Modeling of the rainbow trout feeding in the cage complex of the «Russian Sea – Aquaculture» company

A Beloborodov, E Minchenok
Murmansk State Technical University, Murmansk, Russia

sankhez@yandex.ru, minchenok.elena@yandex.ru

Abstract. The paper describes three models of feeding rainbow trout used in the cage complex of LLC "Russian Sea - Aquaculture". It is shown that the most effective is the method that combines models of three, two, and one-time feeding of rainbow trout. Fish diseases negatively affect feeding efficiency. With the onset of diseases, feed intake decreases sharply. Under marine conditions, rainbow trout are often affected by the salmon copepod Lepeophtheirus salmonis, which damages the mucous membrane and feeds on the blood of fish. Timely use of medicinal feed and chemical delasing has a positive effect on the physiological state of fish and feeding efficiency is restored. It was found that when choosing a feeding model, it is necessary to take into account the length of daylight hours. With an increase in daylight hours in fish, feed saturation increases, and with a decrease in daylight hours, on the contrary, decreases. Maturity stage in cage trout occurs faster than in wild-living individuals, which must also be taken into account when drawing up the feeding regimen. When developing a model for feeding rainbow trout, it is necessary to control the content of dissolved oxygen in the water. With a decrease in oxygen concentration, the fish experiences stress, and food saturation decreases. It has been established that the main factors affecting the choice of feeding model are water temperature, daylight hours, average weight of fish in the cage, physiological state of the fish and its maturity stage. The selection of the most appropriate model should be based both on the biological characteristics of the fish grown and on environmental factors.

1. Introduction
The farming of marketable rainbow trout is a promising direction in the industrial aquaculture development on the Kola North.

The level of modern aquaculture development requires the development and implementation of new intensive methods for the commercial farming of aquatic organisms [1].

The main operation in trout farming is feeding. It accounts for 50-60% of production costs. Feeding should not be limited only to the supply of feed to fish without taking into account the changing conditions: the growth of trout, feed quality, thermal and gas regimes of the reservoir. Only a clear continuous monitoring of feeding technology allows you to get an economic effect in trout farming [2].

In this regard, an important task is to develop an effective model for feeding rainbow trout, which allows to grow high-quality commercial fish, as well as to optimize the cost of the nutritive base and the maintenance of the cage complex.

2. Results
The main purpose of feeding is to provide all fish in the cage with access to feed. Rainbow trout is fed using a feed barge. Food is given according to the scheme (Fig. 1).

![Figure 1. Feed distribution scheme for cages.](image)

The main mechanical elements of feed delivery are: compressor (blower) installed in the feed hopper; feed dispenser; selector for switching feed supply between cages, underwater cameras mounted on cages.

To automate the operation of the feed barge mechanical elements, the AKVA Control computer program is used, with the help of which the cage complex is monitored and controlled. The software accumulates a database, allows you to manage feeding and other technological processes of fish farming (Fig. 2).

![Figure 2. The appearance of the work item of the AKVA Control program.](image)

During the feeding procedure, the fish farm operator must constantly monitor the equipment parameters and the behavior of the fish in the cage.
Using the AKVA Control program, the fish farm operator sets the amount of feed entering each cage (kg) and determines the rate of feed delivering to the cages (kg of feed per 1 minute).

Before feeding, the fish farm operator must check the readings of the water temperature sensors installed on 2, 7 and 15 meters. Based on the readings of water temperature at three depths, the fish farm operator calculates the average temperature, as well as takes readings of oxygen sensors, air temperature and wind speed.

At the beginning, feed is supplied at a slow rate, which allows to form the main school of fish and raise it closer to the surface of the cage (Fig. 3).

![Figure 3](image)

**Figure 3.** The main school of fish in the cage 14.

To monitor the feeding process, the fish farm operator uses underwater cameras mounted on cages. When forming the main school, it is necessary to increase feed delivery to the maximum possible rate (feeding rates are selected for each cage individually and based on the number of fish in the cage, as well as its average weight).

Extruded fish feed (carry a quality certificate from a feed supplier) is used for rainbow trout feeding.

The fish farmer should take into account that the size of the feed fractions (pellets) depends on the weight of the fish (Table 1).

| Fish weight, g   | Pellet size, mm |
|------------------|-----------------|
| below 150        | 2,5-3           |
| 150-600          | 3-6             |
| 600-1000         | 6-8             |
| 1000-2000        | 7-9             |
| 2000-2500        | 7-10            |
| 2500-3500        | 9-12            |
| 3500 and more    | 9-15            |

The switching to a larger granule sizes is carried out gradually by mixing granules of various fractions in the hopper of the feeder platform. The hopper is filled in a ratio of 75% of a smaller
granule fraction to 25% of a larger granule fraction. Variants of mixing different fractions in a ratio of 50% to 50% are possible, providing that most of the fish in the cage can take a larger granule.

The use of underwater cameras makes it possible to feed the fish more efficiently. This type of feeding is called "feeding by saturation." This type of feeding allows to establish the actual daily feed ration, which is different from the recommended daily intake (Table 2).

Table 2. Recommended daily intake of granular feed for juvenile rainbow trout, % of body weight

| Fish weight, g | Water temperature, °C |
|---------------|-----------------------|
| 100           | 1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 |
| 200           | 2  2  2  2  2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 |
| 300           | 0.25 0.36 0.47 0.59 0.71 0.84 0.96 1.15 1.25 1.44 1.54 1.68 1.82 2.02 2.11 |
| 400           | 0.21 0.30 0.39 0.55 0.69 0.79 0.93 1.08 1.18 1.33 1.48 1.57 1.72 1.87 2.02 |
| 600           | 0.19 0.28 0.37 0.51 0.64 0.76 0.89 1.01 1.14 1.26 1.39 1.50 1.64 1.76 1.88 |

Example of feed calculation according to the ration table:
Total biomass of fish in the cage = 110 thousand individuals × 110 g = 12100 kg
Daily feed ration = 12100/100 × 3 = 363 kg of feed
Thus, the daily ration is 363 kg of feed for a cage with a volume of 110 thousand individuals (with an average weight per cage - 110 g) at a water temperature of 10 °C [2, 3].

2.1. Three-time feeding model for rainbow trout
Three-time feeding per day is carried out at a water temperature of 10 °C and above. In this case, the daily ration is divided into three parts according to the formula 50:30:20.

50% of the daily feed ration is delivered in the morning taking into account that the interval between evening and morning feeding is the largest, and accordingly the fish is able to take more feed.

30% of the daily feed ration is given in the daytime.

20% of the daily feed ration is given in the evening.

The main task using three time feeding is to maintain intervals between feedings and to increase the daily ration, which allows to speed up the process of commercial fish growing (Fig. 4).
Figure 4. Three-time feeding model.

If the interval between feedings is decrease, rainbow trout does not have time to digest the obtained food, as a result, the daily ration decreases. To optimize feeding at a favorable average water temperature, the fish farm operator must increase the rate of feed delivery. An increased feed delivery rate allows to reduce the duration of feeding while maintaining the intervals between feedings.

However, a constant increase in the feed delivery rate is impossible, due to the fact that at high rates of feeding the fish does not have time to eat it. Therefore to identify the optimal feed delivery rate, the farmer must calculate the daily ration correctly, and if necessary, reduce it.

A short-term decrease in the daily ration (up to two days) allows most of the fish to completely digest the previously obtained feed and fish actively needs a new batch of feed. This way of feeding ensures a steady increase of daily feed ration for a long time.

When using three-time feeding and when the average water temperatures is high (from 10 °C and above), it is important to take into account that a long-term decrease in the feed ration is not effective, since the rate of feed digestion increases. Therefore, it is necessary to saturate the fish as much as possible during this period to accelerate its fat and muscle mass.

2.2. Two-time feeding model for rainbow trout

Two-time feeding is used when the average water temperature varies from 5 to 10 °C. Using two-time feeding model the daily diet can be divided according to the formula: 60:40 or 70:30. As in three-time feeding, this is due to the fact that the maximum part of the daily ration should be issued after a long interval of feeding during daylight hours (Fig. 5).
A decrease of daylight hours and average water temperature lead to a slight decrease of the volume and feed delivery rate of the evening feeding, and feed is not delivered in the dark time. The exception is when the underwater lighting is installed in the cages. In this case the volume and feed delivery rate of the second (evening) feeding do not change per day.

2.3. One-time feeding model for rainbow trout
If the water temperatures below 5 °C, one-time feeding is used. It is important to consider that the whole daily ration should be delivered every day at the same time (in natural daylight), which allows the entire volume of fish to be equally saturated and digest the feed.

Also it is important to consider that feeding efficiency is reflected in the feed index. Feed index is the amount of natural or artificial feed spent on 1 kg of fish growth. A feed index in excess of the table values indicates a strong increase in the daily feed ration. In such case the fish biomass does not increase, and the feed is consumed inefficiently [4], [5], [6], [7].

The feed index values for calculating the growth of rainbow trout are shown in table 3.

Table 3. The rainbow trout feed index [3], [4]

| Fish weight, g | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|
| 150           | 15.26 | 7.13 | 4.46 | 3.15 | 2.86 | 2.32 | 1.99 | 1.74 | 1.54 | 1.39 | 1.23 | 1.13 |
| 200           | 13.44 | 6.28 | 3.93 | 2.78 | 2.63 | 2.13 | 1.82 | 1.59 | 1.42 | 1.27 | 1.13 | 1.03 |
| 250           | 14.48 | 6.77 | 4.24 | 2.99 | 2.83 | 2.29 | 1.97 | 1.72 | 1.53 | 1.37 | 1.22 | 1.11 |
| 300           | 1.99  | 1.34 | 1.09 | 0.97 | 0.88 | 0.84 | 0.82 | 0.86 | 0.83 | 0.84 | 0.80 | 0.80 |
| 400           | 1.84  | 1.23 | 1.00 | 0.99 | 0.94 | 0.87 | 0.88 | 0.89 | 0.87 | 0.86 | 0.84 | 0.82 |
| 500           | 1.89  | 1.28 | 1.05 | 1.03 | 0.97 | 0.92 | 0.93 | 0.94 | 0.92 | 0.89 | 0.88 | 0.87 |
| 600           | 1.98  | 1.36 | 1.12 | 1.08 | 1.03 | 0.99 | 0.99 | 0.98 | 0.99 | 0.93 | 0.91 | 0.90 |

Figure 5. Two-time feeding model.
The following factors influence feeding efficiency, in addition to saturating fish with food [1], [2], [8], [9], [10], [11].

**Disease.** Various diseases sharply decrease feed intake. Permanent monitoring of the fish condition and health is provided by the hatchery, biological and veterinary services.

*Salmon louse* (*Lepeophtheirus salmonis*) is a copepod of the genus *Lepeophtheirus*. It is a sea louse that lives mainly on salmon species. Attaching to the fish, the copepod damages its mucous membrane. This parasite feeds on the blood of fish, which leads to its death. Special types of medicinal feed are used for fighting the parasite. In case of severe invasion, chemical delasing (the processing fish with a specialized chemical composition) is used. When fish is affected by salmon louse, the intake of feed is greatly reduced.

**Daylight hours.** When a daylight hours increase, saturation of fish increases (increase of daily rations), and respectively vice versa. It is necessary to take into account the length of daylight hours and, therefore, to calculate the daily ration and the feed delivery rate.

**Maturity.** Since cage trout grows extremely quickly, maturity occurs faster than in wild-living individuals. Commercial smolt (fish passed smoltification) has an increased appetite. Extreme temperature variations can lead to fish stress, and therefore the eat ability of the feed decreases.

**Dissolved oxygen level.** When the dissolved in the water oxygen level decreases, the fish experiences stress, and saturation with food decreases. When the dissolved oxygen level is less than 60%, fish feeding is considered impossible and the feed is not given out.

Thus, the organization of complete and effective feeding in the conditions of commercial farming is possible only with knowledge of the biological characteristics of rainbow trout, potential growth, nutritional needs, metabolism in connection with changing environmental conditions.

3. Conclusion
Important factors influencing the choice of feeding model are water temperature, daylight hours, average fish weight in the cage, physiological state of the fish and its maturity stage.

The study of three feeding patterns (models) has revealed that it is impossible to follow only one model. The most effective is combination of models of three, two, and one-time feeding of rainbow trout.

The choice of the most suitable model (feeding model) at a given point in time should be based both on the biological characteristics of the fish grown and on environmental factors (temperature indicators of water and air, oxygen water level, pH, daylight hours, light exposure).

References
[1] Ponomarev S 2006 Industrial fish farming (Moscow: Kolos-s Press) p 320
[2] Privezentsev Y 2004 Fish farming (Moscow: Peace Press) p 465
[3] 2017 Fish and biological standards for cage rearing of Atlantic salmon and rainbow trout Russian Sea - Aquaculture company 9
[4] Ponomarev S 2013 Feed and fish feeding in aquaculture (Moscow: Morkniga Press) p 414
[5] Sklyarov V 2008 Feed and fish feeding in aquaculture (Moscow: VNIRO Press) p 149
[6] Zheltov Y 2006 Feeding valuable fish species of different ages in farm fisheries (Kiev: INKOS Press) p 192
[7] Gamigin E 1977 Starting granular feed for larvae and fry of rainbow trout (Moscow: VNIRO Press) 126 108
[8] Kapalin N 1983 Intensity of oxygen consumption by juvenile rainbow trout at normal and increased oxygen content in water under industrial conditions (Moscow: GosNIORH collection) 194 111-116
[9] Zilanov V 2017 Norway Fisheries (Moscow: VNIRO Press) p 296
[10] Ponomarev S 2016 Aquaculture. P. 1 (Moscow: Morkniga Press) p 437
[11] Ponomarev S 2016 Aquaculture P. 2 (Moscow: Morkniga Press) p 423