Ways of optimization of breeding conditions of fish by using artificial spawning grounds

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ABSTRACT

The monograph presents ways of optimization of the reproduction of fish fauna due to the use of artificial spawning nests. There is classification of fish by nature, terms and conditions of the spawning course. Spawning nests divided according to the nature of fish spawning. There is given characteristic with describing and depicting of spawning grounds designs. It is indicated what species of fish and in what waters they can be used and also the efficiency and cost of their creation, use and maintenance. The book is intended for specialists in the field of ichthyology, ecology, hydrobiology, fisheries, public organizations activists, students and graduate students of higher educational institutions in "Biology" and "Water Biological resources".

Keywords: fish; spawning; artificial spawning ground; artificial reefs; spawning nests
# TABLE OF CONTENTS

## INTRODUCTION

1. BIOLOGICAL BASIS OF FISH REPRODUCTION
   1.1. Classification of fish by nature of spawning
   1.2. Classification of fish by breeding periods
   1.3. Classification of fish by level of spawning dependence on the flood regime
   1.4. Classification of fish by spawning place
   1.5. Classification by the reaction of fish on other environmental factors
   1.6. Classification of fish by time and frequency of spawning
   1.7. Classification of fish by nature of spawning substrate

2. TYPES OF ARTIFICIAL SPAWNING GROUNDS
   2.1. Substrate for spawning grounds
   2.2. Artificial spawning grounds for phytophilous fish species
      2.2.1. Float spawning grounds with various substrate
      2.2.2. Round nests on stilts and leashes as type of spawning grounds
      2.2.3. Floating frame artificial spawning grounds
      2.2.4. Artificial spawning nests on piling
      2.2.5. Frame spawning grounds
      2.2.6. Artificial spawning grounds of the type "kiddle" and "drag"
      2.2.7. Spawning grounds of "canvas" or "vegetative carpet" types
      2.2.8. Artificial spawning nests for pike
      2.2.9. Artificial spawning grounds for catfish
   2.3. Artificial spawning grounds for lithophilous fish species
      2.3.1. Artificial spawning ground of the spawning field type
      2.3.2. Artificial spawning grounds of expanded clay aggregate composite panels
      2.3.3. Spawning nests for zander
   2.4. Artificial spawning grounds for pike
   2.5. Artificial spawning grounds for catfish

3. ARTIFICIAL REEFS AND SHELTERS FOR FISH
   3.1. Artificial reefs
   3.2. Artificial structures as shelter for young fish
   3.3. Places of installation of artificial spawning grounds
   3.4. Terms of installation of spawning grounds
   3.5. Caring about spawning grounds
   3.6. Efficiency of spawning grounds

4. WAYS OF OPTIMIZATION OF REPRODUCTIVE CONDITIONS OF INDUSTRIAL FISH FAUNA ON EXAMPLE OF ZAPOROZHIAN RESERVOIR
   4.1. The efficiency of the artificial nests and the order of their establishment in the Zaporozhian Reservoir
   4.2. The ecological, economic and social effects of the implementation of measures to restore spawning grounds

CONCLUSION
REFERENCES
INTRODUCTION

Creating of artificial spawning nests is the unique and inexpensive way to improve the environmental conditions of water bodies for fish spawning.

Exploitation of spawning nests construction is based on the use of the biological characteristics of fish spawning and implemented in several stages, with considering climatic, hydrological and water temperature factors. Construction of nests protects fish eggs from destruction; they are advanced for specific species of fish and can be characterized by high efficiency of substrate development and increased output of viable young fish. For nest manufacturing it is used modern, durable, environmentally friendly materials (mostly recycled).

It is known that the industrial stock and the spawning level of some fish species are defined by their breeding efficiency [1-3]. This means that the fish populations of natural waters are limited mainly by breeding conditions. In rivers natural reproduction of native fish species is under significant stress factor such as violation of level regime in the spring, adverse condition of breeding grounds, poaching fishing during spawning, etc. [4-8]. The shortage of breeding grounds can be rectified by using integrated environmental, Irrigation and drainage measures that are quite time-consuming and expensive (creating permanent spawning grounds, stocking, clearing wintering holes and spawning grounds, dredging) or by installing artificial spawning nests during spawning, which are able to improve conditions for fish spawning in rivers without major investment in environmental measures [9].

Artificial spawning nests can be used in reservoirs, lakes, rivers and seas for different species to expand areas of natural reproduction and increase an efficiency of fish resources reproduction in conditions of regulated river flow and integrated use of water biological resources, as well as concerning to the negative impact of other factors for the natural fish reproduction [1].

The monograph presents various constructions of artificial spawning nests that can be used for phytophilous, lithophilous and psamophilous species.

In the monograph spawning nests are separated by fish spawning characteristics. There are characteristic with describing and depicting of spawning grounds designs. There is indicated what species of fish in what kind of waters they can be used by and also the efficiency and cost of their creation, use and maintenance.

For the manufacturing of artificial spawning grounds various materials are used, natural and artificial. The natural materials concern plants (pine branches, dry grass, reeds, roots of trees and shrubs, etc), pebbles, and gravel [10]. Artificial materials include synthetic fiber net cloth, nylon thread and other.

The book is intended for specialists in the field of ichthyology, ecology, hydrobiology, fisheries, activists of public organizations, students and graduate students of higher educational institutions in "Biology" and "Water Bioresources".

1. BIOLOGICAL BASIS OF FISH REPRODUCTION

For full understanding the necessity of implementing measures to restore spawning grounds it is necessary to know the biological basis of fish reproduction. This knowledge helps to navigate in the ichthyological terms and concepts, as well as to understand the nature of fish reproduction and its direct dependence on external factors.
This section is devoted to the classification of the nature of fish spawning, breeding periods, degree of the spawning dependence on the flood regime, spawning place, time and frequency of spawning, nature of spawning substrate.

By biotopical affinity fish can be divided into the following groups: reophilous: roach, silver bream, white-eyebream, blue bream, asp, phoxinus, zander, gudgeon, catfish, brown trout, burbot, common barbel, common nase, schneider, chub, vimba; epibiotic: lamprey, spined loach; limnophilous: pike, prussian carp, common rudd, bitterling, bream, eel; eurybiontic: perch, ide, ruffe, bleak, stonemoroko, lepomis [11-14].

1.1. Classification of fish by nature of spawning

The nature of fish spawning is determined, foremost, by the breeding conditions [15]. Some species of fish during the maturation of reproductive products for annual reproductive cycle develops and lays only one portion of eggs, that is a one-time type of laying eggs which has roach, pike, perch, asp, sturgeon, salmon, some sardine and gobies.

Other species such as carp, tench, silver carp, common rudd, silver bream, ruff, some sardines and gobies, bleak have portioned spawning. There are some species of fish (bream, catfish, vimba) with asynchronous oocyte growth, but they have one-time spawning, i.e. all of the spawn is layed wholly at once. Bream, catfish and vimba females in southern waters can have portioned spawning. Thus in these species there is a one-time eggs laying in waters of northern latitudes when only one portion of eggs is getting ready to spawn and can be layed once in the spring. Thereby, these fish have adaptive capacity for adapting to living conditions and in the event of changes in temperature conditions, they can change the nature of spawning [1,15].

1.2. Classification of fish by breeding periods

According to the requirements for abiotic conditions that are necessary for the spawning fish can be divided into four groups (Table. 1).

**Table 1.** Environmental groups of fish by terms of spawning.

<table>
<thead>
<tr>
<th>Group</th>
<th>Fish species</th>
<th>Features of spawning</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Burbot, pike, perch, roach (taran), asp, common nase,ichel, toad goby.</td>
<td>Spawning is early (February – April), short-term (less than one month) at low temperature of water (up to +10°C).</td>
</tr>
<tr>
<td>II</td>
<td>European carp, tench, common rudd, prussian carp, silver bream, chub, catfish, grass carp, silver carp, gobies.</td>
<td>Spawning is late (May – July), stretched over time (more than 1.5-2 months) at high water temperatures (above + 18-20 °C).</td>
</tr>
<tr>
<td>III</td>
<td>Vimba, bream, zander, ruffe, common barbell, white-eye bream, all of the sturgeon (sturgeon, starry sturgeon, beluga, starlet, bastard sturgeon), sardines (herring, sprat).</td>
<td>By all of these indicators, this group of fish is in an intermediate (middle) position. Spawning occurs from April to late May, lasts from 1 to 1.5 months at a temperature of water from12 to 16 °C.</td>
</tr>
<tr>
<td>IV</td>
<td>Salmonids.</td>
<td>Spawning takes place in autumn and winter, the water temperature is 6-8 °C. Spawning is short.</td>
</tr>
</tbody>
</table>
The first group includes fish, that spawning is early (from late February to late March), short (duration of spawning is about 2 weeks) and it takes place at low water temperatures up to 10 °C. 

The second group of fish begins spawning from late spring (May), it lasts more than 1.5–2 months (35–80 days), spawning occurs with the advent of high water temperatures above 18 °C.

The third group of fish is intermediate between the previous groups, according to all these parameters, spawning mainly occurs in April – May, spawning period lasts about one month at a temperature of water +14–16 °C.

The fourth group includes fish with autumn-winter spawning, spawning occurs from October to November at water temperature +6–8 °C.

1.3. Classification of fish by level of spawning dependence on the flood regime

According to the level of spawning dependence on the flood regime (classification of A.F. Koblyt'skoyi) all researched fish can be divided to the following groups: I – spawning does not depend on the course of the flood: pike, perch, zander, vimba, asp; II – spawning success depends on the start time and duration of floods: carp, bream, roach, silver bream; III – spawning occurs later, when spawning grounds are flooded, so spawning does not dependent on the course of the flood: catfish, tench, common rudd, Prussian carp, crucian gold [16].

1.4. Classification of fish by spawning place

By place of spawning fish can be divided into two groups (Table 2):

Table 2. Groups of fish by the location of spawning.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Fish species</th>
<th>Characteristics of spawning location</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Asp, vimba, alburnus, common barbell, salmon, sturgeon, several herrings</td>
<td>River fish species, that have spawning in the running water</td>
</tr>
<tr>
<td>II</td>
<td>Carp, bream, catfish, roach, zander, silver bream, tench, common rudd, Prussian carp, perch</td>
<td>Lacustrine species, the ones that migrate for spawning to the bays, floodplain, oxbow, and they are called limnophils</td>
</tr>
</tbody>
</table>

I – river fish that spawn in flowing waters (asp, vimba, alburnus, common barbell, chub, common nase, salmon, sturgeon, herring.

II – lake fish that come to spawn in the quiet backwaters, oxbow, bays, come into small rivers (carp, bream, catfish, roach, pike, silver bream, tench, common rudd, perch and Prussian carp).

1.5. Classification by the reaction of fish on other environmental factors

According to reaction on other factors of aquatic environment (water flowage and clarity, oxygen content, presence of other gases) fish species can be attributed to these environmental groups (Table 3).
Table 3. Groups of fish by the reaction on other environmental factors.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Fish species</th>
<th>Level of exactingness to environmental factors of spawning</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Vimba, zander, alburnus, asp, common barbell, salmon, sturgeon, some herrings and gobies, silversides.</td>
<td>High level of exactingness (high level of Oxygen in water, good flowage and clean clear water).</td>
</tr>
<tr>
<td>II</td>
<td>Carp, bream, roach, pike, common nase, white-eye bream, sichel</td>
<td>Intermediate level of exactingness to specified environmental factors.</td>
</tr>
<tr>
<td>III</td>
<td>Tench, Prussian carp common rudd, perch, ruffe, silver bream, bleak.</td>
<td>Low level of exactingness to specified environmental factors.</td>
</tr>
</tbody>
</table>

I – high level of exactingness to transparency and flowage of water, oxygen contents, vimba, asp, perch, alburnus, barbell, salmon, sturgeon, herring, some gobies. For this group of fish due to regulation of river flow, intensive hidrobuilding in rivers, overgrown, siltation and drying of their subordinate systems in spring, summer and autumn periods when spawning occurs conditions that contribute to effective progress of their spawning, usually are much lower than optimal, thus the number of them is declining every year, and the industrial catch of these species are found only in single specimen.

II – intermediate level of exactingness to other environmental factors, carp, bream, roach, common nase, white-eye bream, sichel, catfish, pike. The number of some species of this group has survived, but in the volume of industrial fishing it is declined.

III – a low level of exactingness, tench, silver carp, perch, common rudd, silver bream, bleak. The number of fish species has increased, some of them occupy the top spot in catches.

1.6. Classification of fish by time and frequency of spawning

By time and frequency of fish spawning there is following historical sequence of breeding adjustments.

By spawning frequency:
1. Spawning takes place several times a year (fish permanently live in warm, mostly tropical waters).
2. Spawning occurs in a season (spring, summer) several times (fish of middle latitudes).
3. Spawning occurs in a season (spring, autumn) once a year (fish of northern latitudes).
4. Spawning occurs in a season once and it is followed by the death of sires (salmon).

By the time of spawning:
1) Those that spawn in the evening or night time – salmon, burbot.
2) Those that spawn only in the morning and afternoon – most species of fish.

1.7. Classification of fish by nature of spawning substrate

Depending on the particular conditions of reproduction and development, and primarily of the place, where the laying of eggs occurs, there are the following ecological groups of fish (Table 4).
Table 4. Groups of fish by nature of spawning substrate.

<table>
<thead>
<tr>
<th>Group</th>
<th>Fish species</th>
<th>Substrate types</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Carp, bream, roach, tench, perch, common rudd, silver bream, white-eye bream, pike, catfish, bleak, Volga pikeperch, Prussian carp</td>
<td>Phytophilous</td>
</tr>
<tr>
<td>II</td>
<td>Asp, vimba, alburnus, chub, common nase, common barbell, spined loach, sturgeon, salmon, some gobies, lamprey.</td>
<td>Litophilous</td>
</tr>
<tr>
<td>III</td>
<td>Sichel, grass carp, silver carp, herring, sprat.</td>
<td>Pelagophilous</td>
</tr>
<tr>
<td>IV</td>
<td>Benthophiloides brauneri</td>
<td>Psammophilous</td>
</tr>
<tr>
<td>V</td>
<td>Bitterling</td>
<td>Ostrakophilous</td>
</tr>
<tr>
<td>VI</td>
<td>Perch, vimba, roach, Prussian carp</td>
<td>Indifferent</td>
</tr>
<tr>
<td>VII</td>
<td>Zander, toad goby, catfish, monkey goby, Ukrainian stickleback, three-spined stickleback, pipe-fish</td>
<td>Lay eggs into nests and secure them</td>
</tr>
</tbody>
</table>

Litophilous fish such as vimba, asp, chub, common nase, common barbel, ruffe, starry sturgeon, sturgeon, beluga, bastard sturgeon, white-eye bream, trout, almost all species of gobies, schneider, Salvelinus. Litophilous fish breed in dense and rocky or gravel soils, usually in rivers on a flow or at the bottom of oligotrophic lakes. Phytophilous fish reproduce among vegetation, they lay eggs in stagnant water or in water with low flowage, on this year's or last year's vegetation. Caviar of phytophilous fish mostly sticky and adhere to the substrate (Fig. 1). This group includes the following species of fish – pike, carp, bream, roach, catfish, and common rudd. Psammophilous fish are represented by Benthophiloides brauneri lay eggs in the sand. Egg shell of Psammophilous fish is laid by sand. Pelagophilous fish, like grass carp, silver carp, bighead carp, sprat, pontic shad, spined loach, sichel. Fish lay eggs in the water column. Eggs and free embryos develop freely floating in the water. Ostrakophilous fish are represented by bitterling. They lay eggs inside the mantle cavity of bivalve molluscs. Caviar usually develops in the not favorable enough conditions for respiratory.

Figure 1. Phytophilous eggs, layed on a water plant.
Indifferent species, like perch, vimba, roach, Prussian carp and some other fish species, due to deterioration of environmental conditions are adapted to lay eggs on vegetation as well as on stones and other objects. Perch is indifferent to spawning substrate and can lay eggs on aquatic vegetation as well as on rocks or underwater objects. Spawn of perch looks like a reticulate bag with meshes, formed by eggs that stuck together with each other (Fig. 2). In each cell usually there are 4–8 sticky eggs. Perch spawn egresses in thick, long, gelatinous, transparent tapes, consisting of 200–300 thousand eggs, and sometimes more.

![Perch spawn](image)

**Figure 2.** Perch spawn.

Vimba contrary, is a litophilous fish but also lays eggs at plants. There are a lot of such examples

However, the nature of these intermediate (indifferent) or neutral forms are always closer to one of specified environmental groups.

2. TYPES OF ARTIFICIAL SPAWNING GROUNDS

Artificial spawning grounds for pike, bream, roach, perch and other fish species are structurally diverse. The most common are floating frame spawning grounds, spawning nests, spawning kiddle [10].

*Frame spawning grounds* These are the wooden frame with length of 4–6 m and a width of 1 m, made of dried spruce or pine poles or boards (saw-mills waste). For such a frame at a distance of 50–100 cm apart substrate is suspended (branches of spruce, pine, juniper, and others.) (Fig. 3).

At shallow depths (1.5–2.0 m) substrate is attached in one or two tiers, at large (3–5 m) ones in three or four tiers. Several frames are linked together in length, and this connection is established at anchor or if the depth allows attached using pegs. Frame spawning grounds can be used in reservoirs [12].

-8-
Figure 3. Artificial spawning grounds, made from pine branches.

**Spawning nests.** Nest type of spawning ground has a simple construction. This is a wire hoop diameter 1.0–1.5 m with a spawning substrate fixed inside of it. Shape of spawning nests may be different, for example, circle, square, triangle – this is not essential. As a substrate it is used washed roots of plants, old seine or grid, nylon fiber. The bottom of nest is attached with a load (stone, bricks). This spawning ground is placed to the bottom of the reservoir with a float in areas with depths up to 5.6 m. It is appointed mainly for zander, but also can be used by other fish, including bream and roach [10].

Nests may have other design, such as two circles of metal wire with a diameter of 5 mm, interconnected with racks. The diameter of the circles is 0.7–1.0 m; rack height is 20 cm. The upper circle is sheathed by nylon netting with the mesh diameter 10–24 mm. Substrate of pine needles is attached to the netting. Nest is immersed to a depth of 2 m; and leash with float is tied to the circle. Spawning nest may be another type. Instead of a wooden or metal frame with an accordant substrate it can be artificial trees. They are a wooden stake, nailed down in bottom of a reservoir and with a branch of pine, spruce, heather mounted on it. These trees are set in coastal areas of ponds. When they are placed in large quantities, they form the so-called "spawning field." For the first time these spawning grounds have been applied at the Kremenchug reservoir and they gave good results. They can also be used on the reservoirs that do not have major fluctuations in water level during the spawning period.

**Kiddle spawning ground.** This simple structure: 50 cm long wire suspended in the water with styrofoam floats and anchors secured at the ends (Fig. 4). Along the entire length of the wire in every 30–40 cm there are leashes with spawning substrate in one or more layers that depends on the depth of the area. This type of spawning grounds can be used in large reservoirs.

As the best in a constructive relation it should be recognized frame-spawning and spawning kiddle. The most acceptable frame size is 4x1 meters and kiddle length of 50 m. The area of spawning substrate in one spawning frame must be at least 10 m², and the spawning-kiddle 30 m².
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Carcass of spawning grounds can be made with both natural and artificial materials. In the forest zone preference should be given to local materials as more accessible and affordable, and the waters of the steppe zone - synthetic materials (for example, plastic hoses).

2.1. Substrate for spawning grounds

The nature of laying eggs of fish can be divided into groups: phytophilous, when eggs are layed on vegetation, psammophilous – on sand, litophilous – on stones, pelagophilous – in the water, etc. Most fishes of large reservoirs refers to phytophilous [17]. However, among this group there is no clear certainty in selecting spawning substrate [12]. Some are more demanding in this respect, others not so exacting. Carp, for example, spawn only on fresh vegetation, bream also uses green sedge plants, but in their absence as a substrate for spawning can be used macrophyte roots and other objects. Roach is less demanding, it lays eggs on a variety of substrates such as-fresh and last year's vegetation, plant roots, flooded bushes, branches, sunken trees etc.

Until recently for creating artificial spawning grounds it was used exclusively plants substrate – branches of spruce, pine, juniper, old straw, twigs, roots of macrophytes etc. In the water, especially at high temperatures, a substrate rapidly decomposes, loses its original properties and, at best, can be used during one spawning season, which reduces the effectiveness of the measure. Thus it is important to search for such material that can be a spawning substrate, and can be used repeatedly, and it could be used successfully by fish as well as natural (plant) substrates [10].
Researches in this direction have been being carried out for a long time. In recent years, here and abroad it has begun an applying of synthetic materials. Excellent results were obtained for using nylon. It does not rot, as it is known, has high strength, with low volume creates a large surface and, finally, most importantly, can be used for several spawning seasons. Capron can be easily painted by various aniline dyes, which makes it possible to select the color for the substrate, as shown that some species of fish prefer one or the other colors. For example, for pike and carp substrate it is better to use brown and pink colours. That is why the color of the substrate also has significant value. Spawning grounds with dark substrate (black, brown and red) are better mastered by fish. Synthetic materials in the form of bristles, etc. should be widely used for the manufacturing of spawning substrates.

The form of artificial spawning substrate, no matter what material it is made from, has no significance. In practice of fishery in lakes and reservoirs spawning substrate as well in the past and now is used in the form of whole branches of spruce and juniper, or bundles of firewood, some macrophyte rhizomes or panels made of them, mats, woven from willow rods, reeds and sedges, garlands from the old straw or spruce branches in the shape of tree coma etc. (Fig. 5).

![Figure 5. Artificial frame spawning ground with using washed roots of plants.](image)

For creating artificial spawning nests it is advisable to introduce modern resistant synthetic materials. As spawning substrate it can be used an old nylon fiber and mesh, used for transporting fruit and vegetables, these are the recycled materials and are usually thrown in the trash by large networks of retail campaigns (Fig. 6).
Figure 6. Members of Student Scientific Society the “Hydrobiologist” creating artificial spawning grounds with using of old nettings for vegetables.

The dimensions of the substrate, as well as its form, within certain limits are not important for fish, eggs are laid as well on large branches of spruce (1.0–1.5 m) and the small (0.3–0.5 m). The important thing is location of the substrate. Substrate garlands of small spruce twigs that hang in a distance of 80 cm or more from each other, are less attractive to
fish than the same substrate, but more crowded. It is the best of all, if the substrate will be in a distance of 20–30 cm from each other both vertically and horizontally.

Substrate of different materials and shapes is used well by fish if a pond in case of shortage of natural spawning grounds. Thus, in the reservoir on the substrate as nylon netting or snood, pine and poplar branches are very suitable for bream to lay eggs. Density of spawn is quite large – up to 500 thousand eggs or more per 1 m², also it was noticed that mostly eggs are layed on the branches of pine and nylon snood. In the reservoir bream and roach lay eggs in large quantities (up to 200 thousand eggs per 1 m²) on the branches of spruce, juniper, and heather. In order to streamline accounting of artificial spawning grounds it was laid the basis for the accounting unit – the "nest" from area of the substrate 1 m². It is that one spawning frame size 6x1 m must have at least 24 nests (in smaller frame size amount of nests will be less), and 1 ha of spawning fields must accommodate at least 5000 spawning nests with area of 1 m² each. Square of kiddle spawning should also count on the arbitrary nests [10].

2.2. Artificial spawning grounds for phytophilous fish species

With the current water regime in some reservoirs natural repopulation of phytophilous fish is limited. Reservoir water levels in the spring are not stable, it is sometimes observed decline, and there are cases of winter drawdown. By reason of failure of protocol solutions in interdepartmental commission for installing water level in the Dnieper reservoirs that makes drawdown annually in the spring, during the fish spawning. Because of this there are sudden changes in water levels, affecting the course of spawning and the vital functions of aquatic biological resources in general [1; 18].

In some years, fluctuations of water levels in reservoirs greatly exceeds ecologically reasonable standards, that leads to a reduction of spawning stock, atypical movement of sires in the spawning period and total degradation of spawning efficiency. In this mode, reservoirs do not have necessary conditions for the reproduction of fish fauna on the existing natural spawning grounds for phytophilous fish species. Problem with the lack of spawning grounds can be solved to some extent by arranging of artificial spawning grounds [19].

Phytophilous fish are less demanding to spawning substrate, so for their spawning there are numerous variants of artificial spawning nests [18]. For phytophilous species it is mainly used float spawning grounds with various substrate (vegetal or synthetic), round spawning nests, which are mounted on a leash or on stilts, floating frame, artificial spawning grounds, frame spawning grounds, spawning grouns of "kiddle" and "drag" types [10].

2.2.1. Float spawning grounds with various substrates

Float artificial spawning grounds are metal or filar rope for fixing with the float, made of styrofoam or empty plastic bottles (cans) (Fig. 7).

On the top of floats it can be set warning signs that warn about locations of artificial spawning grounds on the area of a reservoir.

This artificial spawning nest is made from coniferous trees, bast, last year's vegetation, nylon waste, netting material, old nets that are fixed on the metal hoops of various sizes and shapes (Fig. 8). Spawning grounds are made of nests of a single-storey or multistorey design. They are installed at a depth of 1.0–2.0 meters in long lines in places of mass fish spawning. These are used for s pike, bream, roach (sprat), and carp spawning.
**Figure 7.** The single-storey float artificial spawning nests. Spawning ground for zander with nylon netting material (A) and with natural substrates (B).

**Figure 8.** Float artificial spawning ground of whole branches of conifers.
After fish spawning spawning nests with fertilized eggs can be transferred to another section of the reservoir, which is better suited for the development of fish eggs and larvae of fish (well heated, has sufficient dissolved oxygen, there is no flow, etc.). The cost of manufacturing of spawning varies depending on the cost of consumables.

2.2.2. Round nests on stilts and leashes as type of spawning grounds

Such artificial spawning nests are widely used in reservoirs of the Dnieper, Danube, small lakes and reservoirs of Dnipropetrovsk region for spawning of bream, roach, perch, silver bream, perch, carp [10].

Round nest made of various materials: metal wire, wicker or willow wooden slats. The diameter of the nest is about 0.4–1.0 m. The created circle inside has frame, which is swifted by net canvas, which is attached with spawning substrate of synthetic fibers, old vegetation (washed roots of reed, cane, wicker, etc.) or fresh coniferous branches, old nets and nylon or fishing line netting materials. Spawning substrate is embedded and fixed at the base of circle to make a solid soft "carpet" (Fig. 9).

![Fixation of coniferous branches on a round spawning nest](image)

**Figure 9.** Fixation of coniferous branches on a round spawning nest.

It is recommended not to use tarred or treated with odorants materials for these spawning grounds, because most fish are sensitive to strong and foreign smells.

These spawning nests are completed in long garlands, and suspended on floating frames or leashes, ropes with floats and a sinker. It is suspended on average 15–20 nests on each frame. Leashes can be installed individually or be connected by a single cable up to 70 m and attached to stakes knocked into the reservoir ground. Artificial spawning nests are attached through every 50–60 cm. These spawning can be established at depths of 1.0–1.5 m to 3.4 m. Most spawning grounds are located at a distance of 3–5 meters from each other. Round spawning nests on leashes can be used for lithophilous fish, and should be set on the bottom of the reservoir and fixed by using leash with float (Fig. 10).

For perch-bottom nests can be used, that are made of a metal frame or wire circle in which by a thin wire or fishing a nylon netting is attached, where nylon fiber is binded.
2.2.3. Floating frame artificial spawning grounds

Figure 10. Round spawning nest for zander.

Figure 11. Scheme of artificial frame spawning nest [10].
The spread of these spawning nests was got in the years 1950–1955 in the Volga reservoirs. They are a wooden frame with length 4.6 m, width 1 m, that are manufactured from dry poles or boards, mainly saw-mills waste (Fig. 11).

To a wooden frame it is attached spawning substrate, which is made from the branches of pine or juniper on long leashes of wire or nylon rope. Spawning substrates are fixed at a distance of 50 cm to 100 cm and placed in several tiers. Several frames with nests are linked together in length, and this frame is fixed to anchors or piles (Fig. 12) [12].

![Floating frame spawning nest for phytophilous species](image)

**Figure 12.** Floating frame spawning nest for phytophilous species [12].

Frame spawning fitofilnyh designed for spawning fish species (pike, roach and bream), they can be used in various shallow reservoirs.

### 2.2.4. Artificial spawning nests on piling

Spawning nests on piling are represent by wood piles, which are crammed driven into the ground or connected by metal wire or wooden rails. Sometimes spawning nests have attached floats. Brooms of coniferous branches are nailed or fixed by means of wire to wooden piles of spawning nest (Fig. 13) [10].

Such spawning grounds can be made any size, depending on the depth and flow of areas of reservoirs where they are installed. These nests are installed in order to improve reproduction of phytophilous fish species, primarily roach and bream. In order to ensure effective reproduction of fish artificial spawning nests are installed in so-called "spawning fields" in places of mass congestion of fish sires before spawning.
Figure 13. The method of spawning substrate fixing [10].

Also brooms of branches are hung on a metal wire between two piles that connect adjacent piles (Fig. 14).

Figure 14. The artificial spawning ground on piles, branches of coniferous trees, placed on a metal wire between two fixed piles.
It is recommended to install those spawning ground in the shallows of quiet bays no deeper than 1.0 m [10]. It is necessary for establishing spawning grounds on piles to keep of that all artificial substrate should be immersed in water to a depth of not less than 0.5 m from the horizon of water, where are no significant wind variations (Fig. 15). To prevent siltation of spawning grounds it is desirable to put them in areas of ponds with sandy bottom and small water flowage.

![Figure 15](image.png)

**Figure 15.** The method of installing artificial spawning ground and location scheme of "spawning fields" [10].

Setting of spawning grounds should maximally approach the timing of spawning of fish species for which they are designed. Spawning grounds are well mastered by phytophilous fish species.

According to fishery protection statement of Rivne, the introduction of "spawning fields" gives good results. In the spring of 2013 in water bodies in the Rivne region it was installed 180 spawning nests with total area of spawning substrate 1080 m\(^2\). Permanent inspection of artificial spawning grounds was being implemented by ichthyologists of fishery protection statement of Rivne jointly with representatives of public organizations that organized the installing of spawning grounds. In general, 1 m\(^2\) of artificial spawning substrate, on average, contained at about 50 thousand eggs of roach, bream, silver bream and other phytophilous fish that, in turn, indicates that it was laid about 58 mln of eggs to artificial spawning grounds.
2.2.5. Frame spawning grounds

Frame spawning of leash type are a set of wooden or wire frames on leashes covered with nylon fiber as artificial spawning substrate. These spawning grounds are immersed to the bottom using anchors and with fixed float on the surface, which is made of styrofoam or plastic bottles. They can be single or connected in kiddle.

Spawning nests on the frame are a metal hoop with a diameter of 0.4–0.8 m, which has an artificial spawning substrate fixed in the middle. Preferably, these nests are round or oval. As the artificial substrate it is used white or green nylon thread, as well as natural materials such as last year's vegetation, washed roots of plants, branches, bushes, pine branches and so on.

Some examples of frame spawning nests manufacturing:

1. Frame spawning can be made with natural materials. For example, the nest frame with diameter of 0.6–0.8 m can be made of grape or willow twigs with tied pine branches. The bottom of nest it is attached an anchor and nylon thread and float.

2. Caracas of spawning nest in a shape of a circle that is made of galvanized wire. The diameter of the frame ranges from 0.5 to 0.7 m. Spawning nest covered by net canvas with 6.5 mm orifice, to which it is attached willow roots or nylon threads as bristles. Nest is fixed on wooden pillars driven into the bottom of the reservoir in coastal areas.

3. Braided of with frame with a substrate of plant roots. Diameter of frame 40–50 cm, below which at a distance of 50 cm it is mounted an anchor and a thread with float on the part with the spawning substrate on a top side [10].

4. Round frame of metal wire, with nylon netting that tighten it. It is attached bundles of netting material that has become unusable or links of nylon threads. Diameter of frame is 40–50 cm.

Frame spawning nests are used well by fish, about 95% of such artificial spawning grounds are mastered by fish during spawning. In the frame nests bream, roach, perch lay eggs. The presence of vegetation as spawning substrate in frame structures sufficiently imitates natural spawning grounds, but quickly rots in the aquatic environment and loses its function [10].

2.2.6. Artificial spawning grounds of the type "kiddle" and "drag"

Artificial spawning of the "kiddle" and "drag" types are used in reservoirs and basins of large rivers for natural reproduction of fish.

Kiddle consists of nylon rope with length of 100 m, on which at a distance of 1 m from each other 5 round spawning nests are attached by leash. Circle of spawning nests is made of steel wire with a diameter of 4 mm, bent into the ring. The recommended circle diameter is 0.5 m, and the area of spawning nests is 0.2 m². Nest is binded by nylon fishing line, to which it is attached a synthetic substrate as individual tufts of unusable nylon netting, spent netting fabric. Nests of this design are completed in long benches of varying heights, depending on the depth of the reservoir. The distance between nests in the bench is 0.5 m, weight of one round spawning nest is about 0.4 kg.

Fixing of spawning nests, that form a garland, is implemented by three lateral leashes of nylon thread, that close at the top into one leash that is attached to the main rope. After a certain distance there are anchors attached to the rope. As the floats it is used styrofoam or empty plastic bottles that are attached to the top of spawning bench (Fig. 16).
The weight of a bench, which contains 10 spawning nests is 4 kg and weight of kiddle with hundred nests is 40 kg. The estimated cost of manufacturing kiddle with 100 nests may reach 300 USD. Efficiency testing of spawning nests should be performed at least once a week during spawning. Kiddles are less effective than the spawning grounds of the "band canvas" type.

After the appearance of fish larvae kiddle should be left in water for 3–4 days, then they are taken out to a coast, dried and kept in a warehouse. In waters that are near coniferous forests controlled by forestry, as a spawning substrate can be used pine branches. Spawning nests are made from branches of conifers that are binded by nylon cord as long garlands. Garlands are attached to the rope with hooks (galvanized or aluminum wire) with length of 50 m directly in water, by 50 garlands, ie 100 spawning nests.

Spawning should be installed at a depth of 2 m. Parallel kiddles are installed at a distance of 1.5–2 meters and thus it creates a spawning area with width of 10 m and a length of 100–150 m. These nests are well mastered phytophilous fish complex (pike, roach, bream) and indifferent species (perch). Density of spawn on the artificial spawning grounds made of coniferous branches can be up to 200 thousand eggs/m². During the period of incubation eggs output is 30–50%. In basins and reservoirs to create drag spawning grounds it is used thick nylon rope, on which in every 30 cm it is hung blown brushes of reedmace sedge or cane. In water spawning nests are fixed by anchors. Depth of structures location is controlled by using floats [10].

The length of a drag depends on a reservoir. Installation is carried out in shallow areas with weak flowage along the coastline at a depth of 50–70 cm. Usually, in these spawning grounds sires of bream, roach and carp lay eggs.

2.2.7. Spawning grounds of "canvas" or "vegetative carpet" types

These structures are used in river basin reservoirs, ponds, reservoirs of central regions of Europe. To produce spawning grounds it is used nylon fine-meshed network (mesh
20 mm), as well as canvas with mesh of 40–100 mm and a length of 20–25 meters, width of 1.5 meters, attached to the edge with a nylon thread.

In this canvas there are separate small bundles of nylon thread as a substrate. The substrate that is attached as bundles, is better than solid cover, imitates the natural substrate, is well washed with water, does not make lumps increases the life of spawning grounds. Spawning substrate must be resilient to keep the same thickness in water. In the river basins as a substrate it is used tree branches, bushes etc. The experience of the operation it was found that the output of eggs on such an artificial spawning is about 90 %, the density of laying eggs on them twice higher than on round spawning grounds.

Separate spawning canvases can be connected to the overall track of a certain length, through spawning fields are created with a certain area (Fig. 17).

![Figure 17. Spawning substrate with vegetation (pine branches).](image)

Spawning-canvases are set at depths up to 5 m in areas of the highest concentrations of bream, perch and other fish species.

Spawning grounds were approved many times. In 1983, some reservoirs were exhibited spawning canvas with total area of 5.5 hectares (272.9 thousand nests). Almost all spawning grounds that were installed were used by fish twice. According to estimates, the industrial return from the use of artificial spawning grounds in 1963 reached 3.8 tons.

It is successfully applied spawning grounds with size of canvas of 1.5x5. Mesh size of nylon netting, which is used as the basis of spawning ground is 7.8 mm. On the canvas there are bundles attached with nylon thread of 0.3 mm (mainly waste products). Threads are cut into bundles with length of 30 cm and it is worn a plastic ring to the middle of the bundle, which is fastened with plastic rivets. This thread bundles are folded in half around the ring in
a furry circle. Then they are attached to the canvas by wire in a staggered manner so their free ends do not touch the canvas on both sides (Fig. 18).

As a floating basis for spawning grounds there are metal or plastic pipes that are made for water. The ends of the pipe tightly sealed from each other at a distance of 5 m. The ends are attached by cargo anchors. In intervals between the pipes there are nylon ropes binded at a distance of 60–70 cm, on which spawning ground is hung.

Figure 18. Spawning grounds "canvas" (1) and "floral carpet" (2, 3).

Spawning ground of the "canvas" type is made in the following specifications: length of canvas is 25 m, height is 1.5 m, width is 0.5 m, diameter of mesh is 3 mm canvas area is 37.5 m², number of conditional nests is 150 pcs., the area of a conditional nest is 0.25 m². These spawning grounds are set both with anchor, and on piles (Fig. 19).
Material consumption: 1.4 kg of netting, 1.6 kg of net canvas, 0.16 kg of nylon thread, 1.3 kg of styrofoam, 60 kg of utilized netting (with 20% of waste fibers). The cost of making one spawning ground of "tape canvas" type ranges due to the cost of consumables.

**Figure 19.** Methods of installing of artificial spawning grounds "canvas" and "floral carpet":
1 – high piles (for carp, bream, roach), 2 – low piles (for zander), 3 – fastening on anchors

In areas with shallow bottom (0.5 m) can be used synthetic nests of "carpet" type that simulate the soft thickets of aquatic vegetation (Fig. 20). The nest is made of a plastic tube (or hose) on which it is attached bundles of fishing line with thickness of 0.2–0.5 mm. Bundles of fishing line simulate vegetation, move well, which improves the aeration of spawn.
At the bottom of the reservoir spawning nests are put parallel to each other at a distance of 30–50 cm; thereby they imitate the overgrown vegetation and create so-called "carpet" (Fig. 21).

Such spawning nests are used well by pike and carp that lay their eggs in shallow water areas. Also spawning modules of the "carpet" are convenient to be transported to other parts of the reservoir for further incubation of eggs.
2.2.8. Artificial spawning nests for pike

Reproduction of pike occurs from February till April on filamentous algae or last year vegetation on flooded vegetation during the spring floods when water temperature is +5 °C. Spawning of pike can be at a depth of 10–30 cm. As laying eggs occurs in shallow water on small depths, it is often noticed drying and death of eggs at sharp decline in flood waters during the spring or reservoir drawdown in hydroelectric power stations.

Usually spawning is noisy, one large female is accompanied by several smaller males. Pike spawn is adhesive and it is laid on the flooded coastal vegetation, it is quite large, it reaches a 2–3 mm in diameter. Hatch of larvae occurs in 10–15 days. The larvae have a length of 8 mm, they briefly stick to vegetation or nest.

Pike is less demanding to spawning substrate than carp. In the absence of spawning substrate it can be used artificial spawning grounds with cattail, sedges, reeds or other vegetation (Fig. 22).

In 0.1–0.5 ha of pond it is set 4–5 nests for pike spawning. At one artificial nest should be about 5–6 m² of spawning substrate. Spawning nests are set to make substrate be at a depth of less than 50 cm to provide that decrease of water temperature did not exceed 1–2 °C in possible cooling during a period of laying eggs.

During service of spawning nests for pike it should be borne in mind that its eggs at first are glued to the substrate, and 2–3 hours later they lose stickiness and easily kept in water at a distance of 8–12 cm from the bottom.

![Figure 22. A sample of artificial spawning grounds for pike with using vegetation.](image)

When prelarvae appear from the eggs, they attach to the substrate and only after 8–10 days proceed to active movement and nutrition, so after pike spawning spawning nests are recommended to be left in the pond for another two weeks.

2.2.9. Artificial spawning grounds for catfish

Catfish has spawning in spring and summer when water temperature is above 18°C. Usually catfish spawning occurs at the end of May – beginning of July. It goes to spawning by pairs. Catfish has spawning in shallow areas of reservoirs in river floodplains, comes to small rivers.
Catfish builds primitive nests in vegetation or digs a hole in the ground and press it down in shallow water [11]. A significant siltation of rivers and shallow areas of reservoirs effective natural spawning areas for this fish species have decreased. To restore spawning grounds it is advisable to use artificial spawning nests, which are put at a distance of 3–5 meters from the shore. With great effect catfish use nests, arranged in a triangular booth 70–120 cm tall, braided with willow or pine branches, roots and netting. The bottom of the booth as well is tightly covered by spawning substrate (Fig. 23).

Figure 23. Scheme of creation of spawning grounds for catfish.

These nests are set in groups of 3–5 pieces in places of traditional catfish spawning (Fig. 24). Reproduction of catfish usually occurs late in the evening or at night, but rarely can last until the morning. Reducing of atmospheric pressure accelerates the process of spawning [20]. In the nest the female lays eggs.

Figure 24. Placing of artificial spawning grounds for catfish.

The male guards the spawn and patrols the area of certain radius from the nest, driving away from spawn fish and other potential enemies (Fig. 25). In case of the appearance
of driftwood and branches on a territory of catfish nest of fish can grab and throw them out of the nest.

![Image of catfish guarding nest]

**Figure 25.** The male of catfish guards the eggs.

The incubation period of eggs lasts for 3–4 days (at water temperature 22°C) [20]. Hatch of free embryos may be 70–80% of the eggs. Temperature reduction to 17–15°C leads to death of embryos. Male guards eggs until the hatch of larvae out 2–3 days after it. Larvae that are emerged from the eggs have size of 7.0–7.5 mm and first days they are near a nest, stuck to its walls. In 5–6 days after the resorption of the yolk – sac larvae with length of 11–15 mm leave the nest and go to an external nutrition.

After the larvae emergence spawning substrate is removed so as not to clog the pond.

### 2.3. Artificial spawning grounds for lithophilous fish species

Pebble-gravel spawning grounds are used for spawning of sturgeon and vimba. They are mounds with thickness of 30 cm with pebbles or rounded gravel of different factions. Spawning filled in riverbed and coastal areas of the reservoir that can be flooded. These spawning grounds were built in the rivers such as Volga, Kuban, Don, Dnepr and other rivers. On the Dniester for lithophilous species it was used method of construction of artificial spawning grounds with use of coquina that was formed by the erosion of the river banks. Also, as the substrate for lithophilous species it is used gravel and pebbles of different factions. These materials are poured in layer of 20–30 cm. In 1979, in river Dniester it was created an artificial spawning ground of three stone and gravel ridges with total area of 0.35 hectares. Number of eggs that vimba has put during spawning at different sites of spawning ground, ranged from 100 to 680 eggs per 100 cm², and in the average 363 eggs/100 cm². Total amount of eggs reached 31.9 million eggs. The cost of creating such spawning ground depends on the price of gravel and the cost of its transportation and fill.
In 1983 in the river Dniester it was designed a building of another spawning ground for lithophilous species. Creating of spawning ground was also planned on existing dams (mounds) that were adjacent to the right and left banks of the river, 2 and 6 spawning grounds on each shore respectively. Dams were made of sand and gravel, poured using local material.

Bulk substrate was represented as a bulk layer of 20–30 cm thick and consisted of pebbles medium and large fractions with impurities of boulders and stones, shells with diameter of 10–20 cm. The length of the ridges was 350 m, the total area of artificial spawning ground was 0.95 hectares. Area and form of spawning fields was determined by the characteristics spawning behaviors of fish, that artificial spawning ground was designed for. Increasing the size of the spawning grounds is associated with the size of fish sires spawning depth and flowage speed, the higher these numbers, the more specific spawning area is necessary [21].

The required area of artificial spawning ground (Si) can be calculated:

\[ S_i = \frac{N}{Z} \times S \]

where: \( N \) is number of females that spawn, ind.; \( Z \) is frequency of spawning ground using; \( S \) is specific area, it is an area that is needed for spawning of one female [21].

The following are parameters of all designed spawning ridges (Table 5).

### Table 5. Parameters of spawning ridges for lithophilous fish [10].

<table>
<thead>
<tr>
<th>Parameters of spawning ridges</th>
<th>Serial number of ridges by flowage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ridges of right bank</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Length of the base, m</td>
<td>45</td>
</tr>
<tr>
<td>Width of the base, m</td>
<td>19</td>
</tr>
<tr>
<td>Width of the ridge, m</td>
<td>12</td>
</tr>
<tr>
<td>Average height, m</td>
<td>1.0</td>
</tr>
<tr>
<td>Front slope, m</td>
<td>1:3</td>
</tr>
<tr>
<td>Back slope, m</td>
<td>1:4</td>
</tr>
<tr>
<td>Area of a front slope, m²</td>
<td>142.3</td>
</tr>
<tr>
<td>Area of a back slope, m²</td>
<td>185.5</td>
</tr>
<tr>
<td>Area of ridge, m²</td>
<td>540.0</td>
</tr>
<tr>
<td>Area of whole surface of a ridge, m²</td>
<td>867.8</td>
</tr>
<tr>
<td>Volume of a ridge, m³</td>
<td>663.5</td>
</tr>
<tr>
<td>Volume of wave-built part of a ridge, m³</td>
<td>492.7</td>
</tr>
<tr>
<td>Volume of piled-up layer (spawning substrate), m³</td>
<td>171</td>
</tr>
</tbody>
</table>
The construction of such artificial spawning ground is intended for spawning of vimba and barbus. Also it was assumed that it will be assimilated by other lithophilous species, such as sterlet.

For vimba spawning it was conducted by UKRRYBVOD in the Lower Dnieper dam construction using gravel of fraction 20–40 mm. These spawning grounds have a length of 150–300 m, 50–60 m of width, height 40–50 cm. Their construction is quite time consuming and depends on the value of the gravel, but can function as spawning grounds for many years [10].

2.3.1. Artificial spawning ground of the spawning field type

Basing on the material, it can be affirmed that the spawning substrate for artificial spawning grounds is required for stimulation of fish sires spawning, laying their eggs, saving it from negative factors, growth of fish eggs and larvae, forming hydrological and hydro-chemical conditions on the spawning grounds [21].

An important prerequisite for the course of spawning is shape, material and size (a fractional composition) of spawning substrate, purity of its surface. For laying eggs, their development and hatch of larvae there are also needed such stable conditions on the spawning grounds:

- Slight change of the depth under the spawning grounds;
- Flow rate and the nature of the water flow;
- Stable position of spawning substrate;
- Chemical neutrality of substrate;
- Slight mobility of artificial spawning ground components.

As a result of years of research it was created spawning ground for lithophilous fish species, spawning field, which is assembled from separate pieces – spawning panels or spawning canvases [21,22].

Spawning consists of basic structures: multilayer rigid panel with different purposes for each layer and artificial spawning canvas with substrate on it. The design of the spawning panel with lightweight spawning substrate has a base made of small fraction expanded clay particles, bonded with a binder. The top layer (actually artificial spawning substrate) is made according to the destination of panel. For example, in the case of manufacturing panels for sturgeon species top layer of panel is formed from big fraction expanded clay particles with an average diameter of 60 mm [21].

Spawning fields with specified size are collected from individual panels and are set on the spawning grounds in early spawning. Such spawning grounds, that are made of spawning panels have an important advantage, because they can be installed on any depth or suspended on the floats, ie retain favorable spawning conditions despite the water level fluctuations in the reservoir. Artificial substrate can simulate pebbles, gravel, vegetation, etc. [21,22].

Spawning panels can be produced with different forms of artificial substrate and specified relative position of separate elements of spawning substrate. During the manufacturing of construction it can be set the size and shape of gaps between elements of the substrate and thereby the location of eggs on the panels can be regulated. If necessary, multilayer panels with different functions of each layer can be set: top is to encourage spawning of fish sires, following layers are for incubation of fish eggs and larvae on the first
During the production of panels it can be installed a certain relative position of layers, even push them, creating a space between the layers if it improves maintaining and incubation of eggs. Fragments of construction of spawning panels for spawning field for different species of fish are shown in Figure 26.

**Figure 26.** Elements of spawning fields A, B, C – three-ply spawning panels with spawning substrate that imitates, respectively, gravel, vegetation, moving gravel; C, D, E – two-layer spawning canvases with a basis of netting and spawning substrate that imitates the pebble (D, E) and vegetation (D); 1 – basis of small-fraction material; 2 – layer of middle fractions material; 3 – spawning substrate, imitating gravel; 4 – reinforcing and fastening cord; 5 – spawning substrate that imitates vegetation; 6 – the substrate that imitates the moving gravel; 7 – base made of bearing canvas; 8 – base made of netting [21].
The construction of artificial spawning grounds for lithophilous fish species can be made as a basis of an artificial material canvas, and there are spawning substrate, floats, nets and fencing, water regulating lattice attached on it. Spawning ground can be set to the necessary depth, on the most favorable for fish spawning areas, and cleaning of the substrate should be carried out on the beach. These spawning canvases can be folded or wrapped to the rolls for transporting [21].

Spawning field can be installed using a pontoon. Panels during the descent from the coastal areas are pivotally or rigidly connected in sections of 5–10 pieces. The front panel is attached to a pontoon or boat [21].

Such artificial spawning grounds are installed in pond areas where conditions are satisfactory (hydrological, hydrochemical, hydrobiological) for fish spawning, but these areas are not used due to lack of spawning substrate. These artificial spawning grounds should be placed in an area where at maximum drawdown of the reservoir or at the lowest losses of watercourse during all period is available depth for spawning and ripening of eggs. Also it should be noticed, that during the spawning period, flow velocity were greater than the minimum for spawning, but did not exceed 0.1–0.3 m/s. For example, to restore spawning grounds of zander spawning fields can be installed in areas with water depths of 2.0–4.5 m with a flow rate above artificial spawning 0.3–0.7 m/s. Speeding the flow can cause eggs flushing from the substrate. The form of artificial spawning ground should be an elongated area which follows the coast line within the spawning depths.

It is not allowed to place artificial spawning grounds near the water intake in the areas of their influence on the flow hydraulic in the reservoir, close to hydraulic structures that may cause harm to fish.

2.3.2. Artificial spawning grounds of expanded clay aggregate composite panels with different substrates

Such spawning grounds are designed for spawning of sturgeon fish species. Artificial spawning of panel type is a trough flattened plastic box (or crate), with length of 2 m, a width of 1 m and a depth of 9 cm. In the middle part, the panel is divided with transverse wall by the width [10].

As spawning substrate it is used expanded clay with fractions from 5–10 to 50–60 mm depending on the fish species, that artificial spawning ground is designed for. Additionally, the substrate can be equipped with bundles of synthetic fibers that imitate aquatic vegetation for spawning of phytophilous species. Expanded clay is filled in layers (lower, the covering layer of small fractions and the top is with big ones). To fix the substrate panel it is used Portland cement. Panel is intertwined by reinforced cord.

By the length of the panel in the middle part of it there is a detent for pipe which acts as a load for sections of the panels. For fastening the panels together it is used cord and pieces of metal pipe with a diameter of 7 cm, which acts also as an extra load. To load a section, composed of individual panels it is used a metal pipe with a diameter of 7 cm and length depending on the number of panels in the section (for example, section of five panels needs only two pipes with length of 4.5 m). Preparation of these spawning grounds and spawning substrate cleaning is implemented on the bank, and installation to the reservoir is directly before spawning, in the most favorable spawning areas for fish. In the spawning lightweight panels spawning substrate base is made of expanded clay with small fractions, bonded with a
binder. The top layer (actually spawning substrate) is manufactured in different ways, depending on the assignment of a panel.

Artificial substrate imitates pebbles or gravel in the manufacturing of panels for spawning lithophilous fish (sturgeon, salmon, vimba etc.), vegetation in the manufacturing of panels for phytophilous species of fish (carp, perch, pike and others) burrows in the manufacturing of panels, for example, for gobies. Thus, the feature of proposed spawning panel is possibility to produce it with the necessary form the substrate and with certain, predetermined and fixed at manufacturing, mutual location of spawning substrate [10].

During the manufacturing, design also allows regulation of the size and shape of gaps between elements of the substrate and thereby the location of eggs on the panels. If it is necessary, the placement of sandwich panels with different functions of each layer is possible: top one is to encourage spawning of sires; the following layers are for incubation of fish eggs and larvae of the first stage of life. Also during the manufacturing of the panels it can be installed a certain relative position of these layers, even push them, creating a space between them when it can improve the preservation and transportation of eggs.

An important advantage of this type of artificial spawning grounds is possibility of its factory manufacturing on the production line. The cost of artificial spawning panel (including manufacturing, construction, and installation into position) depends on the type and size of the panel.

Biological researches of spawning panels have shown that they are suitable for fish spawning [10]. Sturgeon, vimba, pike, perch and gobies laid eggs into panels. In addition, there were settled in large quantities benthic organisms and plants. This suggests that the chosen substrate (expanded clay) is not toxic. In comparative experiments it was observed that fish spawning is the same on the natural substrate (gravel), and the spawning panels of expanded clay. Laid eggs developed normally [10].

2.3.3. Spawning nests for zander

Nowadays, due to a significant siltation of small rivers and reservoirs lithophilous species lost lots of ponds areas suitable for spawning that may be offset by creation of special spawning nests. Lithophilous fish such as perch, lay eggs in nests that are built on sandy or muddy bottom of the reservoir. They clean the bottom site from the dirt, silt and vegetation residues and create a small dimple in a form of plate in the sandy bottom. Spawning of zander occurs in April or early May when water temperature is 11–15 °C [20]. Spawn of perch can be laid on cattail roots, willow twigs, stones or sometimes on a solid bottom, also on artificial spawning grounds, which are set in water. The male is nearby the nest and protects spawn. Thus, in the nest it is better protected from predators.

A common solution of problems with spawning areas for lithophilous species is creation of pond areas with poured gravel to provide a rigid bottom for nesting. This method is quite expensive, and eventually gravel may become muddy again.

As spawning nests for zander it can be used artificial disc spawning nests made of PVC (Fig. 27). Nest looks like concave disc with a diameter of 0.5 m, which is attached to the tripod with height of 10–15 cm. It is characterized by durability and has a hard surface.
Figure 27. The construction of artificial spawning ground for lithophilous fish.

Spawning structure is installed on the bottom of the reservoir in areas of spawning of zander. During spawning zander lays eggs in the nest and protects the eggs. In addition to the edges of the nest can develop periphyton small organisms that can serve as initial food for fish larvae (Fig. 28).

Figure 28. Placing of artificial spawning habitat for spawning of zander.
Such spawning nests are characterized by ease of use and reusability as they do not break down under the influence of aggressive aquatic environment. It is recommended to install 50 such discs on 1 hectare of a reservoir. These artificial discs for spawning of lithophilous species should be put in groups of 3–5 pieces.

Number of artificial spawning nests for zander is determined according to preliminary assessment of reproductive core of population considering that one spawning group may consist of one female and two males that need area of 20 m². Number of spawning nests should match the number of females that will use them. Installed artificial nests should be daily inspected for the presence of eggs, and in case of their absence nests should be washed, gently swinging them in the water. In the case of presence of eggs in spawning modules nest should be noticed with the tag on a float on which it is marked date of spawning progress.

3. ARTIFICIAL REEFS AND SHELTERS FOR FISH

The problem with replenishment of industrial stocks of many fish species, and generally increase the productivity of water may be solved by the construction and installation of artificial reefs. They can serve as spawning grounds and biological filters that simultaneously improve the ecological state of water bodies. It is also one of the most affordable and effective ways to increase spawning areas for fish that lay eggs on a solid substrate.

Restoration of spawning grounds of commercial species is provided and approved by the Cabinet of Ministers of Ukraine in legislative acts "About approval of the Concept of National Biodiversity Conservation Program for 2005–2025" (Decree of 22 September 2004 № 675-p) "About approval of the State Target Economic Program of Fisheries development for 2012–2016" (Resolution of 23 November 2011 y. №1245) [23].

3.1. Artificial reefs

Since the XVIII century, artificial reefs have been developing in 32 countries. There were uses all solid materials, harmless to the environment. In the Azov Sea similar works were started by AzPIvdenNIRO in 1984. The very first scientific results have shown that the installation of them increased number and variety of fish fauna. The most effective they were used as spawning ground by Azov gobies. Installation of 25 thousand plates on bottom square of 300x50 meters can produce annually 50 tons of gobies in industrial returns. The construction of artificial spawning reef was approved at the International Symposium in California, and environmentally reasonable spawning substrate of reef serves as the "underwater incubator" [24,25].

Artificial reefs are structures in coastal waters that are aimed at solving narrowly directed and complex tasks of biodiversity and biological productivity increase. Artificial reefs have different missions, depending on the design, material, size, number and capacity of the reef [26]. With all the variety of designs they are multi-purpose:

- Spawning substrate for industry fish spawn that stuck, restoration of natural reproduction;
- Places of shelter and residence of fish and other aquatic organisms (crustaceans, molluscs, etc.);
- A substrate for various accreting organisms (algae, macrophytes, mollusks), creating a set of stable biocenosis;
- Biological filters that purify the water through the life of various organisms, filter feeders that inhabit the reef;
- Speeding up the circulation of nutrients;
- Concentration of fish and forage organisms;
- Stabilization of bottom soils, strengthen and protection of coast and biocenosis of aquatic plants;
- Space for recreational fishing, spearfishing and underwater ecological excursions;
- Object and way of aquaculture (growing mollusks, algae, crustaceans, fish reproduction industry, etc.);
- Complex fisheries reclamation of water bodies;
- A way to protect fish and aquatic organisms from poaching (inability of trawling, nets installation, etc.);
- Method of disposal of environmentally inert wastes (most reefs are made of recycled materials).

Works on the installation of artificial reefs can be regarded to the main productive activities of any fishery enterprises and have as an objective reproduction and rational use of water biological resources. Moreover, according to the decisions of the Cabinet of Ministers of Ukraine it regards to environmental work that improves ecological state [23,26].

The main objective of artificial reefs introducing is increase of the biological productivity of waters by creating places of guaranteed natural reproduction of fish on artificial spawning grounds on reefs, and implementation in practice of scientific research in aquaculture.

For the construction of artificial reefs it is recommended to use the following materials:
- Ceramic products of baked clay, roofing tiles of all sizes and profiles, waste ceramic ware, waste of plastic food containers, bottles from water and beverages;
- Concrete products based on sand, shells using cement or lime;
- Construction of waste silica and red brick, cinder block, fragments of concrete products, plaster and concrete;
- Natural stones, rubbles and large gravel, limestone, sandstone and coquina;
- Synthetic ropes and strings, metal anchors, chains, etc. [26].

The main structural characteristics for water reefs may be:
- Stationary installations of long-term use made from small planar-linear modules, that are rigidly fixed to the ground by ropes, chains, anchors and rubble filling;
- Connections of spawning reef on base of food plastic bottles, modules of type "Daisy" with sand and cement loading, improved designs of various biomodules;
- Establishing on the soil of solid environmentally sustainable materials that serve as spawning substrate and shelter for young fish, such as ceramic tile, natural stone, gravel, crushed stone, waste of brick, cinder block, limestone, concrete;
- Specially made tile plates made of sand and cement mixture;
- Mobile reefs of different designs: bimodules, penta-dekamodules, "Daisies" etc. (Fig. 29).
Figure 29. Various designs of mobile reefs.

Figure 30. The general scheme of the reef "Daisy".
For manufacturing of mobile reef of "Daisy" type there can be used food plastic bottles (Fig. 30). Production of 1000 such reef modules consumes about 6 thousand bottles that can ensure recovery up to 2000 m$^2$ of spawning ground for lithophilous fish species.

Since fish spawning occurs in shallow water, the fish fry are often victims of piscivorous birds and predatory fish species due to lack of shelter. As artificial spawning grounds that will serve a protective function for young fish there can be used constructions of food plastic bottles with appropriate holes for fish and are connected into groups that are called modules. Creating a mobile reef shelter for young fish with use of plastic bottles can ensure a high survival rate of fry. To create the plot of 500 m$^2$ for youth protection required amount of consumables is determined by calculating – 3620 plastic bottles, 450 meters of rope, 50 anchors. Usually water area for installing artificial reefs should be marked by signal buoys with warning signs.

3.2. Artificial structures as shelter for young fish

Due to the fact that the installation of artificial spawning grounds increases the output of young fish from spawn in coastal areas of water their quantity increases. A large concentration of fish yearlings in shallow can attract predators (piscivorous birds, predatory fish) and according to the absence of a sufficient number of hiding places fish fry can become easy prey. To increase the percentage of survival of young fish in coastal areas of water it is recommended to install artificial shelters, as that may serve driftwood, roots and branches of trees or synthetic cover, made from sustainable materials. Artificial shelter for young fish can be both horizontal and vertical construction. It is advisable to use a combination of horizontal and vertical structures that create safe conditions for the existence of different species of fish.

Horizontal shelter looks like a wooden or plastic cylinder with length of 1.5 m, on which it is fixed 40–60 flexible "branches" that are made of rubber hose with diameter of 3 cm (Fig. 31).

![Figure 31. The design of the horizontal shelter.](image-url)
Figure 32. Shelter of "bush" type.

Figure 33. Artificial cover the "tree".
Figure 34. Examples of combined installation of artificial shelters "buch" and "tree" in the pond.

In 1 hectare of shallows of ponds it is recommended to install 36 horizontal shelters. They are placed at a depth of 0.5–1.2 m. Artificial cover of "bush" type is a plastic hemisphere with a diameter of 1 meter, which carries 40–50 polyethylene hollow "branches"
(or made of hose) with length of 50–60 cm (Fig. 32). This design is used as artificial spawning ground and as a shelter for juvenile fish.

In addition to above listed, with long retention of structures in the water on the surface of artificial shelter periphyton organisms spread (diatoms, filamentous green algae, molluscs) that can serve as an excellent feeding base for young fish.

Artificial shelters of "bush" type should be preferably set by 3–5 pieces per 0.5 hectares of reservoirs at depths of 1–1.5 m.

Sectional design of "tree" type is used by fish to lay their eggs in the spawning period, and also serves as a hiding place for the larvae and juvenile fish. The height of construction reaches 2 m; its diameter is 1.8 m (Fig. 33).

Shelter "tree" has more than 120 flexible polypropylene hollow "branches", each of them has a length of 0.6 m (total length of the "branches" is 72 m). Because of the large size artificial shelter "tree" can be installed at depths of 3–4.5 m. It is also advisable to combine it with shelter "bush" (Fig. 34). The design of "tree" provides creation of about 10 m² substrate for the development of fodder such as algae, insect larvae, and small crustaceans.

Also as a comprehensive shelter for young fish it can be used a construction, made of plastic boxes from the fruit and vegetables. Such plastic boxes are recycled as most stores after the sale of fruits and vegetables throw these boxes or hand them out for free.

Boxes are connected in pairs by nylon or wire, creating a module-cover, which can be combined in various designs. With piles of wooden or plastic rods they can be fixed in shallow areas of ponds, where is a lack of shelter for young fish (Fig. 35).

![Figure 35. Shelter for young fish made from plastic boxes.](image)

Young fish swims into the holes of boxes and can move freely inside the shelter or swim out from the other side. Modular blocks of boxes allow to create different designs for
different species of fish fry. To create such shelters it should be used the boxes of the same size as they are tight to each other and have special clearances for fixing of structures (Fig. 36).

The optimal size of boxes is 40x30x18 cm, these boxes are used to transport fruit and vegetables. They are very compact and stable, with gaps for pairwise combination, and can be used repeatedly for several seasons.

![Figure 36. Location of shelters for young fish made from plastic boxes.](image)

Locations of shelter for young fish should be marked by signal floats or small buoys to warn fishers and fisheries authorities about the presence of water structures.

3.3. Places of installation of artificial spawning grounds

The parts of the reservoir where artificial spawning grounds are installed and time of their installation, greatly influence on the success of the measure. In the practice of the Zaporozhian Reservoir there were times when spawning grounds were seemed to be set at good place but were completely unused by fish or used poorly. The reasons are different, but the main thing is that the installation sites are distant from the spawning routes or they are in such areas that previously (before the regulation of flow) served as spawning grounds. It is known that fish migration instinct is saved for permanent breeding sites. Therefore, the best areas to install artificial spawning grounds are waters of the former spawning grounds. Quite effectively there are used spawning grounds, which are set in bays of rivers, straits between islands and other areas where depth are sufficient (2.5 m) and there are wind-wave phenomena, creating a movement of water mass. In these places water usually warms up well, there is no strong silting of spawning substrate and, overall, conditions are favorable for the development of fish eggs.
Spawning grounds should not be installed in the open reaches with great depths or in shallows where is strong influence of waves. They also cannot be put in small shallow bays with stagnant water, because in these conditions, artificial spawning substrate silts and eggs die. Thus, the choice of location for the installation of artificial spawning grounds is an important point that ensures efficient use of different types of fish. Spawning grounds should not be installed in the open reaches with great depth or in shallows that are exposed to strong influences of waves. Spawning grounds also cannot be put in small shallow bays with stagnant water, because in these conditions, artificial spawning substrate becomes silted and eggs that were laid on it dies. Thus, the choice of location for the installation of artificial spawning grounds is an important point that ensures efficient use of them by different types of fish.

3.4. Terms of installation of spawning grounds

It is equally important the term of installation of artificial spawning grounds. Setting spawning ground long before the spawning period greatly reduces the possibility of its using as a substrate during prolonged stays in water becomes silted and loses its properties. In this state, it does not attract the fish to spawn. Good results are also not expected when spawning ground is installed late, when most fish have finished spawning.

Spawning grounds should be installed not later than 1–2 days before the mass spawning that occurs in various species by these temperature conditions (Table 6)

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Water temperature at the beginning of spawning, t °C</th>
<th>Water temperature of mass spawning, t °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burbot</td>
<td>1</td>
<td>1–3</td>
</tr>
<tr>
<td>Pike</td>
<td>4</td>
<td>6–10</td>
</tr>
<tr>
<td>Perch</td>
<td>7</td>
<td>8–10</td>
</tr>
<tr>
<td>Roach</td>
<td>9</td>
<td>10–14</td>
</tr>
<tr>
<td>Zander</td>
<td>10</td>
<td>11–15</td>
</tr>
<tr>
<td>Prussian carp</td>
<td>12</td>
<td>13–17</td>
</tr>
<tr>
<td>Bream</td>
<td>12</td>
<td>14–16</td>
</tr>
<tr>
<td>Blue bream</td>
<td>12</td>
<td>13–15</td>
</tr>
<tr>
<td>Common rudd</td>
<td>15</td>
<td>16–19</td>
</tr>
<tr>
<td>Silver bream</td>
<td>17</td>
<td>18–20</td>
</tr>
<tr>
<td>Carp</td>
<td>18</td>
<td>20–22</td>
</tr>
<tr>
<td>Tench</td>
<td>19</td>
<td>20–22</td>
</tr>
<tr>
<td>Catfish</td>
<td>20</td>
<td>21–24</td>
</tr>
</tbody>
</table>
The procedure of preparation for the installation of spawning grounds is following. In advance, about a week before spawning, ropes, cables, wire, frames of spawning grounds, spawning substrate, pins, anchors and floats are being prepared and all of these in the finished state is placed on shore in an area where it is scheduled to establish spawning grounds (Fig. 37). Production of artificial spawning grounds can be occurred directly nearby water bodies as prefabricated spawning nests are usually quite bulky and heavy, that can make problems with transportation and requires additional costs for their transportation.

In places where spawning grounds are flooded during floods they can be put directly on the area which will be flooded. Otherwise, they can be transported by boats to fish spawning grounds and make installation of spawning structures there.

Spawning grounds are set to scheduled sites. Previously, these areas are examined: it is determined their depth, soil, topography, protection from winds and waves. Most spawning grounds are installed in areas with hard soil, that to some extent reduces the rate of siltation of spawning substrate.

![Figure 37. Placing of mounted artificial spawning grounds and shelters for young fish in the coastal area of the reservoir.](image)

Spawning nests should be exhibited when in control catches appear first individuals with signs of readiness for spawning. Most fish have weakly expressed sexual dimorphism, males and females are almost indistinguishable externally. Some species have pronounced secondary sexual characteristics: females are larger than males; they have a bright color, elongated fins. Some species of fish in the spawning period due to influence of sex hormones have breeding dress, which disappears after spawning. Many carp fishes and whitefishes have secondary sexual characteristics on the head and body that can be seen in the early spawning. On the head, scales and fins of fish pearl rash appears, it is a kind of outgrowths of keratinized epithelium. More pronounced "breeding dress" have fish males (especially bream, roach, carp) (Fig. 38).
Pearl rash helps to identify the sex of individuals stimulates maturation and facilitates emerging of sexual products by rubbing bodies of fish sires during spawning. At the end of spawning a "breeding dress" disappears without any consequences for the fish. Males of round goby during spawning are completely black. The abdomen of the stickleback males becomes bright red from silver. Bitterling females during spawning have elongated oviduct that turns to ovipositor that allows females to lay eggs by one to siphon of freshwater bivalves.

Salmon (salmon and trout) during spawning have noticeable bright color, which is often called "breeding dress".

Secondary sexual characteristics of some species of fish are available not only during spawning. For example, external rays of abdominal fin of the male of tench are strongly thickened.

3.5. Caring about spawning grounds

Artificial spawning grounds, no matter how well they were installed, should be under constant surveillance. Often in stormy weather they break away from the anchors, stakes and they are moved by flow over long distances. Under any circumstances, it is necessary to review them periodically and repair damage.

But care about spawning grounds is not only that. Eventually substrate and eggs on it become silted and eggs are affected by saprolegnia, that leads to worsening of conditions of
incubation. To avoid this phenomenon, it is necessary in every 3–4 days to review spawning grounds and carefully rinse substrate in water.

In some cases it is necessary to move spawning grounds to other parts of pond. It is in moments of sharp decline in water level caused by hydroelectric operations mode. In such cases with great care not to damage the eggs and do not wash it with substrate spawning grounds are transferred to a place with more depth and put at anchor.

The duration of the incubation of eggs of bream, roach and other fish species on artificial spawning grounds depends on the water temperature. At low temperatures the development of eggs is slower at higher temperatures it is faster. On average this process takes 7–8 days.

Floating spawning grounds should be left in the water at the installation site for 3–4 days after hatching of larvae. At this time, they serve as a shelter, hiding place for fish larvae. In the nests in the first 2–3 days larvae being in suspended state, pass the stage of peace. Then they detach from spawning substrate and begin to swim, using a substrate as a shelter for protection from external influences.

About 3–4 days after hatching, the larvae get away from spawning grounds, distributing in the coastal zone in shallows of a pond. Spawning grounds are free and can be taken away. frames are dried and stored for the next year, the substrate if these are branches of spruce or juniper are laid on the bank, not to clog the reservoir; nylon substrate after washing, as well as the frame must be kept until the next spawning season

3.6. Efficiency of spawning grounds

Artificial spawning with various substrates, especially the branches of spruce and juniper are used by lithophilous fish very well. It is testified by massive laying of eggs on them, including spawn of bream and roach. In one standard frame type floating spawning ground these fish, on average, lay about 2 million eggs.

Often the substrate is completely covered with spawn in several layers. Thick egg layings are made by roach on the substrate, which is located in the upper layers of water; sometimes so many eggs are laid that it forms large clumps and their weight drowns spawning ground. It is characteristically that almost all eggs are fertilized, viable and develop normally. Typically ability to survive in spawn is high; withdrawal is only 10–15 %. Good lighting, adequate warming-up of water and favorable gas mode, the constant movement of water, which prevents silting process and other factors contribute to this. In natural spawning grounds such optimal conditions for the development of eggs often are not created.

At present time there are very little accurate quantitative indicators of survival of eggs and larvae on artificial spawning, but in places where artificial spawning grounds have been exposed, and where nearby there is a shortage of natural spawning grounds it is noted mass congestions of larvae of these species. Undoubtedly, these larvae emerged from the eggs that were laid on artificial spawning substrate of floating spawning grounds installed nearby. There is reason to believe that existing in the littoral zone of the reservoir natural spawning grounds because of objective circumstances do not provide the necessary conditions for spawn.

Every year in many reservoirs water level fluctuations occur that are caused by the regime of the hydroelectric power stations, they cause drying and exposure of spawning grounds, causing the death of spawn. In the spawning grounds in small shallow bays where there is no flow, eggs that were laid on vegetation strongly silt up; they are affected by
saprolegnia and die. The negative impact of these factors on the eggs, that are developing on artificial spawning grounds is greatly weakened, and as a result output of larvae from eggs increases. It is known that the development of fish at all stages, especially at early ones, in the natural environment is accompanied by a high percentage of mortality. Number of fish that survive to mature age is very small. For example, the value of industrial return of bream eggs is only 0.00025–0.004 %, so from 1 mln. of eggs to sexual maturity survive about 25–40 individuals (Table 7) [27]. Thus, the effectiveness of spawning directly affects the stability refill of fish populations with younger generations.

With use of artificial spawning grounds output of larvae from eggs increases significantly at least to 0.02 %, or 5 thousand eggs have one adult. At one spawning, as it is indicated above, there are laid, on average, 2 mln. eggs. Thus, to the industrial size survive about 400 individuals of fish. If it is bream, the fish biomass will be expressed in 440 kg (with an average batch of 1100 g). But at the same spawning not only one type of fish lays eggs. For example, in one spawning nest there were marked eggs of bream and roach. Calculations show that the number of roach eggs is bigger than number of bream eggs (ratio is approximately 2.8:1.2). The average weight of roach is 250 g. So, one spawning ground provides output of 280 individuals of roach (70 kg) and 120 individuals of bream (132 kg).

Table 7. The value of industrial return from spawn of some fish of Dnieper reservoirs.

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Kiev reservoir</th>
<th>Kaniv reservoir</th>
<th>Kremenchug reservoir</th>
<th>Dniproderzhyns reservoir</th>
<th>Zaporozhian Reservoir</th>
<th>Kakhovka reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bream</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.003</td>
<td>0.0025</td>
<td>0.004</td>
</tr>
<tr>
<td>Zander</td>
<td>0.002</td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
<td>0.0015</td>
<td>0.001</td>
</tr>
<tr>
<td>Carp</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0004</td>
<td>0.0005</td>
<td>0.001</td>
<td>0.0005</td>
</tr>
<tr>
<td>Pike</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
<td>0.0012</td>
<td>0.006</td>
</tr>
<tr>
<td>Asp</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Catfish</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td>Chub</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.006</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Roach</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
<td>0.008</td>
<td>0.01</td>
<td>0.006</td>
</tr>
<tr>
<td>Silver bream</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.002</td>
<td>0.004</td>
<td>0.005</td>
</tr>
<tr>
<td>Common rudd</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.01</td>
<td>0.002</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Industrial extraction of bream and roach from reservoir is not associated with any difficulties and it is carried out by usual tools of industrial fishing such as shutters gillnet or pond seines. Fishing of these species in certain periods of the year can be quite effective. From 110–120 kg of fish (output of one spawning ground) in terms of reservoir with modern technology of fishing it can be removed at least 80%, or 90–100 kg. In financial equivalent it covers the costs associated with the manufacture, installation and exploitation of artificial spawning grounds and income from fishing exceed 6–8 times.

According to the General Directorate of Protection of Water Bioresources in Kiev (Holovrybvod) in 2015 to implement measures to improve the conditions of natural reproduction of water biological resources in the fishery water bodies in the control of Hersonryboohorona that were provided by the state target economic program of fisheries in 2012–2016 users of water bioresources and public organizations produced 15.210 artificial spawning nests. They were installed on spawning areas of Kakhovka reservoir and on the lower reaches of the Dnieper. As substrate for artificial spawning grounds there were used different materials such as vegetation (pine, willow branches, etc.) synthetic waste, net canvas.

Every day, more than 80 representatives of users of water bioresources, public organizations, ichthyologists and state inspectors of Hersonryboohorona conducted monitoring of the incubation in artificial spawning grounds and carried out their washing.

In artificial spawning nests were registered spawn of roach, perch, zander, the number of eggs in the nests ranged from 200 to 800 g. Similar work was conducted in the spring of 2014 and during incubation in artificial spawning grounds were received about 349.3 million of larvae of valuable fish species. These measures help to increase the population of industrial herds and increase fish productivity of fishery ponds.

In spring 2015 in the Lower part of Dneproderzhinsk Reservoir by joint efforts of employees of private enterprise "Svit-M", public organizations, fisheries, staff and students of the department of General Biology and Aquatic Biological Resources of Oles Gonchar Dnipropetrovsk National University was produced and exhibited more than 1,000 artificial spawning grounds. They were made of pine branches, and there were used branches of trees that were felled by wind or rejected by foresters, thus there was no damage for forest. Installation of artificial spawning grounds has provided effective spawning substrate for fish and protected eggs from drying out due to fluctuation in the water level of the reservoir. In artificial spawning grounds it was registered spawn of perch, roach, bream and Prussian carp. Amount r of eggs on spawning nests ranged from 70 to 150 g. According to estimates there were received about 15.2 million larvae of commercial fish.

In 2015, as part of the "Save the Dnieper together" project at the Zaporozhian Reservoir near the village of Otradnoe (Zaporizhia region) in Vilna dell with the support of the public organization "Council of Families of Ukraine" were installed artificial spawning

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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Perch</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.001</td>
<td>0.018</td>
</tr>
<tr>
<td>Tench</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.003</td>
<td>0.001</td>
</tr>
<tr>
<td>Prussian carp</td>
<td>0.003</td>
<td>0.004</td>
<td>0.003</td>
<td>0.015</td>
<td>0.005</td>
</tr>
<tr>
<td>Sichel</td>
<td>0.015</td>
<td>0.015</td>
<td>0.01</td>
<td>0.004</td>
<td>0.014</td>
</tr>
</tbody>
</table>
grounds. For funds of public organizations, commercial and trade enterprises necessary materials were purchased (wire frames for nests, fishing nets for making spawning substrate, fuel) and nests were made by the volunteers, environmentalists, students and journalists of the newspaper "Fisherman's Journal" [28].

During 1.5-2 months, organizers carried out observation and maintenance of spawning nests. The process was controlled by ichthyologists of Zaporizharyboohorona. Thanks to ichthyologists there were chosen places for the installation of artificial spawning grounds. On the third day after setting of nests on the spawning grounds was observed spawning of roach that laid eggs on the nests intensively [28].

Two weeks later there was the appearance of juvenile fish. The first few days, larvae were on artificial substrate, and after they were concentrated in the coastal zone of the reservoir. Organizers of the "Save the Dnieper together" noted that the use of artificial spawning grounds in the gulf of Zaporozhian Reservoir have given positive results. According to observations of ichthyologists of Zaporizharyboohorona on spawning nests in the Vilna dell there were noted 4 spawning approaches of roach, that resulted delaying about 145 kg of spawn in spawning nests were. In the summer it was noted that the number of juvenile fish in gulf has increased significantly. Similar works were conducted by initiative public organizations in 2014, and they noted that on artificial spawning grounds was obtained 84 kg of roach spawn, from which were received 18.82 million of larvae [28].

4. WAYS OF OPTIMIZATION OF REPRODUCTIVE CONDITIONS OF INDUSTRIAL FISH FAUNA ON EXAMPLE OF ZAPOROZHIAN RESERVOIR

The current state of Zaporozhian Reservoir can be characterized by increased anthropogenic pressure on the components of aquatic ecosystems. Pollution of reservoir by sinks of technogenic and domestic origin that contain mineral and organic substances, petroleum products, pesticides and radionuclides [29], alters habitat of aquatic organisms that is reflected in their species composition and dynamics of quantitative indicators.

In turn, this leads to the transformation of the species composition of fish fauna, and it reduces the number of valuable commercial fish species (pike, perch, bream, carp) and increases number of low-value eurybiontic shortcycle species of fish (whitebait, bitterling, bleak, gobies) [15,30-33]. This is contributed by the deterioration of the conditions of reproduction of species. It is widely known that the industrial stock and the level of replenishment of some fish species are determined by the efficiency of reproduction [1,15]. This means that the fish populations of natural waters are limited mainly by breeding conditions. In the area of Zaporozhian Reservoir complex of breeding reclamation activities is fairly standard. In recent years it is the installation of artificial spawning nests that number varies year to year, depending on funding of fishery organizations, initiatives of public organizations and efforts of users of water biological resources [1,30]. Thus, in 2002 it was found 16.8 thousand nests in 2004–2005 the number was about 4.5–4.9 thousand pcs., respectively. In 2008, the number of exposed artificial spawning grounds reached 8.2 thousand pcs. [1,30]. In the 2010–2013 there were installed 4.5 thousand nests on two areas: Samara Bay (500 pcs.) and the lower part of Zaporozhian Reservoir near the Krupskaya dell (4000 pcs.). This is several times less than biologically reasonable number of annual installation of artificial nests in Zaporozhian Reservoir. It is noted that the artificial nests are used very effectively by roach, perch, bream, carp and zander.
4.1. The efficiency of the artificial nests and the order of their establishment in the Zaporozhye Reservoir

Reproductive potential of native fish of Zaporozhian Reservoir is implemented today less than by 30%, due to the degradation of spawning grounds, their low efficiency. In addition to recreation areas of fish reproduction by restoring the water content by hidromechanized work is the most effective is creation of artificial spawning grounds in coastal areas of Zaporozhian Reservoir, where is deficit of shallows and bays (especially in the upper and middle areas). Number of artificial spawning grounds should meet the reproductive potential of native fish during their use. In addition, optimization of resource recovery process of valuable fish species may be conducted due to the manufacturing (based on scientific and biological studies) of natural and artificial spawning planes such as stone ridges and mounds that also provide spawning, youth shelter and, accordingly, increase the increment of quantity of fish from fry to industrial size. Installing artificial spawning nests is one of the environmental and economic ways to improve the conditions of reproduction of fish in natural waters [15; 34–36].

Direction of rehabilitation of water bodies to improve their biological productivity was registered in the "State Program on Fisheries of Ukraine" and provided the implementation of complex of breeding and reclamation works on ponds [37]. Installation and exploitation of artificial spawning grounds were discussed and have formed the basis of the "Program of Fisheries in Dnipropetrovsk region for 2010–2014", but in fact over the years 2010–2014 this trend was not implemented [23].

To compensate the reduction of natural breeding places there are created artificial spawning grounds for different fish species [1,38–40]. For phytoplanktonic fish in most cases there are created floating spawning grounds [12]. In terms of Zaporozhian Reservoir they have particular importance because during heavy fluctuations in water level, fixed spawning grounds are unsuitable [1,41,42]. In the spring of 2013 it was conducted study of efficiency of artificial spawning nests in the waters of Zaporozhian Reservoir. During the study weather conditions for spawning were not very favorable. There were significant fluctuations in air temperature during the day and at night, so the water warmed up slowly. The approach to the spawning grounds of sires was extended in time. Roach got to artificial spawning nests first. The first recorded sires were on 24.04., when water temperature was +9 °C. Mass spawning occurred on 28.04., when water temperature was +11–12 °C (Table 8).

Table 8. The terms of spawning of industrial fish species on spawning grounds of Zaporozhian Reservoir, 2013.

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Beginning of spawning</th>
<th>t&lt;sub&gt;water&lt;/sub&gt;, °C</th>
<th>Period of spawning</th>
<th>t&lt;sub&gt;water&lt;/sub&gt;, °C</th>
<th>End of spawning</th>
<th>t&lt;sub&gt;water&lt;/sub&gt;, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower part of the reservoir</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roach</td>
<td>24.04.</td>
<td>9.0</td>
<td>27–2.05.</td>
<td>12.0</td>
<td>07.05.</td>
<td>15.0</td>
</tr>
<tr>
<td>Bream</td>
<td>02.05.</td>
<td>14.0</td>
<td>09–12.05.</td>
<td>16.0</td>
<td>16.05.</td>
<td>18.0</td>
</tr>
<tr>
<td>Zander</td>
<td>06.05.</td>
<td>15.0</td>
<td>09–11.05.</td>
<td>15.5</td>
<td>15.05.</td>
<td>17.5</td>
</tr>
<tr>
<td></td>
<td>Date</td>
<td>Temperature</td>
<td>Date</td>
<td>Temperature</td>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
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<td>-------------</td>
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<td>-------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Samara bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carp</td>
<td>11.05.</td>
<td>16.0</td>
<td>16.05.</td>
<td>8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Roach</td>
<td>14.04.</td>
<td>9.5</td>
<td>17–20.04.</td>
<td>12.3</td>
<td>23.04.</td>
<td>14.0</td>
</tr>
<tr>
<td>Zander</td>
<td>27.04.</td>
<td>14.0</td>
<td>28–30.04.</td>
<td>14.5</td>
<td>03.05.</td>
<td>16.0</td>
</tr>
<tr>
<td>Carp</td>
<td>03.05.</td>
<td>15.5</td>
<td>8.05.</td>
<td>16.0</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

After the roach spawning there was marked approach of perch and Prussian carp that partially ate spawn, laid on natural substrates. Spawning of bream and carp in Zaporozhian Reservoir was delayed due to bad weather conditions, therefore began in mid-May on 09.05. – 12.05., when water heated to 16.0 °C. Artificial spawning nest was represented by a metal hoop with net canvas with cell size of 12–16 mm and with nylon substrate (Fig. 39). Nests were tied to ropes vertically and distance between adjacent spawning nests was 50 cm. Artificial nests were exhibited in long rows of 100 pieces. Spawning bands were arranged in parallel, creating spawning areas or fields in crowded by fish sires places. Bunches of spawning nests were fastened by anchors and floats that allowed to adjust the depth of setting of substrate for fish spawning. Artificial spawning grounds effectively protected eggs from changes in water level in the reservoir that at times reached 30 cm per day.

Figure 39. Artificial spawning nest: A – spawning nests scheme: the figure shows the spawning nest, top view and in the section on AA: 1 – metal frame, 2 – spawning substrate, 3–4 – upper and lower layers of net canvas; B – general view of installed spawning nests.
As a result of the use of spawning nests it was managed to get about 56,680,000 of fish larvae (Table. 9).

**Table 8.** Spawning of fish on artificial spawning grounds.

<table>
<thead>
<tr>
<th>Place of installation</th>
<th>Krupska dell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of spawning nests, pcs.</td>
<td>4000</td>
</tr>
<tr>
<td>Date of installation</td>
<td>12.04 (2000 pcs.) 18.04 (2000 pcs.)</td>
</tr>
<tr>
<td>Beginning of spawning of phytophilous fish</td>
<td>24.04 (9 °C) (roach) 20.05 (16 °C) (bream, carp)</td>
</tr>
<tr>
<td>Amount of nests with spawn</td>
<td>3000</td>
</tr>
<tr>
<td>Average batche of spawn it a nest, g;</td>
<td>72</td>
</tr>
<tr>
<td>Number of eggs in 1 g.</td>
<td>320</td>
</tr>
<tr>
<td>Larvae output</td>
<td>82 %</td>
</tr>
<tr>
<td>Obtained larvae, mln. pcs.</td>
<td>56,680,000</td>
</tr>
</tbody>
</table>

It was noted that sires of phytophilous fish approach spawning grounds not simultaneously but in multiple parties (approaches). Since the nests were put up at the same time, they were almost fully used by first group of sires (Fig. 40). Also, because nests were put quite early (at a temperature of 5 °C) and were washed rarely, some of them got silted, so they were not used for spawning.

For the rational use of artificial spawning grounds it is recommended to exhibit spawning nests gradually, according to the water heating and approach of sires fish to spawning grounds (or purposefully put nests before every approach of sires).

The best time for installation of spawning grounds is before spawning, when temperature is on 2–3 °C below spawning temperature. This optimizes the use of additional spawning areas. If the spawning substrate is filled with eggs by 75%, and spawning of fish still continues, it is recommended to install additional spawning nests. To prevent silting of spawning substrates spawning nests should be washed at least 1 time in two days. During the washing it is recommended to remove foreign objects from spawning modules.

Considering the area of Zaporozhian Reservoir and the number of fish sires in 2016, the number of exposed artificial spawning grounds in the reservoir must be at least 40 thousand pieces (Fig. 41).
Location of spawning nests is recommended to be as follows:

- In the Dnipropetrovsk region – 27 thousand pcs.: Samara bay – 5 thousand pcs, Shyyanka Bay – 2 thousand pcs., estuary of Mokra Sura River – 10 thousand pcs., area of Kizlevyy Island and Krupskaya (Tyahynka) dell – 10 thousand pcs.;
- In the Zaporozhye region 13 thousand pcs.: Ploska Osokorivka Bay – 5 thousand pcs., estuary of Vilinka River – 5 thousand pcs., gulf Gadiucha – 3 thousand pcs.

To improve the conditions of reproduction of fish resources it is necessary to increase gradually every year the number of spawning nests up to the optimal number that is 120 thousand pcs. including supplement: in 2016 it is 40 thousand pcs.; in 2017 it is 20 thousand pcs.; in 2018 it is 30 thousand pcs.; and in 2019 it is 30 thousand pcs.

Using of artificial spawning grounds will optimize natural reproduction and restore spawning areas, by 2019 up to 2 hectares, including: in 2016 to 0.7264 hectares; 2017 to 0.3632 hectares; 2018 to 0.5448 hectares, 2019 to 0.3632 hectares [38].

Works with spawning nests should be conducted as well by users of water biological resources and public authorities, but under the control of fisheries and the environment authorities, and accompanied by researchers’ organizations. Research data can be used to develop comprehensive environmental measures for the rehabilitation of spawning grounds and reproduction efficiency of fishery resources by public authorities, fishery protection authorities, departments of Ecology and Natural Resources, research organizations and users of water biological resources. Further research should be focused on overcoming the environmental problems in the region in the fish industry in the inland waters of Ukraine.
places of installing of artificial spawning grounds;

– recommended places of installing of artificial spawning grounds;

**Figure 41.** Scheme of installation of artificial spawning nests in the waters of Zaporozhian Reservoir.

### 4.2. The ecological, economic and social effects of the implementation of measures to restore spawning grounds

Installation of artificial spawning grounds has both short-term prospects and long-term.

Short-term results:

- In the first year of installation of artificial spawning grounds in the waters of Zaporozhian Reservoir there were improved conditions for fish spawning. It is possible to
obtain a large amount of larvae and juvenile fish (about 57 million ind.), that joined the natural populations of fish and preserved biodiversity of aquatic ecosystems.

Long-term results:
- Environmental effect is improvement of natural reproduction, preservation of biodiversity, restoration of spawning grounds, raising the biological productivity of water;
- Economic impact is that in terms of industrial fish catch from inland waters of Ukraine, installation of spawning nests will help to increase the supply of fish and therefore increase fishing as a strategic natural renewable resource;
- Social impact is that increase of fish productivity helps to provide jobs for population (especially in rural areas) and retains existing jobs in terms of the economic crisis.

The introduction of the practice of setting artificial spawning grounds and artificial reefs affects the development of recreational fishing, eco-tourism and recreation areas on reservoirs of complex appointment.

CONCLUSIONS

In terms of the current hydroecological regime of large reservoirs of complex appointment, a change of which does not meet the fish industry, the introduction of artificial spawning grounds is simple and at the same time perspective step to solve problems of increasing fish productivity of transformed reservoirs. Work in this direction is not costly. In case of spring ban on fishing fishery organizations (users of water biological resources) have opportunities to implement them, because at that time the fishers are free from main trade. In fisheries practice in reservoirs there have already been cases where part of fishermen is allocated for installation and maintenance of artificial spawning grounds.

At a reasonable position to the creation of artificial spawning grounds in reservoirs and the proper affairs of this event it will surely be a very effective way to increase fish stocks in these waters.

Today, some users of water biological resources engaged in targeted fishing in reservoirs, concluded that the installation of artificial spawning nests on spawning areas of water bodies (reservoirs, bays, small rivers, etc.) increases fish productivity of these areas, and in the annual implementation such measures in the future they will receive substantial profits and reduce costs of the search for new, more productive areas of reservoirs.

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