the EU WFD (Anonymous 2000). This assessment involves the so-called initial characterization of all lake water bodies. For Lake Shkodra/Skadar and the other great lakes of the Western Balkans, this important milestone was achieved in 2015 (Peveling et al. 2015).

Information shown in this report, therefore, not only provides insight into current conditions of fish stocks but can as well be used to make next steps towards WFD-compliant ecological status assessments, e.g. by setting appropriate class boundaries.

[2] For similar reports on Lakes Prespa and Ohrid, see Ilik-Boeva et al. (2017) and Spirkovski et al. (2017), respectively.

3 LAKE SHKODRA/SKADAR, FISH AND FISHERIES

3.1 The lake and its fish fauna

The Lake Skadar/Shkodra drainage basin is located at the Montenegrin/Albanian border between 18°41' and 19°47' East and 42°58' and 40°10' North and covers a surface area of about 5,500 km² (Vugdelic 2012a). The lake itself is situated in a karstic terrain within the outer part of the south-eastern Dinaric Alps. With a seasonally fluctuating surface area of approximately 370 to 600 km², Lake Skadar/Shkodra (Figure 1) is the largest of the Balkan lakes. About 60% of the lake area is Montenegrin territory while the remaining part belongs to Albania. The exact genesis of the lake is still under debate but most probably it originates from tectonic depressive processes that took place during the Tertiary or Quaternary and created a large flooded area (de Ferraris & Saraco 2011).

Figure 1. View on Lake Skadar/Shkodra

The main lake inlet is the Morača River at the northern shore. It, on average, discharges about 202 m³/s. Further water sources are atmospheric precipitation, a number of smaller tributaries (e.g., rivers Crnojevica, Karatuna, Vraka) and numerous underwater springs, called "vrulja" or "oko", which are irregularly distributed around the lake's periphery. Together they add about 110 m³/s of water to the lake. The main outlet is Buna/Bojana River at the south, which is a relatively wide lowland river with a length of 40 km. Buna/Bojana River discharges approximately 300 m³/s (Keukelaar et al. 2006). The water residence time in the lake is about 120 days (Keukelaar et al. 2006) which means that the lake's water exchanges three times a year. With a mean depth of 5.0 m the lake is a relatively shallow waterbody, although there are locations as deep as 60 m. These spots are sublacustric springs (e.g., Raduško oko). The lake bottom lies about 6 m above sea-level and the lake's coast line (with islands) sums up to about 207 km long (Lasca et al. 1981). The southern and south-western coasts (as well as the narrow north-eastern part towards Crnojevića River) border to steep mountains and hill slopes, while northern and north-eastern coast are wide lowland areas of swamps, flooded meadows, and lowland forests. In a recent study commissioned by CSBL, the lake sub-basin was divided into six hydrogeomorphological areas (Bajkovic et al. 2017). The study distinguishes five shorezone typologies and 183 homogeneous stretches of shorezone. The study also provides important insight into the location and type of potential fish and spawning habitats in the littoral part of the lake.

The area is exposed to Mediterranean climate with an average number of 130 summer days (days with temperatures equal or higher than 25 °C). There are about 21 winter days (days with temperatures equal or below 0 °C) per year and average annual precipitation is variable but in the range of about 2,000 mm (Šundić & Radujković 2012).

Lake Skadar/Shkodra is a unique ecosystem as it provides excellent conditions for a diverse ichthyofauna. For example, a wide variety of habitats (such as marshland, littoral, tributaries, springs etc.) can be found in the lake and biomass production is high as, thanks to shallowness, most of water masses belong to the photic zone and thus secure both high productivity and high concentrations of oxygen. Although water temperature is variable (ranging from 8 to 24 °C) there are also locations (e.g., "oka") where temperatures are relatively cool and constant throughout the year. In combination with Mediterranean climatic conditions the lake, therefore, allows sympatric occurrence of warmwater (e.g. cyprinid) and coldwater (e.g. salmonid) species.

The ichthyofauna of the lake is composed of a relatively high number of species of freshwater and marine origin, some of which, however, only periodically inhabit the lake (Table 1). The number of fish species in the lake system (Lake Skadar/Shkodra and adjoining rivers) increased over the last 50 years because of uncontrolled stocking of allochthonous fish species (*Hypophthalmichthys molitrix*, *Thymallus thymallus*, *Carassius gibelio*, *Perca fluviatilis*) which mainly originate from the Black Sea drainage area. Beside those introductions, however, the lake system is inhabited by several endemic fish species (*Salmo obtusirostris* (Heckel, 1851)[3]; *Barbatula zetensis* (Šorić, 2000); *Chondrostoma scodrensis* (Elvira, 1987); *Gobio skadarensis* (Karaman, 1937); *Knipowitschia montenegrina* (Kovačić & Šanda, 2007); *Pomatoschistus montenegrensis* (Miller & Šanda, 2008), *Rutilus albus* (Marić, 2010)) of the families Salmonidae, Cyprinidae, Gobiidae and Cobitidae (Marić 1995). Similarly, some further fishes (*Acipenser naccarii* (Bonaparte, 1836), *Acipenser sturio* (Linnaeus, 1758), *Alosa fallax* (La Cepède, 1803), *Rhodeus amarus* (Bloch, 1782), *Telestes montenigrinus* (Vuković, 1963) and *Salmo marmoratus* (Cuvier, 1829)) deserve special protection for conservation purposes and have been specified in the Natura 2000 annexes (Anonymous 1992). Finally, the lake is also spawning place and habitat of larval and juvenile fish, respectively, of several catadromous and anadromous (e.g., *Alosa fallax*, *Anguilla anguilla, Acipenser* spp.) as well as estuarine fish species (*Mugil cephalus*, *Dicentrarchus labrax* and *Platichthys flesus).*

According to Marić & Milošević (2011) there are roughly 50 species registered in Lake Skadar/Shkodra (Table 1), of which about one fifth are introduced.

Table 1. Fish species of Lake Skadar/Shkodra (Marić & Milošević 2011)

Scientific name	English name	Native	Introduced (year)	Species recorded in the past	Presence (migratory type)
Acipenser nacarii	Adriatic sturgeon			+	temporary (anadromous)
Acipenser sturio	Atlantic sturgeon			+	temporary (anadromous)
Alburnoides ohridanus	Ohrid spirlin	+			permanent
Alburnus scoranza	bleak	+			permanent
Alosa fallax	twaite shad	+			temporary (anadromous)
Ameiurus nebulosus	brown bullhead		+ (1978)	+	permanent, not recorded for 15 years
Anguilla anguilla	eel	+			temporary

[3] Taxonomic status of *S. obtusirostris*, however, is unclear; cf. Snoj et al. (2002)

Scientific name	English name	Native	Introduced (year)	Species recorded in the past	Presence (migratory type)
					(catadromous)
Atherina boyeri	big-scale sand smelt	+			temporary
Barbatula zetensis	Zeta stone loach	+			permanent
Barbus rebeli	western Balkan barbel	+			permanent
Carassius gibelio	Prussian carp		+ (1973)		permanent
Chondrostoma scodrensis	Skadar nase			+	questionable taxonomic status, probably extinct[4]
Chondrostoma ohridanus	Ohrid nase	+			permanent
Citharus linguatulus	Atlantic spotted flounder	+			temporary
Cobitis ohridana	Ohrid spined loach	+			permanent
Ctenopharyngodon idella	grass carp		+ (1975)	+	present, but has not established natural populations (i. e. only specimens from previous stocking remain in the lake)
Cyprinus carpio	carp	+			permanent
Dicentrarchus labrax	sea bass	+			temporary
Gambusia holbrooki	mosquito fish		+ (1957)		permanent
Gasterosteus gymnurus	western three-spined stickleback	+			permanent
Gobio skadarensis	Skadar gudgeon	+			permanent
Hypophthalmichthys molitrix	silver carp		+ (1973)	+	present, but has not established natural populations (i. e. only specimens from previous stocking remain in the lake)
Hypophthalmichthys nobilis	bighead carp		+ (1978)	+	present, but has not established natural populations (i. e. only specimens

[4] See Maric (1995)

Scientific name	English name	Native	Introduced (year)	Species recorded in the past	Presence (migratory type)
					from previous stocking remain in the lake)
Liza ramada	thinlip mullet	+			temporary
Megalobrama terminalis	black Amur bream		+ (1973)	+	permanent
Mugil cephalus	grey mullet	+			temporary
Mylopharyngodon piceus	black carp		+ (1983)	+	present, but has not established natural populations (i. e. only specimens from previous stocking remain in the lake)
Oncorhynchus mykiss	rainbow trout		+ (1951)		
Pachychilon pictum	spotted roach	+			permanent
Pelasgus minutus	Ohrid minnow	+			permanent
Perca fluviatilis	perch		+ (1978)		permanent
Phoxinus limaireul	Adriatic minnow	+			permanent
Platichthys flesus	flounder	+			temporary
Pomatoschistus montenegrensis	Skadar goby	+			permanent
Pseudorasbora parva	stone moroko		+ (1977)		permanent
Rhodeus amarus	bitterling	+			permanent
Rutilus albus	white roach	+			permanent
Rutilus prespensis	roach	+			permanent
Salaria fluviatilis	freshwater blenny	+			permanent
Salmo farioides	Adriatic trout	+			permanent (interdromous)
Salmo marmoratus	Marble trout	+			permanent (interdromous)
Salmo obtusirostris	Soft-muzzled trout	+			temporary
Scardinius knezevici	Skadar rudd	+			permanent
Squalius platyceps	Chub	+			permanent
Telestes montenigrinus	Montenegro riffle dace	+			permanent
Tinca tinca	Tench		+ (1981)		permanent

According to other sources (Keukelaar et al. 2006, Mrdak 2009, Mrdak et al. 2011, Nikčević & Hagediš 2012, Palluqi et al. 2011, Sulçe et al. 2013, Talevski et al. 2009b) there are even more fishes (e.g., *Alosa agone, Carassius carassius, Gambusia affinis, Megalobrama amblycephala, Proterorhinus marmoratus, Rutilus ohridana, Salvelinus fontinalis, Salmo trutta fario, S. trutta lacustris, S. montenegrinus, Sander lucioperca* and *Thymallus thymallus*) and Cyclostomata (*Lampetra fluviatilis, L. planeri* and *Petromyzon marinus*) in the lake. However, as pointed out by Palluqi et al. (2011) some species depicted on those various lists may have been misidentified, represent single finds or may have become extinct by now. Recent information from local fishermen point to the occurrence of bream (*Abramis brama*) in the lake; these verbal records, however, still need to be verified.

While all named species are part of the fish fauna of Lake Skadar/Shkodra, it should be kept in mind that they are not evenly distributed in the lake. Based on the specific physiological requirements of the various fishes, occurrence of some species is limited to certain areas in the lake. Additionally, some places are used by the species for specific reasons, such as feeding, reproduction or wintering. According to Grudnik & Gajšek (2011), the tributaries, in particular, of smaller and bigger streams discharging into the lake are habitat of certain endemic species, such as Montenegro riffle dace (*Telestes montenegrinus*) and Zeta stone loach (*Barbatula zetensis)*. The rivers Rijeka Crnojevića and Oraovštica are inhabited by salmonids (*Salmo* spp.) which occasionally move into the lake. Moreover, in view of habitats, inter-annual habitat shifts of economically important species can be observed in spring and autumn. For example, in spring the majority of cyprinid fishes (e.g. carp (*Cyprinus carpio)*, Prussian carp (*Carassius gibelio)*, and Skadar rudd (*Scardinius knezevici*)) congregate in littoral and flooded zones along the northern, north-eastern and eastern shorelines for spawning (Palluqi et al. 2011). On the contrary, at the end of autumn the majority of bleak (*Alburnus scoranza*) migrate to the various "oka" along the western coast of the lake where they are highly abundant during winter. The north-eastern coastal and pelagic zones are used by agone and twaite shad (*Alosa* spp.) for wintering and spawning (Palluqi et al. 2011).

3.2 Important fish habitats of Lake Skadar/Shkodra

For fishes (and also other aquatic species) the lake offers diverse habitats ranging from extensive fields composed of submersed and/or floating plants (such as *Potamogeton* sp., yellow water lilies *Nuphar lutea*, water chestnut *Trapa natans*) to reed (*Phragmites* sp.) belts of various sizes to areas of sparse aquatic shoreline vegetation (Ristić & Vizi 1981, Bajkovic et al. 2017). Among other things, aquatic vegetation provides food (Aufwuchs) for young fish and shelter from predators and physical disturbances (strong waves). Generally speaking, areas of plant cover play an important role in the life cycle of many fishes. On the contrary, there are species (such as *Alburnoides* sp., *Alburnus scoranza*) which for spawning depend on sandy to rocky substrates (i.e. psammophilic and lithophilic species, respectively). In summary, the identification of the ecologically most important fish habitats of a lake depends, among others, on the species that shall receive protection and/or support.

The lake comprises of several habitats that are important for fishes or their developing stages (eggs, larvae). As shown in Figure 2, northern shores of the lake (which are widely covered by macrophytes; see also Bajkovic et al. 2017) are important spawning and nursery grounds, e.g. for carp (*C. carpio*) and other cyprinids (*Carassius* sp., *Scardinius* sp.)

Similarly, on the Albanian territory macrophyte areas nearby the town of Shkodra are also important spawning and nursery sites for carp and other cyprinids. Spawning sites of bleak can be found all along the western and south-western shorelines (Palluqi et al. 2011) while important spawning and wintering areas of *Alosa* spp. are presented in Figure 3. Anthropogenic interferences with the habitats should be omitted or kept to a minimum in order to secure long-term existence of these economically and ecologically important species.

Figure 2. Important habitats for carp (*Cyprinus carpio*) and other fish at the northern shore of Lake Skadar/Shkodra

Figure 3. Valuable spawning grounds (red) and wintering place (yellow) of shad (*Alosa* spp.).
Important spawning place of carp (*Cyprinus carpio*) on the Albanian territory encircled in blue

3.3 Fisheries on Lake Skadar/Shkodra

In view of fish production and fish biomass, the lake is far more productive than other karstic lakes on the Balkan Peninsula. Based on statistical data of annual catches, fish production in the Montenegrin part of the lake is about 80 kg/ha (8,000 kg/km^2; Drecun 1983) which almost equals conditions of eutrophic lakes. Most of the fish is caught in northern, north-western and south-eastern areas. Moreover, fishing takes as well place in the various "oka" of e.g., Raduš, Krnjice, Ckla, Bobovište and Karuč (all at the Montenegrin side). As in other large lakes, only a few fish species dominate in the catches. Carp (*Cyprinus carpio*) and bleak (*Alburnus scoranza*) typically represent more than 70% of the total catch. Additionally, other economically important species such as *Carassius gibelio, Alosa fallax, Anguilla anguilla, Chondrostoma nasus, Squalius platyceps, Scardinius knezevici, Rutilus prespensis* and *Mugil cephalus* are also sought after (Mrdak 2009). It should be noticed though that catch composition not only depends on fish occurrence but also on market demands.

3.3.1 Fisheries on the Montenegrin part of the lake

The exact number of Montenegrin fishermen is not known but based on the number of licenses sold by National Park authorities it can be estimated that currently there are about 300 people conducting commercial fishing (Vugdelic 2012 b). Fishermen are organized in five Fishery Management Organisations (Mrdak 2012). In general, fishing takes place at any season of the year and by use of various gears. Benthic nylon gillnets of different mesh size (so-called bleak nets, carp nets, nase nets etc.) are widely employed, in addition to beach seines, "Kalimera" nets and lines (long lines with hooks laterally attached). Large beach seines are almost exclusively used for fishing in the "oka" and along the lake's shore during winter and spring.

Maximum yield of bleak is obtained during winter and harvest in this period (October-January) adds up to about three quarters of the total yearly *Alburnus* catch (Stein *et al*. 1981). Until the 1980's when the Montenegrin government proclaimed Lake Skadar/Shkodra a National Park, maximum catches of carp (*C. carpio)* occurred during the March-May period in the flooded and littoral areas where this species shoals for spawning.

A precise catch statistics of the Montenegrin part of the lake has been lacking for the last 40 years. There are, however, relatively reliable data for catches in the period of 1947-1976 (Figure 4). During this time period total catches varied from 353-1,311 tons annually (Stein et al. 1981).

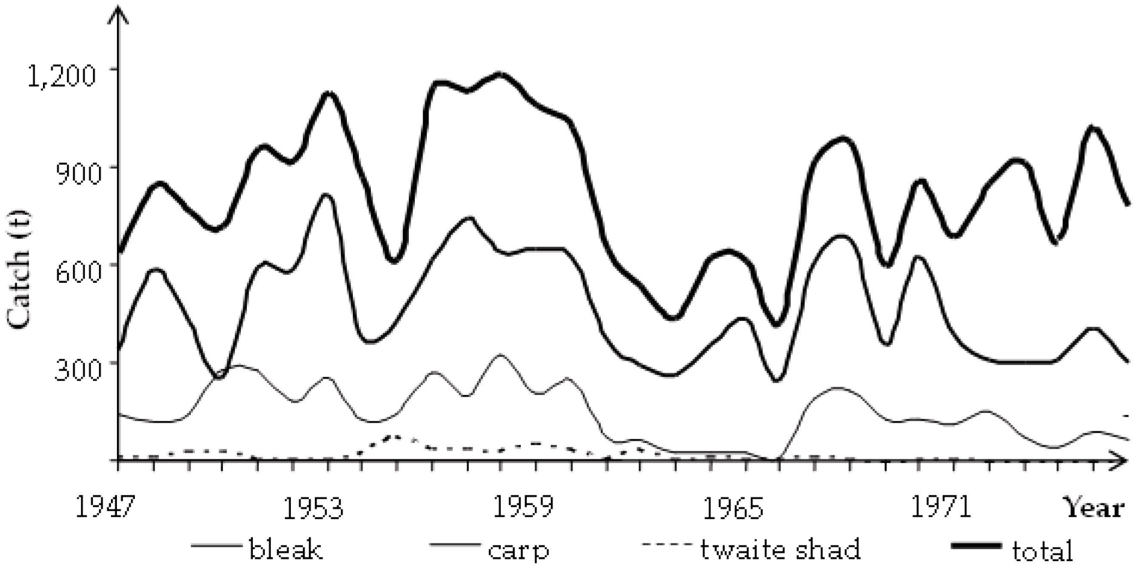


Figure 4. Montenegrin catches of Lake Skadar/Shkodra for 1947-1976 period (Stein et al. 1981)

The average yearly catch for the 1953-1962 period was 1,141 tons. These figures, however, may presumably be 10-15% higher because there are no data for catches (e.g. illegal fishing) other than those from registered fishermen who had been working for public cooperative companies. The average total annual catch of 1,141 tons was composed as follows: 570 tons of bleak, 230 tons of carp, around 35 tons of twaite shad, 30 tons of nase, 25 tons of combined eel, trout and mullet, and 251 tons of other fishes (Stein et al. 1981).

In the 1970's two new (introduced) fish species were noticed in the lake, viz. Prussian carp, *Carassius gibelio*, (Vuković et al. 1975) and perch, *Perca fluviatilis*, (Knežević 1979). The population of Prussian carp increased sharply during the 1980's and 1990's and this fish became a significant part of total catches. Unfortunately, exact data are missing but local fishermen estimate that this fish contributes one third of the total annual catch. Some fishermen suppose that in the 1985-1992 period Prussian carp was more abundant than carp. In present times, the population of Prussian carp seems to be stable but at significantly lower level than during the 1990's. Perch now represents the main predatory fish species in littoral area. Prior to its introduction the only predatory fishes in the lake were salmonids and eel. The perch population grew dramatically and nowadays it is one of the most abundant species in the littoral. In the last two decades of the 20th century, the new species became assorted "scrap fish" having no market demand (Mrdak 2009). This situation, however, may have slightly changed by now as consumers became more familiar with these fishes, resulting in a modest market demand.

During the 1990's there were almost uncontrolled fishing activities on the lake. Although fishing-related legislation (on mesh sizes, ban of fishing during spawning periods, forbidden fishing tools etc.) existed, there was limited implementation of the law. This situation has changed, however. In the last 10 years, management of National Park strictly implements all fishery legislation and rules. National Parks re-established a licensing system for recreational and professional fishing and started controlling and arresting of poachers. Still missing, however, is current catch data and, especially, related fishing efforts.

A whole-lake monitoring of fish stocks has never been performed in the past. Scientific research on Lake Skadar/Shkodra fishes focused primarily on fish taxonomy and ecology of individual species (Bianco & Kottelat 2005; Ivanović 1973; Knežević 1976 a, b, 1984; Knežević & Marić 1979; Kovačić & Sanda 2007; Krivokapić 1992, 1994, 2005, Marić 1989, 1998, 2010; Miller & Šanda, 2008).

3.3.2 Fisheries on the Albanian part of the lake

On the Albanian part of Lake Skadar/Shkodra, fishery is also an important activity of local people. Main fishing communities are the villages of Shiroka, Zogaj and Koplik. According to a recent census of Albanian fishermen there are 210 boats which are used by 410 people that operate in Albanian waters (Palluqi et al. 2011). The Albanian fishermen are organized in a Fisheries Management Organisation (FMO) which is a private entity with legal responsibilities under a fisheries co-management scheme. The FMO represents the interests of their members and ensures further development of fishery in compliance with national legislation, among others.

Similar to Montenegro, fish of is mainly caught by use of benthic nylon gillnets of different mesh sizes, beach seines, and with long-lines with hooks attached. Fishing gear changes throughout the year according to season, target species, weather condition etc. (Palluqi et al. 2011). Large beach seines are typically employed in the winter period for bleak fishery in two localities (Shiroka and Zogaj). The winter period is the season where the majority of the catch is made of bleak while in other seasons other species become more relevant (Table 2).

For the last 25 years almost no reliable data exist on the Albanian catches in Lake Skadar/Shkodra as no comprehensive collection of data has been undertaken. The most recent published information on fish catches of Albanian fishermen derives from Palluqi et al. (2011), which is based on logbook data of registered FMO members. From those calculations it can be estimated that approximately 500 t of fish[5] were caught each year in Albanian waters of the lake. Carp, bleak, Prussian carp and other cyprinids (summarized as "roach") are most abundant in the catches (Palluqi et al. 2011) although there are seasonal differences in catch composition (Figure 5).

[5] The report of Palluqi et al. (2011) shows an amount of 300 t of fish, but is restricted to a reporting period of only eight months.

Table 2. Monthly composition of species in total commercial catch in 2012 (in t, Palluqi et al. 2011)

Species	Feb	Mar	Apr[1]	May[1]	June	July	Aug	Sept	Oct	Nov
Carp	1.5	1.5	-	1.9	19.7	4.2	5.3	5.5	6.7	2.5
Crucian carp[2]	3.3	2.9	-	2.3	12.9	6.7	7.1	7.0	4.2	4.8
Mullet	0	0	-	0	0	0	3.3	2.2	7.6	4.5
European eel	1.8	1.8	-	0.6	0	0	0	0	0.2	0
Roach[3]	7.0	7.0	-	6.4	20.4	16.3	14.7	17.1	17.1	16.0
Twaite shad	0.6	0.6	-	0	0	0	0	0	0	0
Bleak	2.4	2.4	-	0	0	0	0	0	10.0	9.3
Total	16.6	16.2	0	11.2	53.0	27.2	30.4	31.8	45.8	37.2

[1]April and half of May are closed season for commercial fishery; [2]presumably misidentified as Prussian carp; [3]various (cyprinid) species

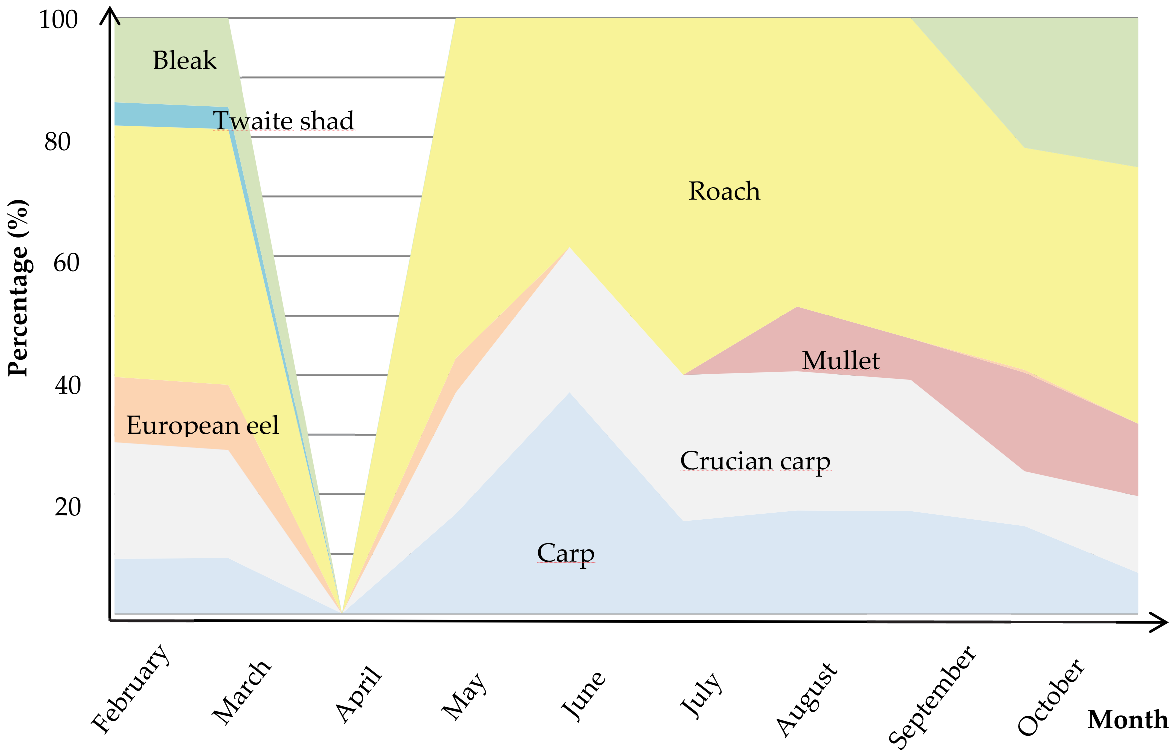


Figure 5. Catch composition of Albanian commercial fishermen in 2011 (Palluqi et al. 2011). *April and half of May are closed season for commercial fishery

Illegal, unreported, and unregulated (IUU) fishing takes still place at Lake Skadar/Shkodra (AASD 2012) and is a topic of concern, but local FMO and also state authorities undertake great efforts to reduce such activities and have become more successful over the last years (A. Cinari; personal communication).

3.4 Management and fishery legislation

3.4.1 Management of Lake Skadar and fishery legislation in Montenegro

In 1983 the Montenegrin part of Lake Skadar and surrounding areas were declared a National Park which has since been managed by Public Enterprise for National Parks (PENP) of Montenegro. The mandate, structure and procedures of the National Parks management body are laid out in the **Law on National Parks** (Official Gazette 56/09), which is a *Lex specialis*.

The **Law on Freshwater Fisheries** (Official Gazette 11/07) governs the methods of use, protection, preservation, farming and catch of fish in fishery waters. It, among others, defines that the lake is a fishing area for the purpose of commercial and recreational fishing.

The **Order on Fishing Prohibitions, Restrictions and Measures for the Protection of Fish Stocks** (Official Gazette 21/12) sets restrictions in terms of closing periods (fishing ban), fishing gear and methods, minimum fish dimensions and catch limits for different fish species in the lake and associated waters. It also addresses measures for the control of fish diseases.

The **Rules of Conduct within National Parks Biogradska Gora, Lovćen, Durmitor and Skadar Lake** (Official Gazette 32/05) endorsed by the Management Board of PENP identifies the mode of use of national park assets, which also concerns the taking of fish.

The **Decision on the Modes and Conditions for Commercial Fishing on Skadar Lake** issued by the Management Board of PENP defines conditions for fishing (purchase of licenses, allowed fishing gear and fishing areas) in the lake.

The **Decision on the Fees and Modes of Payment for Using the Goods of National Parks, Carrying out Activities and Offering Services** (Official Gazette No. 31/02) includes information about fees related to fishing in National Parks. The Decision was prepared by the Management Board of PENP.

Further Montenegrin legislation with reference to fishing is as follows:

- Environmental Law (Official Gazette of the RM, No. 12/96, 55/00);
- Law on Nature Protection (Official Gazette of the RM, No. 36/77,2/89);
- Decree on Protection of Rare, Scarce, Endemic and Endangered Plant and Animal Species (Official Gazette of the RM, No. 36/82);
- Law on Waters (Official Gazette of the RM, No. 16/95);
- Law on the Protection of Cultural Monuments (Official Gazette of the RM, No.47/91);
- Law on Local Self-Government (Official Gazette of the RM, No. 75/05);
- Environmental Impact Assessment Decree (Official Gazette of the RM, No. 14/97);
- Decree to Prohibit the Use of Vessels with Engine Power more than 4.5 HP by Physical Persons on Skadar/Shkodra Lake (Official Gazette of the RM, No. 9/86);
- Law on Freshwater Fishery (Official Gazette of the RM, No. 39/76, 51/76, 34/88, 29/89, 39/89, 48/91, 4/92, 17/92, 27/94);
- Law on Inspection (Official Gazette RCG, No. 50/92).

3.4.2 Management of Lake Shkodra and fishery legislation in Albania

In Albania the actual protection status of Lake Shkodra is "Managed Natural Reserve" (IUCN Category IV), declared by the Albanian Government with the Decree of Council of Ministers No. 684, of 02.11.2005.

According to APAWA & CETI (2007), the protected areas at the Albanian side of the lake are divided into different categories of protection:

a. The *Core Zone* comprises the lake shore from the western extreme of Zogaj village to the border between Albania and Montenegro, the slope of Taraboshi Mountain from altitude 494 m in the south to 200 m within the lake waters, in the segment Zogaj-Albanian-Montenegrin border in the north. The second level of protection is applied to this area.
b. The *Habitat Management Area* includes the whole lake water surface, except the one included in the area mentioned above; the Albanian western shore from Buna/Bojana bridge in the east, to Zogaj village in

the west including the entire latitude of this segment up to an altitude of 300 m on the Taraboshi mountain slope in the south. The third level of protection is applied to this area.

c. The *Traditional Development Area* is composed of the whole eastern surface of the lake, bordering on the west with the area mentioned above of this point up to Shkodër-Hani i Hotit motorway to the eastern and Shkodra city to the south-eastern end. The fourth level of protection is applied to this area.

The exceptional value of Lake Shkodra has also been acknowledged by the Albanian Government. The Albanian part of the lake area has been declared a Ramsar site (Ramsar Convention "On internationally important wetlands, especially as waterfowl habitats") by the Ramsar Secretariat and the Decree of Council of Ministers No. 683, dated 02.11.2005 of the Albanian Government. There are some recent joint efforts to declare Lake Skadar/Shkodra a UNESCO Biosphere Reserve.

The fisheries legislation framework includes all levels of legal and normative acts, such as laws, by-laws, regulations, decrees of the Council of Ministers, normative acts etc. Overall, legislation in the fishery sector is complete and contemporaneous. It addresses not only fishery issues but also other related topics, such as biodiversity and environmental protection, socio-economic aspects etc. There are several legislative acts regulating fishing activities.

The Law No. 64/2012 provides the framework for a good management of the fishery sector and explains many of the terms and concepts related to the sector. It should be stressed that the main intentions of the law are:

- to ensure a rational and accountable exploitation of aquatic biological resources and development of aquaculture;
- to provide protective conservation measures in order to ensure protection of biological aquatic resources, and
- to support the sustainable development of fishery and aquaculture sectors, as well as to create better socio-economic conditions for producers.

Based on the regulation referring to Law 64/2012, the Albanian fishery at Lake Shkodra is regulated as follow:

- Each boat is permitted to have 2,000 meters of entangling nets (1,000 meters of trammel nets and 1,000 meters of gillnets). For each trammel net, 500 meters have 80 mm mesh size and 500 meters have a mesh size of 35-40 mm. The same length (500 meters each) and the same mesh sizes are applicable for gillnets.
- The number of hooks for each boat has not been established yet. There are two seiners with 28 mm of mesh size for the bleak fishery in winter situated in the villages of Shirokë and Zogaj. Three further seiners are used for carp and Prussian carp fishery in Shirokë, Zogaj and Kamicë. Shirokë and Zogaj also have two sorting boxes for the selection of bleak and carp.

As mentioned previously, FMOs play an important role in the Albanian fishery, including on Lake Shkodra. Their legal status is based on Law No. 7908 ("On Fishery and Aquaculture") and People's Assembly Decision No. 8870 ("On amendments to Law No. 7908, dated 05.04.1995 "On Fishery and Aquaculture"), dated 21.3.2002.

Further Albanian laws with references to fishery are:

- Law "On the Land" (1991);
- Law "On Biodiversity Protection" (2006);
- Law "On Fauna Protection" (2008);
- Law "On the Regulatory Framework of the Water Supply Sector and of Disposal and Treatment of Waste Water" (1996);
- Law "On Protected Areas" (2002, new draft law passed in 2017);

- Law "On Protection of Marine Environment from Pollution and Damage" (2002);
- Law "On Protection of Transboundary Lakes" (2003);
- Law "On Hunting" (2010);
- DCM "On the Approval of the List of Wild Fauna Species Subjected to Hunting" (2010);
- Law "On Environment Protection" (2011);
- Law "On Environmental Impact Assessment" (2011);
- Law "On Integrated Management of Water Resources" (2011);
- Law "On Fishery" (2012);
- DCM "On the Approval of Lists of Natural Habitat Types, Plants, Animals and Birds with Interest for European Community" (2014).

3.4.3 Comparative overview of fishery regulations in Montenegro and Albania

Table 3 and Table 4 summarize the main lake fishery regulations in Montenegro and Albania.

Table 3. Fishing ban season by species and country

	Montenegro		**Albania**	
Species	**from**	**to**	**from**	**to**
Carp	15th March	15th May	15th April	15th May
Chub	15th March	15th May	15th April	15th May
Nase	1th February	1st June	15th April	15th June
Roach	15th March	15th May	15th April	15th June
Bleak	15th March	31st October	1st April	31st July
Trout	1st November	1st April	-	-

Table 4. Minimum allowed dimensions for fishing of some commercial species

Common name	**Scientific name**	**Montenegro**	**Albania**
Carp	*Cyprinus carpio*	40 cm	30 cm
Chub	*Squalius* spp.	Not specified	15 cm
Prussian carp	*Carassius gibelio*	Not specified	15 cm
Nase	*Chondrostoma* spp.	Not specified	15 cm
Roach	*Rutilus prespensis*	Not specified	12 cm
Bleak	*Alburnus scoranza*	12 cm	10 cm
Perch	*Perca fluviatilis*	Not specified	15 cm
Brown trout	*Salmo farioides*	25 cm	Not applicable
Mullet	*Mugil* spp.	25 cm	Not specified
Marble trout	*Salmo marmoratus*	50 cm	Not applicable
Lake trout	*Salmo farioides*	30 cm	Not applicable

As can be seen from Table 3 and Table 4, there are differences between Albania and Montenegro with regard to timing of the fishing ban seasons (shorter in Montenegro, Table 3) as well as in view of minimum allowable landing sizes of fishes (smaller in Albania for carp and bleak, Table 4). For a sustainable management of stocks harmonized regulations are recommended.

4 MATERIAL AND METHODS

4.1 Fish sampling by use of MMG

Fish sampling was conducted based on the European standard EN 14757 (European Committee for Standardization 2015). As recommended for large waterbodies, the lake was divided into several sub-basins. On Montenegrin territory, sub-basins Vranjina / Virpazar / Grmožur and Central Lake were defined, while sampling areas on the Albanian side were near the villages of Koplik and Shirokë (Figure 6). Sub-basins were subsequently treated as individual habitats and sampled according to the European standard with regard to sampling time, number of nets used, consideration of different depth strata etc. (European Committee for Standardization 2015).

Figure 6. Sampling sites (1- Vranjina / Virpazar / Grmožur, 2- Central Lake, 3- Koplik, 4- Shirokë)

The Vranjina / Virpazar / Grmožur sub-basin is a relatively shallow part of the lake with almost no spot below 6 m of depth. It is composed of a variety of fish habitats in terms of submerged, emerged and floating vegetation as well as with regard to bottom type (gravel, rocky and muddy substratum). On the contrary, the pelagic Central Lake sub-basin is typically deeper than 6 m and shows a more or less monomorphic muddy ground. Both the Koplik and Shiroka sub-basins on the south-eastern and southern shores are also deeper than 6 m and their bottom is mainly covered by mud, in particular at greater depth. However, the Shiroka sub-basin also reveals large areas of rocky substratum.

Commercial standard benthic MMG were employed for sampling. Individual MMG were 30 m long and 1.5 m high, resulting in a net surface area of 45 m^2. Each net consisted of twelve 1.5 × 2.5 m panels of different mesh sizes in the following sequence: 43 mm, 19.5 mm, 6.25 mm, 10 mm, 55 mm, 8 mm, 12.5 mm, 24 mm, 15.5 mm, 5 mm, 35 mm and 29 mm (knot to knot).

MMG sampling was performed in autumn of 2013, 2014 and 2015. Care was taken to avoid periods of fish shoaling (spawning or wintering). For representative sampling all nets were set randomly within each sub-basin and depth. Merely in 2013, MMG in Vranjina / Virpazar / Grmožur sub-basin were posed in regular quadrant order. Three depth layers (strata) were defined: 0-3 m, 3-6 m, and 6 m+ (i. e. below 6 m). Directions of the nets were either parallel, perpendicular, or in a 45° angle to the closest lakeshore. All nets were in water overnight. They were placed at about 7:00 PM and lifted at 7:00 AM so that each net was fishing for a time period of 12 hours. The number of MMG used in the respective years, sub-basins and strata varied. Details are shown in Table 5.

Table 5. Number of multi-mesh gillnets used to collect fish in various sub-basins of Lake Skadar/Shkodra in 2013-2015

Sampling year	Locality* and stratum (depth)						Total number of nets
	0-3 m		3-6 m		6 m+		
	VVG	Ko, Sh	VVG	Ko, Sh	CL	Ko, Sh	
2013	8	15, 13	16	12, 11	-	9, 12	96
2014	12	12, 12	12	12, 12	12	12, 12	108
2015	12	12, 12	12	12,12	12	12,12	108

VVG: Vranjina / Virpazar / Grmožur basin; CL: Central Lake basin; Ko: Koplik basin; Sh: Shirokë basin

4.2 Electrofishing

In addition to MMG fishing, in 2013 electrofishing was performed in the 0-3 m stratum of the Vranjina / Virpazar / Grmožur sub-basin (Figure 7). In order to cover varying habitats, three different localities were chosen. The first one (T1) was near the Morača River mouth, where the bottom is sandy to muddy and the area impacted by fresh riverine water. The second electrofishing site (T2) was located at the southern edge of this sub-basin and revealed rocky to muddy bottom and moderate plant coverage. The third fishing site (T3) was situated in a north-western bay of the basin. This site was characterized by muddy bottom and extensive plant coverage.

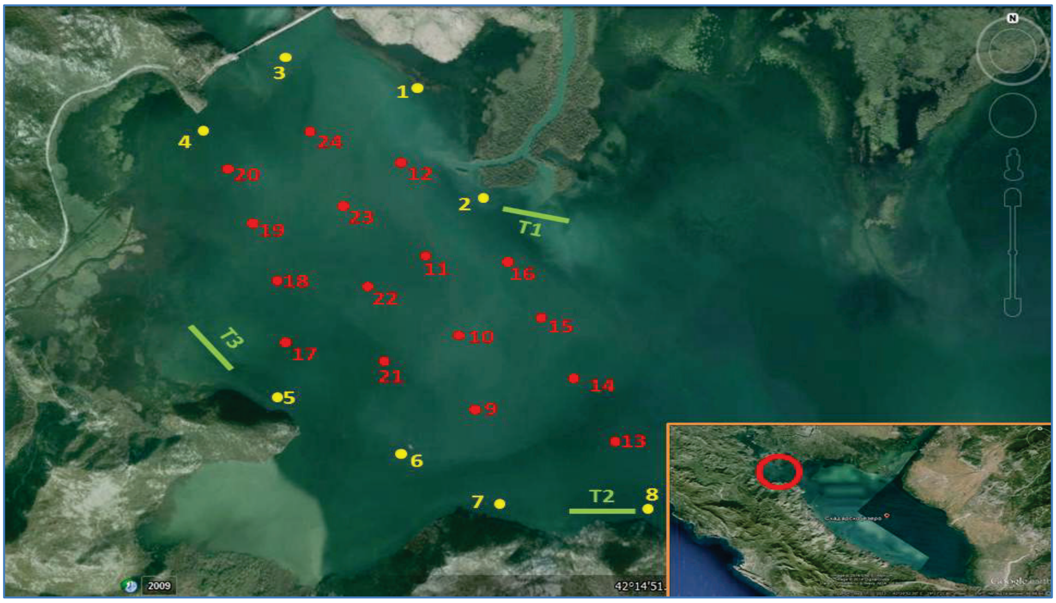


Figure 7. Exemplary sampling scheme (2013) of a fishing campaign in the Vranjina / Virpazar / Grmožur sub-basin (yellow: position of individual MMG in the 0-3 m stratum; red: position of individual MMG in the 3-6 m stratum; green lines: electrofishing transects T1)

A standard electrofishing gear (SUSAN-735MP) was employed according to technical instructions and by use of a motorboat. At each of the three fishing sites, a 500 m transect was fished. As the electric field of the gear covered a distance of 4 m (2 m at each side of the boat), the resulting total area per transect was 2,000 m^2. Each fish caught was identified to species level. Subsequently, total length (TL) and body mass (TW) of the fish were measured.

4.3 Sampling of commercial bleak catches (Raduš Bay)

During winter period (December 2013 and February 2014) industrial harvesting of bleak was performed by the concessioners in Raduš Bay, MN. For this purpose a stationary "Kalimera" net[6] was used, which was 30 x 30 m in size. A subsample of one bucket of harvested fish (approximately 8 kg) was taken from the center of the net. Each fish was determined to species level and main morphological parameters (TL, TW) were measured.

4.4 Data analysis

Fish sampled by MMG were determined to species level and total length (TL, to nearest mm) and total weight (TW, to nearest g) of each specimen were measured separately for each panel of individual MMG.

Catch per unit of effort (CPUE) and number per unit of effort (NPUE) were calculated for each net and sampled species as a relative measure of species biomass and species abundance, respectively.

CPUE and NPUE of each MMG were calculated as follows:

- CPUE (g/m^2) = biomass of total catch (in grams) of a MMG (all panels) divided by total net surface (45 m^2)
- NPUE (individuals/m^2) = total number of individuals per MMG (all panels) divided by total net surface (45 m^2).

CPUE and NPUE were as well calculated for individual species:

- $CPUE_n$ (g/m^2) = biomass of species n in total catch (in grams) of a MMG (all panels) divided by total net surface (45 m^2)
- $NPUE_n$ (individuals/m^2) = total number of individuals of species n per MMG (all panels) divided by total net surface (45 m^2).

Since all MMG were placed in water for the same time span (12 hours), for each year average CPUE and NPUE, respectively, were calculated for individual species in each stratum (0-3 m, 3-6 m and 6 m+):

- Mean $CPUE_n$ = sum of CPUE values of species n in the respective stratum divided by number of nets in the respective stratum
- Mean $NPUE_n$ = sum of NPUE values of species n in the respective stratum divided by number of nets in the respective stratum

CPUE values of **electrofishing** campaigns were calculated as a total weight (g) of species x divided by the transect area of 2,000 m^2.

"Kalimera" catches were analyzed with regard to diversity (species composition), biomass and length frequency (bleak only).

[6] At Lake Skadar/Shkodra, "Kalimera" nets are commonly employed during winter when large numbers of fish (mainly bleak) aggregate for wintering. "Kalimera" nets of various sizes exist. They are posed horizontally in water for several hours until lifted, thereby catching the fishes in the above water column.

5 RESULTS

5.1 Whole Lake

During the three years of sampling in various parts of the lake (northern and southern basins, shorelines and open water, various mesh sizes, electrofishing and "Kalimera" nets), a total of 19 fish species were detected (Table 6).

Table 6. Fishes of Lake Skadar/Shkodra caught in the course of the project (2013-2015)

Taxon (family)	Species name	Fishing method*
Cyprinidae	carp (*Cyprinus carpio*)	MMG, E, K
	bleak (*Alburnus scoranza*)	MMG, E, K
	roach (*Rutilus prespensis*)	MMG, E, K
	rudd (*Scardinius knezevici*)	MMG, K
	Prussian carp (*Carassius gibelio*)	MMG, E, K
	spotted roach (*Pachychilon pictum*)	MMG
	white roach (*Rutilus albus*)	MMG
	nase (*Chondrostoma nasus*)	MMG, E
	spirlin (*Alburnoides ohridanus*)	MMG
	chub (*Squalius platiceps*)	MMG, E, K
	bitterling (*Rhodeus amarus*)	MMG
	stone moroko (*Pseudorasbora parva*)	MMG
Salmonidae	marble trout (*Salmo marmoratus*)	MMG
	Adriatic trout (*Salmo farioides)*	K
Percidae	perch (*Perca fluviatilis*)	MMG, K
Mugilidae	grey mullet (*Mugil cephalus*)	MMG
Blenniidae	blenny (*Salaria fluviatilis*)	MMG
Clupeidae	twait shad (*Alosa fallax*)	MMG
Cobitidae	Ohrid spined loach (*Cobitis ohridana*)	MMG

*MMG = multi-mesh gillnet, E = electrofishing, K = "Kalimera" net

Among the fishes caught were several non-indigenous species, such as *Perca fluviatilis*, *Carassius gibelio*, *Pseudorasbora parva* and *Rhodeus amarus*. In terms of numbers, perch, stone moroko and bitterling combined comprised about 20 % of fishes sampled in any one year (Figure 8). The most abundant species over the three years was roach, followed by bleak and perch (Figure 8). In contrast, only one single marble trout was caught throughout the years.

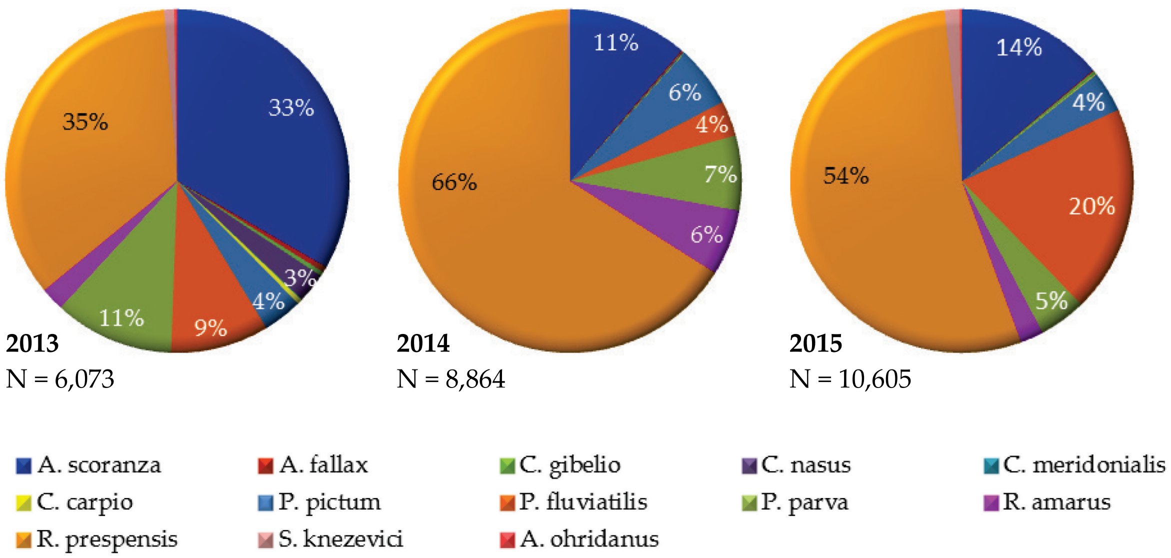


Figure 8. Relative species abundance (%) in annual catches of 2013 (left), 2014 (centre) and 2015 (right) for Lake Shkodra/Skadar (Montenegrin and Albanian locations combined). N provides the total number of specimens caught by MMG. The following species with few individuals are not shown: *S. platyceps, B. fluviatilis, M. cephalus, Rutilus albus* and *Salmo marmoratus*

Results based on MMG fishing show that the CPUE values (biomass) varied irregularly between the years and ranged from about 25 to 35 g / m² (Figure 9). On the contrary, mean NPUE values increased slightly over the sampling period and reached about two individuals per square meter of net in 2015 (Figure 9).

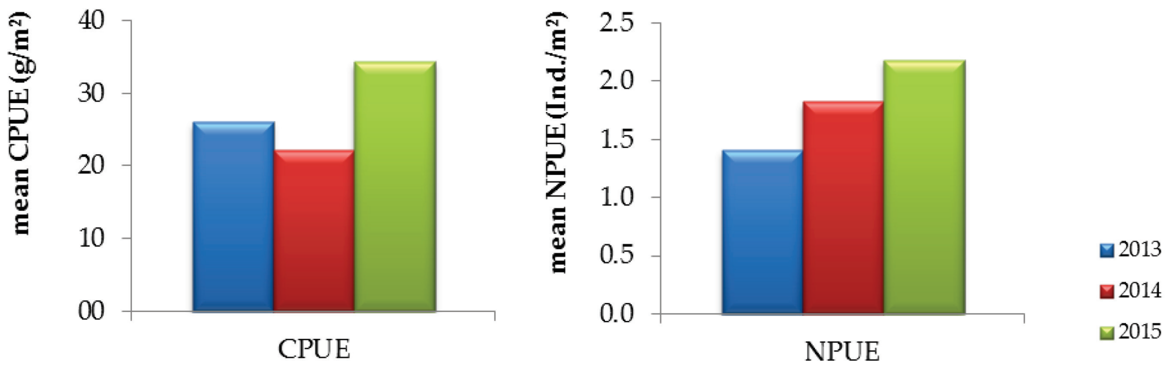


Figure 9. Standardized catches of biomass (CPUE - left) and number (NPUE - right) in the three years of MMG fishing. Data for the whole lake (Montenegrin and Albanian locations combined)

Species were not evenly distributed in the lake. MMG fishing revealed that, in terms of biomass, for example, the proportion of bleak, Prussian carp, chub and perch in the total catch was higher in the North than in the South (Figure 10, Figure 11 and Figure 12) while white roach, grey mullet and blenny were caught in the North only. In contrast, spotted roach and stone moroko formed much higher biomasses in southern lake parts (Figure 10, Figure 11 and Figure 12). With regard to abundance, carp, stone moroko, bitterling and spirlin were more numerous or caught only, respectively, at southern sampling sites (Figure 13 and Figure 14). *Cobitis ohridana* was detected in the deepest layers of southern lake areas.

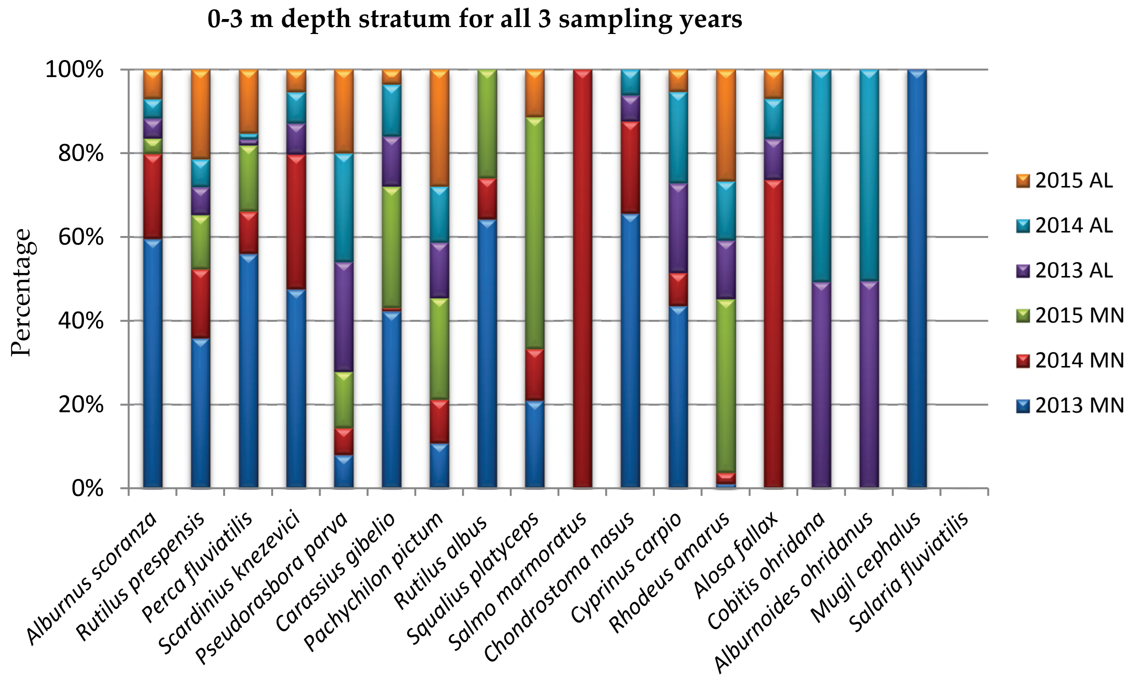


Figure 10. Comparison of mean CPUE (biomass) share (0-3 m stratum, MMG, all sampling years) between northern (MN) and southern (AL) sites of Lake Shkodra/Skadar

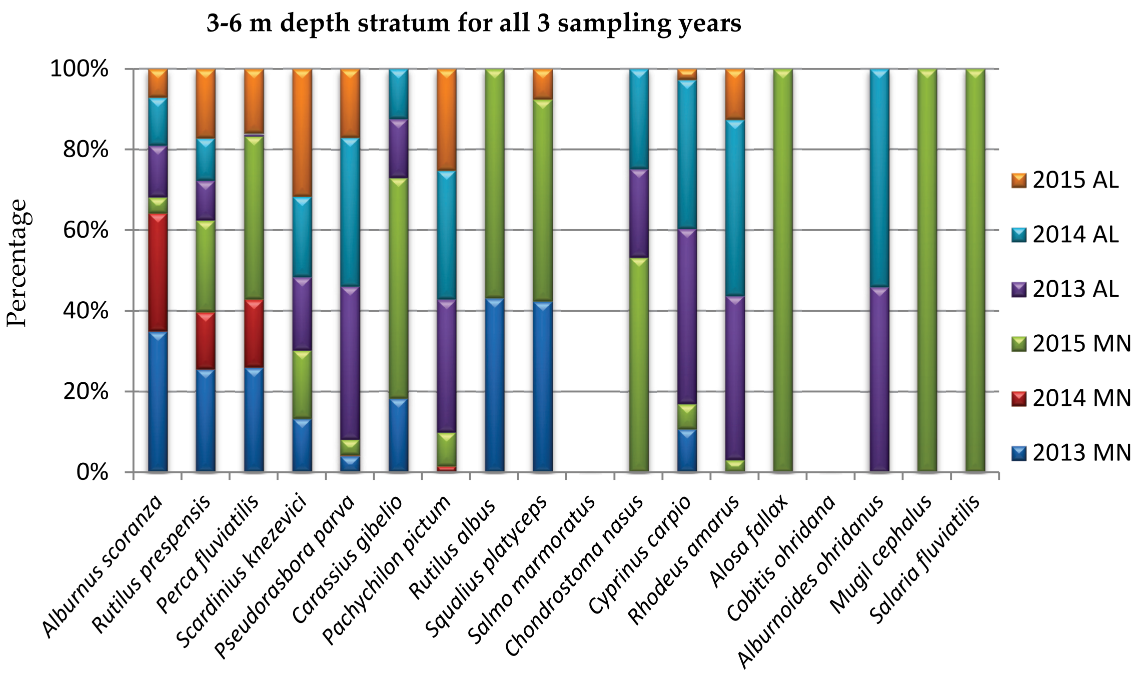


Figure 11. Comparison of mean CPUE (biomass) share (3-6 m stratum, MMG, all sampling years) between northern (MN) and southern (AL) sites of Lake Shkodra/Skadar

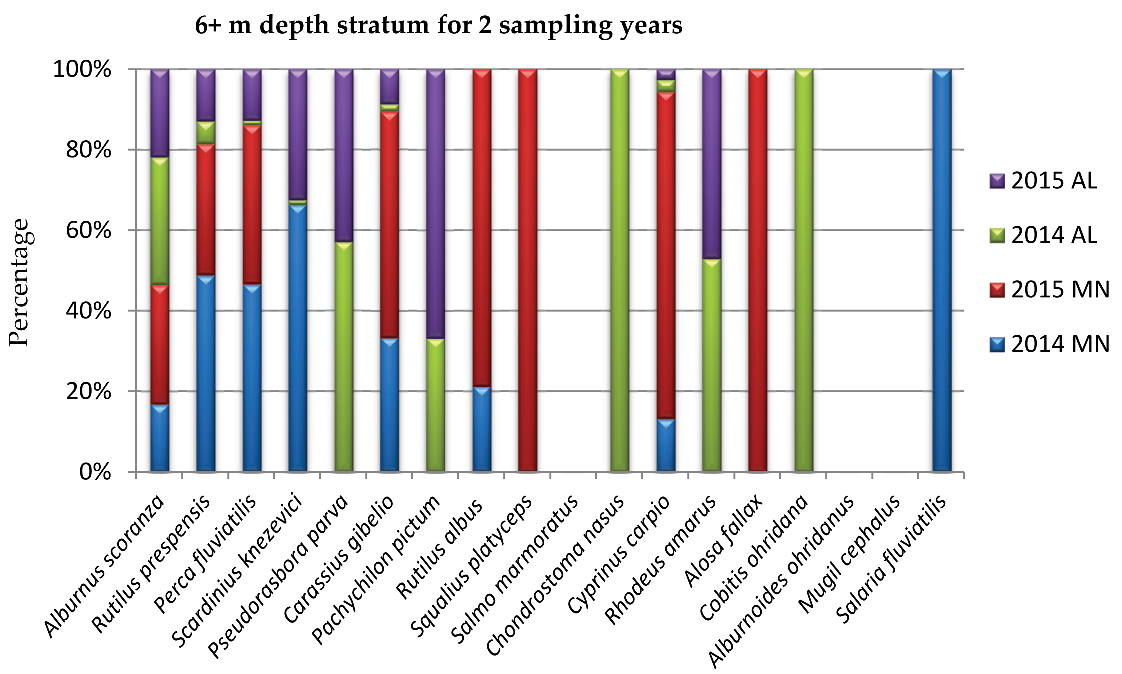


Figure 12. Comparison of mean CPUE (biomass) share (6 m+ stratum, 2014 and 2015) between northern (MN) and southern (AL) sites of Lake Shkodra/Skadar

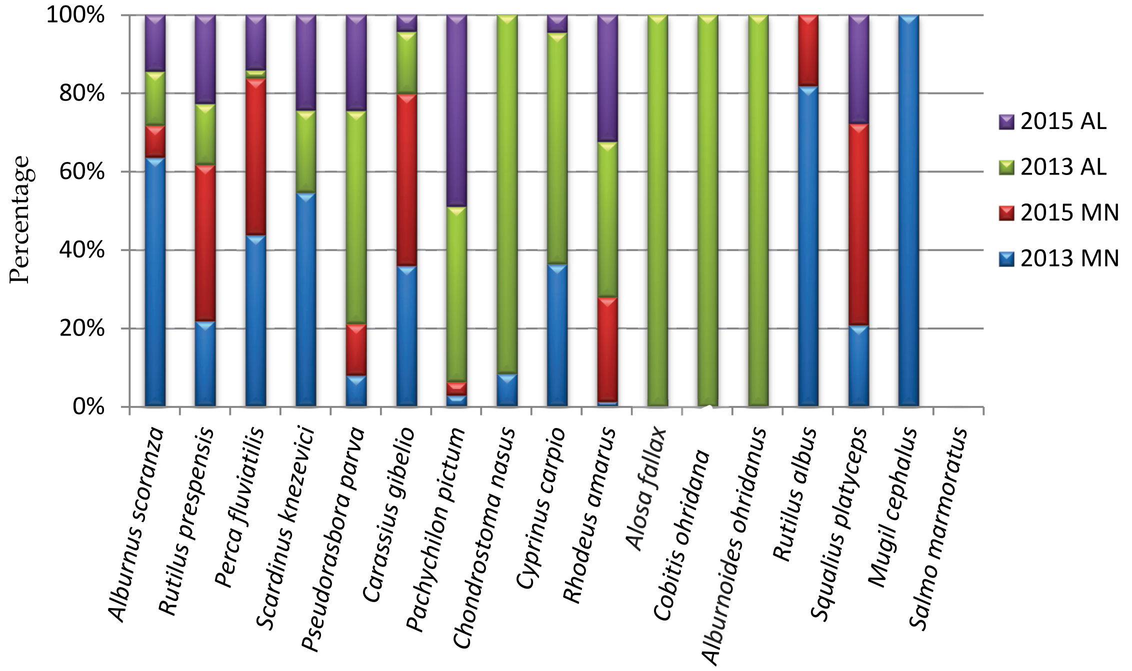


Figure 13. Comparison of mean NPUE (individuals/m²) share (0-3 m stratum, 2013 and 2015) between northern (MN) and southern (AL) sites of Lake Shkodra/Skadar

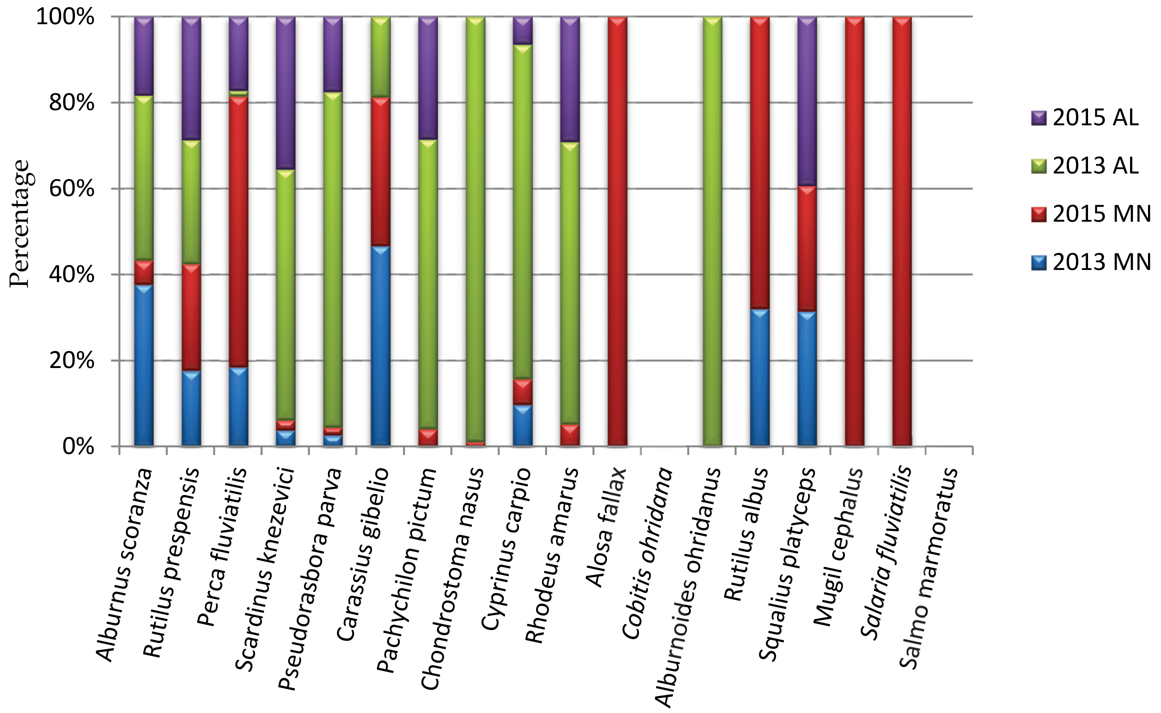


Figure 14. Comparison of mean NPUE (individuals/m²) share (3-6 m stratum, 2013 and 2015) between northern (MN) and southern (AL) sites of Lake Shkodra/Skadar

5.2 Montenegrin part of Skadar Lake

5.2.1 General findings

During the three years of sampling *at the Montenegrin part* of the lake, a total of 18 fish species were detected (Table 7). Among the fishes caught were several non-indigenous (alien) species, such as *Perca fluviatilis, Carassius gibelio*, *Pseudorasbora parva* and *Rhodeus amarus*. Individuals of *Pachychilon pictum, Rhodeus amarus* and *Chondrostoma ohridanus*, in tendency, seemed to prefer shallow waters while other species were caught in both deep and shallow parts of the lake (Figure 15).

Table 7. Fishes of the Montenegrin part of Lake Skadar caught in the course of the project (2013-2015)

Taxon	Species name	Fishing method*
Cyprinidae	carp (*Cyprinus carpio*)	MMG, E, K
	bleak (*Alburnus scoranza*)	MMG, E, K
	roach (*Rutilus prespensis*)	MMG, E, K
	rudd (*Scardinius knezevici*)	MMG, K
	Prussian carp (*Carassius gibelio*)	MMG, E, K
	spotted roach (*Pachychilon pictum*)	MMG
	white roach (*Rutilus albus*)	MMG
	nase (*Chondrostoma nasus*)	MMG, E
	spirlin (*Alburnoides* ohridanus)	MMG
	chub (*Squalius platiceps*)	MMG, E, K
	bitterling (*Rhodeus amarus*)	MMG
	stone moroko (*Pseudorasbora parva*)	MMG
Salmonidae	marble trout (*Salmo marmoratus*)	MMG
	Adriatic trout (*Salmo farioides)*	K
Percidae	perch (*Perca fluviatilis*)	MMG, K
Mugilidae	grey mullet (*Mugil cephalus*)	MMG
Blenniidae	blenny (*Salaria fluviatilis*)	MMG
Clupeidae	twait shad (*Alosa fallax*)	MMG

*MMG = multi-mesh gillnet, E = electrofishing, K = "Kalimera" net

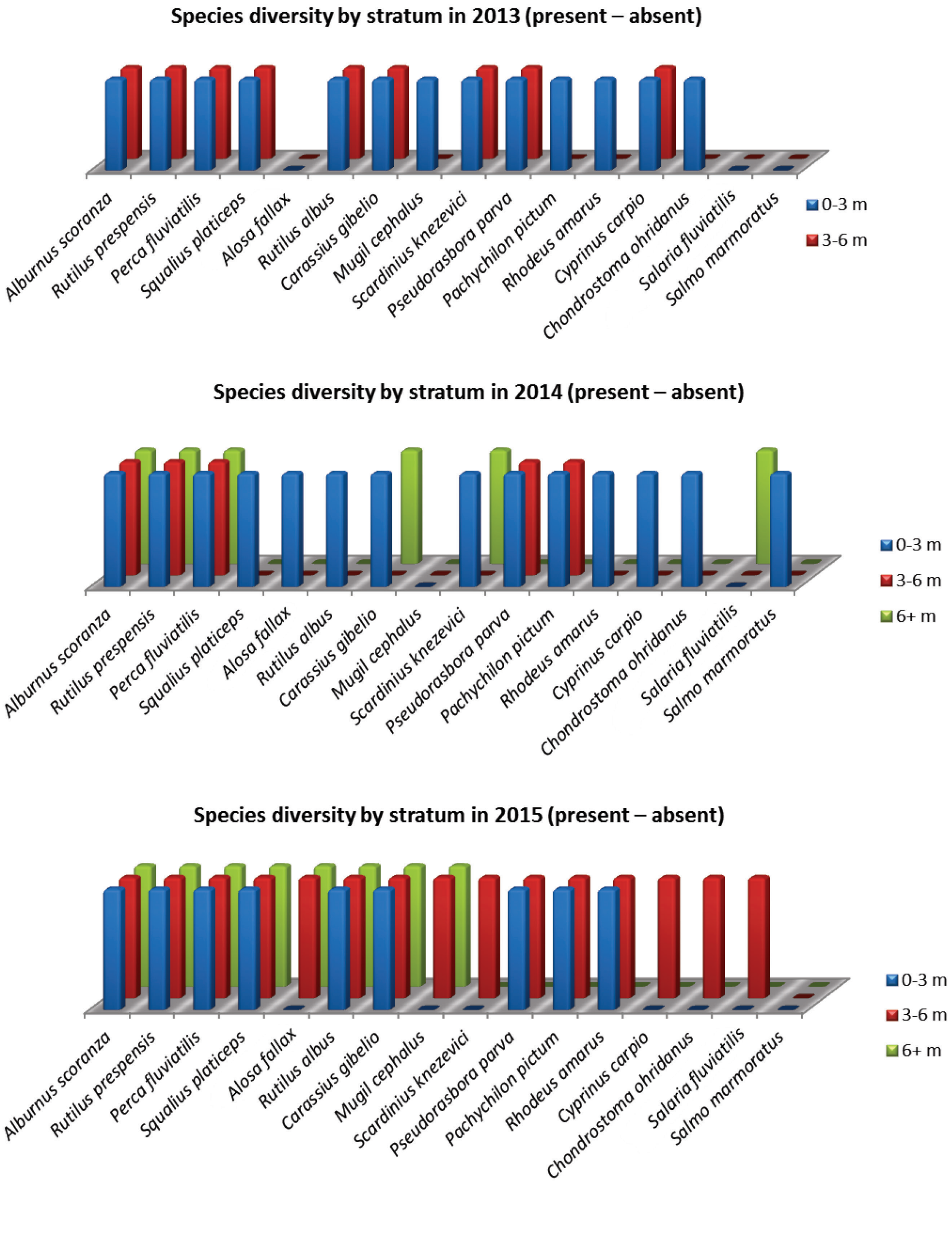


Figure 15. Fish species diversity at Montenegrin sampling sites (all depth strata) of Lake Skadar in 2013, 2014 and 2015

Over the three years, the most abundant species at the Montenegrin side of the lake were *Alburnus scoranza*, *Rutilus prespensis* and *Perca fluviatilis*. In terms of abundance, combined these three species contributed with about 95 % to the catch in any one stratum and year (Figure 16). In contrast, *Salmo marmoratus* occurred only in low numbers and was caught only during the 2014 sampling campaign.

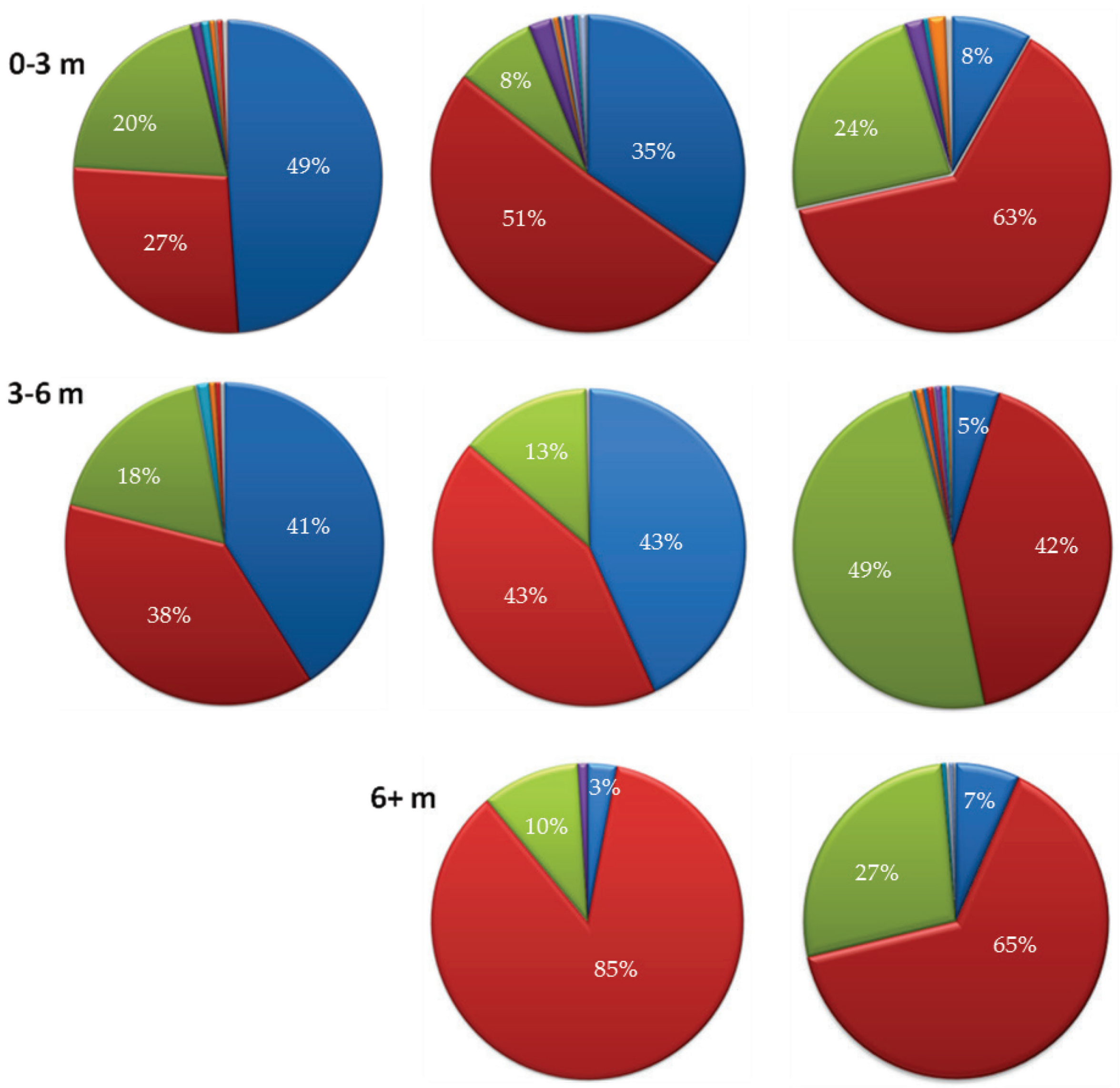


Figure 16. Relative species abundance (%) in annual catches of 2013 (left), 2014 (centre) and 2015 (right). The depth strata 0-3 m and 3-6 m represent catches in Vranjina / Virpazar / Grmožur sub-basin; the 6+ stratum shows catches of the Central sub-basin. (Blue: *A. scoranza*; red: *R. prespensis*; green: *P. fluviatilis*; abundance of other species ≤ 3% each)

Mean biomass per m^2 of net varied between years and depth strata, and ranged from 31 to 109 g/m^2. At the Montenegrin side, the highest biomass was noted in 2013 (Figure 17).

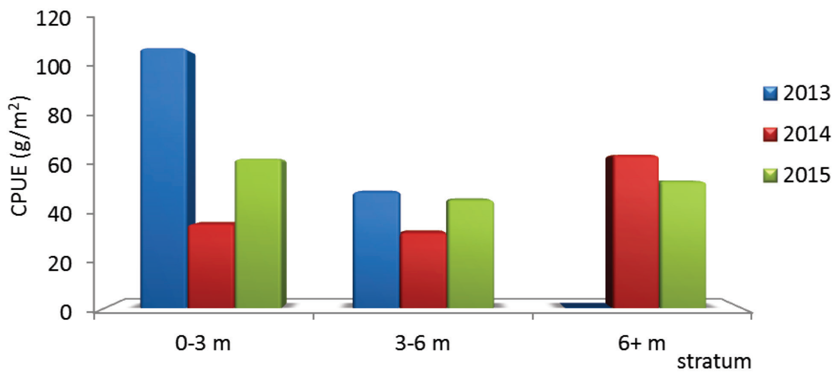


Figure 17. Temporal course of mean biomass (CPUE) per single net set in three depth strata of the Montenegrin side of Skadar Lake

For detailed information on annual changes in biomass of the most abundant species, see Annex I (Figure 37, Figure 38, Figure 39, Figure 40).

The temporal course of mean fish abundance varied in a similar manner as biomass. Most fish were caught in the shallow (0-3 m) and deep (6+ m) zones. Over the years, mean abundance ranged from 0.9 to 4.3 individuals per m^2 of net (Figure 18).

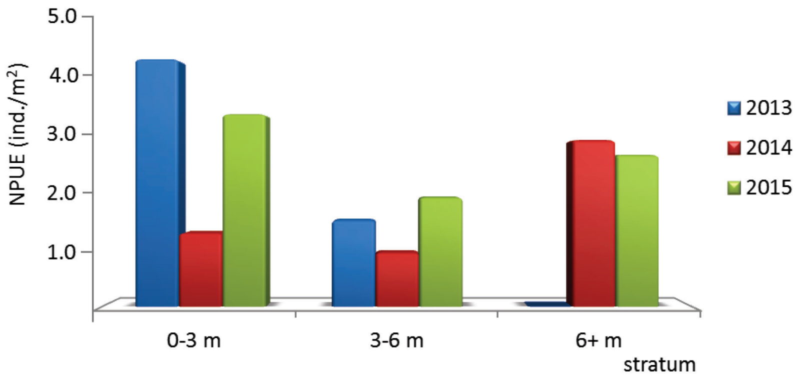


Figure 18. Temporal course of mean abundance (NPUE) per single net in three depth strata of the Montenegrin side of Skadar Lake

For further information on annual changes in mean abundance (NPUE) of the fishes, see Annex I (Figure 37, Figure 38, Figure 39, Figure 40).

5.2.2 Population structure of fish from the Montenegrin side of Lake Skadar

5.2.2.1 Bleak (*A. scoranza*)

In the course of the three years, more than 1,800 specimens of *A. scoranza* were sampled by MMG. Annual size structure (length frequencies) over time in the different depth strata is shown in Figure 19. In shallow waters (0-3 m) the number of adult (big) bleak constantly dropped over the years and almost no large-sized fish was collected in 2015 anymore. Almost identical trend occurred in the 3-6 m stratum where the amount of large specimens significantly decreased over time. In the deeper parts of the lake (6 m+) the number of large bleak was always low and this situation did not change from 2014 to 2015 (Figure 19).

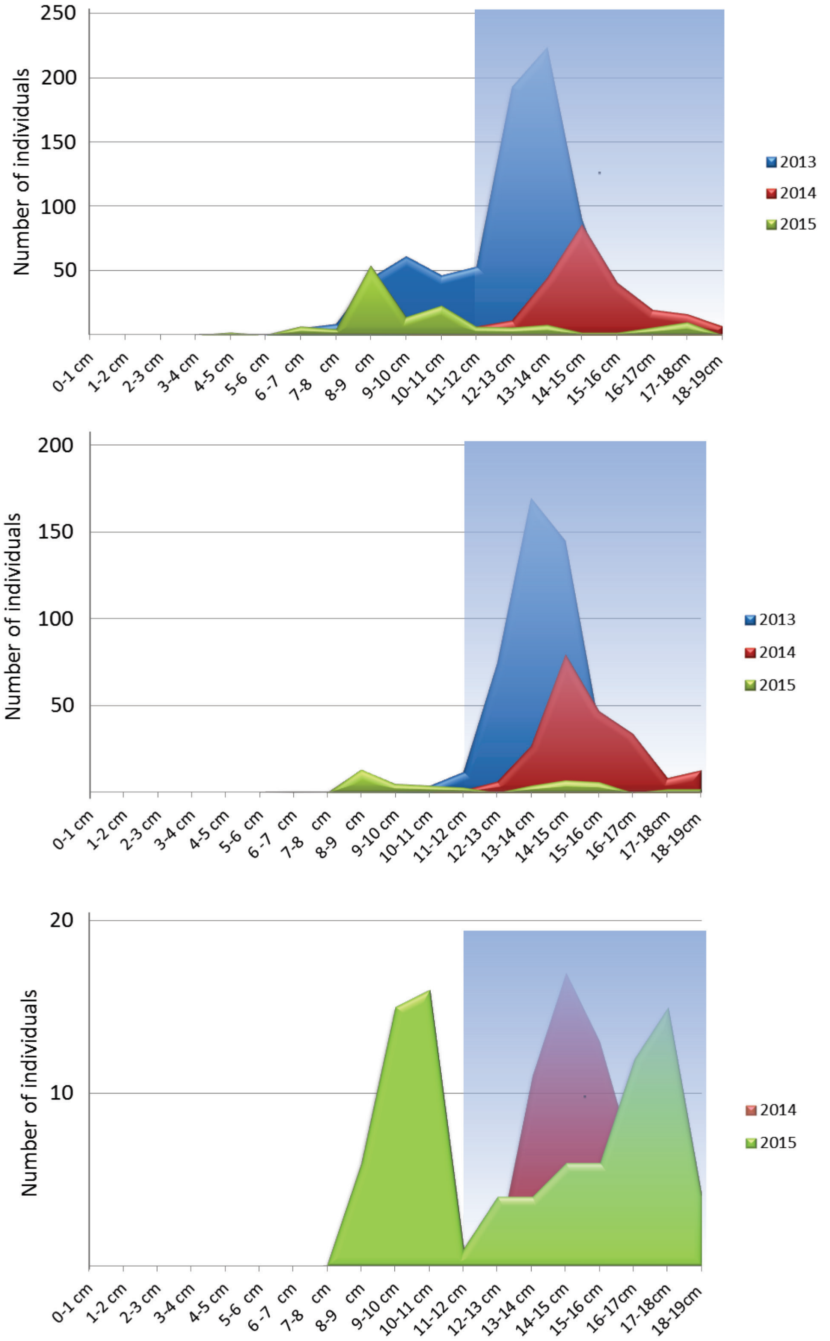


Figure 19. Annual length frequencies of bleak (*Alburnus scoranza*) caught in the 0-3 m (top), 3-6 m (middle), and 6 m+ (bottom) stratum of the Montenegrin part of Skadar Lake (size classes caught by standard "bleak" gillnets (mesh size 15.5 mm) are shaded in blue)

5.2.2.2 Roach (*R. prespensis*)

Using MMG, a total of 5,186 roach were caught and analyzed during the project. Overall, small size classes dominated in the annual catches in any one year (Figure 20). However, while in 2013 and 2014 roach population structure was similar in the 0-3 m stratum, in 2015 a very pronounced increase in abundance of juveniles (i. e. fish with TL < 12 cm) was noted.

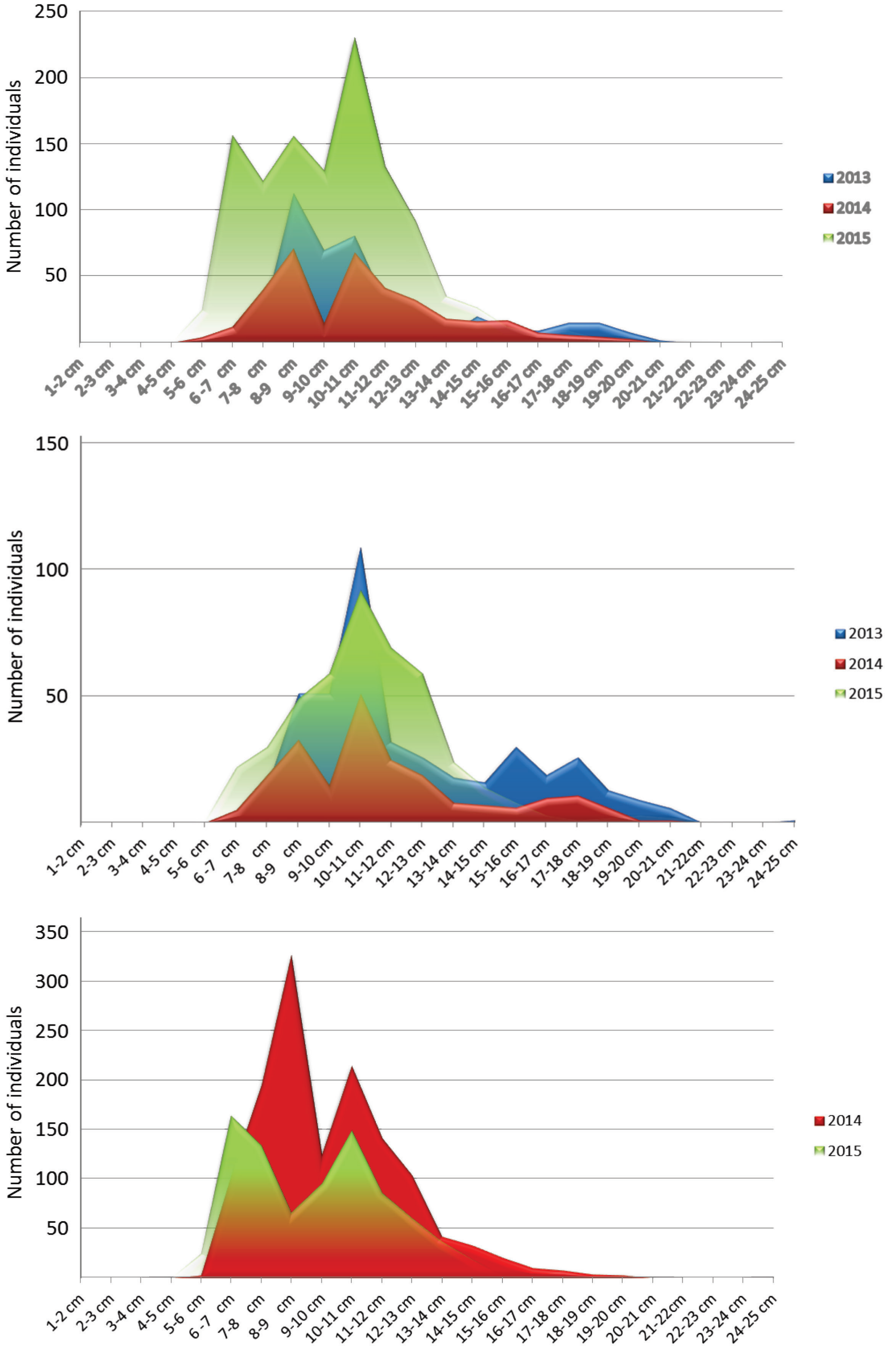


Figure 20. Annual length frequencies of roach (*R. prespensis*) caught in the 0-3 m (top), 3-6 m (middle), and 6 m+ (bottom) stratum of the Montenegrin part of Skadar Lake

A similar trend was noted in the 3-6 m stratum. Compared to 2013, numbers of juvenile roach dropped in 2014, followed by a distinct increase in 2015. Large roach were rare during the last year of sampling. In the deepest water layer (6 m+) a different situation was found. Roach had almost the same size structure in 2014 and 2015 but the number of individuals of different length classes was distinctly lower in 2015 than in 2014.

5.2.2.3 Perch (*P. fluviatilis*)

During the project more than 2,000 perch were caught and analyzed (Figure 21). Most of the fish were relatively small having a total body length of 13-19 cm. Single individuals, however, were up to 29 cm long. In all depth strata a similar trend in length frequencies was found: in 2014 distinctly lower numbers of individuals of all length classes were caught relative to 2013, while in 2015 a recovery of juvenile perch (i. e. fish with TL < 15 cm) was noticed, particularly in 3-6 m and 6 m+ strata.

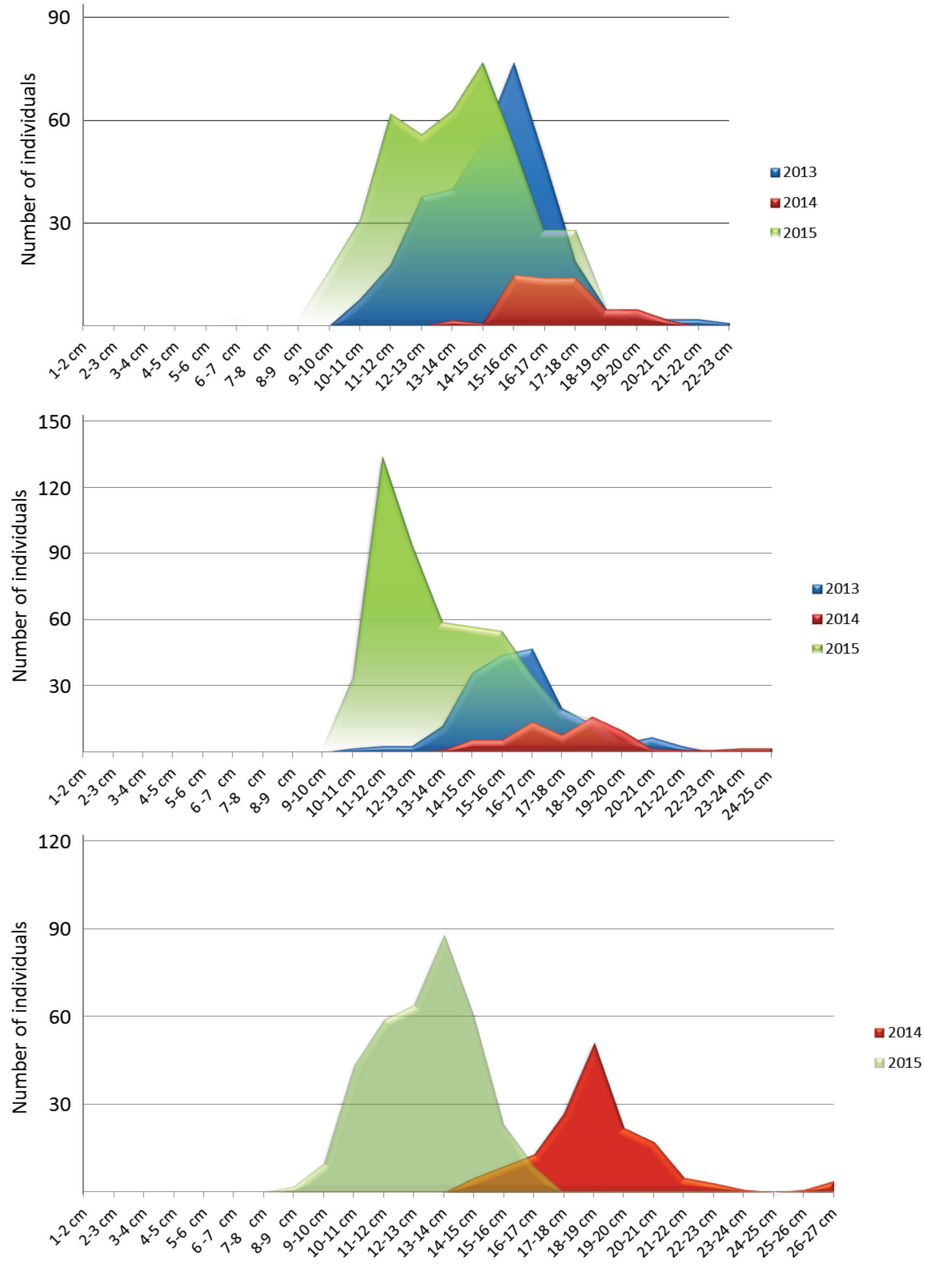


Figure 21. Annual length frequencies of perch (*P. fluviatilis*) caught in the 0-3 m (top), 3-6 m (middle), and 6 m+ (bottom) stratum of the Montenegrin part of Skadar Lake

5.2.3 Results of electrofishing campaigns

In all three transects combined, a total of nine species was detected (Figure 22).

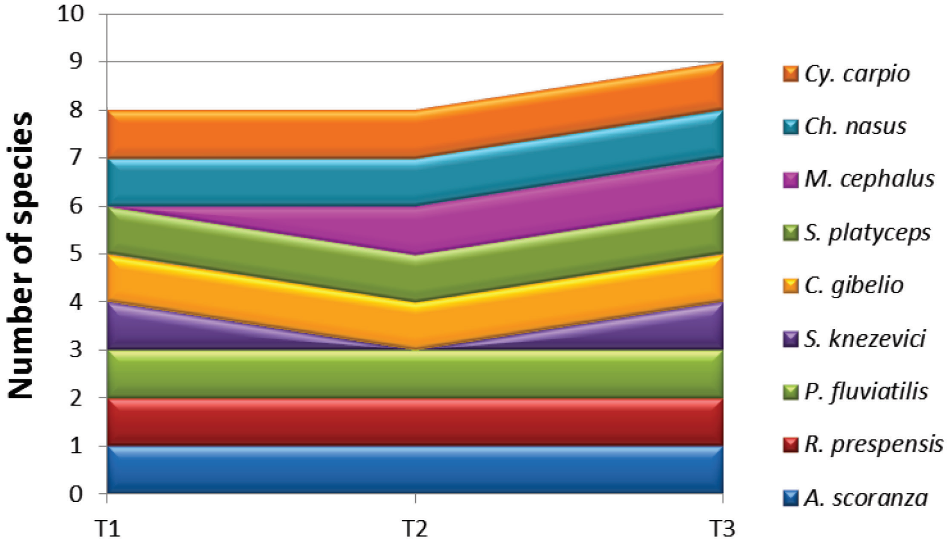


Figure 22. Fish species diversity at transects T1, T2 and T3

In terms of biomass (CPUE, g/m²), carp (*C. carpio*) was dominant at T2 and T3, while at T1 chub (*S. platyceps*) contributed most to the overall biomass (Figure 23).

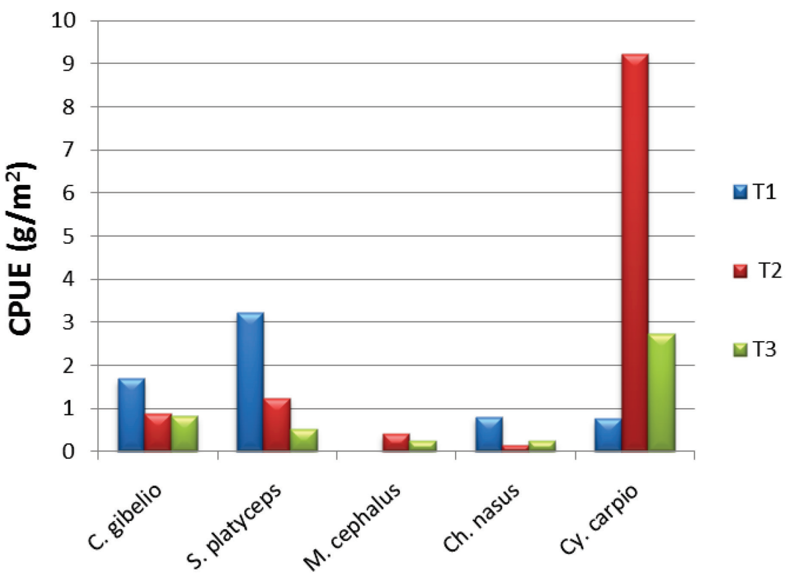


Figure 23. Biomass (g/m²) of Prussian carp (*C. gibelio*), chub (*S. platyceps*), grey mullet (*M. cephalus*), nase (*Ch. nasus*) and carp (*Cy. carpio*) at three electrofishing transects of Lake Skadar

Similarly, chub was most abundant at transects T1 and T3 while carp revealed the highest abundance at the T2 transect (Figure 24).

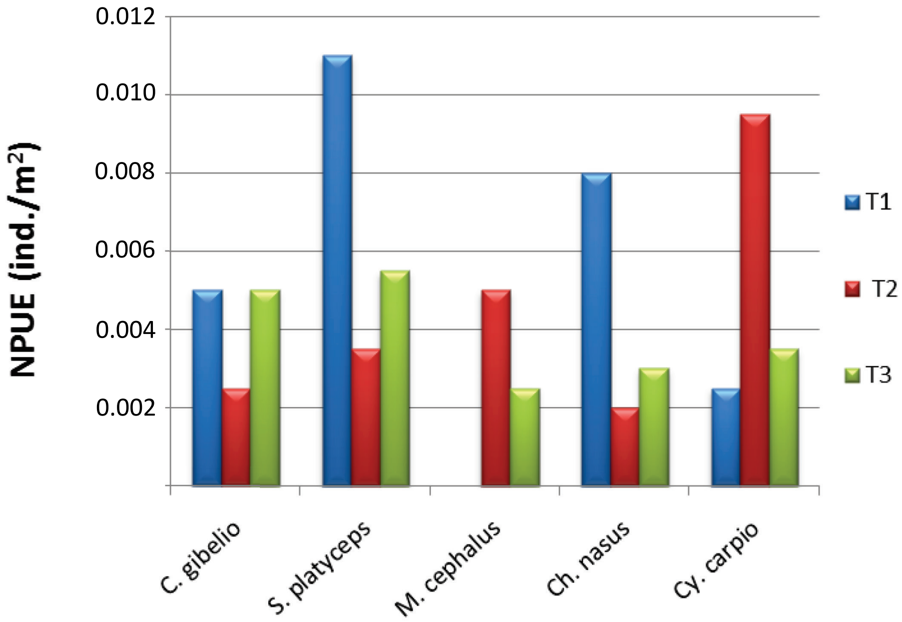


Figure 24. Abundance (individuals/m²) of Prussian carp (*C. gibelio*), chub (*S. platyceps*), grey mullet (*M. cephalus*), nase (*Ch. nasus*) and carp (*Cy. carpio*) at three electrofishing transects of Lake Skadar

5.2.4 Commercial bleak harvesting at Raduš Bay ("Kalimera" fishing)

The following eight species were caught with help of a "Kalimera" net: bleak, perch, roach, chub, carp, rudd, Prussian carp and Adriatic trout (Figure 25). Although species diversity was greater in February 2014 (6 species) than in December 2013 (4 species), with regard to biomass bleak was the dominant species in both sub-samples (Figure 25).

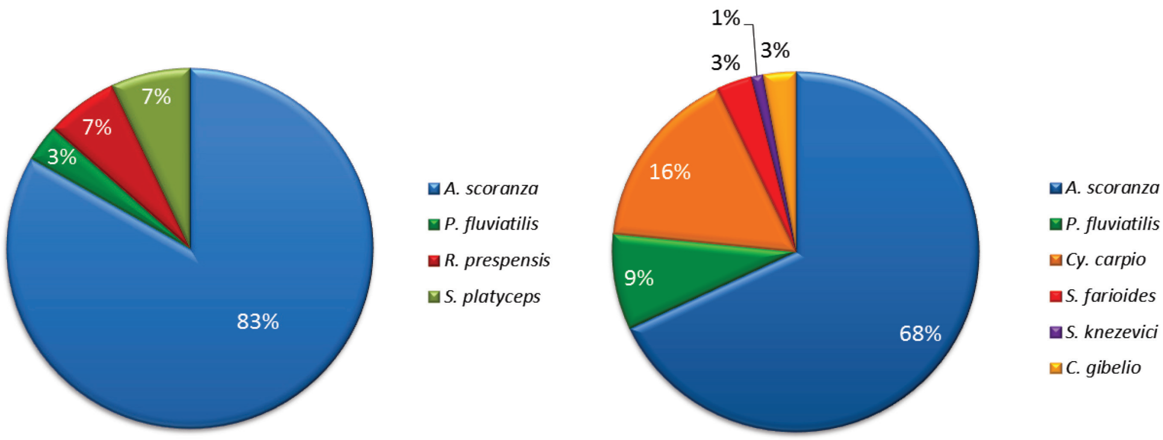


Figure 25. Diversity and relative biomass of species on sub-samples of "Kalimera" catches in December 2013 (left) and February 2014 (right)

In terms of population structure of bleak from "Kalimera" fishing at Raduš Bay, dominant length classes in December catches were 11-12 cm, 12-13 cm, and 13-14 cm, respectively. The sub-sample taken in February was numerically dominated by the 12-13 cm and 13-14 cm length classes, respectively (Figure 26). Interestingly, smaller fish (i. e. younger age classes) were missing at both sampling dates.

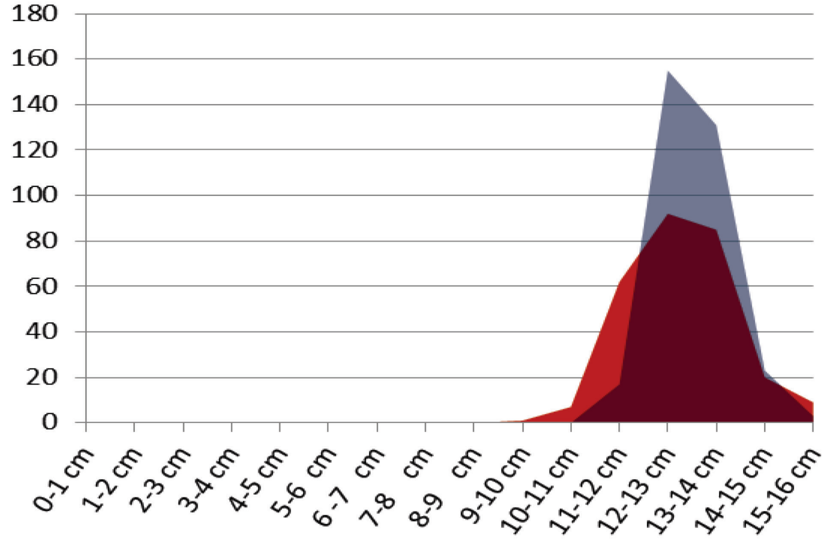


Figure 26. Length frequency of bleak (*Alburnus scoranza*) sampled at Raduš Bay in December 2013 (red) and February 2014 (blue)

5.3 Albanian part of Shkodra Lake

5.3.1 Overall findings

During the three years of sampling at the *Albanian part* of the lake, a total of 14 fish species was detected (Table 8).

Table 8. Fishes of the Albanian part of Lake Shkodra caught with multi-mesh gillnets in the course of the project (2013-2015)

Taxon	Species name
Cyprinidae	carp (*Cyprinus carpio*) bleak (*Alburnus scoranza*) roach (*Rutilus prespensis*) rudd (Scardinius. *knezevici*) Prussian carp (*Carassius gibelio*) spotted roach (*Pachychilon pictum*) nase (*Chondrostoma nasus*) spirlin (*Alburnoides ohridanus*) chub (*Squalius platiceps*) bitterling (*Rhodeus amarus*) stone moroko (*Pseudorasbora parva*)
Percidae	perch (*Perca fluviatilis*)
Clupeidae	twait shad (*Alosa fallax*)
Cobitidae	Ohrid spined loach (*Cobitis ohridana*)

Among the fishes caught were several non-indigenous species, such as *Perca fluviatilis*, *Carassius gibelio*, *Pseudorasbora parva* and *Rhodeus amarus*. The most common species over the three years were *Perca fluviatilis*, *Alburnus scoranza* and *Rutilus prespensis* while chub (*Squalius platiceps*) was detected only once (2015). Species were evenly distributed at the two southern sampling sites. Regarding vertical distribution *Alosa fallax*, *Carassius gibelio*, *Scardinius knezevici* and *Alburnoides ohridanus* showed, in tendency, a preference for shallow water while *Cobitis ohridanus* was caught primarily in deeper waters (Figure 27).

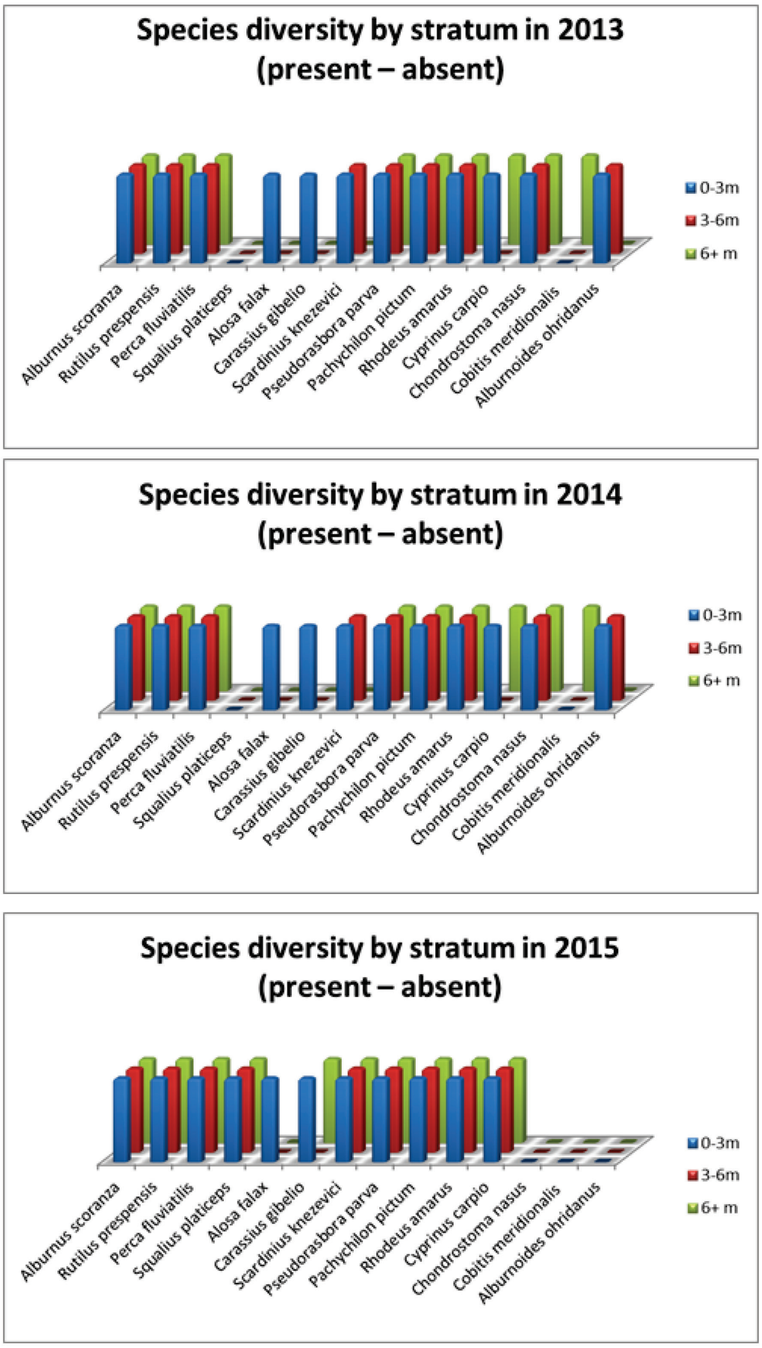


Figure 27. Occurrence of fish species in various depth strata and years at Albanian sampling sites in Lake Shkodra

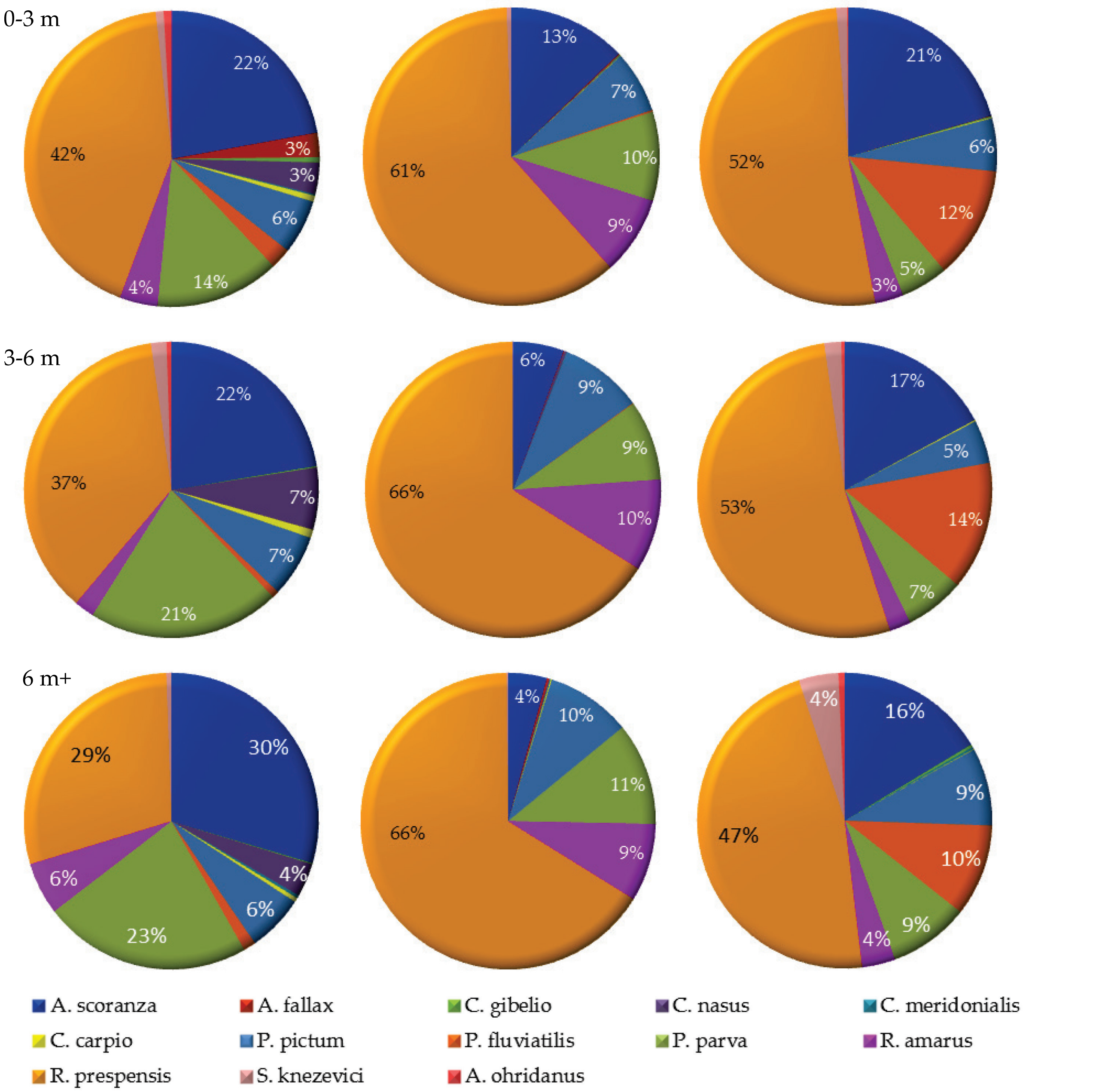


Figure 28. Relative species abundance (%) in total annual catches of 2013 (left), 2014 (centre) and 2015 (right) on Albanian side of Lake Shkodra

At the Albanian territories, relative species abundance was almost even between years (Figure 28). Most of the fish caught were roach and bleak, and also stone moroko contributed in significant numbers to the overall catch in any one year and in any depth strata. Nase and spotted roach (*P. pictum*) occurred regularly but in smaller numbers, while perch became abundant in the final year of sampling (Figure 28).

On the Albanian side of Lake Shkodra the mean biomass of fish caught per net (CPUE) was relatively constant between 2013 and 2014 but increased distinctly in 2015 (Figure 29). With regard to the abundance of fish, the trend was different, with comparably high numbers of fish in 2014 and 2015 relative to first year of sampling (Figure 30). For further details on standardized catches (CPUE, NPUE) separately for each Albanian sampling site, see Annex 1 (Figure 41, Figure 42, Figure 43, Figure 44, Figure 45, Figure 46).

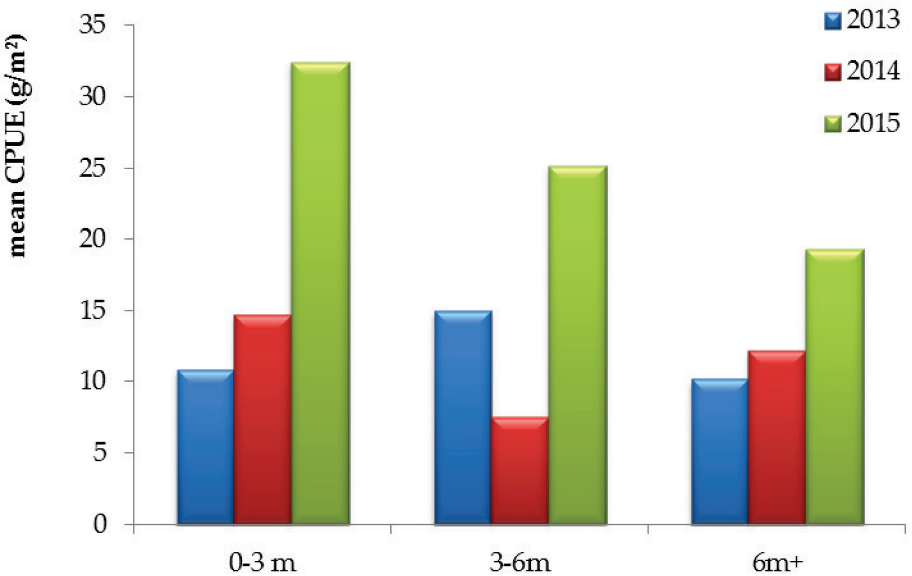


Figure 29. Temporal course of mean biomass (CPUE) of fish per single net set in three depth strata of the Albanian side of Shkodra Lake

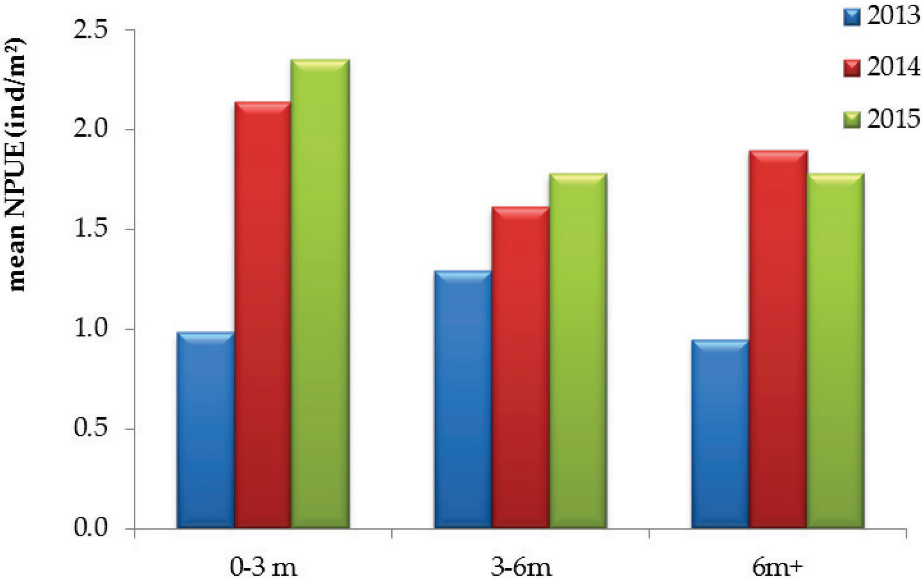


Figure 30. Temporal course of mean abundance (NPUE) of fish per single net in three depth strata of the Albanian side of Shkodra Lake

5.3.2 Population structure of fish from the Albanian side of Lake Shkodra

5.3.2.1 Bleak (*Alburnus scoranza*)

On the Albanian side of Lake Shkodra (sub-basins Koplik and Shirokë) a total of 2,489 bleak were caught during 2013-2015. By using MMG, three size classes of fish were sampled in all three depth strata: first, fish with TL of about 5 cm, second, fish of about 9-10 cm TL, and third, bleak of around 15 cm in length (Figure 31). Within years, different size classes dominated the catch. For instance, in 2013 most fish belonged to the largest size class whereas in 2014 and 2015 most of the sampled fish were small. Between years, numbers of bleak of the smallest size class (app. 5 cm) were relatively constant, while numbers of fish of the largest size class (15 ± 2 cm) differed somewhat but were highest in 2013.

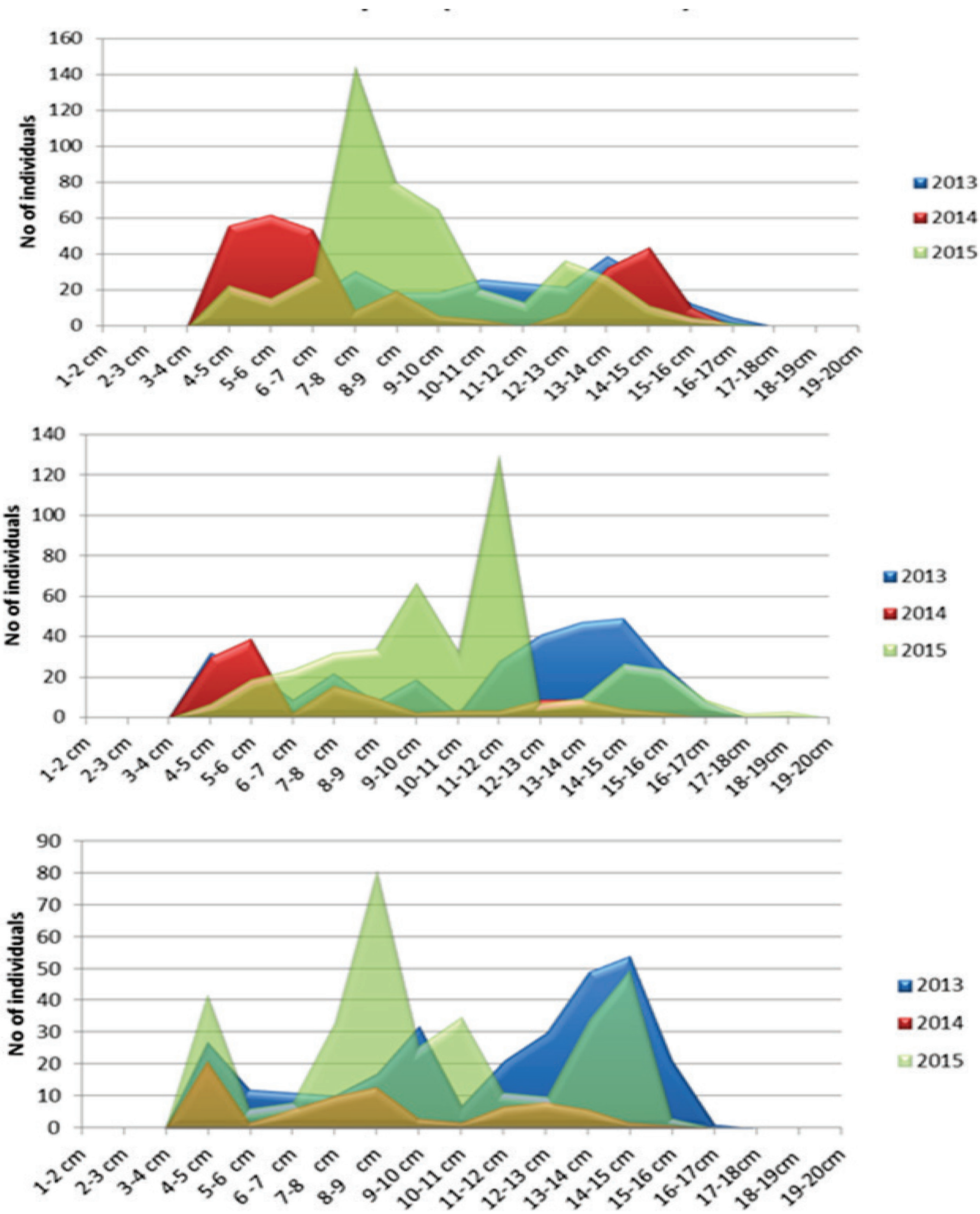


Figure 31. Annual length frequencies of bleak (*Alburnus scoranza*) caught in the 0-3 m (top), 3-6 m (middle), and 6 m+ (bottom) stratum of the Albanian part of Shkodra Lake

5.3.2.2 Roach (*Rutilus prespensis*)

In the Albanian waters of Lake Shkodra, a total of 8,421 roach were caught and analyzed during the project. Overall, in 2014 and 2015 distinctly higher numbers of both small (TL of about 7 cm) and large (TL of about 12 cm) roach were sampled than in 2013 (Figure 32). In 2014, small roach markedly outnumbered large ones in all depth strata. In 2015, however, portions of small and large roach were almost even.

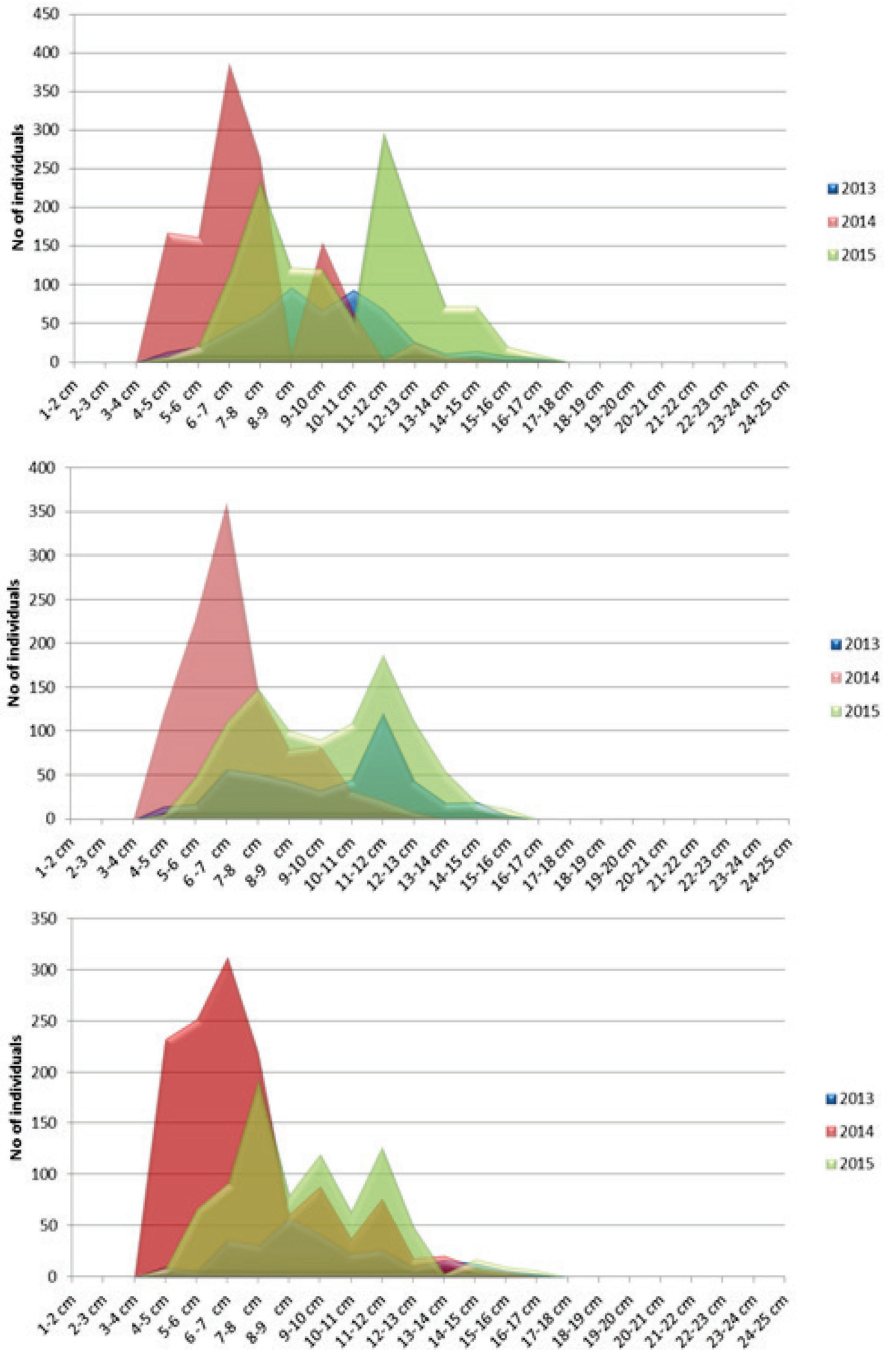


Figure 32. Annual length frequencies of roach (*Rutilus prespensis*) caught in the 0-3 m (top), 3-6 m (middle), and 6 m+ (bottom) stratum of the Albanian part of Shkodra Lake

5.3.2.3 Perch (*Perca fluviatilis*)

On the Albanian side of Lake Shkodra, a total of 830 perch were sampled. Most of the fish were collected in the final year (2015). The majority of perch were 12-15 cm long (Figure 33). Only single individuals having a TL of 5-6 cm were caught. The largest perch measured 20 cm in total length.

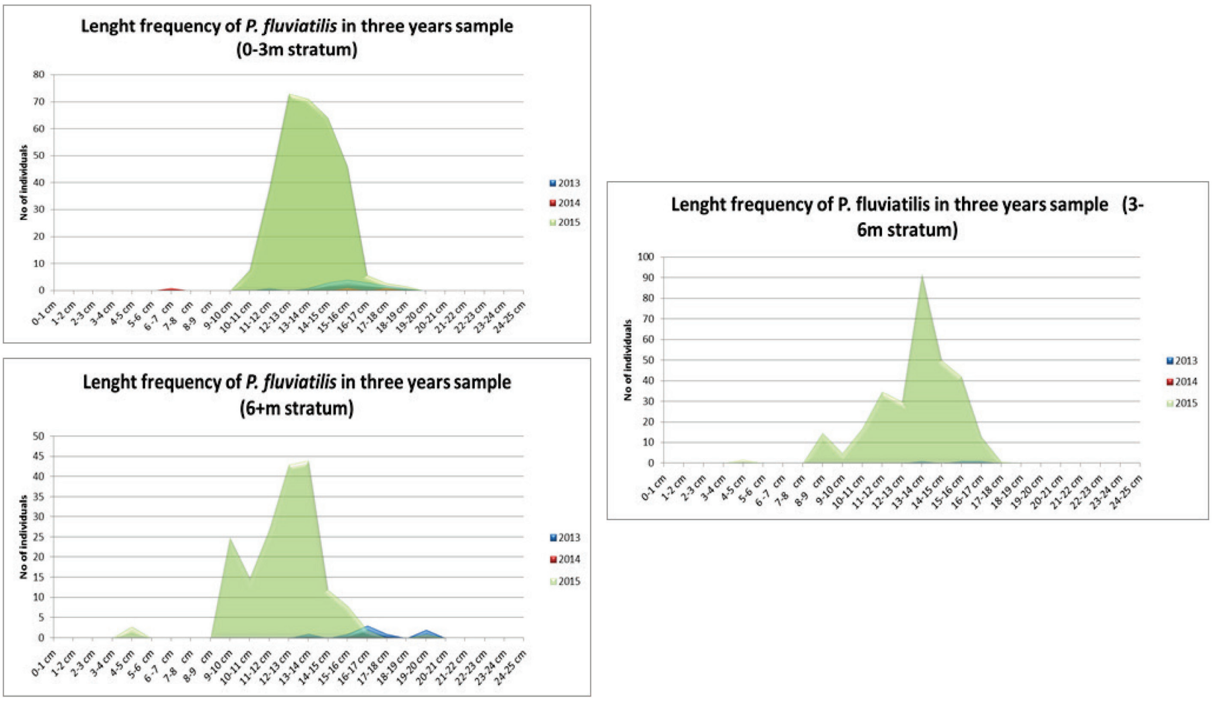


Figure 33. Annual length frequencies of perch (*Perca fluviatilis*) caught in the 0-3 m (top), 3-6 m (middle), and 6 m+ (bottom) stratum of the Albanian part of Shkodra Lake

6 DISCUSSION

6.1 Use of MMG and fish community considerations

Using MMG, a total of 18 fish species were collected in Lake Shkodra/Skadar during the sampling periods of 2013, 2014 and 2015. In addition, Adriatic trout was caught by use of "Kalimera" net. In view that the lake is believed to harbour about 50 fish species (Marić & Milošević 2011, Sulçe et al. 2013) it can be stated that, roughly, 50% of the recorded species were sampled. However, it should to be taken into consideration that several fishes (especially marine species such as flounder, big-scale sand smelt, sea bass) occur only temporarily in the lake or, for various reasons, have not been caught for many years (like brown bullhead or Adriatic and Atlantic sturgeons, respectively) (Talevski et al. 2009 a). Moreover, grass carp, silver carp, black carp and bighead carp, which were introduced in the beginning of the 1980s, were not able to establish stable populations. Remaining individuals (if still present) most probably are very large and, therefore, difficult or even impossible to catch with MMG at a maximum mesh size of 55 mm. Similarly, other species, such as eel (*Anguilla anguilla*) are generally not sampled by use of gillnets. Taken together it can, therefore, be concluded that MMG fishing provides a reasonably good picture about fish assemblages of the lake. Similar results about the application of MMG fishing for fish inventory studies were obtained by Petriki et al. (2017) in other Mediterranean lakes. To obtain data about migratory or otherwise specialized fish, however, MMG fishing needs to be complemented by specific fishing techniques. Use of electrofishing gear, for example, can be more selective towards large fish, as an electromagnetic field poses a stronger impact on large-bodied specimens. Electrofishing is a common method used to uncover fish diversity in running waters and areas that are difficult to fish with nets (Heggenes et al. 1990). Likewise, sampling with a so-called "Kalimera" net can also be considered highly selective as, at Lake Shkodra/Skadar, it is primarily employed during winter shoaling of fish at selected sites.

MMG fishing revealed that non-indigenous fishes are widely distributed in Lake Shkodra/Skadar and can be encountered in all depth strata (Figure 13 and Figure 14). Individual species, such as perch (*P. fluviatilis*) and stone moroko (*P. parva*) occur regularly in the catch and have established noteworthy population sizes by now. While this fact as such has been known for several years (Keukelaar et al. 2006, APAWA & CETI 2007, Grudnik & Gajšek 2011), the current report provides quantitative information about the extent of non-indigenous species occurrence relative to other fishes (Figure 16 and Figure 28), as well as (for perch, for example) data on population structure (Figure 21 and Figure 33) and length-weight relation (Figure 47 to Figure 49). Furthermore, current data also suggest that there are spatial differences in occurrence of allochthonous fishes between northern and southern sampling sites. Stone moroko, for example, was more abundant in the southern (Albanian) part of the lake than in northern (Montenegrin) areas. On the contrary, perch was present primarily in catches taken from northern sites (Figure 13 and Figure 14) and appeared in southern lake areas in noteworthy numbers in 2015 first. This observation (spread of perch from north to south) conflicts with statements of other authors who mentioned that *P. fluviatilis* had entered Lake Shkodra/Skadar via Rragami Channel (APAWA 2012) and the Drin River, respectively (Pastorelli & Ungaro 2011), but is supported by Shumka et al. (2008) who were unable to find this fish in the wider Drin River system.

Spatial differences in species distribution were also noticed in terms of autochthonous fishes. White roach (*Rutilus albus*), marble trout (*Salmo marmoratus*) and Adriatic trout (*S. farioides*) as well as grey mullet (*Mugil cephalus*) and freshwater blenny (*Salaria fluviatilis*) were caught in the Montenegrin sites only while Ohrid spined loach (*Cobitis ohridana*) was found exclusively in Albanian areas (Figure 13 and Figure 14). Likewise, quantitative differences in the occurrence of species were noticed between northern and southern shorelines. For example, in view of biomass (CPUE) and abundance (NPUE) bleak and chub were more common in the North than in the South (Figure 10 to Figure 14). Such a situation (i. e. the absence of some species in a particular part of the lake) does not mean that those species occur in only one part of the lake. It may rather indicate that their abundance may generally be low and, therefore, that these species may not be detectable at all sites at any time. Considering that large differences in spatial distribution were found among species that are not in focus of commercial fishery it can be excluded that fishing activities are the main drivers for that situation. Rather, detected patterns suggest that qualitative and/or quantitative differences in fish community composition of the two sampled areas (Montenegrin and Albanian sites) are caused by different environmental conditions. For example, water inflow (by Rivers Moraca and Crnojevica) presumably has a stronger impact on northern than on southern lake water quality, resulting in differential fish community structure (species composition and abundance) at those two sampling areas. As the current data show, fish assemblage at Montenegrin sites is largely dominated by three undemanding species (roach, bleak, perch) in contrast to Albanian sampling spots, where the species distribution is more even (Figure 28). Indications of spatial differences in water quality of Skadar Lake have also been found in other studies. According to the initial characterization of the lake using phytoplankton and macrophytes as biological elements (indicators), the level of eutrophication is generally higher in the northern than in the southern part of the lake (Peveling et al. 2015). Presumably, sublacustric springs located at the south-eastern and south-western shorelines (Lasca et al. 1981) add notable amounts of clear water to the system which, in combination with self-purification processes leads to changes in the structure of the biota. Importantly, knowledge about spatial differences in fish occurrence needs to be taken into consideration when sampling sites are chosen in either monitoring programs or when fishing for specific species is intended. In addition to that, differences in species occurrence and abundance have as well to be considered in the transboundary management of stocks.

6.2 State of Lake Shkodra/Skadar fish stocks

Fish stock assessment methods have a relatively long history in fishery science (Baranov 1914, Beverton & Holt 1957). The driving force behind research on assessments is to obtain knowledge about size (biomass) of fish stocks in order to provide recommendations for potential (long-term) exploitation rates (maximum sustainable yield) of these renewable aquatic resources. Over the years, various models of different complexity have been developed which address this topic. Most of the models derive from marine fishery science. Like any other model, all of the fish stock assessments are founded on specific assumptions and thus also entail uncertainty. For the proper assessment of freshwater fish stocks there is limited experience although some techniques (such as mark-recapture methods (Gresswell et al. 1997, Welcomme 1975) and acoustic surveys (Hughes & Hateley 2002)) have been developed and successfully applied to collect appropriate data for stock modelling. Generally, precision of stock assessments increases with data availability. Having said that, field sampling of fish population data inherently faces highly variable situations. For example, fish may not be evenly distributed in the different water bodies, which affects comparability of generated data. As well, catchability as a measure of fishing success is associated with fish abundance, but also depends on fish behaviour, population biology including population dynamics, quality and amount of fishing effort, fishing strategy and environmental conditions, among others (Arreguín-Sánchez 1996). In consequence, for a sound fish stock assessment, long-term data are suited best.

The European standard EN 14757 has been developed and applied for WFD-related purposes to obtain estimates of species diversity and abundance (CPUE), as well as size (age) structure of fish populations in a given waterbody (European Committee for Standardization 2015). It is not a specific tool to assess the size of a fish stock or to calculate maximum sustainable yields. Nonetheless, data on (body) size structure of fishes generated in the present study can provide indications of the status of the respective species. In terms of **bleak** (*A. scoranza*) fish of all size classes (small, medium, relatively big) were caught in all years at both Albanian and Montenegrin sampling sites. Adult fish formed the majority of the Montenegrin bleak catches (Figure 50, Figure 51 and Figure 52). However, in both countries the portion of spawners (body length ≥ 10 cm) dropped dramatically from 2013 to 2015 (Figure 19 and Figure 31), although some recovery might have taken place in selected depth strata. In this context it should also be kept in mind that the size of spawners is important too as egg numbers and egg quality for several species were shown to be positively correlated with the body length of spawners, i. e. larger and older fish produce both more and better eggs than their smaller (and younger) conspecifics (Gwinn et al. 2015 and references therein). In addition, with only few exceptions numbers of small bleak were low too in any one year of sampling. In conclusion, bleak obviously respond very fast to external (natural and anthropogenic) pressures and thus a constant monitoring and adjustment of allowable catches or catchable sizes (minimum length) to actual population structures seem advisable.

Carp (*C. carpio*) is of major economic importance to local fishermen and, therefore, is one of the main target species. In the course of the current study relatively few specimens were sampled by using MMG despite the fact that this species forms large parts of commercial catches (cf. Figure 4 and Figure 5). Identical results were obtained during recently performed MMG fishing at Prespa Lake (Ilik-Boeva et al. 2017). Most probably, larger mesh sizes than those used in the course of the current investigation (maximum of 55 mm knot-to-knot) have to be employed in order to also catch larger individuals. According to Šmejkal et al. (2015), standard MMG with panels of mesh sizes ranging from 5-55 mm do not mirror exact conditions of the fish community composition and additional use of net panels of 70, 90, 110 and 135 mm has been proposed by these authors. In conclusion, for carp further sampling is required to generate more comprehensive data which enable assessments of the condition of the stock.

The current data on **perch** (*Perca fluviatilis*) provide evidence that this species is well established in Skadar/Shkodra Lake, at least in its northern parts. Juvenile and adult specimens were caught in worth mentioning numbers in any sub-basin and any one year (Figure 47, Figure 48, Figure 49). Perch is one of the few species that, in terms of numbers, is very well represented in the overall fish community. At the northern parts of the lake, in particular, perch is very abundant and length-frequency data (Figure 21) show that adults (TL > 15 cm) are quite common in that area. It must be mentioned though that, under natural conditions, perch may grow up to 60 cm in size (Froese & Pauly 2017) which, in combination with its fine taste, can make it an interesting object for commercial fishery. In view of low fishing mortality of perch from Skadar/Shkodra Lake it seems that other than anthropogenic factors prevent the fish from reaching larger sizes. As perch prefers temperatures between 10-22 C (Froese & Pauly 2017) it is conceivable that perch experiences thermal stress at this habitat and temperature, therefore, may be a significant driver of annual perch population dynamics.

Roach was the most frequently caught species during the three years of sampling (Figure 8), indicating that this species is highly abundant throughout the lake. Length-frequency analyses show that among the specimens caught were large numbers of adults (i.e., potential spawners), in particular at the southern part of the lake (Figure 20 and Figure 32). Taken together, at present there is no indication that roach at Shkodra/Skadar Lake is at any particular risk and the roach stock in general seems to be in good condition (Figure 53, Figure 54, Figure 55). With regard to horizontal distribution, roach can be found particularly at the 0-3 m and 6+m depth strata (Annex I).

Spotted roach (*Pachychilon pictum*) occurred regularly in the catches and accounted for about 5% of caught individuals per year (Figure 8). The spotted roach samples as well consisted of good shares of juveniles and spawners suggesting a good condition of the population (Figure 56).

The alien **stone moroko** (*Pseudorasbora parva*) was also well represented in annual catches (Figure 8). Length-frequency analysis revealed that most fishes were mature (Figure 57). As stone moroko is a small-sized fish (having a maximum length of 11 cm (Spirkovksi et al. 2012)) it is conceivable that juveniles were just too small for being caught by MMG.

For another alien, the **bitterling** (*Rhodeus amarus*), the same seems to be true as was just discussed for stone moroko above. Bitterling specimens were sampled regularly, although it was generally less abundant than stone moroko. Samples consisted primarily of adult individuals (Figure 58) which most probably is attributable again to the small size of the fish so that juveniles rarely enter the MMG catchability.

6.3 First steps towards the development of a WFD compliant assessment system based on fish data

The information obtained during the project could be used to make further steps towards the development of a fish-based index to assess the ecological status of Lake Shkodra (Lake Fish Index - LFI). The first steps in the development of such an LFI (compliant with the WFD) were taken during two meetings of Albanian, Macedonian, and Montenegrin fishery experts participating in the project supported by the IfB. Generally, an LFI which is compliant with the requirements of the WFD includes a typology, a selection of metrics and a certain scoring procedure. The following list provides some selected references related to these topics:

- for typology: Ecostat (2004), Poikane (2009), Ritterbusch et al. (2014);
- for the theoretical background of system development and scoring: Birk et al. (2013), CIS (2003 a, b, 2009, 2011, 2015), Lyche-Solheim et al. (2013), Poikane et al. (2015);
- for overviews of existing systems with descriptions of typology, metrics, and scoring: Argillier et al. (2013), Gassner et al. (2014), Olin et al. (2014), Ritterbusch et al. (2017 a, b).

A typology summarizes lakes with comparable geographic, morphometric or physico-chemical characteristics. Possible factors for characterization are ecoregion, altitude, depth, size, geology, water residence time, temperature, or mixing characteristics (Annex II of the WFD). Lakes of a common type should have a comparable fish community, at least under undisturbed conditions. However, Lake Shkodra could not be categorized as a certain type together with other lakes. The lake is not comparable with other lakes in the surrounding, e.g. with respect to surface, depth or altitude. It was decided, therefore, that an individual assessment of the lake would be necessary. This decision is supported by the thresholds proposed for typologies in Annex II of the WFD.

Metrics are traits of the fish community that are likely to be influenced by human impacts. An LFI is usually based on multiple metrics in order to be safer against accidental results. The WFD provides normative descriptions of what a high, a good and a moderate status are in terms of fish traits. Three categories of traits are used in this description: fish abundance, species composition and development/reproduction. To follow the WFD as close as possible, fish metrics of each of these categories should be part of the index. Some promising metrics for a future fish index for Lake Shkodra were proposed:

- Standardized catches: a standardized measure of the catch in terms of weight or number is a common measure in LFI. High catches can indicate a change of the fish abundance due to eutrophication.
- Percentage of native species: the replacement of native species by non-native species is a deterioration of the natural species composition. As non-natives are or were introduced by humans, this indicates an anthropogenic ecological degradation of the lake. If the ecological requirements of the various alien species differ considerably from each other, it is possible to use specific individual species as metrics. For Lake Shkodra, *Perca fluviatilis* and *Pseudoasbora parva* are potential candidates to be used as metrics.
- The rudd (*Scardinius knezevici*) is a phytophilic species. A reduced share of rudd in the fish composition might indicate anthropogenic deterioration, e.g. by destruction of littoral vegetation.
- The percentage of eel (*Anguilla anguilla*) or mullet (*Liza ramada*) could be a metric for human impacts on the ecological connectivity of the lake.
- The presence/absence or abundance of juvenile specimens of certain species can be used for the indication of human influences on development and/or reproduction. For this purpose, length-frequency distributions of abundant fish species can be used, e.g. from bleak (*Alburnus scoranza*) or roach (*Pachyilon pictum*) (see Figure 19, Figure 31, Annex III).

For finalization of the LFI, each metric needs to be scored. This requires the setting of class boundaries and the assignment of points. The ranges for metric scoring are not prescribed. However, scores are frequently set in accordance with the WFD classification of 1 to 5. In this case, 1 signifies a very high impact (bad status) and 5 a negligible impact (high status). Finally, the metrics are combined to a total score, e. g. as sum or mean. This final score needs to be transposed to the range from 0 to 1 in order to be comparable with other systems. The final score is termed EQR (ecological quality ratio), and a five-step normative category is assigned: high, good, moderate, poor, or bad. The setting of class boundaries for the metrics, the scoring and the final calculation of an EQR for Lake Shkodra could not be achieved during the project. Main reason is the lack of comparable data for the derivation of thresholds. Therefore, the scoring at this point has to be heavily based on expert judgment which requires further discussions between multiple stakeholders. Examples for the scoring procedure can found by Ilik-Boeva et al. (2017) and Spirkovski et al. (2017) for Lakes Ohrid and Prespa, respectively.

7 PROPOSED SAMPLING SCHEME FOR MONITORING FISH STOCKS OF LAKE SKADAR/SHKODRA

On the basis of fishery data obtained by use of MMG in the course of the CSBL project, as well as expert judgement of fishery scientists, a fish monitoring scheme (Table 9) is proposed to assess stock development of Lake Skadar/Shkodra fishes. The scheme includes sampling sites at both Albanian and Montenegrin territories and aims at collecting data about the state of both economically interesting species (such as bleak and carp), as well as fishes that deserve special attention because of their ecology (invasive species) and/or conservation status (e.g. European eel).

By using standardized sampling methods and calculation of catch-per-unit-effort (CPUE), inter-annual comparisons shall be made possible and assessments of the dynamics of fish populations can be undertaken. Importantly, fishing effort (e.g. number of nets, fishing hours, fished areas etc.) needs to be recorded to enable spatial and temporal comparisons. Additionally, whenever possible, fishing shall be performed according to existing standards (such as MMG fishing in line with EN 14757). For example, the European standard EN 14962: 2006 ("Guidance on the scope and selection of fish sampling methods") provides a methodological overview of the estimation of fish abundance and evaluation of fish populations. It also informs about existing fishing methods and evaluates their suitability in relation to the category of individual water bodies (European Committee for Standardization 2006). Similarly, the European standard EN 14011: 2003 ("Sampling of fish with electricity") is a guideline for the estimation of the composition, abundance and diversity of fish using electric gear. The norm includes details on gear and methods, but also safety standards. The minimum sampling effort (i.e. the shoreline length that needs to be sampled) is described in dependence on water body type, and information about fish handling and measurement is presented (European Committee for Standardization 2003).

In view of Skadar/Shkodra Lake it is proposed to collect fish at various seasons of the year, depending on species and age group (Table 9 and Table 10). Random sampling with MMG should preferentially be conducted during the October-November period. In this time-frame, there is no fish gathering as opposed to e.g. during times of spawning, wintering or intense feeding. Moreover, this period is favoured as current MMG fishing was conducted during the same periods in 2013, 2014 and 2015 which make future comparisons meaningful. Additionally, downstream eel migrations towards the Adriatic Sea start in fall so that eels can be caught relatively easy, especially by using fish traps in the Buna/Bojana River near the city of Skhodra. Lastly, since bleak harvest is conducted from December to February, samples from commercial catches can only be taken during this period. In contrast to the above, during late spring and summer, samples of fish larvae and juveniles shall be performed.

In future fish monitoring, MMG should be employed similar to the current study. By doing so, data will become comparable. On Montenegrin territory it is suggested to continue applying the same numbers of nets, 12 MMG in the 0-3 m stratum, 12 MMG in the 3-6 m stratum and 12 MMG in 6 m+ stratum. For the Albanian side, sampling at Koplik and Shirokë can be combined as these two spots generated similar results. In conclusion, six nets can be posed at each of the two sites in the 0-3 m stratum and in the 3-6 m stratum (resulting into 12 nets per stratum). Twelve additional MMG can be set at a depth of 6 m+ in the middle part of the lake where the two named sub basins meet (Figure 34).

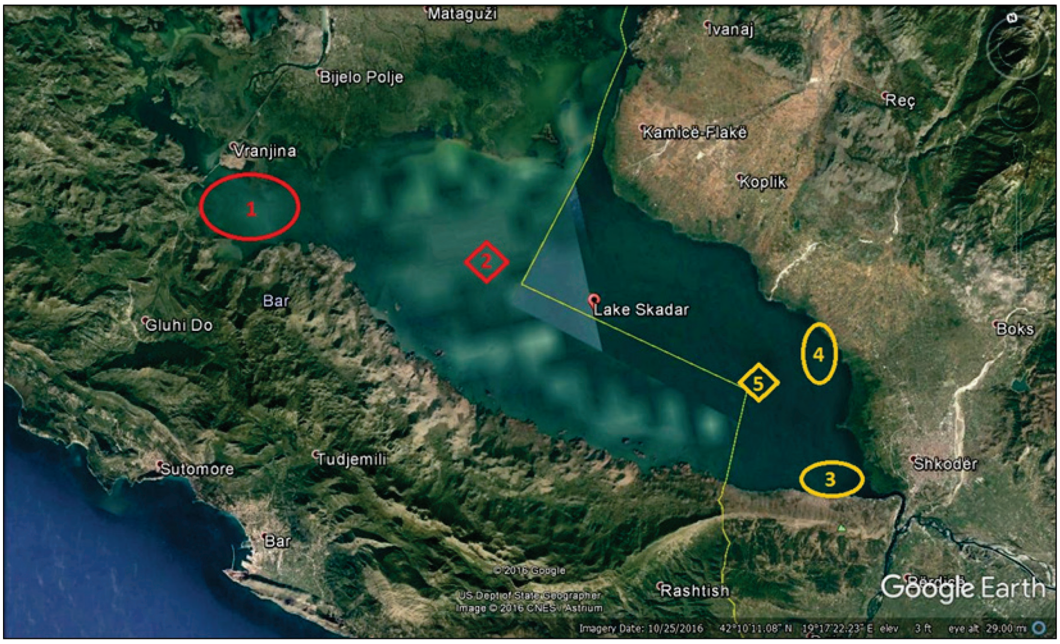


Figure 34. Proposed monitoring sites at Lake Skhodra/Skadar (1– Vranjina / Virpazar / Grmožur area for 0-3 m and 3-6 m strata, 2 – Central Lake MNE for 6 m+ stratum, 3 – Shirokë area for 0-3 m and 3-6 m strata, 4 – Koplik area for 0-3 m and 3-6 m strata, 5 – Central Lake AL for 6 m+ stratum)

In order to also collect sufficient data on carp, use of so-called "carp nets" is recommended. These nets should be 100 m long and 2 m high with a mesh size of 70 mm (knot to knot). If possible, three such nets should be set on each lake side, i.e. one each at the 0-3 m, 3-6 m and 6 m+ stratum, respectively (Figure 35).

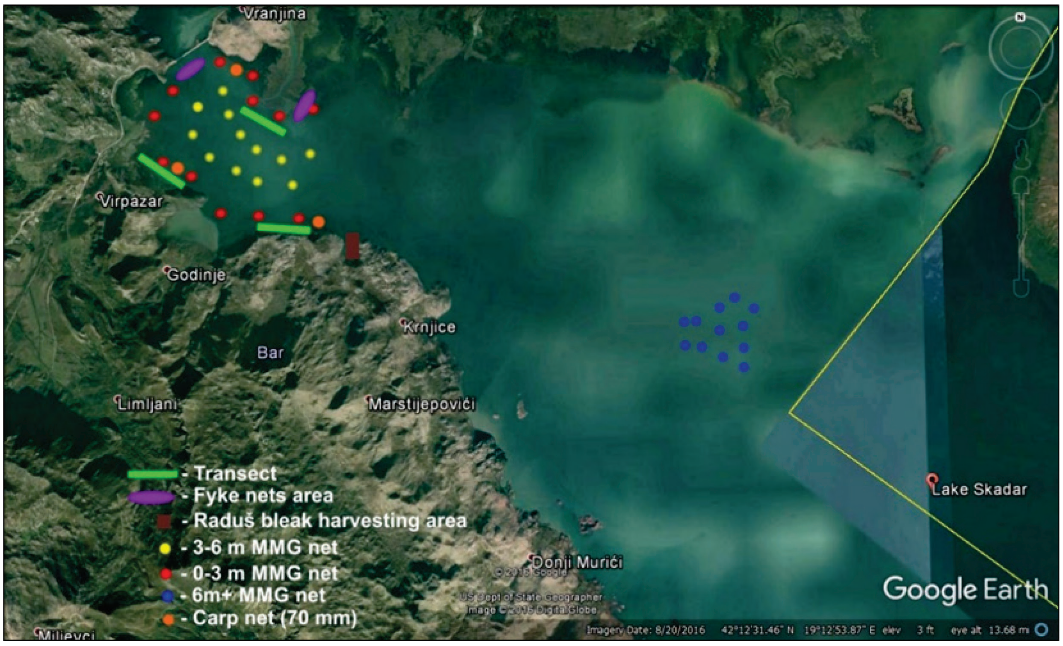


Figure 35. Details of proposed employment of fishing gear at the Montenegrin part of the lake

To generate information on the population structure of fish that are difficult to catch by MMG, application of electrofishing is endorsed. Individual electrofishing transects shall be 500 m in length. Electrofishing should preferentially be performed in shallow areas (0-3 m stratum).

Use of fyke nets and monitoring at the fish trap at the Buna/Bojana River in Albania (Figure 36) aim, in particular, to collect data on European eel (*A. anguilla*). Monitoring of bleak harvest in Raduš Bay is proposed by taking subsamples of commercial catches collected with "Kalimera" nets (or beach seines at the Albanian side). Bleak stock data from these catches can be analysed and will back up the information generated from random MMG samplings. Lastly, in order to monitor spawning success and development of juveniles, use of experimental beach seines is recommended.

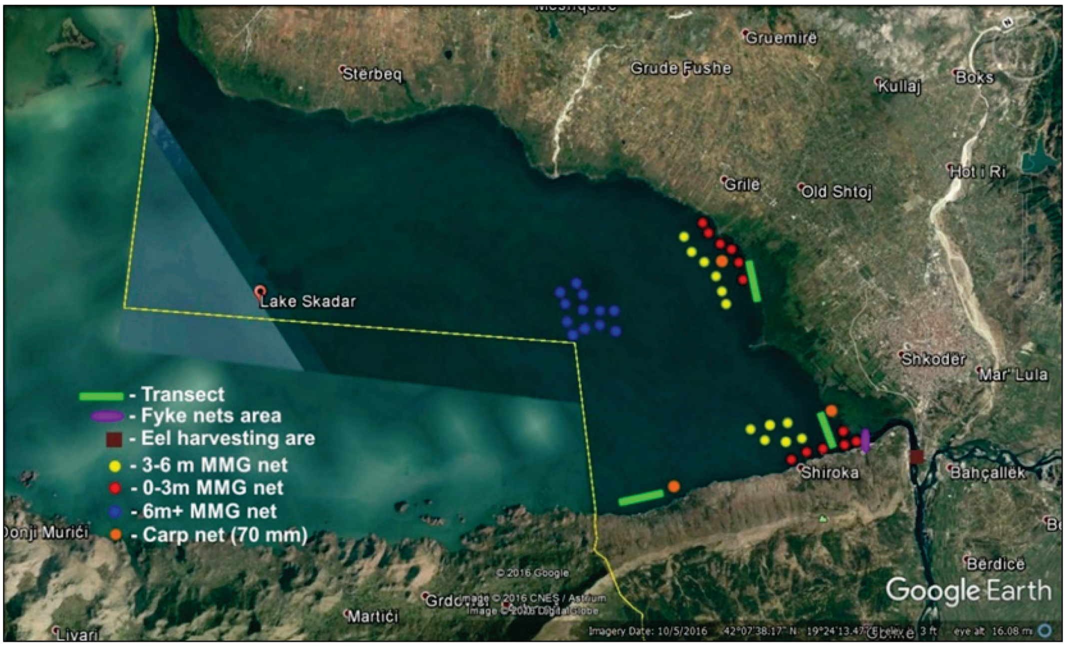


Figure 36. Details of proposed employment of fishing gear at Albanian part of the lake

Table 9. Proposed sampling scheme for transboundary fish monitoring at Lake Shkodra/Skadar (Montenegrin territory)

Method	MONTENEGRO											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Benthic MMG (EN 14757)									Vranjina - Virpazar - Grmožur, Central Lake	Vranjina - Virpazar - Grmožur, Central Lake	Vranjina - Virpazar - Grmožur, Central Lake	
Gillnet 70 mm (carp net)									Vranjina - Virpazar - Grmožur	Vranjina - Virpazar - Grmožur	Vranjina - Virpazar - Grmožur	
Fyke net											R. Moraca estuary, embankment bridge	R. Moraca estuary, embankment bridge
Kalimera net (bleak harvest)	Raduš Bay	Raduš Bay										
Electrofishing transects									Vranjina - Virpazar - Grmožur	Vranjina - Virpazar - Grmožur		
Experimental beach seine (fish larvae)				Vranjina - Virpazar - Grmožur	Vranjina - Virpazar - Grmožur	Vranjina - Virpazar - Grmožur			Vranjina - Virpazar - Grmožur			
Catch data												

Table 10. Proposed sampling scheme for transboundary fish monitoring at Lake Shkodra/Skadar (Albanian territory)

Method	**ALBANIA**											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Benthic MMG (EN 14757)										Koplik, Shirokë	Koplik, Shirokë	
Gillnet 70 mm (carp net)										Koplik, Shirokë	Koplik, Shirokë	
Fyke net				Koplik, Shirokë	Koplik, Shirokë	Koplik, Shirokë					Buna River	Buna River
Common beach seine	Shirokë											Shirokë
Experimental beach seine (fish larvae)				Koplik, Shirokë	Koplik, Shirokë	Koplik, Shirokë			Koplik, Shirokë			
Fish weir			Buna River	Buna River							Buna River	Buna River
Catch data												

8 CONCLUSIONS

During the 3-year fishing campaign on both sides of the lake (MN and AL territories), a total of 18 species was found in the samples. In view that certain fish species reported for Skadar/Shkodra Lake have not been detected for decades, while others occur only temporarily, the MMG fishing method works reasonably well to obtain an overview about species composition, abundance, biomass, and size structure. Importantly, MMG fishing provides the opportunity of standardized data collection and thus enables comparability not only with data from previous and future years, but also with data sets from other lakes where this technique was applied too. It is, therefore, recommended to continue to use this method in future fish monitoring programs.

During sampling it became obvious though that standard MMG sampling also has some limitations. Specifically, large carp which are regularly caught by local fishermen did not appear in the MMG catches. It is, therefore, suggested to expand standard MMG by panels having larger mesh sizes. Šmejkal et al. (2015) proposed additional use of net panels of 70, 90, 110 and 135 mm to also catch representative samples of large specimens.

In the course of the project not a single European eel (*Anguilla anguilla*) was collected. This finding does not surprise as eels are typically not captured by use of gillnets. However, as eel is an important species which, among others, also receives Europe-wide protection knowledge on the eel stock of Skadar/Shkodra Lake is desirable. More importantly, an eel management plan is part of the *Acquis communautaire* (EU Eel Regulation) and development of such a plan, therefore, is a prerequisite for EU accession. In order to obtain data on eel it is suggested to also apply electrofishing in future samplings and to use catch data from eel catches at the fish weir at the Buna/Bojana River.

Minor differences in number of detected species were noticed between sampling years (for example, one individual of *Salmo marmoratus* was found in 2014 only). Such situation, most probably, results from extremely low abundance of these species and, in consequence, their catch may just be a matter of coincidence (i. e. low likelihood of becoming caught due to low numbers of individuals).

Spatial differences in species occurrence and/or abundance were noticed between the northern (Montenegrin) and southern (Albanian) parts of the lake. Perch and Prussian carp, for example, were more common in northern parts while stone moroko, bitterling and carp occurred in higher numbers in the South. For a future monitoring of the entire fish community, sampling sites that cover both parts of the lake are needed. Moreover, the uneven occurrence of species needs to be taken into account in fishery management.

Introduced species (such as perch, stone moroko and bitterling) showed relatively constant abundances and biomasses (NPUE and CPUE) throughout the sampling period which indicates that these fish species have established stable populations (at least in certain parts of the lake) and could be marked as invasive for the lake. Their exact impact on local fish communities, however, still needs to be determined.

Based on data obtained in this study it can be stated that stock dynamics of bleak was different in Montenegrin and Albanian waters. While biomass and abundance of bleak from Albanian parts were alternating over the years, a decreasing stock development was noticed in Montenegrin waters. Such differences, in particular for species of economic and/or ecological importance, underline the need for transboundary monitoring and management of Lake Skadar/Shkodra fishes. It furthermore shows that bleak stock dynamics may be heavily affected by local variables (in contrast to large-scale environmental factors, such as climate, which equally affect the lake). This topic, however, also requires further studies.

In order to obtain further population parameters, especially to reconstruct natural mortality of bleak (and other species), information on species fecundity is desirable.

Fish are one of the biological quality elements used to assess the ecological status of water bodies according to the WFD. The fishery data obtained in the course of this project can be used for making further progress in the WFD-compliant assessment. The setting of class boundaries should be the next step in the assessment process.

In order to recognize trends in size structure and population dynamics of fish stocks, to avoid overexploitation, and to respond timely to detected fluctuations in structure and composition of the Lake Skadar/Shkodra fish community, it is essential not only to report catches but also to document fishing efforts. For the same reasons, a transboundary management of the stocks is needed.

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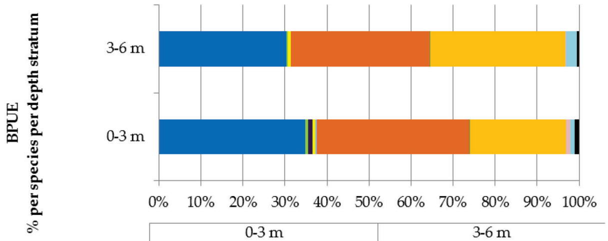
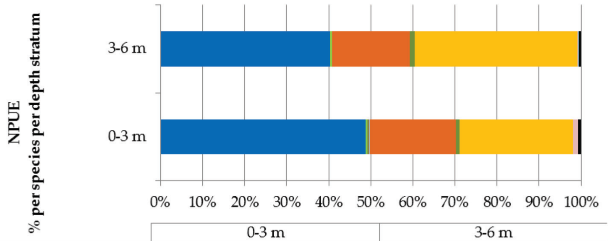
ANNEXES

Annex I. Standardized catches for the sub-basins

Sub-basin 1 - Vranjina / Virpazar / Grmožur

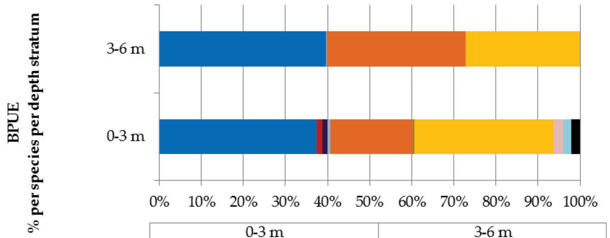


	0-3 m	3-6 m
Alburnoides ohridanus		
Alburnus scoranza	37.98	14.57
Alosa fallax		
Carassius gibelio	0.69	0.18
Chondrostoma nasus	1.20	
Cobitis meridionalis		
Cyprinus carpio	0.76	0.27
Pachychilon pictum	0.44	
Perca fluviatilis	39.56	15.85
Pseudorasbora parva	0.14	0.09
Rhodeus amarus	0.00	
Rutilus prespensis	24.85	15.42
Scardinius knezevici	1.22	0.07
Squalius platyceps	1.12	1.26
others	1.10	0.22

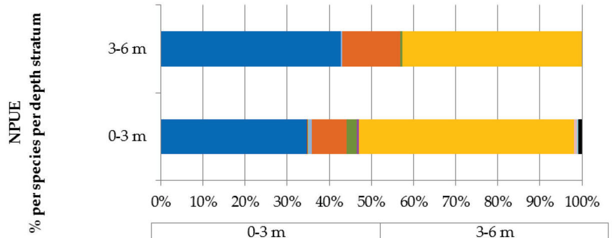


	0-3 m	3-6 m
Alburnoides ohridanus		
Alburnus scoranza	2.10	0.60
Alosa fallax		
Carassius gibelio	0.03	0.01
Chondrostoma nasus	0.01	
Cobitis meridionalis		
Cyprinus carpio	0.01	0.00
Pachychilon pictum	0.01	
Perca fluviatilis	0.88	0.27
Pseudorasbora parva	0.04	0.02
Rhodeus amarus	0.00	
Rutilus prespensis	1.17	0.57
Scardinius knezevici	0.05	0.00
Squalius platyceps	0.01	0.00
others	0.03	0.01

Figure 37. Standardized catches per unit of effort for sub-basin 1 of Lake Skadar/Shkodra during the sampling campaign of 2013. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.

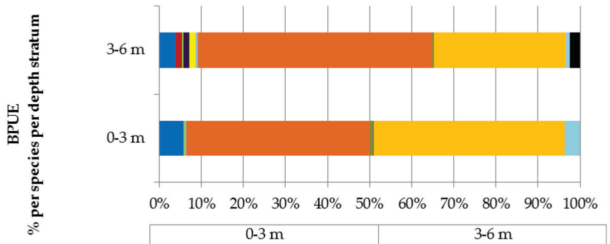


	0-3 m	3-6 m
Alburnoides ohridanus		
Alburnus scoranza	13.08	12.70
Alosa fallax	0.43	
Carassius gibelio	0.01	
Chondrostoma nasus	0.40	
Cobitis meridionalis		
Cyprinus carpio		
Pachychilon pictum	0.28	0.08
Perca fluviatilis	6.83	10.57
Pseudorasbora parva	0.11	0.01
Rhodeus amarus	0.01	
Rutilus prespensis	11.49	8.72
Scardinius knezevici	0.86	
Squalius platyceps	0.67	
others	0.70	

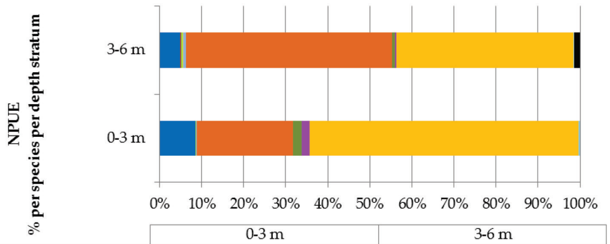


	0-3 m	3-6 m
Alburnoides ohridanus		
Alburnus scoranza	0.45	0.41
Alosa fallax	0.00	
Carassius gibelio	0.00	
Chondrostoma nasus	0.00	
Cobitis meridionalis		
Cyprinus carpio		
Pachychilon pictum	0.01	0.00
Perca fluviatilis	0.11	0.13
Pseudorasbora parva	0.03	0.00
Rhodeus amarus	0.01	
Rutilus prespensis	0.66	0.41
Scardinius knezevici	0.01	
Squalius platyceps	0.00	
others	0.01	

Figure 38. Standardized catches per unit of effort for sub-basin 1 of Lake Skadar/Shkodra during the sampling campaign of 2014. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.



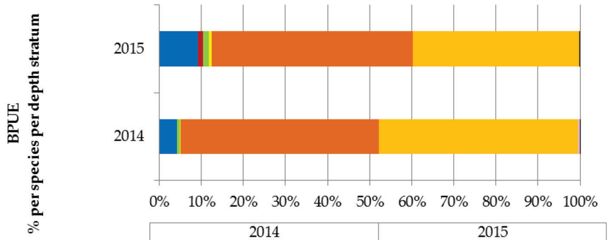
	0-3 m	3-6 m
Alburnoides ohridanus		
Alburnus scoranza	3.55	1.74
Alosa fallax		0.70
Carassius gibelio	0.25	0.15
Chondrostoma nasus		0.59
Cobitis meridionalis		
Cyprinus carpio		0.67
Pachychilon pictum	0.23	0.22
Perca fluviatilis	27.30	24.88
Pseudorasbora parva	0.38	0.09
Rhodeus amarus	0.10	0.01
Rutilus prespensis	28.28	13.96
Scardinius knezevici		0.09
Squalius platyceps	2.31	0.35
others		1.10



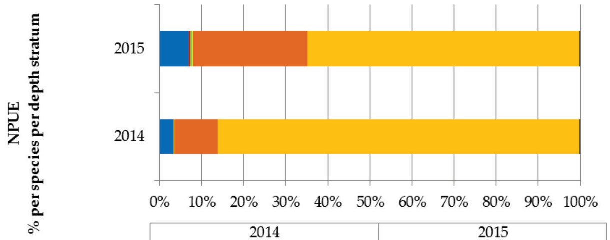
	0-3 m	3-6 m
Alburnoides ohridanus		
Alburnus scoranza	0.29	0.09
Alosa fallax		0.01
Carassius gibelio	0.01	0.00
Chondrostoma nasus		0.00
Cobitis meridionalis		
Cyprinus carpio		0.00
Pachychilon pictum	0.01	0.01
Perca fluviatilis	0.79	0.95
Pseudorasbora parva	0.07	0.01
Rhodeus amarus	0.06	0.01
Rutilus prespensis	2.23	0.81
Scardinius knezevici		0.00
Squalius platyceps	0.01	0.00
others		0.03

Figure 39. Standardized catches per unit of effort for sub-basin 1 of Lake Skadar/Shkodra during the sampling campaign of 2015. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.

Sub-basin 2 – Central Lake (water depths > 6 m)



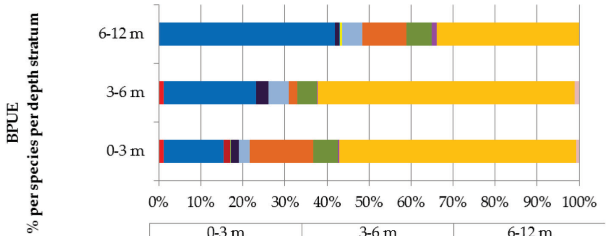
	2014	2015
Alburnoides ohridanus		
Alburnus scoranza	2.66	4.41
Alosa fallax		0.59
Carassius gibelio	0.45	0.70
Chondrostoma nasus		
Cobitis meridionalis		
Cyprinus carpio	0.10	0.30
Pachychilon pictum	0.01	
Perca fluviatilis	30.00	23.06
Pseudorasbora parva		
Rhodeus amarus		
Rutilus prespensis	30.15	19.01
Scardinius knezevici	0.29	
Squalius platyceps		
others	0.04	0.11



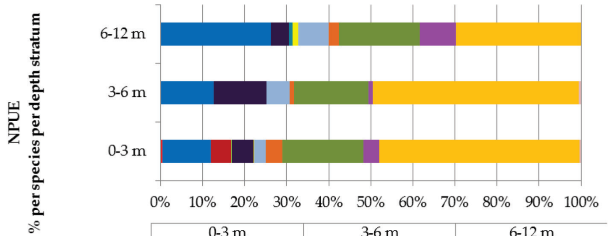
	2014	2015
Alburnoides ohridanus		
Alburnus scoranza	0.10	0.17
Alosa fallax		0.01
Carassius gibelio	0.00	0.01
Chondrostoma nasus		
Cobitis meridionalis		
Cyprinus carpio	0.00	0.00
Pachychilon pictum	0.00	
Perca fluviatilis	0.30	0.66
Pseudorasbora parva		
Rhodeus amarus		
Rutilus prespensis	2.47	1.58
Scardinius knezevici	0.00	
Squalius platyceps		
others	0.00	0.01

Figure 40. Standardized catches per unit of effort for sub-basin 2 of Lake Skadar/Shkodra during the sampling campaign of 2014 and 2015. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data represent the depth stratum > 6 m.

Sub-basin 3 - Koplik

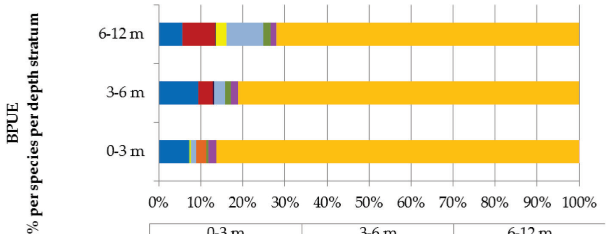


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus	0.13	0.15	
Alburnus scoranza	1.58	2.86	3.27
Alosa fallax	0.17		
Carassius gibelio	0.02		
Chondrostoma nasus	0.20	0.39	0.09
Cobitis meridionalis			0.01
Cyprinus carpio	0.02		0.03
Pachychilon pictum	0.27	0.61	0.39
Perca fluviatilis	1.69	0.26	0.82
Pseudorasbora parva	0.65	0.61	0.47
Rhodeus amarus	0.03	0.02	0.10
Rutilus prespensis	6.27	7.96	2.65
Scardinius knezevici	0.07	0.14	
Squalius platyceps			
others			

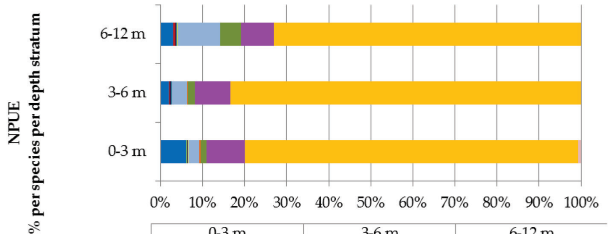


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus	0.00	0.00	
Alburnus scoranza	0.12	0.14	0.20
Alosa fallax	0.05		
Carassius gibelio	0.00		
Chondrostoma nasus	0.05	0.14	0.03
Cobitis meridionalis			0.01
Cyprinus carpio	0.00		0.01
Pachychilon pictum	0.03	0.06	0.05
Perca fluviatilis	0.04	0.01	0.02
Pseudorasbora parva	0.20	0.20	0.14
Rhodeus amarus	0.04	0.01	0.06
Rutilus prespensis	0.48	0.56	0.22
Scardinius knezevici	0.00	0.01	
Squalius platyceps			
others			

Figure 41. Standardized catches per unit of effort for sub-basin 3 of Lake Skadar/Shkodra during the sampling campaign of 2013. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.

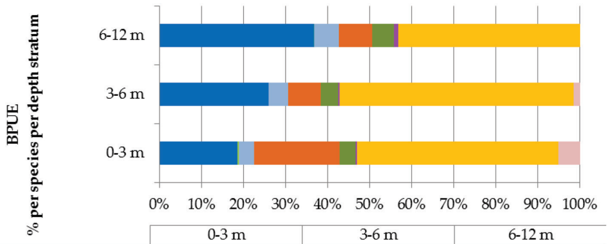


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus			
Alburnus scoranza	1.08	0.67	0.90
Alosa fallax		0.26	1.26
Carassius gibelio	0.04		
Chondrostoma nasus	0.00	0.02	0.01
Cobitis meridionalis	0.01	0.01	0.01
Cyprinus carpio	0.02		0.42
Pachychilon pictum	0.18	0.18	1.41
Perca fluviatilis	0.37	0.00	
Pseudorasbora parva	0.06	0.09	0.29
Rhodeus amarus	0.28	0.13	0.23
Rutilus prespensis	12.98	5.84	11.66
Scardinius knezevici	0.01		
Squalius platyceps			
others			

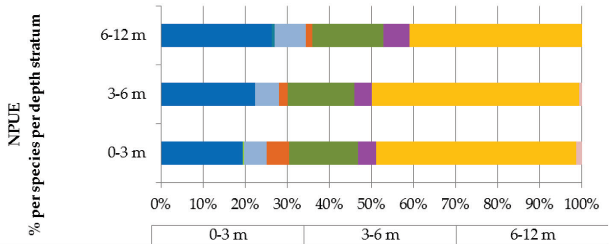


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus			
Alburnus scoranza	0.11	0.02	0.06
Alosa fallax		0.00	0.01
Carassius gibelio	0.00		
Chondrostoma nasus	0.00	0.00	0.00
Cobitis meridionalis	0.00	0.00	0.00
Cyprinus carpio	0.00		0.00
Pachychilon pictum	0.04	0.04	0.19
Perca fluviatilis	0.01	0.00	
Pseudorasbora parva	0.02	0.02	0.09
Rhodeus amarus	0.16	0.09	0.14
Rutilus prespensis	1.38	0.94	1.37
Scardinius knezevici	0.01		
Squalius platyceps			
others			

Figure 42. Standardized catches per unit of effort for sub-basin 3 of Lake Skadar/Shkodra during the sampling campaign of 2014. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.



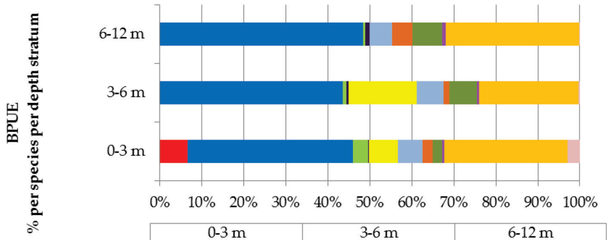
	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus			
Alburnus scoranza	2.99	4.09	5.38
Alosa fallax			
Carassius gibelio	0.05		
Chondrostoma nasus			
Cobitis meridionalis			0.01
Cyprinus carpio			
Pachychilon pictum	0.58	0.76	0.87
Perca fluviatilis	3.25	1.22	1.16
Pseudorasbora parva	0.61	0.64	0.77
Rhodeus amarus	0.04	0.07	0.14
Rutilus prespensis	7.71	8.79	6.35
Scardinius knezevici	0.82	0.23	
Squalius platyceps			
others			



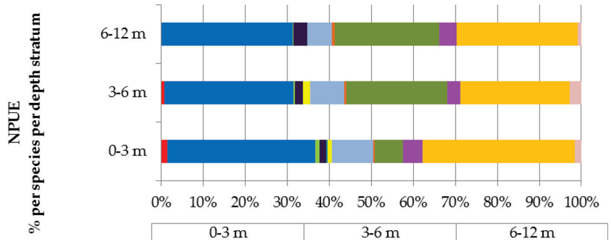
	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus			
Alburnus scoranza	0.26	0.30	0.38
Alosa fallax			
Carassius gibelio	0.00		
Chondrostoma nasus			
Cobitis meridionalis			0.01
Cyprinus carpio			
Pachychilon pictum	0.07	0.08	0.11
Perca fluviatilis	0.07	0.03	0.02
Pseudorasbora parva	0.22	0.21	0.24
Rhodeus amarus	0.06	0.06	0.09
Rutilus prespensis	0.63	0.67	0.59
Scardinius knezevici	0.02	0.01	
Squalius platyceps			
others			

Figure 43. Standardized catches per unit of effort for sub-basin 3 of Lake Skadar/Shkodra during the sampling campaign of 2015. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.

Sub-basin 4 - Shirokë

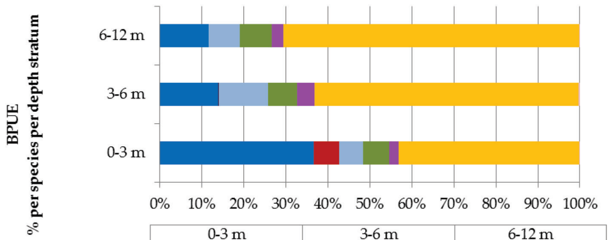


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus	0.71	0.03	
Alburnus scoranza	4.18	7.50	5.84
Alosa fallax			
Carassius gibelio	0.38	0.14	0.06
Chondrostoma nasus	0.02	0.09	0.11
Cobitis meridionalis	0.00		
Cyprinus carpio	0.73	2.81	
Pachychilon pictum	0.64	1.09	0.65
Perca fluviatilis	0.25	0.25	0.58
Pseudorasbora parva	0.23	1.14	0.87
Rhodeus amarus	0.06	0.08	0.10
Rutilus prespensis	3.12	4.08	3.83
Scardinius knezevici	0.31	0.05	0.01
Squalius platyceps			
others			

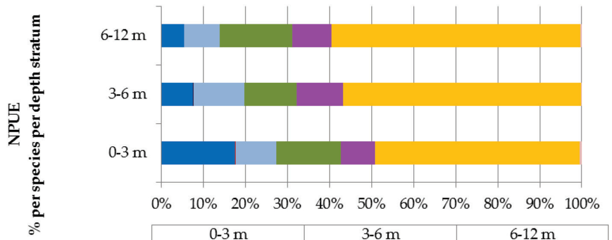


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus	0.01	0.01	
Alburnus scoranza	0.34	0.45	0.34
Alosa fallax			
Carassius gibelio	0.01	0.00	0.00
Chondrostoma nasus	0.01	0.03	0.04
Cobitis meridionalis	0.00		
Cyprinus carpio	0.01	0.02	
Pachychilon pictum	0.09	0.12	0.06
Perca fluviatilis	0.00	0.01	0.01
Pseudorasbora parva	0.06	0.35	0.27
Rhodeus amarus	0.04	0.05	0.05
Rutilus prespensis	0.34	0.38	0.32
Scardinius knezevici	0.02	0.04	0.01
Squalius platyceps			
others			

Figure 44. Standardized catches per unit of effort for sub-basin 4 of Lake Skadar/Shkodra during the sampling campaign of 2013. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.

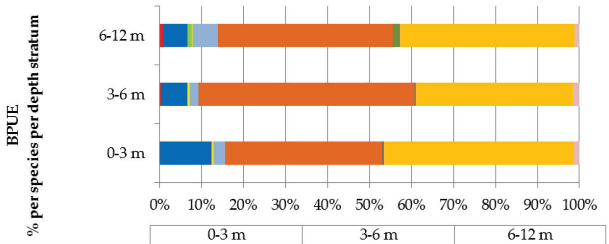


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus			
Alburnus scoranza	5.27	1.10	0.96
Alosa fallax	0.87		
Carassius gibelio			
Chondrostoma nasus		0.02	
Cobitis meridionalis			
Cyprinus carpio			
Pachychilon pictum	0.81	0.93	0.60
Perca fluviatilis			
Pseudorasbora parva	0.90	0.54	0.63
Rhodeus amarus	0.30	0.33	0.22
Rutilus prespensis	6.19	4.99	5.78
Scardinius knezevici	0.01	0.02	0.01
Squalius platyceps			
others			

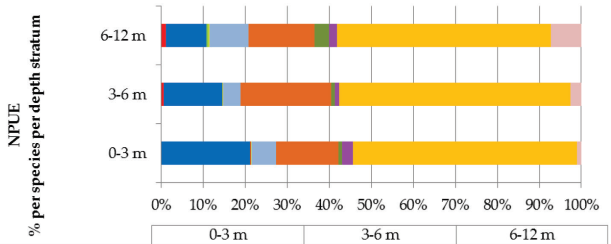


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus			
Alburnus scoranza	0.44	0.16	0.11
Alosa fallax	0.01		
Carassius gibelio			
Chondrostoma nasus		0.01	
Cobitis meridionalis			
Cyprinus carpio			
Pachychilon pictum	0.24	0.25	0.16
Perca fluviatilis			
Pseudorasbora parva	0.39	0.26	0.33
Rhodeus amarus	0.21	0.23	0.18
Rutilus prespensis	1.24	1.19	1.14
Scardinius knezevici	0.01	0.00	0.01
Squalius platyceps			
others			

Figure 45. Standardized catches per unit of effort for sub-basin 4 of Lake Skadar/Shkodra during the sampling campaign of 2014. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.



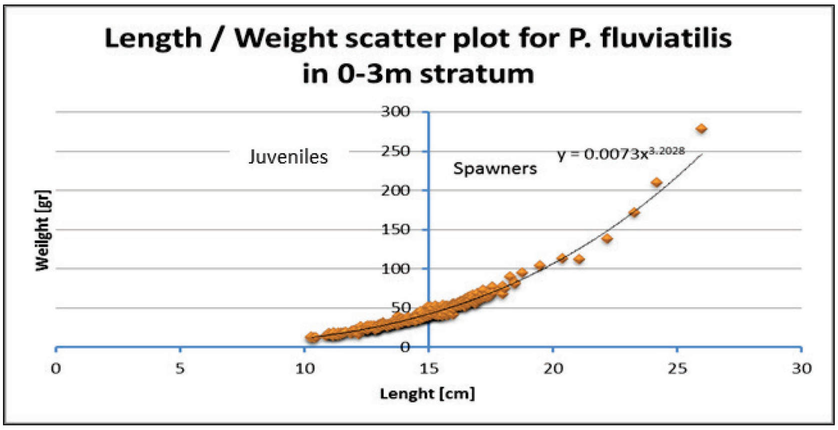
	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus	0.02	0.09	0.18
Alburnus scoranza	5.89	2.19	1.42
Alosa fallax	0.13		
Carassius gibelio	0.07		0.24
Chondrostoma nasus			
Cobitis meridionalis			
Cyprinus carpio	0.18	0.17	0.04
Pachychilon pictum	1.32	0.72	1.47
Perca fluviatilis	18.23	17.71	9.98
Pseudorasbora parva	0.10	0.10	0.35
Rhodeus amarus	0.15	0.05	0.06
Rutilus prespensis	22.15	12.89	9.98
Scardinius knezevici	0.63	0.54	0.29
Squalius platyceps			
others			

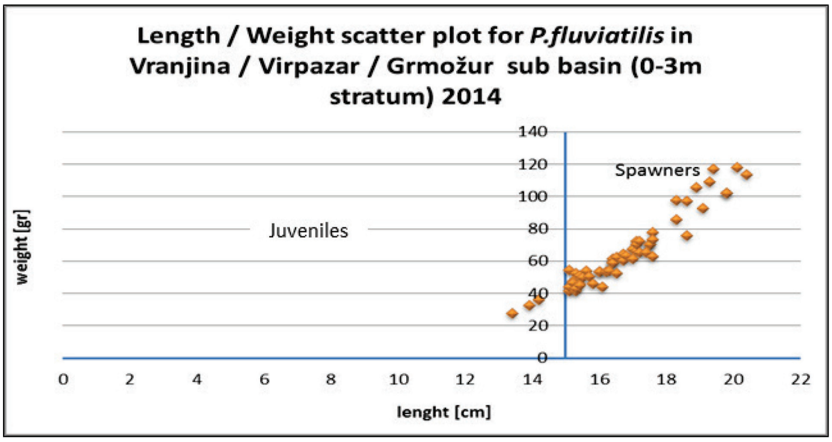


	0-3 m	3-6 m	6-12 m
Alburnoides ohridanus	0.01	0.01	0.02
Alburnus scoranza	0.71	0.31	0.21
Alosa fallax	0.00		
Carassius gibelio	0.00		0.01
Chondrostoma nasus			
Cobitis meridionalis			
Cyprinus carpio	0.00	0.01	0.00
Pachychilon pictum	0.20	0.09	0.20
Perca fluviatilis	0.51	0.47	0.34
Pseudorasbora parva	0.03	0.02	0.07
Rhodeus amarus	0.09	0.03	0.04
Rutilus prespensis	1.80	1.21	1.08
Scardinius knezevici	0.04	0.06	0.16
Squalius platyceps			
others			

Figure 46. Standardized catches per unit of effort for sub-basin 4 of Lake Skadar/Shkodra during the sampling campaign of 2015. Left: biomass/m² of net (CPUE in g/m²). Right: number of individuals/m² (NPUE in ind./m²). Upper bars show the respective percentage of species. Data are given separately for the depth strata.

Annex II. Length / Weight scatter plots





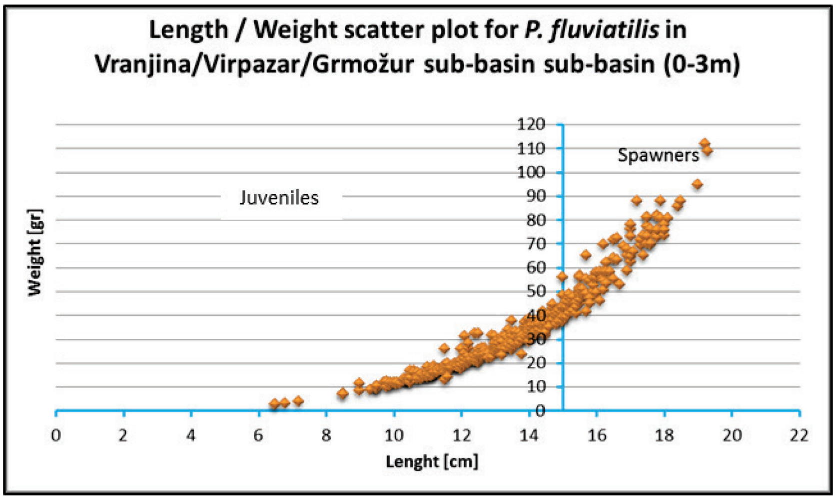
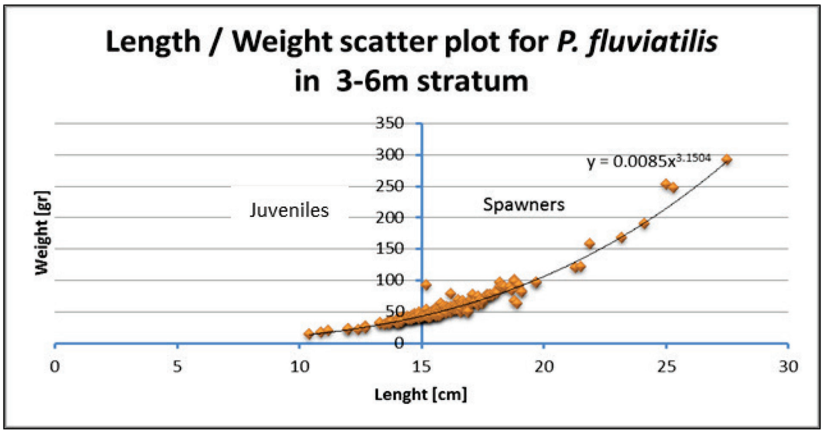
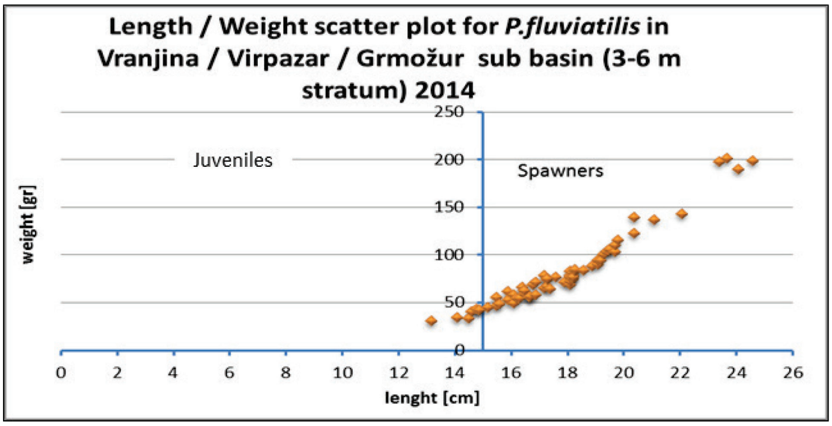


Figure 47. Length/Weight scatter plot for perch (*Perca fluviatilis*) in 0-3 m stratum of Vranjina / Virpazar / Grmožur sub-basin in 2013 (top), 2014 (middle) and 2015 (bottom)





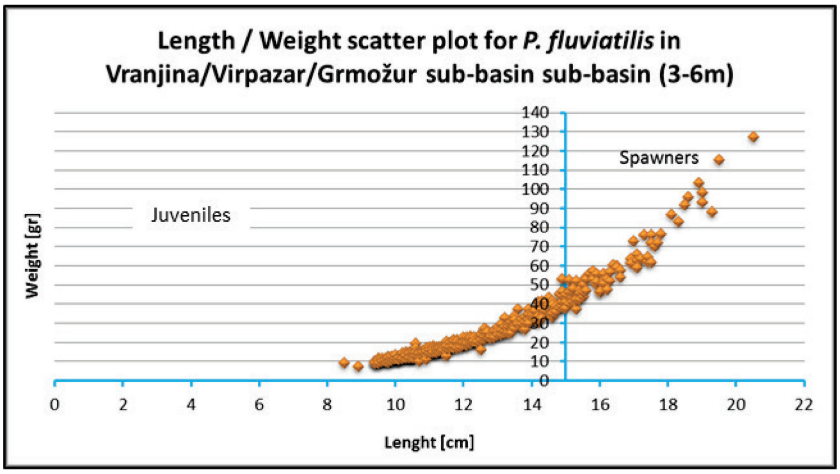
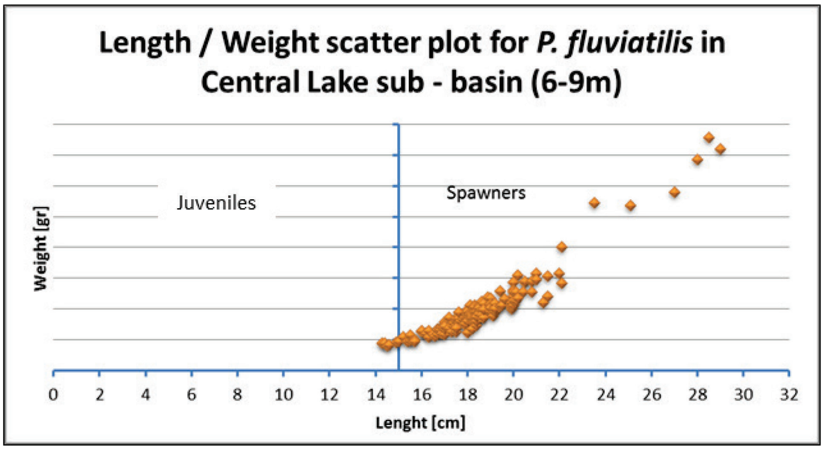


Figure 48. Length/Weight scatter plot for perch (*Perca fluviatilis*) in 3-6 m stratum of Vranjina / Virpazar / Grmožur sub-basin in 2013 (top), 2014 (middle) and 2015 (bottom)



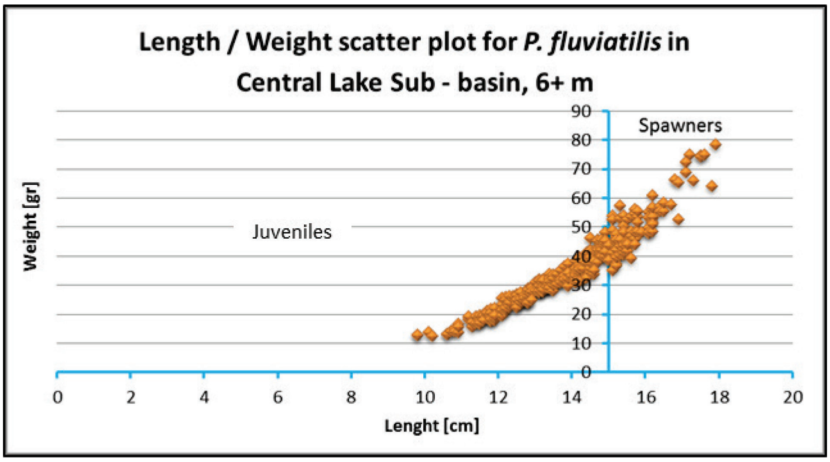


Figure 49. Length/Weight scatter plot for perch (*Perca fluviatilis*) in 6 m+ stratum of Central Lake sub-basin in 2014 (top) and 2015 (bottom)

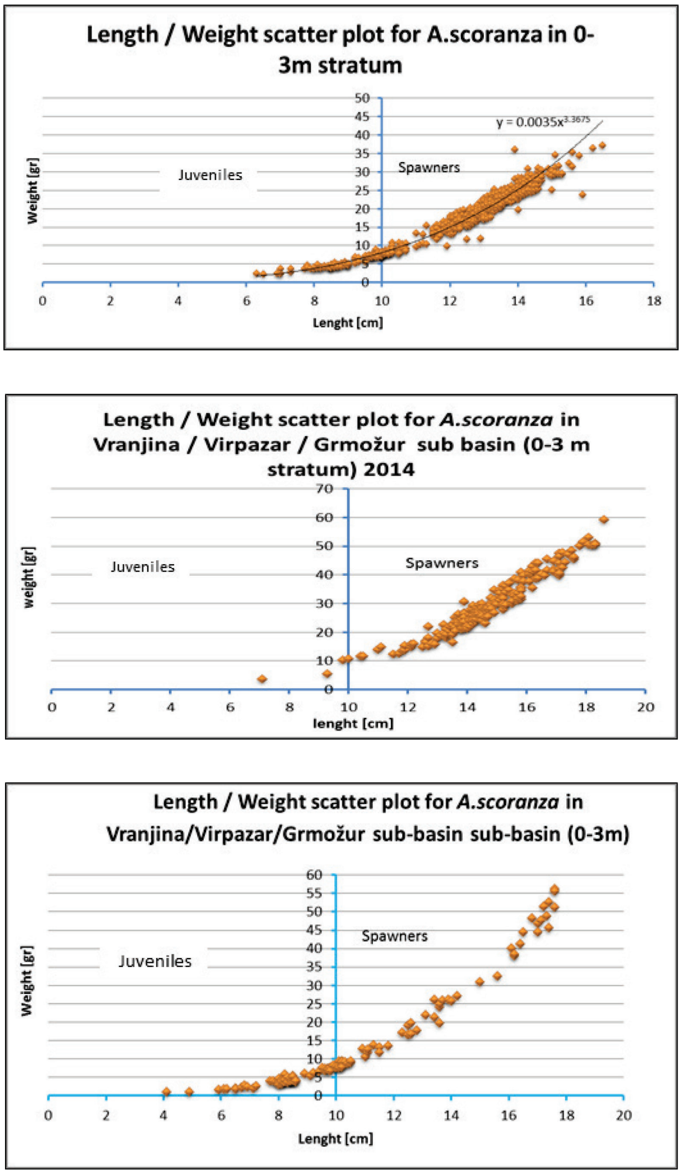
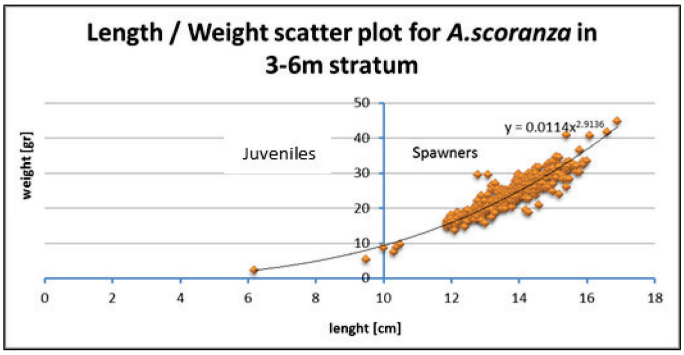
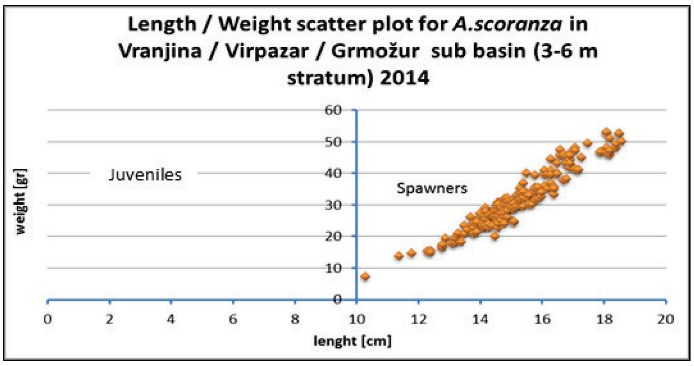


Figure 50. Length/Weight scatter plot for bleak (*Alburnus scoranza*) in 0-3 m stratum of Vranjina / Virpazar / Grmožur sub-basin in 2013 (top), 2014 (middle) and 2015 (bottom)





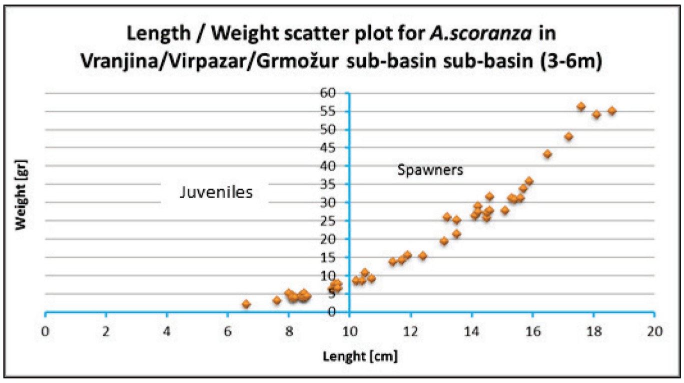
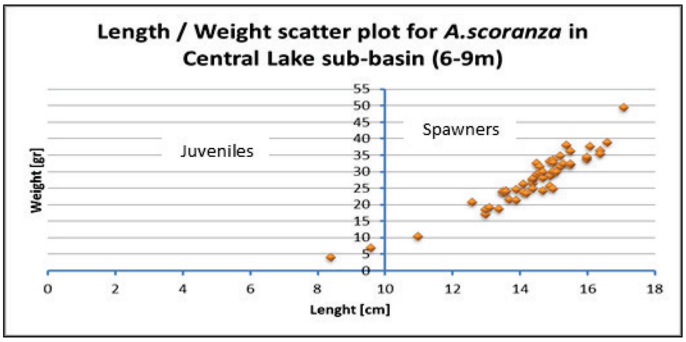


Figure 51. Length/Weight scatter plot for bleak (*Alburnus scoranza*) in 3-6 m stratum of Vranjina / Virpazar / Grmožur sub-basin in 2013 (top), 2014 (middle) and 2015 (bottom)



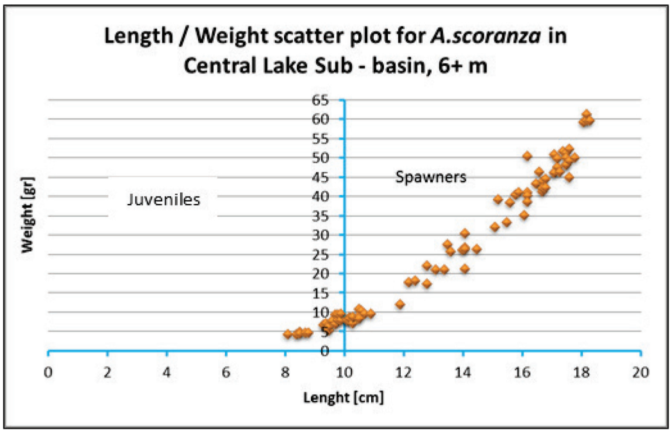
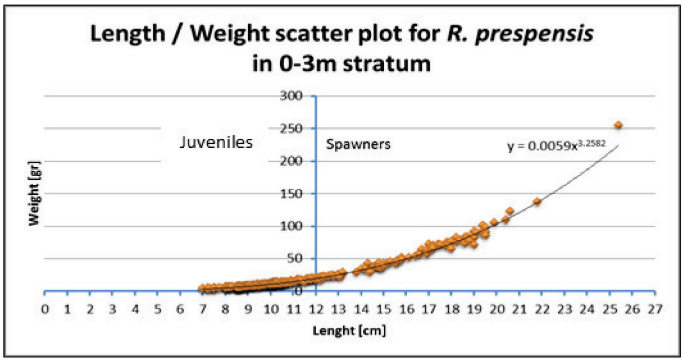
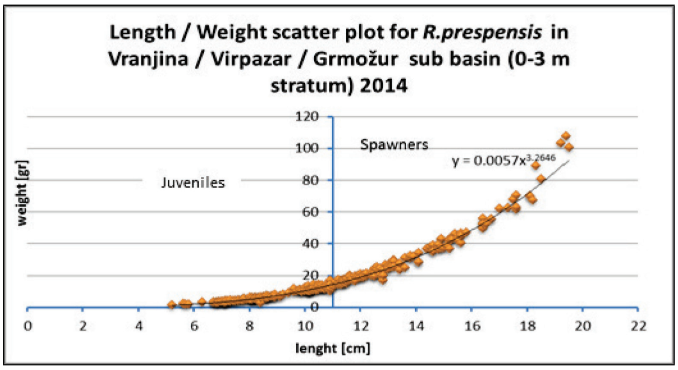


Figure 52. Length/Weight scatter plot for bleak (*Alburnus scoranza*) in 6 m+ stratum of Central Lake sub-basin in 2014 (top) and 2015 (bottom)





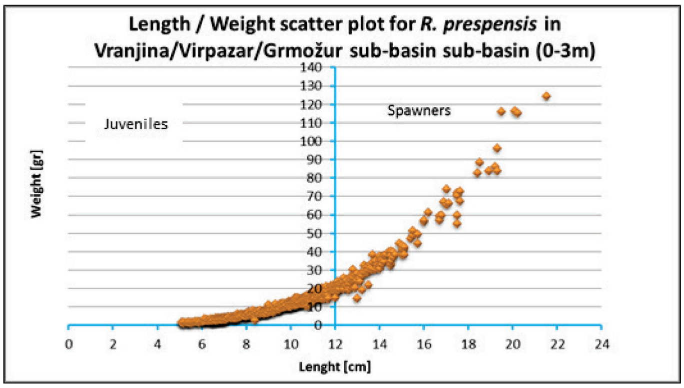


Figure 53. Length/Weight scatter plot for roach (*Rutilus prespensis*) in 0-3 m stratum of Vranjina / Virpazar / Grmožur sub-basin in 2013 (top), 2014 (middle) and 2015 (bottom)

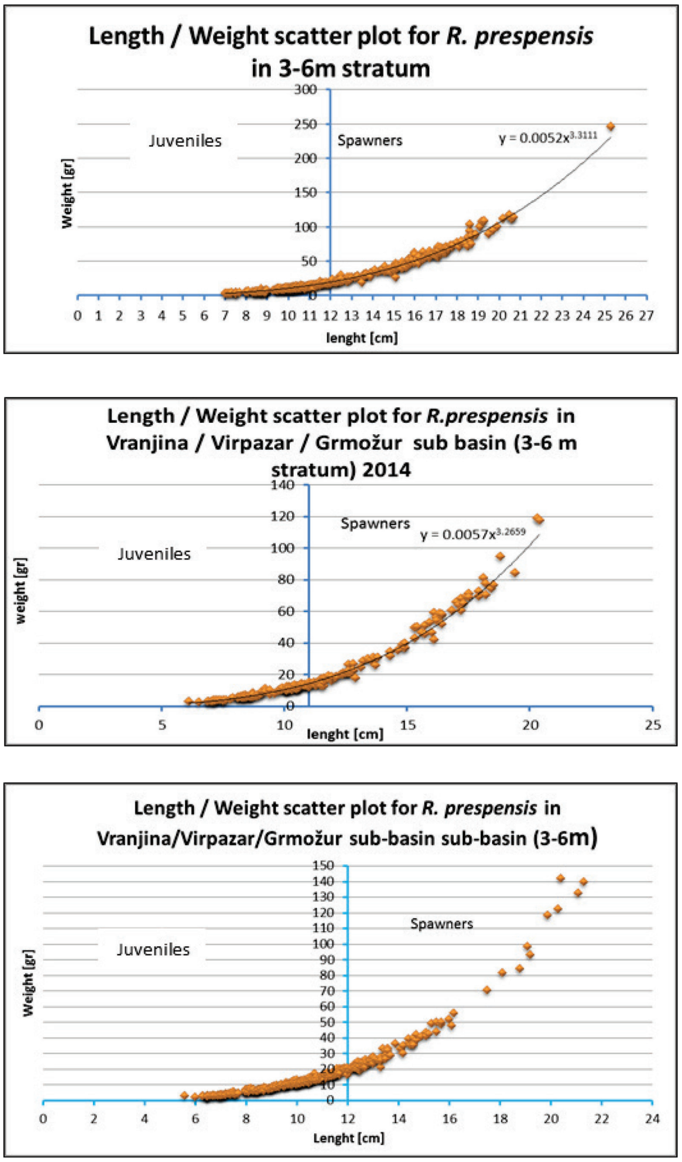


Figure 54. Length/Weight scatter plot for roach (*Rutilus prespensis*) in 3-6 m stratum of Vranjina / Virpazar / Grmožur sub-basin in 2013 (top), 2014 (middle) and 2015 (bottom)

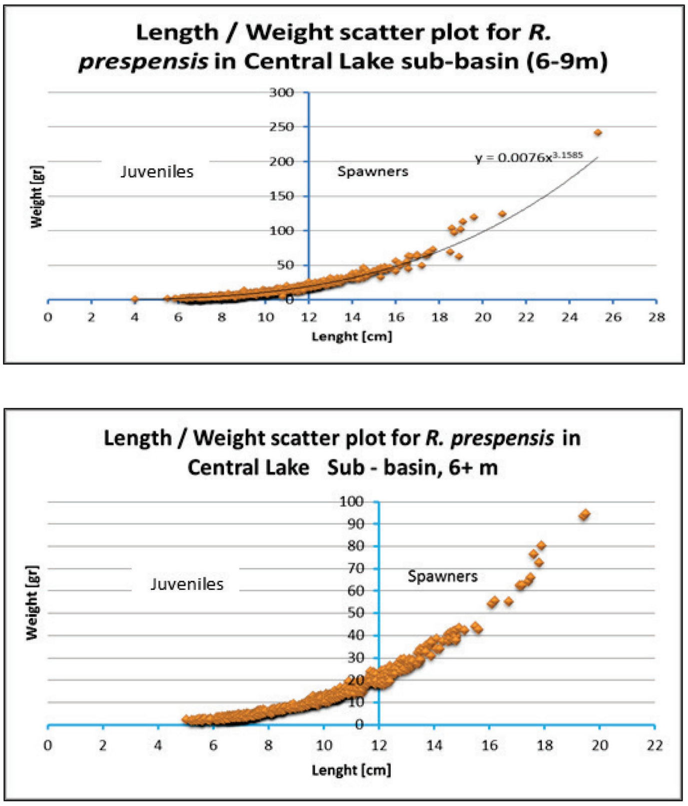
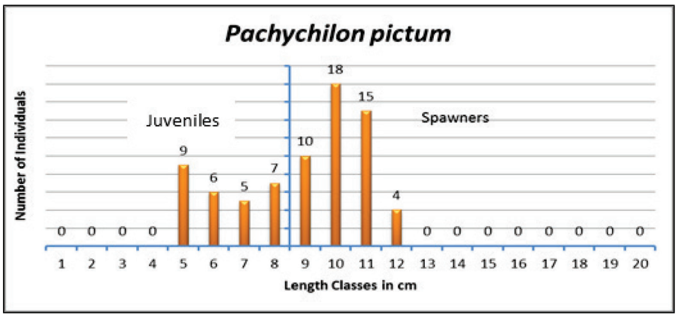


Figure 55. Length/Weight scatter plot for roach (*Rutilus prespensis*) in 6 m+ stratum of Central Lake sub-basin in 2014 (top) and 2015 (bottom)

Annex III. Length-frequency distributions



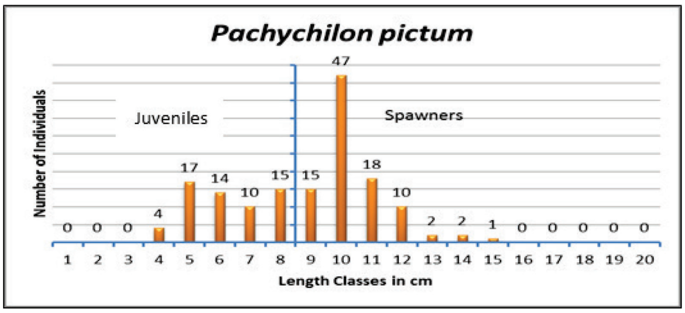


Figure 56. Length frequency of *Pachychilon pictum* in total catch of Koplik (top) and Shirokë (bottom) sub-basins (2013)

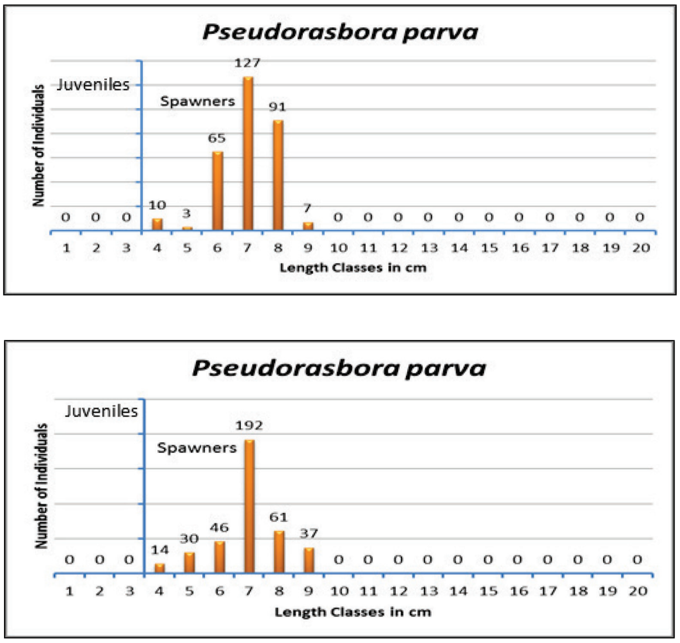


Figure 57. Length frequency of *Pseudorasbora parva* in total catch of Koplik (top) and Shirokë (bottom) sub-basins (2013)

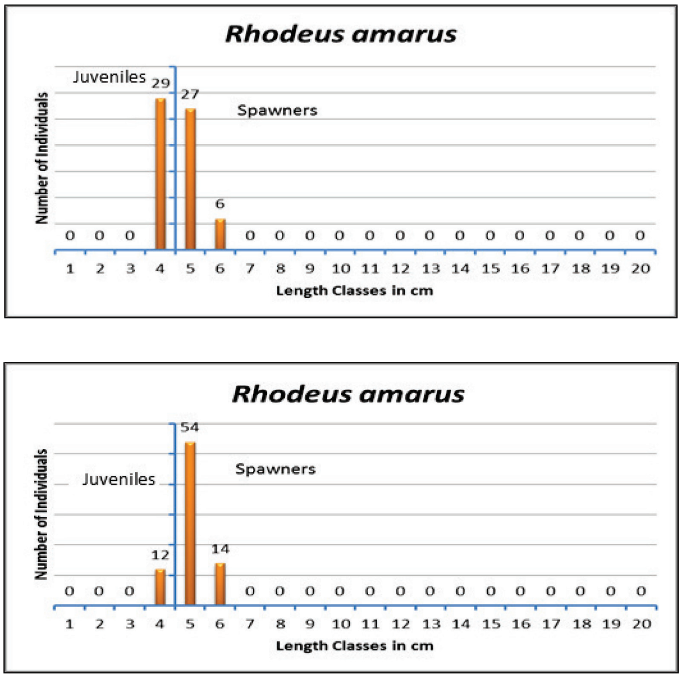


Figure 58. Length frequency of *Rhodeus amarus* in total catch of Koplik (top) and Shirokë (bottom) sub-basins (2013)