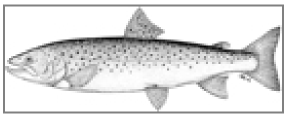
Cultured Aquatic Species Information Programme

# *Salmo trutta* (Berg, 1908)

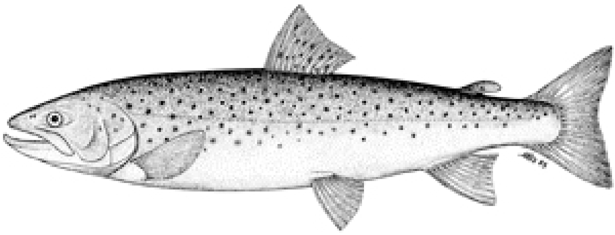




## Identity

***Salmo trutta*** **Berg, 1908 [Salmonidae]**

**FAO Names: En - Sea trout, Fr - Truite de mer, Es - Trucha marina**



### Biological features

Fusiform body shape with 57-59 vertebrae, 3-4 dorsal spines, 10-15 dorsal soft rays, 3-4 anal spines, 9-14 anal soft rays, caudal fin with 18-19 rays, adipose fin with red margin. Highly variable colour - from blue-grey to brown-yellowish for resident river trout and silvery for lake and sea morphs, with black spots and red spots mostly in riverine forms. May be difficult to distinguish from Atlantic salmon (*Salmo salar*) in two cases: the freshwater phase of Atlantic salmon compared to young sea trout, and adult Atlantic salmon compared to sea trout. Distinguishing features: upper maxilla extends mostly after the eye in sea trout while it extends to below the rear part of the eye in Atlantic salmon. Juvenile Atlantic salmon have a deeply forked caudal fin and a grey adipose margin *versus* a red adipose margin in sea trout. Adult sea trout have spots under the lateral line but Atlantic salmon do not.

### Images gallery

Sea trout rearing in freshwater

Rearing of sea trout in sea water

Sea trout being vaccinated against vibriosis before transfer to sea

Sea trout after 13 months of sea farming

## Profile

### Historical background

Sea trout is probably the first species of fish for which artificial reproduction was performed. This probably occurred in Germany around 1739 and the first sea trout hatchery was established in 1841 in the UK. The technique of artificial fertilization was optimized in the 1850s. Since then, sea trout has been produced extensively in Europe and introduced to all continents as a sport fish. However, in North America sea trout is considered as invasive in many places as it can out-compete local species like brook trout (*Salvelinus fontinalis*).

Sea trout was never really domesticated for food fish production, as the principal aim of sea trout culture was always the restocking of natural waters. At the end of the 1980s the culture of sea trout in sea cages was seen as an alternative to salmon production in the French waters of Brittany. This led to the development of sea trout strains selected for fast growth but the production of sea trout as a food fish never developed to a level other than for niche markets. FAO statistics for 'sea trout' include the aquaculture production of *Salmo trutta* in freshwater and sea water.

### Main producer countries

According to FAO aquaculture production statistics (which amalgamate the production of all morphs of *Salmo trutta* under the statistical category of 'sea trout'), the main producers (>100 tonnes/year) of *Salmo trutta* in sea water or freshwater in 2010 were the Russian Federation (80 percent of the global total, almost all in freshwater), Italy, Romania, France, the United Kingdom, Germany, Denmark and Bosnia and Herzegovina.


*Main producer countries of Salmo trutta (FAO Fishery Statistics, 2010)*

In addition to the countries reported by FAO Statiscs, sea trout production has also been recorded in Albania, Bolivia, Croatia, Czech Republic, Georgia, Ireland, Kazakhstan, Kenya, Lebanon, Morocco, Pakistan, Poland, Turkey and Zimbabwe.

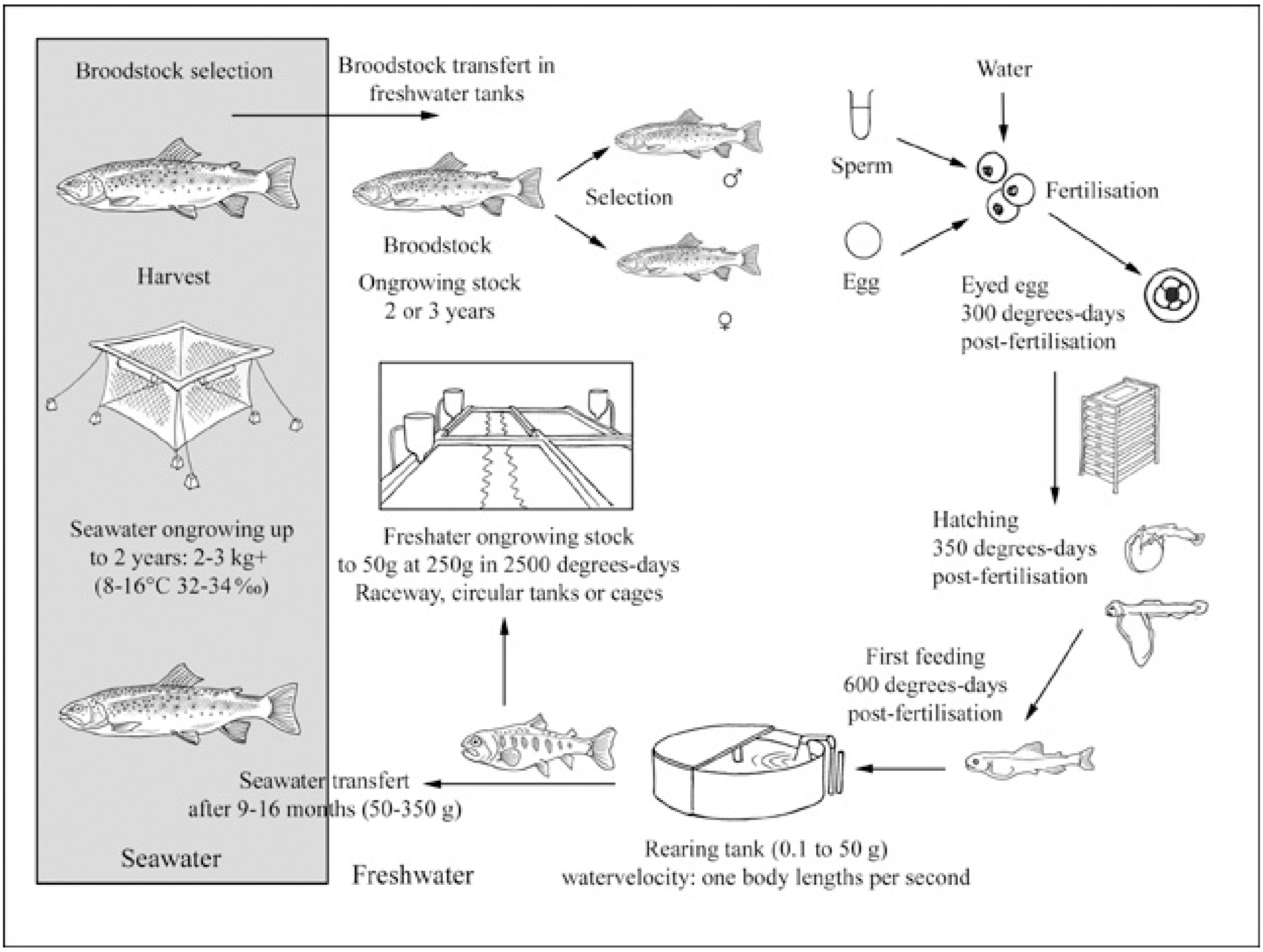
### Habitat and biology

Sea trout live in cold rivers and lakes, and spawn in rivers and streams with clean gravel beds. Migrating forms grow in lakes and the sea to a large size, but migrate upwards to spawn in rivers. Sea-migrating trout may smoltify more or less completely but there is apparently little if no genetic differentiation between migrating and non-migrating fish in the same river.

Sea trout usually spawn in late autumn (November-December). Females usually produce 1 500 eggs/kg of body weight (range: 1 000-2 000). The eggs are large, and their size tends to increase with female age (50 mg in 2 year-old females, 80 mg in 3 year-old females). Hatching typically occurs at 380 degree-days. Post fertilization and yolk resorption takes another 220 degree-days . The optimal temperature for incubation is 8 °C (range 4-12 °C). Sea trout can tolerate water temperatures between 1-27 °C. However, they will feed and grow only when water temperature exceeds 4 °C. The optimal temperature for growth is 14 °C (range 12-16 °C). Sexual maturity normally occurs at 1-2 years of age for males and 2-3 years of age for females, depending on water temperature.

## Production

### Production cycle




*Production cycle of Salmo trutta*

## Production systems

Sea trout are almost exclusively produced in intensive monoculture systems. The only variations are linked to broodstock supply (wild or farmed) and the age at which the product is sold (eggs, swim-up fry, fingerlings, pan-size fish). Due to the usually small size of farms, the trend to the move towards the ongrowing recirculation systems that are seen in rainbow trout farms (e.g. in Denmark) is not observed in sea trout culture.

### Seed supply

Seed supply is an important component of sea trout culture because an important part of the production output is sold as eggs, fry or fingerlings. Broodstock may be domesticated (originating from cultured fish) or captured from the wild. Wild-caught fish usually produce fewer eggs/kg than domesticated broodstock but they may be of interest for restocking purposes in order to stay as close as possible to the wild population. However, collection of wild broodstock is generally regulated and their regular use is generally restricted to official services or angling associations; these organizations are also less concerned by the profitability issues caused by the use of poorly productive broodstock.

As fish will mostly be used for restocking it is important when using domesticated broodstock to keep enough genetic variability by using highly effective numbers of broodstock to produce the successive generations; this avoids depleting the genetic variability of natural stocks. Another important factor is the high genetic diversity of the natural populations of sea trout, and the fact that restocking with exogenous material has already caused a lot of mixing of genetic pools. To avoid this, it has been suggested that, at a minimum, fish from the same lineage should be used, or sterile triploid fish (see later) should be used for restocking to avoid interbreeding with wild fish; this is already done in the United Kingdom.

### Broodstock

Male and female broodstock can either be maintained separately or mixed, as they will not spontaneously spawn in holding tanks (at least for domesticated broodstock). During the reproduction season (usually November-December), females are checked weekly for ovulation by gently pressing their abdomen. Ovulated females can retain eggs in their body cavity for 8-10 days without significant loss in fertilization rate. Eggs are manually stripped in dry plastic containers. Sperm is also stripped from males and kept in dry tubes (it is important to avoid any contact with water of sperm and eggs prior to fertilization). For fertilization, sperm and eggs are mixed, and then water or a fertilization medium is added. Fertilization is completed within one minute. If several males are used, it is better to separate the spawn in batches, each fertilized by a single male, because mixing several sperms will inevitably result in heavily unbalanced male contributions due to spermatic competition; this has detrimental effects on the conservation of genetic variability in the offspring.

During the first 30 minutes following fertilization, eggs absorb water and harden. They can be manipulated between 30 minutes and 24 h following fertilization, after which any shock should be avoided until the eyed stage. Eggs are incubated in trays or in Californian incubators, with a maximum of 2 layers of eggs. Fertilized eggs should be kept in the dark, water exchange should be moderate (one renewal per hour, eggs should not move) and the dissolved oxygen level kept at 100 percent saturation. The water temperature should be stable and kept between 4 and 12 °C. Dead (white) eggs should be manually removed every day. At the eyed stage (typically 300 degree -days), eggs can be manipulated again and sold if requested.

Hatchery production

Eyed eggs are hatched in the trays (typically 380 degree-days) and egg shells are removed at that stage. The normal hatching rate is >90 percent. Yolk resorption is completed in the same structures, still in the dark. When the fry have almost completed their yolk resorption and start swimming, they can be fed for the first time with dry feeds (0.4 mm diameter, 55 percent protein and 12 percent lipid content). When all fish are swimming, they are transferred to nursery tanks or sold as swim-up fry.

If triploid sterile fish are to be produced, they should be ‘shocked’ for 5 min post-fertilization. The shock can either be a temperature shock (28 °C for 10 minutes) or a pressure shock (500-600 atm for 3 minutes) in order to retain an additional copy of the maternal genome, which will ensure the sterility of the fish.

Nursery

Nursery tanks are typically circular or oblong with a depth of 30-40 cm and have a relatively fast water current (1-2 times body length/second at the periphery). Stocking density should be kept below 15 kg/m$^3$ with a water renewal rate of 200 percent/hour. Fish are fed dry extruded pellets of 0.5 mm diameter (or 0.4 mm which are recommended for very small fry). In the first stage feed with a high protein content (>53 percent) and low lipid content (10-15 percent) is used. Up to a fry size of 0.5 g a feeding rate of 5 percent/BW/per day at 12 °C is followed. The protein level can be lowered to 50 percent when the fry reach 10 g, while the lipid level may be increased as high as 18 percent. The food must be distributed by automatic feeders or belt-feeders throughout the entire day.

Ongrowing techniques

## Ongrowing in freshwater

In the first stage, after the fry have achieved 4-5 g Body Weight (BW), they can be transferred to outdoor grow-out facilities. Circular tanks with a water depth of 0.8-1 m are best suited for farming sea trout. A circular tank provides a better water flow than a raceway. A water current of one body length/second has been shown to increase weight gain (22 percent higher than the control group at zero current) and to stimulate muscle development, leading to a higher condition factor. It is preferable to cover about half of the tank surface in order to decrease the stress of the fish. When the fish exceed an average weight of 50 g, it becomes feasible to raise them in raceways.

The water exchange rate must be adequate to maintain 7 ppm dissolved oxygen and an ammonia level of <0.3 mg/litre at the outlet. Experiments have defined an optimum density of about 40 kg/m$^3$; above this there is a decrease in fish performance (growth, survival and FCR). Grading is unnecessary if the feeding management is optimal (sufficient quantity and distribution modalities to provide access to food for all animals). The coefficient of variation of the weight remains stable (20-25 percent) throughout the growing season. Grading often leads to decreased growth in this species, as the stress involved is very significant and may increase its susceptibility to diseases (furunculosis). The necessity to cease feeding two or three days before grading also causes a decrease in growth. Despite this, fish that are to be used for restocking must have a flawless appearance. They are therefore graded by hand before sale to eliminate unwanted fish, which can be sold for consumption or processing. Finally, for animals intended for farming at sea, an effective grading performed during vaccination against vibriosis, three weeks before transfer to sea water, is sufficient to obtain sufficient homogeneity of the stock.

Sampling fish quantity and size twice monthly allows estimations of growth rates, feed conversion, and closeness to carrying capacity to be calculated; these are essential considerations for proper farm management. The growth rate depends on ambient temperature. At 10 °C it is usually possible to rear fish to a table size (25-30 cm) within 14 months.

**Ongrowing in sea water**

Sea trout rearing can be an alternative to the culture of Atlantic salmon and rainbow trout when salinity and summer temperatures are too high. The transfer process at sea is always a delicate operation. Unlike the Atlantic salmon, sea trout does not really smoltify in culture (no changes in colour, swimming behaviour).

Juvenile fish (50-350 g) are directly transferred to full-strength sea water. Their adaptation is very fast (24-48 hours) but it causes profound but temporary osmotic and physiological imbalances. Sea trout withstand these changes if their physiological condition is already good and if the conditions of transfer are optimal, that is:

- Fifty grams minimum size (below this, survival is uncertain).
- Minimal distance between the freshwater and sea water sites.
- Transport tanks supersaturation (>150 percent) avoided, to prevent the gills burn.
- Minimal temperature differential between freshwater and sea water, and sea water temperature below 12 °C.

Subject to compliance with these conditions, the transfer of sea trout to sea water occurs without excessive mortality (2-3 percent). After an adaptation period, which can be very rapid (one to three days) if the transfer went well, the behaviour of sea trout at sea changes radically. It almost resembles that of rainbow trout or salmon. The growth rate that can be obtained shows that it is possible to rear fish to >2 kg after one year at sea, when using fish selected for growth and optimal farming practices are adopted. A key point is the possibility of transferring larger juveniles (average size 250-300 g) at the end of the autumn, taking advantage of the mild temperatures at that time for good growth after the adjustment phase. High summer temperatures can sometimes slow down or even completely stop growth.

**Control of sex and sexual maturation**

Sexual maturation results in a sharp decrease in growth, some sea mortality and a deteriorating quality of the flesh and colour, thus exhibiting an obstacle to obtaining large sized, commercially interesting animals. Raising sterile females is therefore a very interesting option. Their continued growth, not affected by sexual maturation, results in individuals weighing up to 4 kg. Sterility can be obtained by thermally induced triploidy induced by dipping fertilized eggs in a warm water bath (28 °C) for a few minutes.

**Feed and feeding**

Trout producers usually try to grow their fish as quickly and efficiently as possible while maintaining uniformity of growth and degrading water quality as little as possible. To accomplish these goals it is important to feed the correct amount. Fish feed requirements are generally determined by two parameters: fish size and water temperature. The general principles of the effect of water temperature are well known. Feed requirements increase with temperature up to a threshold temperature that is considered to be the optimum (16 °C for sea trout) and then decreases. Other factors may be involved, such as health status, physiological state, environment and farming system. However, even for a given temperature, size is insufficient to precisely determine feed requirements. Indeed, the requirement for maintenance is mainly a function of size, while the requirement for growth is, among other things, dependent on the genetic potential of the strain used. Precise assessment will require many observations and subsequent adjustments by the fish farmer.

Despite their imperfections the feeding tables provided by commercial feed manufacturers take into account the weight and water temperature. They only apply to the particular feed used, with the sole objective of fast growth. These tables are provided for information only and have to be adapted to the farming conditions and the characteristics of the fish. However, it is rare that the actual weight and temperature correspond exactly to those indicated on the table and linear interpolation may be necessary. The relevance of the tables to the needs of fish, is assessed by regularly monitoring performance, especially the food conversion ratio (FCR), which must remain within the limits usually accepted for the species and density energy of the food used.

### Feed supply

The feed ration can be distributed according to several modalities. Hand feeding is labour intensive and may not be practical on a large commercial farm and, in the case of the sea trout, it is very difficult to practice due to the low domestication of this species. An automatic feeder is more practical, allows the distribution of the ration throughout the whole day, and has been shown to improve FCR. An interesting alternative for sea trout is to use a demand feeder system. This allows the fish to obtain only the amount of food that is necessary. Trout weighing more than 5 g can easily be trained to feed themselves. With careful adjustment, rapid weight gain and efficient feed utilization can be attained by the use of demand feeders. The use of demand feeders can eliminate the sharp oxygen decline that occurs when fish are fed by hand or machine a few times each day. Demand feeders also reduce the labour costs associated with daily hand feeding. The disadvantages of this system include the tendency to overfeed because of improper feeder adjustment. In this case, an electronic device can control the response time to requests from fish on a pendulum and modulate the amount distributed at each solicitation. Several days' feed can be loaded in the hopper, but for best feeding efficiency it should not be replaced until the daily feeding period has elapsed, to avoid stressing the fish. The advantage of this method of distribution is to adapt to the voluntary feed intake of fish, but the cost of investment, especially if electronic control systems are used, may be prohibitive for small farms. An important point is that whatever feeding methods are adopted, feed should be dispersed throughout the whole of the rearing tank, pond or raceway.

Sea trout are fed the same commercially available feeds as rainbow trout, both in sea water and in freshwater. The current trend is to increase the levels of lipid, which have increased from 10 to 30 percent over the last 20 years.

### Harvesting techniques

Methods of harvesting vary but the fish are generally starved for up to three days beforehand. The fish are crowded in net-pens using sweep nets (or by the use of grids in raceways) and are either pumped from out alive and transported to the slaughter plant, or slaughtered at the side of the pens.

### Handling and processing

Generally fish are initially stunned using an automated stunner or a blow to the head. Bleeding is then carried out by rapidly cutting the gill arches and the fish are immersed in iced water. However, this method is widely believed to expose the fish to unnecessary pain and suffering; the industry is consequently seeking an alternative method that offers improved welfare of the fish at slaughter. Electric stunning of fish in water has been identified as a suitable method. Carcass yield greatly increases between 1 and 3 days and then more slowly up to 3 weeks. The whole process is carried out with the aim of keeping stress to a minimum, thus maximizing flesh quality. The impact of nutrition or genetics on meat quality have been shown to be less important than the technological factors (slaughter and post-mortem conditions) for the quality of the final product.

## Diseases and control measures

Sea trout are affected by several bacterial diseases. They are highly sensitive to furunculosis and BKD and may also moderately suffer from yersiniosis, rainbow trout fry syndrome and vibriosis. A vaccine exists for furunculosis and vibriosis. The main viral diseases affecting sea trout are VHS, IHN and IPN. They are moderately susceptible to pancreatic disease, caused by a salmonid togavirus. Sea trout may also suffer from fungal infections, especially during the reproductive season (males are especially sensitive), and parasitic infections.

**In some cases antibiotics and other pharmaceuticals have been used in treatment but their inclusion in this table does not imply an FAO recommendation.**

| DISEASE | AGENT | TYPE | SYNDROME | MEASURES |
|---|---|---|---|---|
| Furunculosis | *Aeromonas salmonicida* | Bacterium | Inflammation of intestine; reddening of fins; boils on body; pectoral fins infected; tissues die back | Antibiotic mixed with food; vaccination |
| Vibriosis | *Vibrio anguillarum* | Bacterium | Loss of appetite; fins & areas around vent & mouth become reddened; sometimes bleeding around mouth & gills; potential high mortality | Same as furunculosis, plus vaccination for greater protection |
| Bacterial kidney disease (BKD) | *Renibacterium salmoninarium* | Bacterium | Whitish lesions in the kidney; bleeding from kidneys & liver; some fish may lose appetite & swim close to surface; appear dark in colour | Antibiotic mixed with food or injection |
| Bacterial gill disease | Flavobacterium | Bacterium | Loss of appetite; swelling & reddening of gills; eventually gill filaments mass together & become paler with a secretion blocking gill function in later stage | Bathing in bacteriocide & regular filtering of water supply to remove particles in water |
| Yersiniosis | *Yersinia ruckerii* | Bacterium | Loss of appetite; usual effects of systemic bacterial diseases on internal organs (pale liver, enlarged spleen); characteristic pink/red tongue (caused by many small haemorrhages); pinpoint (petechial) haemorrhaging of the belly | Vaccines available in many countries; responds well to antibiotics |
| Infective Pancreatic Necrosis | IPN | Virus | Erratic swimming, eventually to bottom of tank where death occurs | No treatment available; eradicate disease by removal of infected stock |
| Salmon Pancreas Disease Virus | SPVD | Togavirus | Weight loss; emaciation; mortalities | Withholding feed; vaccination |
| Infective Haematopoietic Necrosis | IHN | Virus | Erratic swimming eventually floating upside down whilst breathing rapidly after which death occurs; eyes bulge; bleeding from base of pectoral fins, dorsal fin & vent | No treatment available; eradicate disease by removal of infected stock |

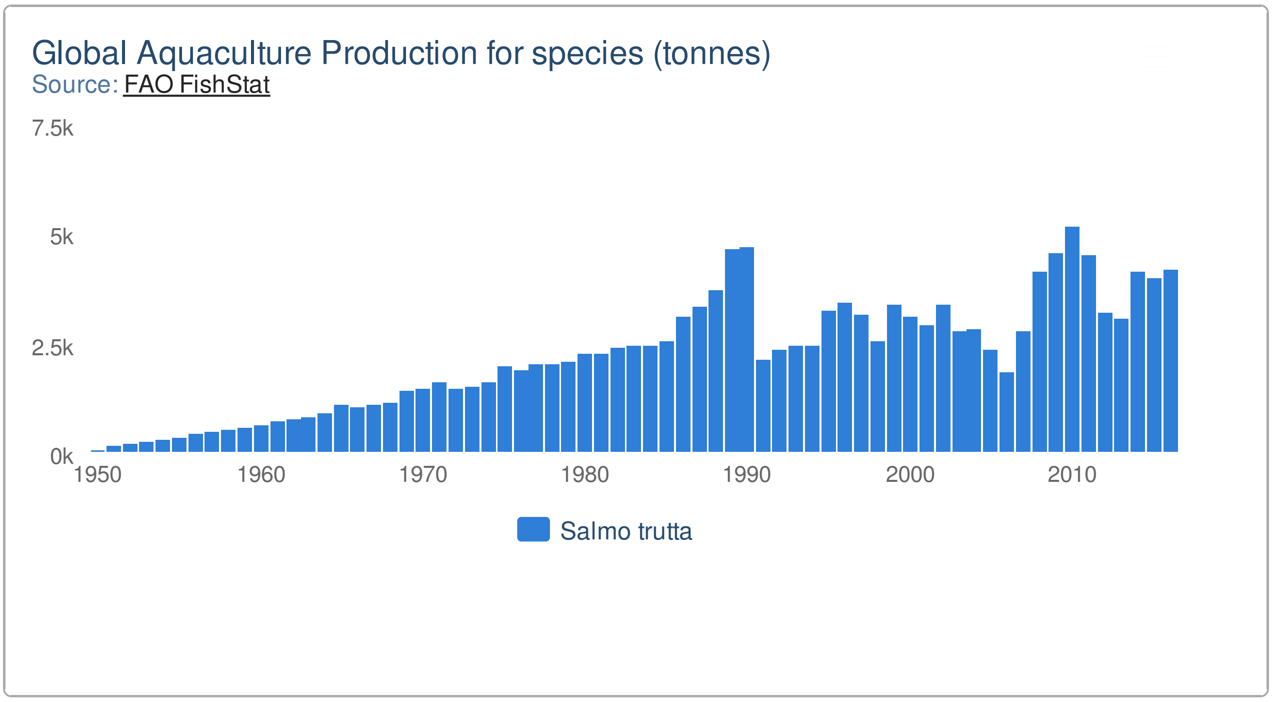
| | | | | |
|---|---|---|---|---|
| Viral Haemorrhagic Septicaemia | VHS | Virus | Bulging eyes &, in some cases, bleeding eyes; pale gills; swollen abdomen; lethargy | No treatment available; eradicate disease by removal of infected stock |
| White spot | *Ichthyophthirius multifilis* | Protozoan | White patches on body; becoming lethargic; attempts to remove parasites by rubbing on side of tank | Peracetic acid or formalin bath for surface parasites; prevented by surface cleaning ponds |
| Costiasis | *Costia necatrix, Ictiogodo necatrix* | Protozoan | Blue-grey slime on skin which contains parasite | Formalin bath |
| Ciliated protozoan parasite | *Chilodonella* spp. | Protozoan | Flashing; rubbing the gill cover & body against the tank; darkening of the skin; lethargy; breathing difficulties | Formalin bath |
| Fluke | *Gyrodactylus* sp. | Trematode | Parasites attached to caudal & anal fins; body & fins erode, leaving lesions that are attacked by Saprolegnia | Formalin bath; peracetic acid bath |
| Kudoasis | *Kudoa thyrsites* | Myxosporean parasite | Does not cause significant disease problems in host fish but the symptoms are lethargy & paleness. However, its presence does reduce product quality & value by affecting the appearance & texture of the flesh, which may disintegrate on cooking | No treatment available |
| Proliferative kidney disease (PKD) | *Tetracapsuloides bryosalmonae* | Myxozoan parasite (needs bryozoans as intermediate hosts) | Infected fish listless; swimming in circles; kidneys become enormous & nodular, dotted with gray spots | No treatment available |

## Statistics

### Production statistics

Of the sea trout total global production in 2010 (2 417 tonnes) only 0.9 percent was reared in sea water. Most production of sea trout is directed towards restocking for recreational fisheries, and therefore represents a small production in volume, often sold at a young age but at high price. This is probably the reason why the production is not well reported in aquaculture production statistics.

According to other information, French production of sea trout was 1 248 tonnes in 1991, 1 868 tonnes in 1997 and 975 tonnes in 2007 (when 338 sites were recorded as producing sea trout). In Great Britain in 1997, 74 sites produced approximately 478 tonnes of re-stockers and around 479 000 fry per year. In Iceland the maximal production reached was 40 tonnes in 1989, and there is no production of table size sea trout in that Country afterwards.




## Market and trade

Sea trout production is small; generally, production is destined for local consumption or for restocking. The output consists of:

- Eyed eggs (used for production or restocking in Vibert boxes or directly in gravel beds in rivers).
- Swim-up fry, mainly for restocking.
- Fingerlings for production or restocking.
- Market-sized fish for human consumption (mainly a niche market) or recreational fishing.

No market statistics are available. As sea trout are mostly sold live, they are subject to national regulations concerning the transfer of live fish (e.g. Directive 2006/88/CE in the European Union).

## Status and trends

The 'Prosper' programme, an optimized mass selection procedure followed for four generations in France, yielded more than 86 percent in weight at one year of age in one line, when compared to an unselected control line from the same base population. In a second line, however, the response was smaller less 25.2 percent after 4 generations. This difference may arise because the lines came from a different selection environment; the one where the response was lower being more competitive, possibly leading to the selection of more aggressive fish.

More care is being taken in the use of farmed sea trout for restocking, either by using local strains or by restocking with sterile triploid fish (as in the United Kingdom).

Today, sea trout reared in seawater cannot outcompete salmon; however, it has a potential advantage as it can tolerate higher summer temperatures, thus global warming, in the long term, may favour sea trout again.

Restocking activities are more and more criticized, so here again the prospects are not highly favourable. It is therefore predicted that, for some time, sea trout will remain a niche species in aquaculture production.

## Main issues

Interactions between wild and domesticated stocks have been extensively studied in sea trout, especially in the Mediterranean area, where restocking with Atlantic populations has occurred for a long time. It appears that in many cases, stocked trout, even if restocked at very young stages, are more susceptible to angling than wild trout. The admixture of domesticated trout in heavily restocked rivers may remain remarkably low, but this is highly site specific and in some cases high admixture proportions are observed. Even when wild parents are used, a reduction in the effective size of the population appears to be common. Interactions can be avoided or mitigated either by the use of local strains and/or by the use of sterile triploids for restocking.

**Responsible aquaculture practices**

Sea trout farming is generally conducted responsibly. As the main production is juvenile production for restocking in small farms, it generally contributes to rural development. Moreover, the fact that the fish are sold live promotes the production of healthy fish. Trout farmers are encouraged to adhere to the principles contained in the FAO Code of Conduct for Responsible Fisheries and the FAO Technical Guidelines for Responsible Fisheries (Aquaculture Development). In Europe, where many of the largest producers are, the provision of regulations and incentives for improving sustainable aquaculture practices through appropriate planning has been recognized by the Federation of European Aquaculture Producers (FEAP).

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## Related links

Aquafind

Aquatic Animal Pathogen and Quarantine Information System - AAPQIS

Aquatic Network

AquaTrace species leaflet - Salmo trutta

Database on Introductions of Aquatic Species - DIAS

European Aquaculture Society - EAS

FishBase

FAO FishStatJ – Universal software for fishery statistical time series

GLOBEFISH

Network of Aquaculture Centres in Asia-Pacific - NACA

World Aquaculture Society - WAS