Introduction to Freshwater Fish Ecology and Management

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A Presentation of Applied Methods

By

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Cambridge Scholars Publishing

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INTRODUCTION

This is an introduction to freshwater fish biology and applied research, with a presentation of freshwater fish species in Norway, and their immigration, distribution, and ecological roles. It is based on Norwegian and Scandinavian conditions, with an environment characterized by pronounced seasonal variation, with annual ice cover and cool summer temperatures. Due to the topography and postglacial history of freshwater organism invasion, the number of species is quite low, and a lot of lakes and streams have only one or two fish species. This makes them especially vulnerable to the introduction of new species.

Prehistory and Evolution

Life on Earth originated in the sea, about three billion years ago, with living organisms defined as "something" with metabolism and an ability to multiply. After an additional one billion years, some organisms developed the ability to extract energy from sunlight and to build organic molecules from carbon dioxide and water, with oxygen in molecular form (O_2) as a byproduct. The first bacteria conducting photosynthesis, the basis for most of what we know of life on the planet today, started the "oxygen revolution".

The sea slowly received oxygen from these organisms, and the environmental conditions changed in perpetuity. This meant disaster for organisms that did not tolerate oxygen (the strictly anaerobic), forcing them to retreat to oxygen-free areas in the sediments of oceans and lakes. For others, this offered new opportunities and future success. Most multicellular and advanced forms of life depend on oxygen, produced by algae and plants. Among procaryotic organisms (bacteria and archaea), some evolved the ability to fix atmospheric nitrogen (N_2, which makes up 78% of the air) by converting it into ammonium (NH_4^+), which is bioavailable. Some cyanobacteria in lakes gain from this when access to phosphorus is abundant (normally the limiting factor to primary production in freshwater), and this may boost algal blooms. This property was long considered exclusive to prokaryotic organisms, but new research has shown that some algae also possess this skill (Coale et al. 2024, 217).

Evidence of the oldest known multicellular organisms has been left in 600-million-year-old fossils, some of which have living descendants, but numerous forms have emerged in the meantime. The earliest fish known to date is a more than 500-million-year-old fossil (Morris 2008, 424). These were the first chordates provided with vertebra for the attachment of limbs and muscles and for the protection of the important spinal nerve. The earliest skeletons were of cartilage, which is still found in sharks. Sharks have inhabited the world's oceans for 400 million years, and they were a success from the beginning, having existed with minor changes since then. Bony fish appeared concurrently, whereas the modern ray finned bony fish developed during the last 200 million years (Benton 1990, 472).

THE CONSTRUCTION AND FUNCTION OF FISH

Morphology

Bony fish have their skin covered by scales and a protective mucus layer, a tailfin, dorsal fin(s), anal fin and the paired pectoral and pelvic fins, which point towards the more advanced vertebrates, tetra pods with two pairs of limbs, amphibians, reptiles, birds, and mammals. The vertebral column extends from head to tail fin and is, together with the dorsal musculature and fins, the main tool for locomotion/swimming. The design of fins, with or without rays, spiny fins or soft fins, and the location relative to each other characterize species and taxonomic groups, as do the shape of scales, and the shape and location of the mouth (the length of jawbones). In contrast to sharks, bony fish have opercular bones that help to pump water over the gills when the fish is at rest. The number and design of the fish's teeth are adapted to its way of life. Predatory, fish such as pike (*Esox lucius*), have numerous sharp teeth, not only in the jaws but also in the groom, for grasping and holding prey before swallowing, without chewing. Plankton-feeding fish, however, like most of the coregonids, whitefish and vendace, and many cyprinids, have no teeth. An exception here is the small (< 15 cm) plankton-feeding salmonid, the smelt (*Osmerus eperlanus*), with predator's teeth and a potential to develop as a piscivore and grow relatively large (>25 cm). Cyprinids have their pharyngeal teeth in the roof of the pharynx, with which it can crush food items like shells of mollusks.

Anatomy and Physiology

The pharynx leads from the mouth to the esophagus, then further to the stomach and to the intestine, continuing to the anus. Close to the stomach a varying (with species) number of pylorus tubes are attached to the intestine. Glands are the kidney, liver, spleen, and gall bladder, the latter partly translucent with a characteristic greenish color; the others are typically dark red. The heart has a pyramidal form, is dark red, and situated in the bottom of the belly. It has a ventricle and an atrium. Blood is pumped forward and up through the gill filaments to emit carbon dioxide and absorb oxygen, before being pressed backward in a dorsal vein and distributed to the body

vascular system, being collected again and leading to the ventral cardiac atrium and ventricle.

Freshwater environments have requirements for organisms different than marine environments due to their low salinity, which creates an osmotic pressure that attempts to squeeze salt out of and water into the fish, aiming to equalize the concentrations. To cope with this, fish must conduct an active salt uptake (e.g., sodium and chloride) and an active fluid outward transport. This takes place in different organs of the fish, although both monovalent ions such as sodium Na^+ and Cl^- chloride and divalent ions such as calcium Ca^{2+} and Mg^{2+} are exchanged mainly through the gills, some is exchanged through skin, gut, and kidney (Beyenbach 2004, F811; Maetz 1971, 209; Sanderson, Derry, and Hendry 2021, 6053). Water is excreted in urine from the kidney (an organ running along the roof of the body cavity). Sharks lack an excretion organ, and their body fluids have approximately the same salinity as seawater. This makes them fit for a life in the ocean, but the low salinity of freshwater makes it an unsuitable habitat for sharks. There are exceptions, however.

The nervous system of a fish has its center, the brain, in the head's upper part, and it is associated with the spinal nerve connected to the smaller nerves in the body. In the fish brain there are some small bones, the otoliths, located in slime bags, which tell the fish its vertical orientation. The largest pair of these, the sacculus otoliths, are used for the age determination of many species. Some special features of bony fish include sidelines and the swim bladder. The sideline is a channel filled with mucus and nerve receptors, running along each side of the body wall, through the scales. Nerves register when the mucus canal is subjected to pressure changes. The swim bladder is an elongated "balloon" (salmonids and percids) on top of the abdominal cavity, against the kidney and backbone. In cyprinids, the swim bladder consists of two consecutive "balloons". The pressure is adjusted to the pressure outside the fish, that is, according to the depth at which the fish is situated and the present atmospheric pressure. In some species the swim bladder is connected to the pharynx (the physostome species, like salmonids), whereas in other species (the physocliste species, like percids) the pressure in the bladder is regulated by the blood, which can emit or capture gas, respectively, from thin veins at two locations in the swim bladder.

Gonads, male milt, and female roe, which develop prior to the breeding season, are located along the swim bladder. In most species, there are two gonads. The color, length, thickness and grain size (roe size in females) tell us whether it is male or female and whether the fish is mature and preparing

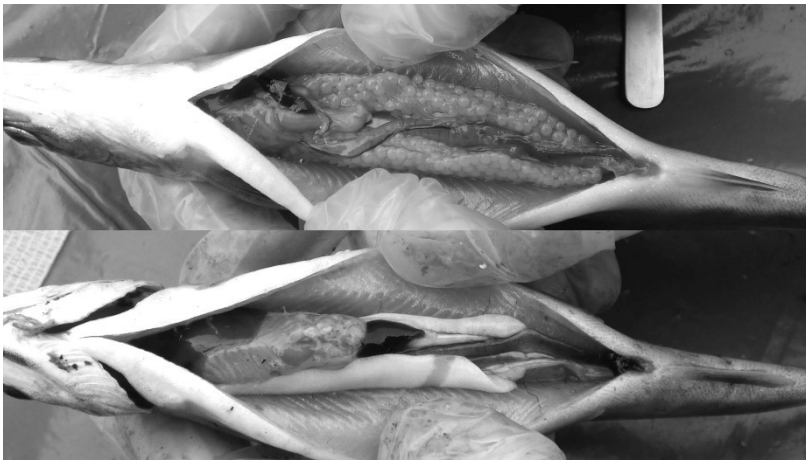

Figure 1. Mature brown trout female (upper) and male (lower).

for spawning (Fig. 1). In percids the females have only one gonad situated in the posterior of the body cavity.

As poikilothermic animals, the body temperature of fish varies due to the ambient surrounding environmental temperature. Due to this, physical activity, swimming activity and speed, as well as the speed of metabolic processes increase with temperature, but within certain intervals depending on species adaptation and individual acclimation.

Populations and species spawn at a certain time of the year adapted to the local environmental conditions and the species traits. Larvae must hatch when suitable food is available. The incubation time (from spawning to hatching) depends on water temperature and the population's adaptation. A certain input of thermal energy input measured as Accumulated Thermal Units (ATU) (or temperature sum) is needed. Thermal units are measured as daily temperature measurements summarized over days, i. e., 10 °C in ten days is 100 ATU, whereas 5 °C in 10 days is 50 ATU. The demand varies between species (Sternecker, Denic, and Geist 2014, 2749) and populations (Berg and Moen 1999, 636).

EUROPEAN FRESHWATER FISH SPECIES

Freshwater fish species in Europe are represented by 26 families, and the number of species is a matter of discussion, as this varies with the species concept (Hausdorf 2011, 923; Cowx, Fisher, and Broughton 1986, 95; Cowx 1991, 154). Kottelat and Freihof (2007) define approximately 525 freshwater fish species of Europe, of which numerous species are endemic in small locations, and some may be regarded, by other biologists, as ecotypes or morphological variants due to isolation. Nevertheless, the definition of species is crucial, as it is a management unit and of great importance in conservation work. Endemic species in small, restricted areas will appear as threatened and will call for protection, but this is not the case for a local population of a widely distributed species. The cyprinids (with six subfamilies) and salmonids (with three subfamilies) are two of the most species-rich families. They are important to humans and also play important ecological roles in freshwater ecosystems. They both include species represented in most of Europe, often in high densities, whereas some species have very limited distribution, and some are threatened. Others occur as alien species after their introduction to new areas by humans. The management of these species therefore demands very different strategies. Perch (*Perca fluviatilis*) and pike (*Esox lucius*) represent two families of relatively few species that are paid much interest by both fish managers and anglers. In the following text, some selected European freshwater fish families and species are presented alphabetically, focusing on species present in Norway and Scandinavia and their immigration history.

Freshwater Fish Immigration in Western Scandinavia

An understanding of the distribution and assumed immigration history of the 32 naturally occurring freshwater fish species in Norway is based on an old fundamental work by Huitfeldt-Kaas (1918), which still holds true, with some exceptions mostly due to human-induced changes. The number of species is low, due to the location of the sea, the topography and glacial history, with consequences for the availability of fish in water courses and lakes.

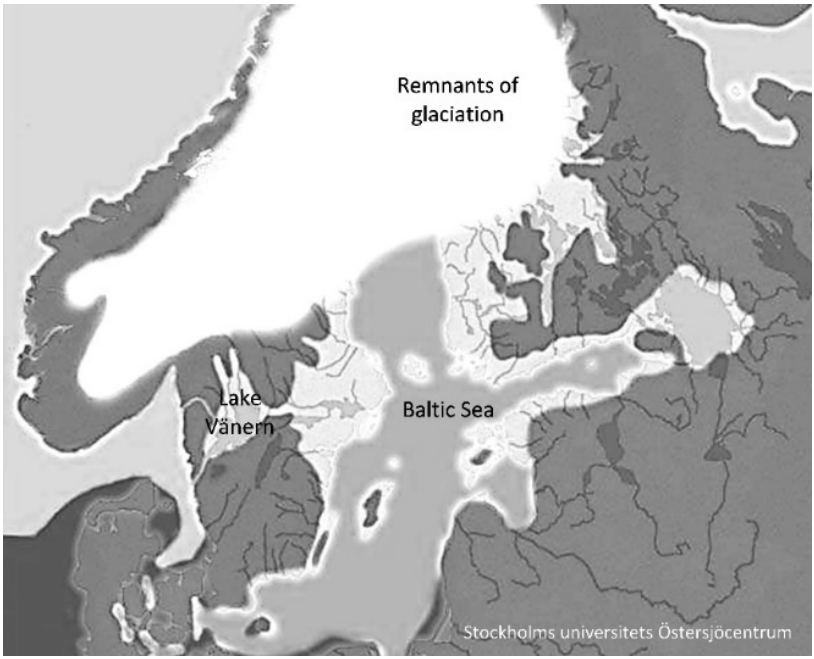

Figure 2. The freshwater Lake Ancylus (10,500 years BP). covering the present Lake Vänern and the Baltic Sea, with some surrounding land. The white area represents the remnants of Fennoscandian glaciation (after Andrén (2003, 8), in "Havsutsikt").

The western immigrants comprise species that can live in saltwater, primarily anadromous species, spawning in freshwater and migrating to the sea to seek nourishment, before maturation and returning to spawn.

The European eel (*Anguilla anguilla*), which is catadromous, does it the opposite way, spawning in the sea (Saragasso), the larvae crossing the Atlantic and spending much of their young stages in freshwater.

The eastern immigrants are divided into the southeastern species, which entered from Lake Ancylus (Fig. 2), once covering parts of current southern Sweden and the Baltic region, and northeastern immigrants, which entered from current Finland and Russia. Among these we find the (obligate) freshwater fish species dependent on continuous freshwater systems to immigrate.

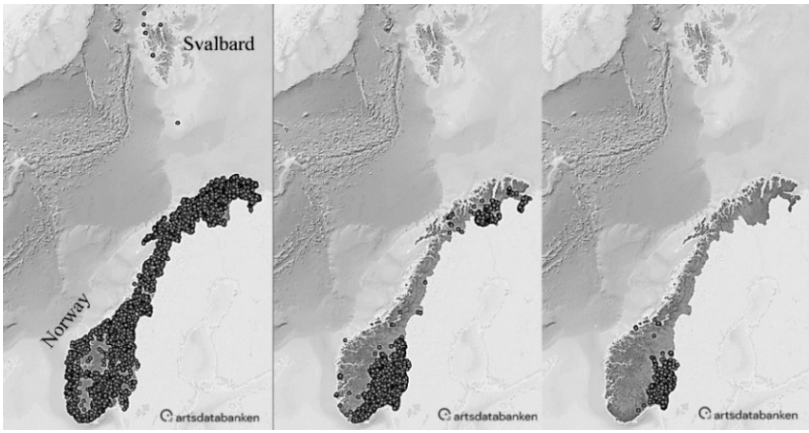

Figure 3. Geographic distribution of three fish species representing three different distribution patterns: the Arctic charr as both an eastern and western immigrant (left), the perch as a southeastern and northeastern immigrant (middle), and the roach as a southeastern immigrant (right). Single occurrences outside the clusters of observations are the results of stocking, though the Arctic charr in Svalbard is natural (after Artsdatabanken (2023).

Some species were introduced by humans during the last 100–150 years. Three species, the rainbow trout (*Oncorhynchus mykiss*), the Canadian brook trout (*Salvelinus fontinalis*) (first time in 1876) and the lake trout (*Salvelinus namaycush*), were introduced deliberately and legally during the 19th and the 20th centuries, while two species, the sunbleak (*Leucaspius delineatus*) and the gudgeon (*Gobio gobio*) have been introduced to some locations illegally during the past 30 years. The minnow (*Phoxinus phoxinus*) is a naturally occurring species in southeastern parts of Norway, but has been spread for a long time, probably by anglers using it as bait. Other species have been spread by people who then want to fish them. Lately, carp (*Cyprinus carpio*) seems to have been spread by people with an interest in modern bait fishing.

Western Immigrants

The western immigrants include the anadromous Atlantic salmon (*Salmo salar*), the brown trout (*Salmo trutta*), the Arctic charr (*Salvelinus alpinus*) of the salmonid family, and the three-spined stickleback (*Gasterosteus aculeatus*). They spawn in freshwater but can live in saltwater as adults; but they can also be freshwater resident, although it is exceptional for the salmon. The anadromous salmonids develop through several stages, from

larvae and **fry** the first season (like other species), followed by the **parr** stage. The parr has colors that help to camouflage it when it is near the bottom in streams, and it has some characteristic vertical spots along the body sides, the parr marks. The next stage is the smoltification, with physical and physiological changes that make the **smolt** able to live in saltwater, prior to the first migration to the sea. Their ability to live in saltwater made the whole coastline available to these species, and they were naturally present in all river systems from the sea up to migration obstacles. The brown trout and Arctic charr have been stocked in numerous lakes, and also in mountain areas, and they are now widely distributed (Fig. 4). The three-spined stickleback can be freshwater resident, anadromous, but can also spend their whole life in brackish and saltwater.

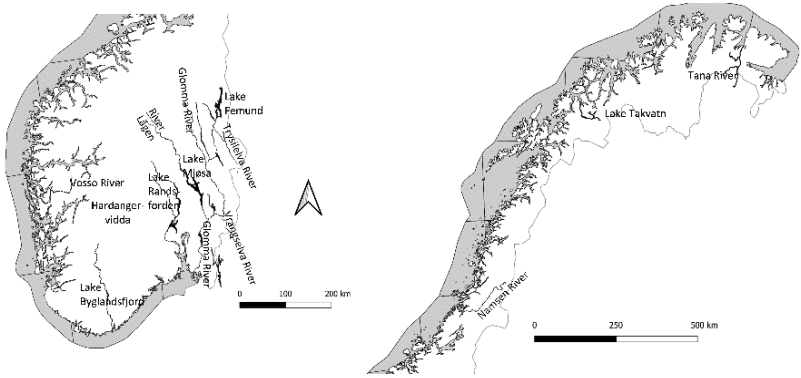

Figure 4. Maps showing south Norway (left), mid, and north Norway (right). Some names and rivers mentioned in the text are marked.

Two species of the *Alosa* genus of the order *Clupeiformes* (herrings), the river herring (*A. alosa*) and the twaite chad (*A. fallax*) are anadromous; they occur rarely in Norway but are more common in southern parts of Europe and in the Mediterranean Sea. The marine flatfish, the European flounder (*Platichthys flesus*), may spend parts of its life, primarily as young, in freshwater.

Southeastern Immigrants to Norway

10,000 years ago, Lake Ancylus covered the Gulf of Bothnia, with coastal areas that are currently dry land in Sweden, Finland, the Baltics, and northwest Russia. This freshwater sea, named after the freshwater snail species *Ancylus fluviatilis*, was recorded by the Swedish geologist Henrik

Munthe as fossils in ancient sediments on Gotland. The species still exists within the area previously covered by Lake Ancylus. The lake drained westward through the current Lake Vänern and Götaälv River. From this freshwater sea, freshwater fish and other freshwater organisms descended north- and westward to southeast Norway, through the Glomma River, which, until 8,000–9,000 years ago, drained into Lake Vänern through the present Vrangselva River. Freshwater fish entered the Glomma River until the river turned to the west, collecting the tributary from Lake Mjøsa, and ended on the eastern side of the Oslofjorden (Fig. 3). This opened a new immigration pathway to the lower parts of Glomma from the Oslofjorden, which was brackish due to freshwater from the ice melting. Among the species that came from the east, there were grayling (*Thymallus thymallus*), smelt (*Osmerus eperlanus*), vendace (*Coregonus albula*), whitefish (*Coregonus lavaretus*), perch (*Perca fluviatilis*) (Fig. 4), ruffe (*Gymnocephalus cernuus*), pike (*Esox lucius*), burbot (*Lota lota*), nine-spined stickleback (*Pungitius pungitius*) and ten cyprinid species. Some species tolerate brackish water and could enter coastal areas on the western side of the Oslofjorden, and some even reached southernmost Norway (perch) and southwestern Norway (whitefish), whereas the cyprinid distribution is limited to the coastal area around Oslofjorden, the lower and middle parts of the Glomma River system, and river systems further east, draining to Sweden.

Northeastern Immigrants to Scandinavia

Perch, pike, burbot, grayling, and whitefish are present in rivers in the eastern part of northernmost Norway, the county of Finnmark. Grayling is also present in some rivers in the counties of Trøndelag (mid-Norway), Nordland, Troms and the western part of Finnmark. This group also includes the brown trout and Arctic char, the two most widespread freshwater resident species in northern Norway, and along with salmon, form anadromous stocks in all the rivers in the region. In addition to natural immigration, humans have introduced to locations outside the species natural occurrence species important as livestock – brown trout, grayling, whitefish, perch (Fig. 4), and, to a lesser extent, vendace. Burbot may have been stocked in the mountain lakes. It has a large vitamin-rich liver and have been an important source of vitamins to humans.

FISH SPECIES NATURALLY OCCURRING IN NORWAY

Burbots (family *Lotidae*, order *Gladiformes*)

The **burbot** (*Lota lota*) is the only cod relative in freshwater. It dwells near the bottom of lakes, but also in rivers and streams. It is widespread in eastern water systems in Norway and Sweden. It is brown with dark spots, light on the belly, typically disguised for a life on the bottom, and can be up to 7–8 kg, though 0.5–1.5 kg is the usual. It has a club- or tube-like body shape with a slightly flattened head and a wide mouth and is distinctly predatory. They mature at 3–4 years of age and spawning takes place from December to March over the bottom of sand, gravel, or solid clay, in shallow or deep water. In several areas there is the tradition of "clubbing" burbot when it comes into the shallow waters to spawn under the ice. It may be visible under the (steel) ice, and a powerful punch on the ice with a mallet or a cane will at least stun the fish until the ice is cut open and the fish can be retrieved.

Bullhead (*Cottidae*)

The **Alpine** (or Siberian) **bullhead** (*Cottus poecilopus*) of the cottidae family, with most of its relatives in marine environments, is relatively widespread in Scandinavia, contrasting with two other freshwater cottus species. *C. poecilopus* is present in the Trysil watercourse to Lake Femunden and in the Glomma River system up to a waterfall downstream of Lake Aursunden, approximately 500 km from the sea. Tributary rivers to Glomma are the Rena watercourse with Lake Storsjøen and River Atna with Lake Atnsjøen, both harboring the Alpine bullhead. In the Lågen River it is present up to the Harpefossen waterfall, 77 km upstream of Lake Mjøsa. It is present in the northernmost county of Finnmark and in some rivers in the neighboring county of Troms. Bullheads have a characteristic broad and slightly flattened head (giving them their name), two dorsal fins and large pectoral fins. In Norwegian, there are several local names, "stein-purke" ("stone-sow") is one example. It usually grows to 10–12 cm long, lives in both standing and running water, and always dwells on the bottom. It has internal fertilization and eggs are deposited in nests in spring and are

guarded by the male until hatching. It feeds on insect larvae and other benthic animals and can catch eggs and fish fry. It can be a competitor to small brown trout, but it is also a prey for larger brown trout. It is used as bait for trout fishing.

The **European bullhead** (*Cottus gobio*) is much like the Alpine bullhead but is less widespread. The biology of the two species is also quite similar. The difference is that the European bullhead has a sideline that goes backwards to the tail fin and ventral fins that do not reach as far back as the anus, and it misses the transverse stripes on the ventral fins that the Alpine bullhead has. It is 12–15 cm long, spawns in the spring and has internal fertilization.

The **four-horn sculpin** (*Triglopsis quadricornis*) is present in Lake Mjøsa and some other large lakes in Scandinavia, where it lives at > 90 m in depth. It has a long tail set, giving it a sleeker look than the other sculpins. It is also larger, up to 20 cm, and in the brackish waters of the Baltic Sea lengths of 30–35 cm are not uncommon. Its name comes from the four bony protuberances on the top of the head, but these are lacking in freshwater populations. The spawning biology is little known, but it is believed to spawn in late autumn or winter in the lake. From elsewhere it is known to have internal fertilization, and the eggs are spawned in nests on the bottom, where they are guarded by the male.

Cyprinids (*Cyprinidae*)

This is the most species-rich family of freshwater fish in Europe. Many species have large, silvery scales, and some may be difficult to distinguish from each other. We can count the scales along the sideline and dissect the pharyngeal arches, as they have a pspecies-specific shape and number of teeth. The number of scales along the sideline varies within species and may overlap between some, and do not always provide a definitive answer. Experienced people recognize species by body height, width, and color shades that are not easily characterized by words. The size, location, and shape of the fins are also important characteristics for many species. The digital database of fish species, FishBase (2023), names nine species of the *Rutilus* genus, whereas Kottelat and Freyhof (2007) name 13 species.

The **roach** (*Rutilus rutilus*) is clearly the most widespread cyprinid species after the minnow (*Phoxinus phoxinus*), although in Norway it is naturally present only in the southeastern part of the country (Fig. 3). It is far more prevalent in Sweden and Finland, and also in the north, near the coast of the White Sea in Russia. Cyprinids usually occur at their highest density in eutrophic water, where they stand up well in competition with

other species for several reasons. They are effective plankton feeders but can also feed on benthos and even algae, macro vegetation and sediments. They can live at oxygen concentrations lower than perch and trout can withstand. The roach resembles several other cyprinids, with its silvery exterior and large circular-shaped scales, but the reddish color in the fins, and its red eyes, are usually the simplest characteristic of a roach. The roach matures usually at 2–3 years old, at a length of 12–15 cm, and spawns in May, one to two weeks later than the perch (*Perca fluviatilis*). The eggs are sticky and are deposited on rock or vegetation in running water and in lakes, above the bottom surrounded by oxygenated water. They hatch within 10 days, faster at higher temperatures.

The **common dace** (*Leuciscus leuciscus*) in Norway is restricted to the Glomma River system, including Lake Mjøsa, and the lower part of river systems entering the Oslofjorden from the west. Its body shape and musculature make it a more proficient swimmer than many other cyprinids. It has a nice silvery color and large scales. It is sexually mature at 12–14 cm length, at age 2–3 years, and spawns on sand and gravel at the bottom in running water in May–June. It can be more than 30 cm, but is more commonly 15–25 cm.

The **bleak** (*Alburnus alburnus*) has a prevalence like that of the common dace, with silvery colored large scales. It is higher in body shape and more laterally flattened than the dace and roach and tends to display a more pelagic behavior. Its distribution is like that of common dace but goes slightly higher up in the easternmost watercourses. It reaches more than 20 cm in length. It sexually matures at 10 cm in length, at age 2–3 years, and spawns in lakes in May–June.

The **ide** (*Leuciscus idus*) occurs naturally in the Glomma River system up to Eidsfossen in Glomma 250 km from the sea and in Lake Mjøsa. It is one of the largest growing cyprinids, up to 4 kg. It is powerful, with a not particularly high body shape, but is wide across the back, with large scales, tawny at the sides and gray on the back. It sexually matures at 3–4 years of age, and spawns in April–May, on rocks and gravel in both standing and running water.

The **common rudd** (*Scardinius erythrophthalmus* L.) have a limited distribution in Norway, up to the Mørkfossen Falls in Glomma 70 km from the sea, and in the lower parts of the Drammen River and some rivers further west. It is present in some lakes in coastal areas in southernmost Norway. The body shape is high, laterally compressed, and the color is silvery interspersed with green and red fins. Sexual maturation occurs after 2–3 years, at 10–12 cm in length, and it spawns in May–July in shallow water in lakes.

The **chub** (*Leuciscus* (*alt. Squalius*) *cephalus* L.) is present in the lower parts of rivers in southeast Norway, the Tista River, in Glomma River to Lake Øyeren and the tributaries Nitelva and Leira Rivers, and in the lowest part of the Drammenselva River. The chub is more powerful than most other cyprinids. It has a broad back but otherwise a slim body shape, often 30–40 cm long, and sometimes twice that. Large individuals are piscivorous and are popular with anglers. It spawns in running water in April–June, depositing the sticky eggs on rocks and vegetation.

The **asp** (*Leuciscus aspius* L.) is present in the Glomma River up to Lake Øyeren and the lower parts of the tributary Nitelva River. The asp is sleek, with silvery sides, darker on its back, and the belly has a sharp keel between the abdominal and anal fin. It may grow more than 50 cm long and, as an adult, it is the predominant predator, which is quite unusual among cyprinids. It spawns in running water in April–May and the eggs are sticky, attaching to gravel, stones, and vegetation. The meat is tasty, and it is also popular with anglers because of its size.

The **white bream** or silver bream (*Blicca bjoerkna*) has a very limited distribution in Norway, in the Glomma River up to Lake Øyeren, some locations east of Glomma River, and a few locations in coastal areas in southernmost Norway. It has a high body shape, ventrally compressed, resembling a small bream, but the eyes are relatively larger and may have a reddish tinge. It is usually up to 20 cm long and lives in shallow lowland lakes with rich vegetation, eating planktonic crustaceans and benthos: insects and mollusks, and fish fry. It becomes sexually mature at age 3–5 years, and spawns in June–July in vegetation in flooded shorelines, attaching the sticky eggs to vegetation.

The **crucian carp** (*Carassius carassius*) is a special species in several ways. It is a close relative of the **prussian carp** (*Carassius gibelio*) and the **goldfish** (*Carassius argentus argentus*), and is probably a descendent of the prussian carp, which is not naturally present in Norway. The crucian carp was probably stocked by humans in Norway, and has a limited distribution, whereas the other two species are not present. Crucian carp was possibly introduced during the country's Catholic era (before 1536) by monks and pilgrims, and this was a fairly easy process as crucian carp can live for quite some time without oxygenated water over the gills. Its body shape varies; it often has a deeper body shape in water with predator fish such as pike. In small ponds, the crucian carp rarely exceeds 15 cm in length, but it may become several kilograms in other circumstances, such as in Lake Øyeren. The crucian carp stores sugar in the brain by accessing oxygen and food and can draw on this during periods when neither is available. The combustion is set to a minimum in a hibernation state, and it can survive in the mud in

lakes and ponds where water is oxygen-free, in hot summers or during ice-covered winters. The crucian carp can thus become the ruler in such environments as other species die in such conditions. In diverse fish communities, in which multiple carp species are often present, the crucian carp is not seen so much because it is not particularly competitive. In addition, they hide from pike predation. The crucian carp becomes sexually mature at 2–5 years of age, approximately 10 cm, but may reach 40 – 50 cm. It spawns between May and July in vegetation belts in ponds/lakes, where the sticky eggs attach themselves to vegetation.

The **tench** (*Tinka tinka*) was introduced by humans in Norway and exists in some lakes in the southern counties of Agder, Vestfold and Telemark, Viken, and Innlandet. The tench has a deep body shape, a tawny and brown color, and small scales differing from other cyprinid fishes. In addition, it has two small barbells that distinguishes it from all other Norwegian freshwater fishes. It is usually up to 40 cm long and becomes sexually mature at 3–4 years of age. Spawning takes place in several stages in June–July in the macro vegetation, where the sticky eggs attach themselves to plants.

The **minnow** (*Phoxinus phoxinus*) is naturally widespread in southeast Norway, from the Numedalslågen River in the west to the Dovre Mountain area bordering the county of Trøndelag (mid-Norway), and in some places in Trøndelag. The minnow is used as bait by anglers, and also as live bait, though it is illegal, and it has probably been spread to new areas by anglers. It lives in both standing and running waters, albeit not in tough rapids, and is rarely much longer than 10 cm. It has small scales, and the yellow and brown color varies with their environment. Those that live in humus-colored water have a darker color, but the characteristic in all environments is a lateral dark stripe on a light yellowish bottom. It feeds partly on the same food as brown trout fry and is therefore an important competitor to this. The spreading of minnows to new areas, originally dominated by brown trout, is very undesirable and of course illegal. Minnows become sexually mature after 1–2 years and spawn in shoals in June–July. Spawning takes place over rocky bottoms and the eggs stick to the bottom.

Eels – *Anguillidae*

The **European eel** (*Anguilla anguilla*) is (like the American eel) especial in both its appearance and life history. A snake-like body shape and a coherent fin from back to haul and forward the belly make it easily recognizable. In freshwater, only the even more special lampreys may resemble it. The eel is also known for its migration in different life stages. The fry emerges from

the Saragasso Ocean, partly with the ocean currents, towards the shores of Europe as glass eels, and enter the rivers as elvers. They live in rivers and lakes as yellow eel until they become sexually mature. Then they become shiny on the belly and are called silver eels on venturing back to Saragosso. This takes a long time: for males 4–10 years (35–45 cm) and for females 6–25 years (40–150 cm), which means that they can be fished upon for many years before they migrate to spawning areas. Eels are caught in traps and had economic significance before stocks decreased and the species was characterized as threatened in many areas. Today, artificial breeding is important for market supply, but so far, the methods for the artificial reproduction of eel are not developed, and farming is based on glass eels caught in the wild – a questionable method considering that the species is endangered.

The Perch Family (*Percidae*)

The **perch** (*Perca fluviatilis*) is clearly the most prevalent species of this family. In Scandinavia, perch immigration was restricted by topography and its low tolerance to sea water. Its natural occurrence therefore does not include the western part of Norway, neither mid nor northern Norway, except the far northeast, where perch immigrated from the east (Fig. 3). In south Norway, the perch is supposed to have immigrated from Lake Ancylus.

The perch, with its rigid body and deep shape, is not a fast swimmer. It exists in the slow-running stretches of large rivers, but is primarily associated with small lakes and tarns, where it often dominates the fish community numerically and ecologically. Perch spawn in the spring, usually in the second and third weeks of May in the lowlands, at water temperatures between 8–10 °C. The eggs are spawned in a mucus tube that swells in water to form protection for the eggs. They must be deposited on submersed objects preventing them from ending up on the lake sediments. After 10–14 days, depending on water temperature, the eggs hatch, and fry with a small yolk sac start to eat small food animals like rotifers and small plankton crustaceans. Perch gradually begins to eat larger prey, and insect larvae (mayflies, caddisflies, alderflies, chironomids) are important for adult perch. Growth stagnates between 15 and 20 cm, in small nutrient-poor ponds at 12–14 cm, but some individuals turn piscivore, especially in larger lakes with a diverse fish community. The smelt (*Osmerus eperlanus*) is important as prey fish, as are conspecifics and cyprinids. The piscivores do not stagnate in growth and, with an annual length increment of 2–3 cm, they