
The Biological Characteristics of Organisms Involved in Blue Biotechnologies

1.1. Fish

1.1.1. *Tilapia*

The genus *Tilapia* includes some 40 species from East Africa. In the vernacular, the term “tilapia” is used to designate species belonging to the genus *Tilapia* and also to the genera *Oreochromis* and *Sarotherodon*. Two species are mainly exploited for human consumption: Nile tilapia (*Oreochromis niloticus*) (see Figure 1.1) and Mozambique tilapia (*Oreochromis mossambicus*). Tilapia are freshwater fish with an omnivorous diet, but with a strong herbivorous tendency.

Nile tilapia is the most consumed species and contributes to the diet of many populations on the African and Asian continents. This species, raised in Ancient Egypt, was able, after introduction, to adapt to different ecosystems far from its continent of origin (Japan, Thailand, Vietnam, Brazil, China). It is a tropical fish that lives in shallow waters and has a strong aptitude for colonizing ponds and streams. However, the Nile tilapia is very sensitive to water temperature. Temperatures below 11°C and above 42°C prove to be lethal for this organism. Water depth is also a parameter that plays a significant role in mortality (El-Sayed et al. 1996). A depth of 200–300 cm reduces mortality observed for fish living at a depth of 50 cm by approximately 50% (see Figure 1.2).

This is an important criterion, particularly for breeding this species. In addition to habitat depth, temperature has a major influence on growth (see Figure 1.3). It also plays a role in the reproductive process, since spawning, after sexual maturation, is only possible when water temperature reaches 24°C.



Figure 1.1. *Oreochromis niloticus* or Nile tilapia (photo credit © Tørrissen B.C. 2012, Wikimedia/CC BY-SA 3.0)

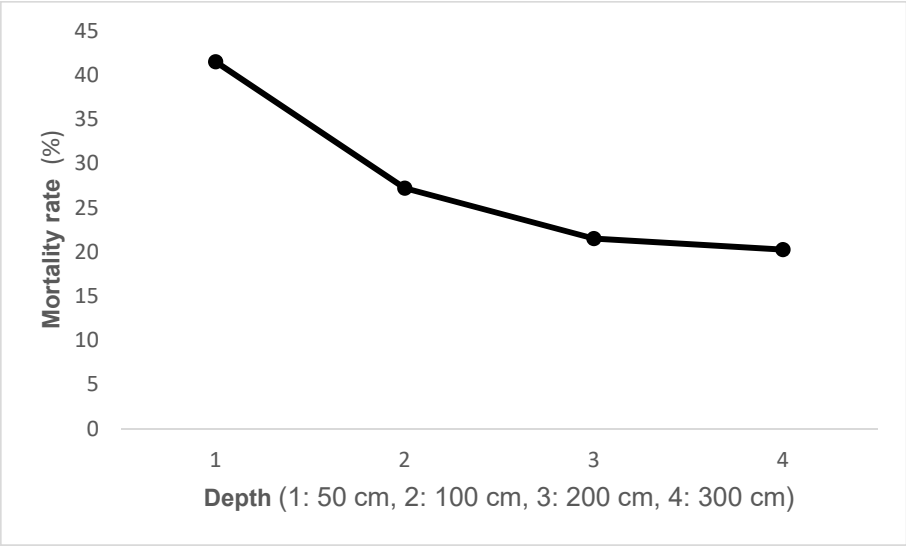


Figure 1.2. Impact of pond depth on the survival of Nile tilapia (*Oreochromis niloticus*) (average over 10 months of rearing) (from El-Sayed et al. (1996))

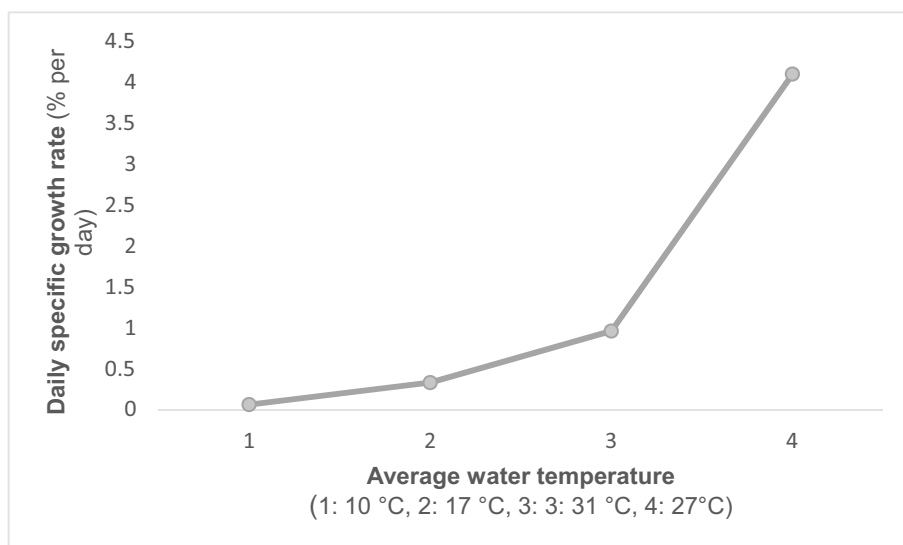


Figure 1.3. Impact of pond temperature on the specific growth rate of Nile tilapia (*Oreochromis niloticus*) at a depth of 3 meters (from El-Sayed et al. (1996))

1.1.2. Trout

“Trout” is the common name for several species of fish belonging to the Salmonidae group. Two distinct taxa or genera, the genus *Oncorhynchus* and the genus *Salmo*, are listed principally. A third, the genus *Salvelinus*, including the species *Salvelinus fontinalis*, known as speckled or blue trout, is included in the common trout group. The common trout found in whitewater rivers generally belong to the *Salmo trutta* species (see Figure 1.4). In contrast, rainbow trout, which is used worldwide in aquaculture, is listed under the scientific name of *Oncorhynchus mykiss*. Other trout species, or even subspecies, are also harvested or exploited in aquaculture but are more limited than the previous two species. They live in a wide variety of environments, including whitewater rivers, lakes and the marine environment (see Table 1.1). Like salmon, some trout species are anadromous. This is particularly true of rainbow trout (*Oncorhynchus mykiss*), which leave the marine environment to reproduce in freshwater rivers. Trout are carnivorous fish, feeding on aquatic and aerial insects and various invertebrates. Examples of cannibalism by trout towards their fry have also been reported for some species and under some conditions

(Lestage 1937). This is particularly true of *Salmo trutta* and *Salvelinus alpinus* (Arctic trout) (Klemetsen et al. 2003).

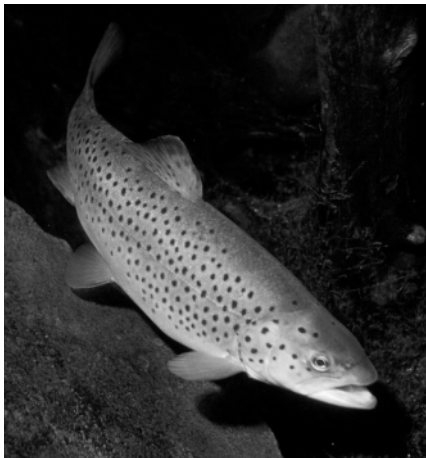


Figure 1.4. *Salmo trutta fario* or common trout
(photo credit © Engbretson E. 2006, Wikimedia/public domain)

Trout species or subspecies	Common name	Living environment
<i>Oncorhynchus mykiss</i>	Rainbow trout or salmon	Well-oxygenated seas and rivers
<i>Oncorhynchus mykiss aguabonita</i>	Golden trout	High-altitude lakes and rivers (> 2,100 m)
<i>Oncorhynchus clarkii</i>	Cutthroat trout	Seas (Alaska) and rivers (Northern California)
<i>Salmo trutta trutta</i>	Sea trout	Seas (Atlantic and Mediterranean)
<i>Salmo trutta fario</i>	Brown trout	Mountain streams, rivers, brooks
<i>Salmo trutta lacustris</i>	Silver trout	Lakes
<i>Salmo trutta ferox</i>	Ferox trout	Lakes (Iceland, Scotland)
<i>Salmo trutta labrax</i>	Black Sea salmon	Sea (Black, Azov, Caspian and Aral seas)

Table 1.1. Examples of different trout species and their habitats (based on FAO (2020) and Wikipedia)

1.1.3. Atlantic salmon

The term “salmon” is applied to various species belonging to the Salmonidae group. There are three main genera (*Oncorhynchus*, *Hucho*, *Salmo*), with varying numbers of species (see Table 1.2). The genus *Salmo* is represented by one species, *Salmo salar* (see Figure 1.5), known by its common name of Atlantic salmon. This species occurs naturally in the northern Atlantic zone and along its watershed. However, the significant development of aquaculture activity around this species has led to its presence in fish farms in the Southern Hemisphere, such as in Chile, which is one of the three main producers of Atlantic salmon, along with Norway and the United Kingdom. The genus *Hucho* comprises two species found mainly in the rivers of eastern Europe and the Far East (Siberia). Finally, the genus *Oncorhynchus* comprises eight species found in the northern part of the Pacific Ocean and its watershed. Most salmon species are anadromous, similar to some trout species (see section 1.2).



Figure 1.5. *Salmo salar* or Atlantic salmon
(photo credit © Fjeld H.P. 2006, Wikimedia/CC BY-SA 2.5)

Some species belonging to the genus *Oncorhynchus* may be known by more than one common name. This is particularly true of *Oncorhynchus keta*, which is known by four different common names (see Table 1.2).

Salmon is a carnivorous fish that feeds on small aquatic insects and mayflies in freshwater. In the marine environment, their diet is based on the predation of various crustaceans, including shrimps rich in astaxanthin, the pigment that gives salmon its red flesh. They also feed on fry or small fish of different species. Independently of this aspect, cannibalism is also known to exist in the *Salmo salar* species (Klemetsen et al. 2003).

Salmon species	Common names	Natural geographical area
<i>Salmo salar</i>	Atlantic salmon	North Atlantic and watershed
<i>Oncorhynchus kisutch</i>	Silver salmon Coho salmon	North Pacific and watershed
<i>Oncorhynchus keta</i>	Dog salmon Pacific salmon Keta salmon Chum salmon	North Pacific and watershed
<i>Oncorhynchus tshawytscha</i>	Chinook salmon King salmon	North Pacific and watershed
<i>Oncorhynchus masou masou</i>	Japanese salmon Masu salmon	Far East
<i>Oncorhynchus nerka</i>	Nerka salmon Red salmon	North Pacific and watershed
<i>Oncorhynchus gorbuscha</i>	Pink humpback salmon	North Pacific and watershed
<i>Hucho hucho</i>	Danube salmon Huchen	Eastern and northern Europe

Table 1.2. *Examples of species grouped under the generic name of salmon and natural geographical areas (from Wikipedia)*

1.1.4. Carp

As before, the common name carp encompasses a number of different fish species. These belong to the Cyprinidae group. The common carp is identified by its Latin name, *Cyprinus carpio*. Other species with multiple common names are also listed (see Table 1.3). In particular, the name “Asian carp” covers several different species, which have in common that they live in the geographical area of the Asian continent or Eastern Siberia. Carp are freshwater fish that live in the middle and lower reaches of rivers. In addition to this habitat, the common carp is also found in the wild in flooded areas, lakes and reservoir waters. They are omnivorous fish, feeding mainly on plant debris and plants (algae), as well as on mollusks and invertebrate larvae (insects, worms and crustaceans).

Carp species or subspecies	Common names	Natural geographical area
<i>Cyprinus carpio</i>	Common carp	Europe
<i>Cyprinus carpio carpio</i>	Leather carp Japanese carp Koi carp Mirror carp	Asia
<i>Hypophthalmichthys molitrix</i>	Silver carp Silver love carp Asian carp Chinese carp	China, Eastern Siberia
<i>Ctenopharyngodon idella</i>	Grass carp Herbivorous carp Amour carp Asian carp	Amur River (China–Siberia)
<i>Mylopharyngodon piceus</i>	Black carp Asian carp	China, Vietnam, Siberia
<i>Hypophthalmichthys nobilis</i>	Bighead carp Marbled carp Asian carp	Asia, North America

Table 1.3. Some examples of species grouped under the common name of carp (from Wikipedia)



Figure 1.6. *Hypophthalmichthys molitrix* or silver carp (photo credit © Strauss T. 2006, Wikimedia/CC BY-SA 3.0)

1.2. Algae

Algae are a marine resource often used in blue biotechnologies. They are eukaryotic photosynthetic organisms found mainly in aquatic environments and also in other particularly humid environments.

A distinction is made between multi-cellular algae or macroalgae and unicellular algae, known as microalgae.

Macroalgae are often transformed by biotechnological processes (enzymatic hydrolysis, fermentation, etc.) for food applications. Microalgae are subjected to other biotechnological processes, such as genetic transformation to produce new therapeutic molecules (Fleurence 2021a).

1.2.1. *Microalgae*

Microalgae are unicellular, eukaryotic organisms that can associate to form colonies. Botanically, they are categorized into three phyla: Chlorophytes (green algae), Rhodophytes (red algae) and Chromophytes (golden brown algae) (Fleurence 2021a) (see Figures 1.7–1.9).

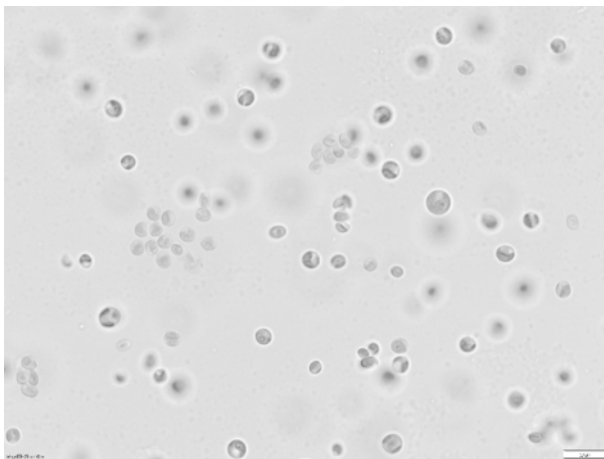


Figure 1.7. Example of a Chlorophyte: *Chlorella vulgaris* or *Chlorella* (scale: 20 μm) (photo credit © Isomer, Petit A. 2022)



Figure 1.8. Example of a Rhodophyte: *Porphyridium cruentum* or *Porphyridium* (scale: 20 μm) (photo credit © Isomer, Petit. A. 2021)

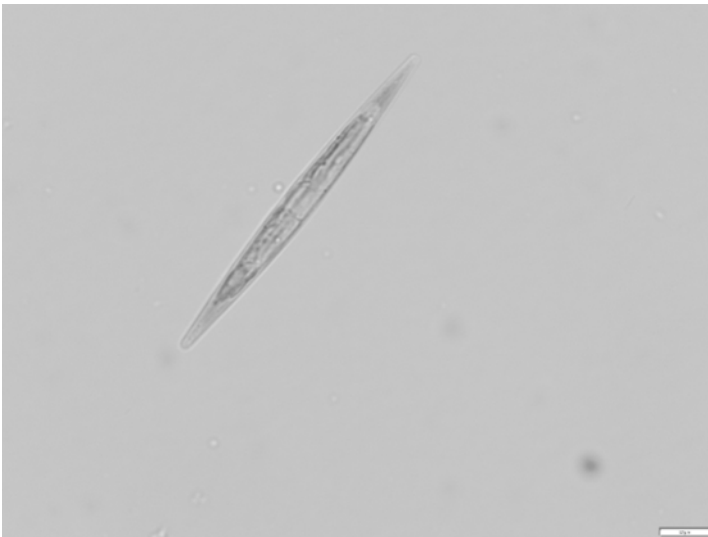


Figure 1.9. Example of a Chromophyte: *Haslea ostrearia* (diatom) (scale: 10 μm) (photo credit © Isomer, Petit. A. 2019)

Microalgae are present in a wide range of wet environments. These include aquatic environments (marine, brackish, freshwater) as well as terrestrial environments (damp building facades) and aerial environments (atmospheric layers). In the atmospheric environment, microalgae are released from the aquatic or terrestrial environment and transferred to the atmosphere via a process known as “aerolization” (Fleurence 2021a). The main species concerned belong to the Chlorophytes (*Chlamydomonas* sp., *Chlorella* sp., *Nannochloris* sp.) or Chromophytes (*Heterococcus* sp., *Vaucheria* sp., *Nitzschia* sp., *Navicula* sp.) (Sharma and Rai 2011). In the marine environment, microalgae and diatoms in particular are present in the water column (phytoplankton) or live on the seabed (microphytobenthos). The latter can be resuspended in mid-water by currents, in which case they are referred to as tychoplanktonic microalgae. This lifestyle also applies to microalgae living in freshwater or estuarine environments.

Cyanobacteria, formerly known as “blue-green algae” or cyanophyceae, are not considered microalgae, since they are prokaryotic organisms. From an evolutionary point of view, they belong to the eubacteria, not the eukaryotes, as in the case of microalgae. Despite this, some species, such as *Arthrospira platensis* (*Spirulina platensis*), better known as Spirulina, are still presented as “microalgae” in industrial and commercial communications.

1.2.2. Macroalgae

Macroalgae are multi-cellular organisms that live mainly in marine environments (see Figure 1.11). However, they can also be found in brackish or freshwater environments. This is particularly true of green algae of the genus *Cladophora*, cosmopolitan algae that can live in all three types of environment (see Figure 1.10). Algae with these ecological characteristics are also known as macrophytes. However, this term is not restricted to algae. It also applies to macroscopic aquatic plants such as duckweed (see section 1.3 and Figure 1.12), which live in wet zones in continental environments.



Figure 1.10. Example of a cosmopolitan green alga (marine, brackish, freshwater) *Cladophora* sp. (photo credit © Fleurence J. 2022)



Figure 1.11. Examples of Rhodophytes (*Palmaria palmata*), Chlorophytes (*Ulva* sp.) and Chromophytes (*Fucus* sp.) on the foreshore (photo credit © Fleurence J. 2022)

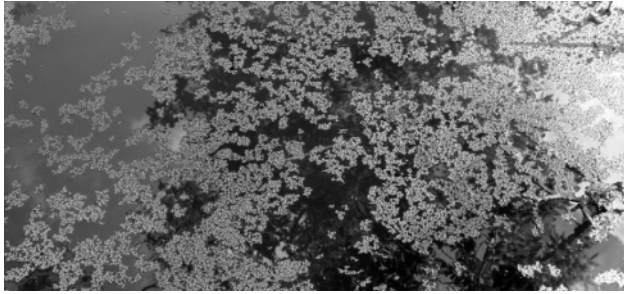


Figure 1.12. Example of a freshwater macrophyte, duckweed (*Lemna minor*) (photo credit © Fleurence J. 2022)

Just like microalgae, multi-cellular algae belong to three phyla: Chlorophytes, Rhodophytes and Chromophytes (see Figure 1.11).

1.3. Other aquatic plants

Some macrophyte species, found mainly in freshwater, are the subject of recent interest in human nutrition (Appenroth et al. 2018). These include duckweed in particular. The name “duckweed” is a common term applied to certain aquatic plants whose morphology is similar to that observed in duckweeds. This name covers three main genera: *Lemna*, *Spirodela* and *Wolffia*.

Duckweeds are aquatic organisms with a worldwide distribution. Thanks to their mode of reproduction, which is mainly based on vegetative multiplication, these organisms can proliferate to excess depending on favorable environmental conditions (temperature, light). In this case, the duckweed forms a carpet quickly covering the surface of the watercourse and more particularly the surfaces of stagnant water. The most widespread and cosmopolitan species is called *Lemna minor* or small duckweed. It is characterized by the presence of oval leaves, of just under a centimeter in size. It is a phanerogam whose flowers have a size of the order of a millimeter. As a phanerogam, duckweed is distinguished from algae, which lack floral organs.

Species of the genus *Wolffia*, and *W. globosa* in particular, are currently cultivated and processed for human and animal consumption.