© *Acta hydrotechnica* **24/41 (2006)**, Ljubljana
ISSN 1581-0267

UDK / *UDC*: 597:626.882:627.13(497.12)
Strokovni članek – *Professional paper*

Prejeto/*Received*: 6. 3. 2010
Sprejeto/*Accepted*: 14. 11. 2010

TIPI RIBJIH PREHODOV IN PREGLED RAZMER V SLOVENIJI
TYPES OF FISHWAYS AND OVERVIEW OF SITUATION IN SLOVENIA

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V prispevku so predstavljeni tipi ribjih prehodov, s katerimi se zagotavljajo ribje migracije čez neprehodne ovire v vodotokih. Tip ribjega prehoda se izbere na podlagi bioloških podatkov, podatkov o značilnostih območja ter hidroloških in hidravličnih značilnosti vodotoka. Pomembno je, da je ribji prehod dimenzioniran na način, ki zagotovi prehajanje najmanjših in najšibkejših ribjih vrst, s čimer se omogoči izmenjava genskega materiala, pomembnega za razvoj in ohranjanje ribjih vrst. Posebno pozornost pri gradnji ribjih prehodov je treba posvetiti vhodu in izhodu iz ribjega prehoda. Zagotoviti je treba ustrezne razmere za privabljanje rib k vhodu, omogočen mora biti nemoten prehod čez ribji prehod, izhod iz ribjega prehoda pa mora biti pravilno orientiran, da *vodi ribe gorvodno po vodotoku. Zgolj izgradnja ribjega prehoda še ne pomeni rešitve problematike ribjega migriranja, saj bi moral biti vsak zgrajen ribji prehod učinkovit pri svojem delovanju in redno vzdrževan. Prehajanje rib po ribjem prehodu je mogoče spremljati in nadzirati vizualno, z lovljenjem in z video nadzorom.*
Ključne besede: *hidrologija, urejanje vodotokov, vodne zgradbe, ribji prehodi, ihtiologija, ribje migracije, migratorne ovire*

The following article introduces different types of fishways enabling fish migration over impassable barriers in watercourses. The type of fishway is selected on the basis of biological data, site characteristics and hydrological and hydraulic characteristics of a watercourse. A fishway should be dimensioned in a way to ensure the transition of the smallest and weakest fish species. This enables the exchange of genetic material, which is of key importance for the development and preservation of various fish species. Special attention in designing fishways should be devoted to entrance and exit points of the passage. It is vital to ensure favourable conditions for attracting the fish to the entrance point, to enable uninterrupted transition through the pass and to provide an oriented exit that directs the fish upstream. However, the pass construction alone does not solve the problem of fish migration entirely, as this would require for each fishway to function perfectly, as well as a regular maintenance schedule. The control of fish migration through a pass can be monitored and controlled visually, by trapping techniques and video surveillance.
Key words: *hydrology, river engineering, hydraulic structures, fishways, ichthyology, fish migrations, migration barriers*

1. UVOD

Potreba po gradnji ribjih prehodov se je povečala okoli leta 1850, ko se je začela gradnja hidravličnih turbin in jezov za potrebe proizvodnje električne energije. Prvi dokumentirani prehodi za ribe so bili zgrajeni v letih 1852–1854 na reki Ballisodare na Irskem. Kontinuirano rečno okolje brez neprehodnih ovir (jezovi, zajezitvena jezera) je nujno potrebno za preživetje migratornih rib, saj jim nudi drstitvene in vzrejne habitate. Ta

1. INTRODUCTION

The need for fishway construction arose around the year 1850 when first hydraulic turbines and dams were being built for electric energy production. The first documented fishways emerged between the years 1852–1854 on the Ballisodare River in Ireland. Continual river environment without impassable barriers (dams, dam reservoirs) is essential for the survival of migratory fish since it offers them spawning and rearing območja so nemalokrat uničena ali nedosegljiva zaradi izgradnje visokih pregrad, plovnih poti, hidroelektrarn, zajezitev in onesnaženja vode. Prehodi za ribe so posebne gradnje, ki omogočajo ribam selitev bodisi na drstišča ali pasišča. S strani hidravličnih lastnosti so prehodi za ribe zgradbe za disipacijo energije vode. Delovanje ribjega prehoda je pogojeno tako z biološkimi kot s hidravličnimi dejavniki (Kamula, 2001).

Ribji prehod je poseg na oviri, ki omogoča neposredno gibanje rib čez točko v vodotoku, ki predstavlja migratorno oviro in se navezuje na inženirske in biološke vidike vzpostavitve prostih prehodov na prečnih objektih v vodotokih. Ribji prehod je:

- prehod vode okoli ali čez oviro, narejen na tak način, da zagotavlja primerne hidravlične pogoje;
- primeren za ribe, če lahko preidejo oviro brez stresa, zadržkov in poškodb.

Migracijo rib definiramo kot gibanje rib med dvema ali več ločenimi habitati. Pomembno je, da imajo vse ribe možnost prostega gibanja med habitatnimi območji znotraj njihovega okolja. Prosto gibanje ribam omogoča iskanje hrane in zavetij, ter dostop do drstišč. Od gibanja posameznih rib je odvisna izmenjava genskega materiala, pomembnega za ohranjanje in razvoj sposobnosti ribjih vrst in njihove prilagodljivosti na spremembe (Thorncraft & Harris, 2000).

2. VRSTE RIBJIH MIGRACIJ

Migracije sladkovodnih rib delimo na več oblik glede na različne migratorne razdalje:

- potamodromne migracije: ribe migrirajo samo v celinskih vodah. Reprodukcijska in prehranjevalna območja so lahko oddaljena od nekaj metrov pa do 100 kilometrov (Larinier, 2000);
- diadromne migracije: da ribe dosežejo primerna območja za drstenje in prehranjevanje, morajo migrirati med sladkovodnimi vodami in morjem v razdaljah nekaj 1000 kilometrov (Larinier, 2000).

Diadromne migracije delimo še na:

- anadromne migracije: diadromne ribe preživijo večino svojega življenja v morju

habitats. Such areas are often affected by high barrier constructions, shipping waterways, hydroelectric power plants, water impoundments and water pollution. Fishways are defined as special structures which enable fish migrations to their spawning grounds or feeding areas. From the perspective of hydraulics, fishways represent energy dissipating structures. Operation of a fishway is conditioned by biological and hydraulic aspects (Kamula, 2001).

A fishway is an intervention in the barrier which allows the fish to move past the point in a watercourse that represents a migratory obstruction, and relates to engineering and biological aspects of restoring free passages on transverse barriers. A fishway is:

- a water passage around or through a barrier, designed in a way to ensure proper hydraulic conditions,
- suitable for fish if they can pass a barrier without stress, delay and physical trauma.

Fish migration is defined as a mobility of fish between two or more separate habitats. It is important that all fish have the possibility of free movement between habitat areas within their environment. Free movement allows the fish to search for food and shelter and to access spawning grounds. Movements of individual fish are also important for the exchange of genetic material essential for the preservation and development of fish species and their adaptability (Thorncraft & Harris, 2000).

2. TYPES OF FISH MIGRATION

Freshwater fish migrations are divided into several categories according to migratory distances:

- potamodromous migrations: fish migrate exclusively within fresh water. Reproduction and feeding areas may be separated by distances between a few metres and up to 100 kilometres (Larinier, 2000);
- diadromous migrations: in order to reach their spawning grounds and feeding areas, fish need to migrate between fresh and marine waters in the distance of several 1000 kilometres (Larinier, 2000).

Diadromous migrations are subdivided into:

- anadromous migrations: diadromous fish

in migrirajo v celinske vode na drstenje (npr. losos);
- katadromne migracije: diadromne ribe preživijo večino svojega življenja v celinski vodi in migrirajo v morje na drstenje (npr. jegulja);
- amphidromne migracije: diadromne ribe migrirajo med morjem in sladko vodo, vendar ne zaradi drstenja, temveč zaradi potreb po iskanju hrane in zavetišč (npr. bradač) (Thorncraft & Harris, 2000).

Za ribe, ki migrirajo na velike razdalje in za njihov življenjske krog, posebno za anadromne in katadromne vrste, pomanjkanje ribjih prehodov pomeni lokalno izumrtje gorvodno od neprehodnih ovir. To lahko značilno zmanjša velikost populacij dolvodno od ovire. Za vse ribje vrste trajne neprehodne ovire v rekah pomenijo neposredno grožnjo, spremembo ribje populacije, kar se odraža v celotni strukturi favne rečnega ekosistema. Trajne neprehodne ovire, kot so pregrade, jezovi, pregradni objekti itd., imajo najbolj negativne učinke. Začasne migratorne ovire za ribe so na primer nizke pregrade ali pregradni objekti, ki so ob nizkih pretokih neprehodne. Razmere, zaradi katerih se migracije rib pojavljajo le v določenih obdobjih, ovirajo vsakoletno naravno periodiko migracij. V takšnih pogojih je v gorvodnih predelih vodotokov število rib manjše, v določenih primerih pa se poveča smrtnost zaradi plenilstva, zaradi česar se posledično zmanjša produktivnost sistema. Preprečitev ribjih migracij v spodnjem toku vodotoka povzroča večjo škodo še posebno za diadromne vrste, saj so na splošno v večjem številu zastopane v spodnjem delu vodotokov (Thorncraft & Harris, 2000).

3. MIGRATORNE OVIRE

3.1 FIZIČNE OVIRE

Prehajanje rib po vodotoku je lahko ovirano na številne načine. Ovire v primeru visokih pretokov in posledičnih visokih hitrostih vode in močne turbulence ustvarjajo pogoje, ki so za ribe nespremenljivi. Različni tipi ovir čez vodotoke spreminjajo longitudinalno

that spend the majority of their life in marine waters and migrate to fresh waters to spawn (e.g. salmon);
- catadromous migrations: diadromous fish that spend the majority of their life in fresh waters and migrate to marine waters to spawn (e.g. eel);
- amphidromous migrations: diadromous fish that migrate between marine and fresh waters, not to spawn but to find food and shelter (e.g. striped mullet) (Thorncraft & Harris, 2000).

For fish that migrate long distances in their life cycles, especially anadromous and catadromous species, the absence of fishways causes local extinctions upstream from impassable barriers. This may severely reduce population sizes downstream of the barriers. For all fish species, permanent impassable barriers in rivers represent a direct threat in terms of change in population structure, which is reflected in the faunal structure of a river system. Permanent impassable barriers such as dams, weirs, barrages etc. have the most negative effects. Temporary migration barriers for fish are low barriers or barrier structures that are impassable at low stream flows. Conditions which allow fish migrations to occur only in certain periods pose a threat to natural annual migration patterns. Under such conditions the number of fish upstream decreases and in some cases the mortality rate increases due to predation, which ultimately lowers the system's productivity. Prevention of fish migration in lower parts of a watercourse has the most detrimental effect on fish populations, especially on diadromous species as they are found in larger numbers in the lower stream (Thorncraft & Harris, 2000).

3. MIGRATION BARRIERS

3.1 PHYSICAL BARRIERS

Fish passage may be obstructed in numerous ways. Barriers in cases of high water discharges, consecutive high water velocities and strong turbulences create conditions not acceptable for fish. Different types of obstructions across watercourses kontinuiteto struge vodotoka in prečnega profila ter vplivajo na ribje populacije. Ribe glede na različne migracijske razdalje plavajo z različnimi hitrostmi, na kratke razdalje se gibljejo hitreje kot na daljše razdalje, pri katerih uporabljajo normalno hitrost plavanja. Razdalja, ki jo morajo preplavati, da premagajo fizično oviro, je kritična spremenljivka pri gradnji ribje steze. Lahko se zgodi, da ribe priplavajo do polovice in jih nato zaradi izčrpanosti odplakne nazaj. Salmonidne vrste rib imajo najboljše skakalne sposobnosti, s čimer lahko premagujejo višje ovire v primerjavi z drugimi vrstami rib. Višine, ki jih lahko premagajo salmonidne vrste, se gibljejo do približno dveh metrov. Atlantski losos na primer skoči v višino do 1,94 metrov, rjava postrv pa lahko premaguje višine do 1,10 metra (Meixler et al., 2009). Med fizične ovire spadajo pregrade, jezovi, zapornice, objekti za zadrževanje vode za potrebe kmetijstva, nasipi, prepusti, cevi, kanalizirani vodotoki, erozijska zaščitna dela in druge regulacije vodotokov. Naštete fizične ovire spreminjajo vzorec distribucije rib v rečnem ekosistemu.

3.2 VEDENJSKE OVIRE

Vedenjske ovire nastanejo zaradi sprememb strukture habitata. Habitat je lahko spremenjen z izgradnjo akumulacij v pretočnih rečnih sistemih ali s spremembo naravnih struktur vodotoka v izravnan vodotok, pri čemer je ponavadi uničena tudi obrežna vegetacija, ki predstavlja varovalne migracijske poti za določene vrste rib in za mladice. Sprememba naravnih pretočnih režimov v reguliranih rekah moti oziroma zavira ribje migracije in tako ustvari vedenjske ovire. Vedenjske ovire pri prehajanju rib so lahko odraz sprememb v vodnem okolju, ki vpliva na fiziologijo rib. Najbolj tipični so škodljivi vplivi zaradi onesnaženja vode, temperature (npr. izpusti hladne vode iz akumulacijskih jezer), nizkega pH iz kislih sulfatnih zemljin ali pa nizkih vsebnosti raztopljenega kisika, svetlobnih motenj, električnih zaščit, zaves iz zračnih mehurčkov in zvoka (Larinier, 2000; Internet 3).

interrupt the longitudinal continuity of the riverbed and transverse water profile and consequently affect fish populations. Depending on migration distances, fish swim at different speeds, moving faster at short distances compared to an average speed at longer distances. The distance to swim in order to overcome a physical barrier represents a critical variable at constructing a fish passage. It may occur that the fish overcome part of the way but are washed back halfway due to exhaustion. Salmonid fish species have best jumping abilities so they can overcome different barrier heights compared to other fish species. The heights salmonid species can overcome are up to approximately 2 meters. For example, Atlantic salmon can jump 1.94 meters high and brown trout can overcome heights of up to 1.10 meters (Meixler et al., 2009). Physical barriers include dams, weirs, farm dams, floodgates, dikes, culverts, pipes, channelized streams, erosion protection structures and other watercourse regulation structures. These physical barriers interrupt the fish distribution pattern in a river system.

3.2 BEHAVIOURAL BARRIERS

Behavioural barriers occur due to changes in habitat structure. A habitat may undergo changes due to accumulations in river systems or by altering natural structures of the watercourse into a straight watercourse, which often damages riverine vegetation that provides safe migration paths for certain fish species and juvenile fish. Alterations of natural flow regimes in regulated rivers obstruct and interfere with fish migrations and thus contribute to behavioural barriers. Behavioural barriers to fish passage may be a result of changes to the aquatic environment that have a direct impact on fish physiology. The most typical detrimental effects are due to water pollution, temperature (e.g. cold water releases from accumulation lakes), low pH from acid sulphate soils or low dissolved oxygen content, light disturbance, electric screens, air bubble curtains and sound (Larinier, 2000; Internet 3).

4. PRIPOROČILA PRI PLANIRANJU RIBJIH PREHODOV

Značilnosti ribjega prehoda opišemo s fizičnimi, hidrološkimi in biološkimi podatki. Pred konstruiranjem je treba zbrati vse možne podatke in izvesti analize.

Podatki, ki jih je treba upoštevati, so biološki podatki, podatki o območju in podatki o hidravličnih lastnostih (Bates, 2000).

4.1 BIOLOŠKI PODATKI

Ribji prehod se konstruira na podlagi biološkega kriterija. Prehod za ribe je treba dimenzionirati za najbolj šibke ribe znotraj vrste. Pomembni biološki podatki so:

- podatki o ciljnih migratornih ribjih vrstah, za katere bo prehod grajen,
- cikli migriranja,
- plavalne sposobnosti rib in
- njihov vedenjski vzorec.

Vedenjski vzorec ribjih vrst je ključen pri načrtovanju ribjega prehoda. Za posamezne vrste je treba poznati:

- način migriranja, ki vključuje sledenje obalni liniji,
- globino gibanja,
- mesta, kjer se ribe zadržujejo,
- odziv rib na različne hidravlične razmere in
- odziv na svetlobne razmere.

Upoštevati je treba tudi migriranje mladic, saj pomembno vplivajo na gorvodno in dolvodno porazdelitev ribje populacije (Bates, 2000).

4.2 PODATKI O OBMOČJU

Za dimenzioniranje ribjega prehoda je treba poznati najprej fizične značilnosti ovire v vodotoku, ki vključujejo topografijo območja, hidravlične razmere, geologijo, dostopnost območja in informacije o visokih vodah, skupaj s podatki o prodonosnosti in količinami naplavin (Bates, 2000).

4. FISHWAY DESIGN GUIDELINES

The characteristics of a fishway are defined by physical, hydrological and biological parameters. Before design process, all the existing data need to be gathered and analyses carried out.

The data that should be taken into consideration are biological data, site data and hydraulic characteristics (Bates, 2000).

4.1 BIOLOGICAL DATA

A fishway design is based on biological criteria. Fish pass should be dimensioned to accommodate the weakest individuals within the species. Crucial biological data include:

- data on migrating fish species targeted for the fish passage,
- migration cycles,
- swimming abilities of the fish,
- fish behavioural patterns.

The behavioural pattern of a fish species is crucial to fishway design. For individual species it is critical to identify:

- type of migration, including the shoreline orientation,
- depth of movement,
- fish gathering areas,
- their response to hydraulic conditions and
- light conditions.

Migration of juvenile fish needs to be taken into consideration because of important effect on upstream and downstream distribution of the fish population (Bates, 2000).

4.2 SITE DATA

The relevant data for designing a fishway should include physical characteristics of the obstruction in watercourse, including topography of the area, hydraulic conditions, geology, accessibility and information on flooding along with the bed load and debris quantity information (Bates, 2000).

4.3 PODATKI O HIDRAVLIČNIH LASTNOSTIH

Treba je preučiti statično in dinamično obnašanje toka vode skozi oviro kakor tudi analizirati in modelirati hidravlične lastnosti. Nadalje moramo analizirati tudi kroženje vode pri različnih globinah in pretokih ter vodostaje oziroma globine vode pri različnih pretokih (Bates, 2000).

4.4 VHOD IN IZHOD IZ RIBJEGA PREHODA

Vhod je najbolj kritičen element pri projektiranju ribjega prehoda, od katerega je v največji meri odvisna njegova učinkovitost. Pomembno je, da ribe v vodotoku najdejo vhod v ribji prehod. Gibanje v samem prehodu je za ribe enostavno. Na samem začetku gradnje prehoda je treba preučiti okolico ter lokacije, kjer so se ribe zadrževale pred oviro in migracijske poti za njihovo optimalno gibanje. Čez vhod se mora prevajati določen pretok, ki dolvodno privablja ribe. Dlje kot curek potuje dolvodno, bolj učinkovito privablja ribe. V kolikor teče čez vhodni del prehoda nizek pretok, potem mora biti vhod postavljen pravokotno na strugo, da se poveča vpliv dosega curka čim dlje v strugo. Pri visokih pretokih se vhodni del postavi pod kotom 30 stopinj. Prednost vhoda pod kotom je, da curek prodre dolvodno po vodotoku v večjem obsegu kot pa, če je poravnan pravokotno in s tem izpostavljen turbulenci in velikim hitrostim.

Izhod iz ribje steze mora biti nameščen in orientiran ob obrežni liniji ter proti ustreznemu toku, da ribe vodi gorvodno. Globina izhoda prehoda mora biti primerljiva z globino vode znotraj ribjega prehoda. Izogniti se je treba izhodom preblizu prelivnih polj in turbin. Prav tako izhod ne sme biti izpeljan v območje, kjer voda ne kroži, saj obstaja nevarnost, da je onesnažena. Po ribjem prehodu mora teči voda iste kakovosti, kot teče skozi prelivna polja ali turbine hidroelektrarne (Bates, 2000).

4.3 DATA ON HYDRAULIC CHARACTERISTICS

It is necessary to examine static and dynamic behavior of the water flow through the barrier as well as to analyze and model the hydraulic properties. In addition, water circulation at different depths and flow rates, as well as water surface levels or depths at different flow rates need to be analyzed (Bates, 2000).

4.4 ENTRANCE AND EXIT POINTS OF A FISHWAY

Entrance is the most critical element of the fishway design and crucial to its success and effectiveness. The main step is to bring the fish to the entrance of the fishway. Once inside the pass, the movement is fairly simple for the fish. At the starting stage of construction it is important to study the environment and locations of fish gathering below the obstruction and find migration paths to ensure their optimum movement. A certain degree of flow rate through the entrance point is required to attract the fish downstream. The further the jet of water travels downstream, the better it performs the function of attracting the fish. Low flow entrance should be aligned perpendicular to the channel in order to increase and prolong the penetration of the jet into the tailwater. High flow entrances should be placed at a 30 degree angle to the flow. A benefit of the angled entrance is that the jet penetrates the tailwater to a greater extent than if aligned perpendicular and exposed to turbulence and high velocity.

The exit of the fishway must be placed and oriented to the riparian line and into the current that will guide the fish upstream. The depth of the exit should be comparable to the water depth of the fishway. Exit points should not be placed in the vicinity of spillways and turbines. Areas of stagnant water should also be avoided because of the risk of water contamination. The water quality in a fishway should be the same as the water from spillways or power–plant turbines (Bates, 2000).

5. VRSTE RIBJIH PREHODOV

Obstaja veliko tipov ribjih prehodov. V svetu so razdeljeni na sedem glavnih kategorij: bazenski tip (posebno znan je ribji prehod s prekati), prehod Denil, zapiralno ribje dvigalo, dvigalo sistema ujemi in transportiraj, skalna drča, obhodni kanal in specifični ribji prehodi za jegulje in njihove mladice (Thorncraft & Harris, 2000). Obstajajo tudi drugi načini, s katerimi omogočamo migracije rib in sicer s splavnicami in s fizičnim premeščanjem rib.

Odseki vodotokov se delijo na ribje regije, ki predstavljajo tipične ribje vrste na določenih odsekih vodotoka. Izkušnje kažejo, da sta za zgornji tek vodotoka najbolj značilna predvsem rjava postrv (Salmo trutta f. fario) in lipan (Thymallus thymallus), srednji tek naseljujejo v glavnem mrene (Barbus barbus), spodnji tek pa ploščiči (Abramis brama). Izbira tipa ribjega prehoda je odvisna tudi od ostalih ribjih vrst na območju prekinjene vzdolžne kontinuitete. Dimenzije ribjega prehoda so odvisne od velikosti ribjih teles in plavalnih sposobnosti, s čimer je omogočeno migriranje najšibkejših ribje vrst oziroma rib v najšibkejši razvojni stopnji (FAO/DVWK, 2002).

5.1 BAZENSKI TIP RIBJIH PREHODOV

Med prvimi ribjimi prehodi so bili razviti prehodi bazenskega tipa. Sestavljeni so iz vrste povezanih bazenov, ki so speljani tako, da obidejo oviro. Na začetni stopnji razvoja je bilo njihovo delovanje neučinkovito, saj so bili nekateri preveč potopljeni ter tako primerni samo za ribe, ki se gibljejo ob dnu. V primeru nepravilne izvedbe pride do prekomernih hitrosti vode in turbulence. V takšnih primerih je ribji prehod neprimeren za večino ribjih vrst.

Koncept uporabe bazenski tipov ribjih prehodov je zelo star, njegova uporaba pa razširjena po vsem svetu. Prehod je razdeljen na serijo padcev, ki tvorijo bazene. Prehod vode iz enega v drug bazen je lahko omogočen:

- s površinskim prelivanjem,
- skozi eno ali več potopljenih odprtin, ki so nameščene na ločevalno steno med dvema bazenoma,

5. TYPES OF FISHWAYS

There are several different types of fishways. They are divided into seven main categories worldwide: the pool type (especially known is the vertical–slot design), Denil, lock fishway, trap–and–transport fishway, rock–ramp fishway, bypass fishway and a special fishway for eels and their elvers (Thorncraft & Harris, 2000). There are also alternative ways of fish migration: navigation locks and physical transportation of fish.

Stream sections are divided into fish regions representing a typical fish species on a particular river stretch. In the upper stream reaches, the most significant species are mainly brown trout (Salmo trutta f. fario) and grayling (Thymallus thymallus), the middle stretches are inhabited mainly by barbel (Barbus barbus) and lower reaches by bream (Abramis brama). The selection of type of fish passage also depends on other fish species in the area where longitudinal connectivity is disrupted. The dimensions of the fish passage depends on the size of fish and their swimming abilities so as to enable migration of the weakest fish species and fish species in weakest life stages (FAO/DVWK, 2002).

5.1 POOL–TYPE FISHWAY

Pool–type fishways were the first type of fish pass developed. They consist of a number of interconnected pools directed to bypass an obstruction. First poll–type fishways were not efficient as they were too deep and thus appropriate only for bottom–swimming fish. In case of incorrect realization of the construction, water velocity and turbulence may increase significantly. In that case, fish pass is unsuitable for most fish species.

The concept of the use of a pool–type fishway dates back a long time and is still widely used. The pass is divided into a series of small drops forming the pools. The passage of water from one pool to another is enabled:

- by surface spillover,
- through one or more under–water opening placed in the dividing wall between two pools,
- through notches or slots and

- skozi odprtine oziroma reže in
- kombinacijo ureditev (npr. preliv in odprtina)

Glavni parametri bazenskega tipa so dimenzije bazenov in geometrijske lastnosti ločevalnih sten (prekatov) med posameznimi bazeni. Geometrijske lastnosti, skupaj z gorvodnimi in dolvodnimi robnimi pogoji (nivo, hitrost), določajo hidravlične lastnosti ribjega prehoda. Bazeni imajo dvojni učinek, in sicer so namenjeni za počitek rib in za disipacijo energije iz enega bazena v naslednjega. Standardne geometrijske značilnosti bazenskih tipov ribjih prehodov so prikazane v preglednici 1.

Kot učinkovit bazenski tip ribjih prehodov se je uveljavil ribji prehod z vertikalnimi prekati (slika 1). Pri takšnih ribjih prehodih se ustvari maksimalna hitrost padanja vode v naslednji prekat, zato se dolvodni bazen obnaša kot disipator energije, obenem pa služi kot območje, kjer ribe počivajo. Pomembna značilnost ribjih prehodov s prekati je, da lahko delujejo ob različnih nivojih zgornje in spodnje vode, s čimer je ribam omogočeno, da preidejo ribji prehod ob katerikoli globini. Takšni ribji prehodi so primerni za pregrade, katerih višina se giblje med 1 in 6 metri (Thorncraft & Harris, 2000).

- combination of regulations (e.g. spill and notch).

The main parameters of the pool type fishway are the dimensions of the pools and geometric characteristics of separating walls (slots) between the pools. Geometric characteristics, together with upstream and downstream boundary conditions (level, speed), determine the hydraulic properties of the fishway. The pools have a double objective offering a resting place for fish and ensuring energy dissipation from one pool to another. Standard geometric characteristics of a pool–type fishway are shown in Table 1.

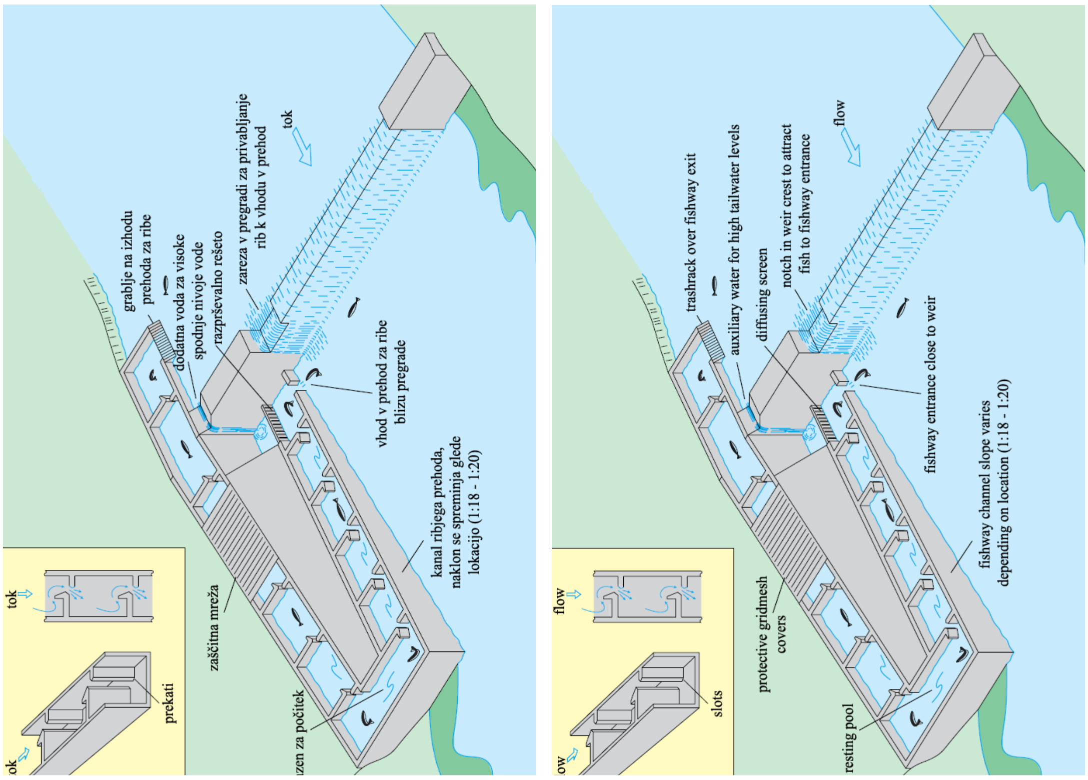
An efficient pool–type fishway is considered to be a vertical–slot design (Fig. 1). With this kind of fishway, maximum velocity of water falling into the following compartment is achieved, with the downstream pool acting as an energy dissipater and at the same time providing a resting area for the fish. An important characteristic of a vertical–slot design is its ability to operate at different headwater and tailwater levels, which enables the fish to pass the fishway at any depth. Such designs are suitable for barriers with the height between 1 and 6 metres (Thorncraft & Harris, 2000).

Preglednica 1. Priporočene dimenzije za bazenske tipe ribjih prehodov (FAO/DVWK, 2002).
Table 1. Recommended dimensions for pool–type fishways (FAO/DVWK, 2002).

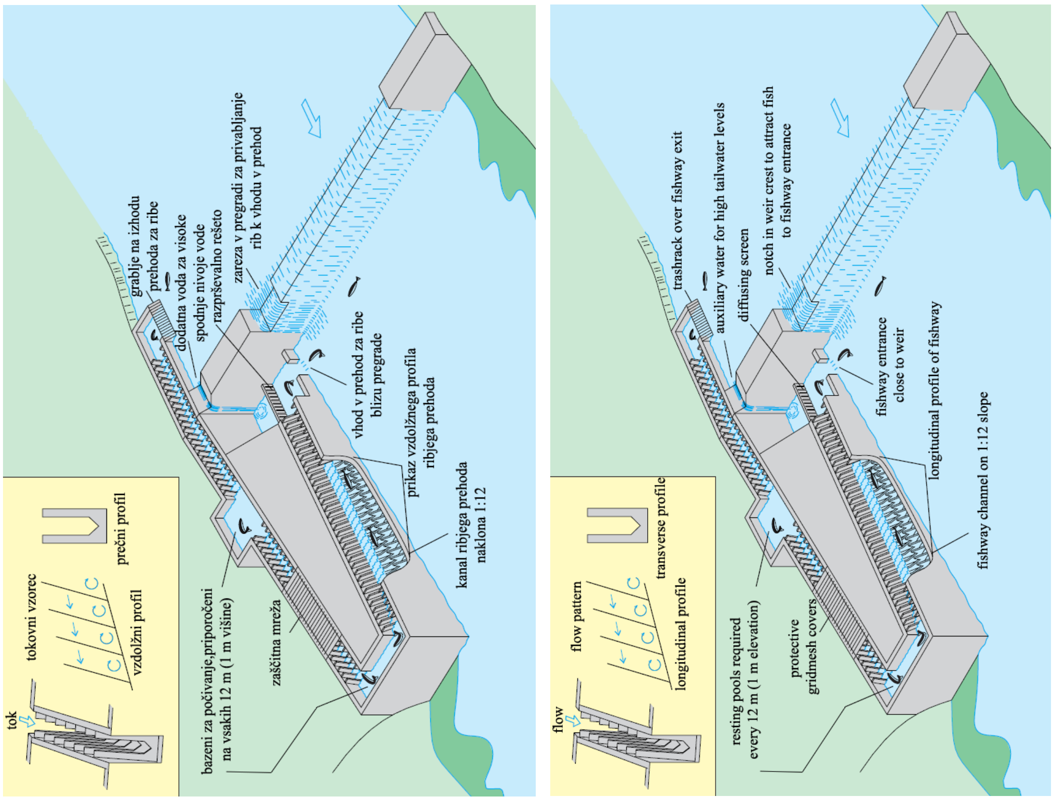
Ciljne ribje vrste *Target fish species*	Dimenzije bazena[1)] *Pool dimension [1)]*			Pretok skozi ribji prehod[1)] [m³/s] *Discharge trough the fish pass[1)] [m³/s]*	Maksimalna razlika med vodno gladino Δh[2)] [m] *Maximum difference in water level Δh[2)] [m]*
	Dolžina bazena [m] *Pool length [m]*	Širina bazena [m] *Pool width [m]*	Globina [m] *Water depth [m]*		
Jeseter/*Sturgeon*	5 – 6	2,5 – 3	1,5 – 2	2,5	0,20
Losos/Morska postrv/Sulec/*Salmon/Sea trout/Huchen*	2,5 – 3	1,6 – 2	0,8 – 1,0	0,2 – 0,5	0,20
Lipan/Klen/Ploščič/ /Drugo/*Gayling/Chub/ Bream/Others*	1,4 – 2	1,0 – 1,5	0,6 – 0,8	0,08 – 0,2	0,20

1) Vrednosti pretokov so bile izračunane za razliko vodne gladine $\Delta h = 0{,}20$ m
The discharge rates were calculated for water level difference $\Delta h = 0.20$ *m*

2) Razlika v vodni gladini se nanaša na razliko v gladini med bazeni
The difference in water level refers to the difference in level between pools



Slika 1: Ribji prehod z vertikalnimi prekati, povzeto po Thorncraft in Harris (2000).
Figure 1: A vertical–slot fishway, adopted from Thorncraft and Harris (2000).



Slika 2: Denil ribji prehod, povzeto po Thorncraft in Harris (2000).
Figure 2: A Denil fishway, adopted from Thorncraft and Harris (2000).

5.2 DENIL RIBJI PREHOD

Ta tip ribjega prehoda je razvil belgijski inženir Denil za migriranje atlantskega lososa (slika 2). Notranja oblika prehoda povzroča učinkovito disipacijo energije. V začetnih fazah razvoja Denil prehod ni imel vmesnih delov, kjer bi ribe lahko počivale. Nato so razvili Denil prehode z bazeni za počivanje, ki so postavljeni na intervalih od 10–12 m za odrasle losose in 6–8 m za manjše ribe, kot so rjave postrvi ali druge odrasle potadromne vrste (npr. mrene). Ta tip ribjega prehoda se v splošnem uporablja za ribe z dobrimi plavalnimi sposobnostmi (Larinier, 2000; FAO, 2001). Denil ribji prehod ima niz poševnih, gorvodno usmerjenih ovir oziroma odbojnikov v obliki 'U' profila. Izvedba omenjenih ribjih prehodov omogoča uporabo v bolj strmih strugah zaradi njihove hidravlične učinkovitosti ter njihove izvedbe in stroškov izgradnje. Zaradi omenjenih lastnosti se Denil prehod namešča tudi kot sanacijski ukrep v neučinkovite bazenske tipe ribjih prehodov. Večji bazeni, namenjeni za počivanje rib, so priporočeni na vsak višinski meter. Denil ribji prehodi niso tako hidravlično ustrezni kot ribji prehodi s prekati, ker se učinkovitosti vertikalnih asimetričnih odbojnikov z naraščanjem globine manjša (Thorncraft & Harris, 2000).

5.3 ZAPIRALNO RIBJE DVIGALO

Zapiralno ribje dvigalo deluje tako, da privablja ribe skozi vhod, ki je podoben bazenskemu tipu ribjega prehoda, vendar namesto da bi ribe plavale gorvodno po prehodu, se zbirajo v za to namenjenem zadrževalnem območju (slika 3). Zadrževalno območje se nato zapre s pomočjo zapornice in napolni z vodo do nivoja gorvodne vode, kjer se zapornice ribjega dvigala odprejo, da lahko ribe splavajo ven. Da se ribe vzpodbudi h gibanju v vstopni del in da nato izstopijo, se uporabljajo tokovi, ki jih privabljajo (Thorncraft & Harris, 2000).

Dokazano je bilo, da so številna zapiralna ribja dvigala neučinkovita. Njihova slabost je, da imajo omejeno kapaciteto zajema rib v primerjavi z drugimi ribjimi prehodi.

5.2 DENIL FISHWAY

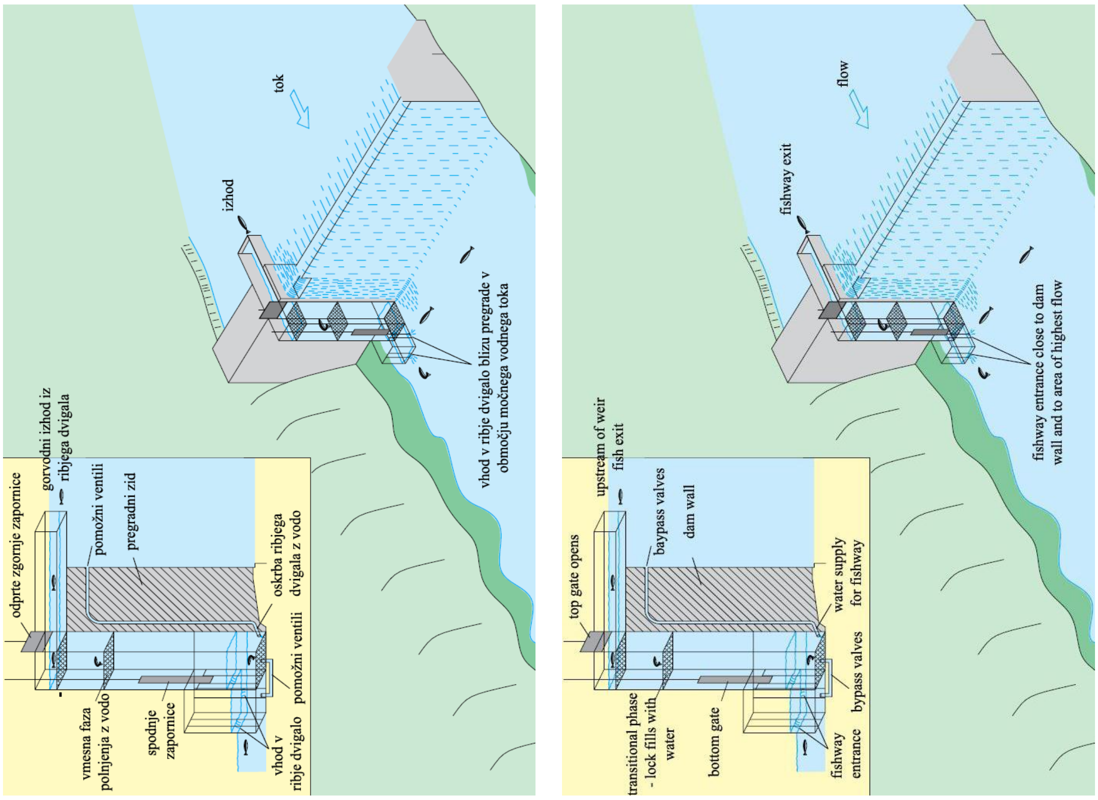
This fish pass was developed by the Belgium engineer Denil for Atlantic salmon migration (Fig. 2). The interior design of the pass enables efficient energy dissipation. In the beginning phase of its development, the Denil pass didn't contain the in–between parts serving as fish resting areas. Later, a Denil fishway with resting pools was developed, with the pools following at intervals of 10–12 m for adult salmon and 6–8 m for smaller fish such as brown trout and other adult potadromous species (e.g. barbel). This type of fishway is generally used for fish with good swimming abilities (Larinier, 2000; FAO, 2001). A Denil fishway consists of a range of upstream tilted U–shaped baffles. This type of fishway is especially suitable for steeper channels due to its hydraulic efficiency, building realization and related financial costs. These features also allow the Denil fishway to be installed as a rehabilitation measure into ineffective pool–type fishways. However, it is recommended to install a larger resting pool at every meter of altitude. Denil fish passes are not as adequate in terms of hydraulics as vertical–slot fishways, as the effectiveness of vertically asymmetrical baffles decreases with depth (Thorncraft & Harris, 2000).

5.3 LOCK FISHWAY

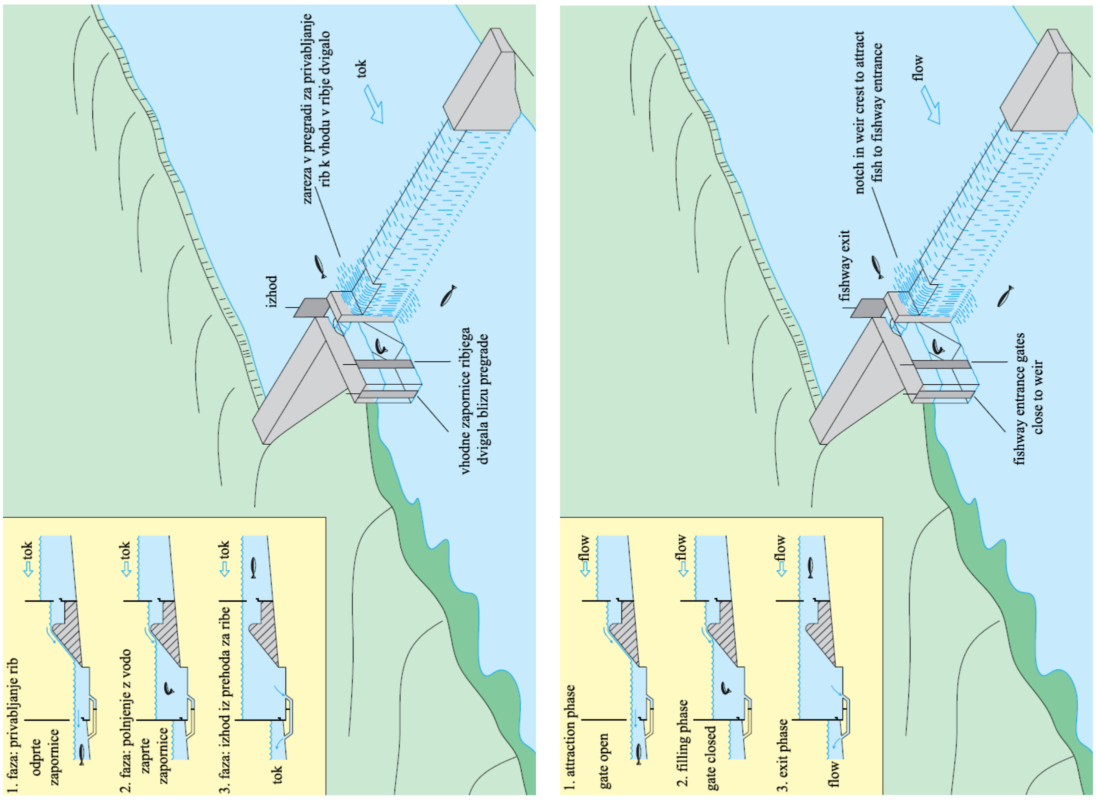
Lock fishway operates in a way to attract the fish through an entrance similar to the pool–type fishway, but instead of swimming upstream along the passage, the fish are accumulated in a special collection area (Fig. 3). The collection area is then locked and filled with water to reach the upstream water level, where the lock is released for the fish to swim out. To attract the fish to entrance and exit points of the lock, water currents are used (Thorncraft & Harris, 2000).

It has been assessed that many lock fishways are ineffective. Its disadvantage is a limited capacity of fish collection compared to other types of fishways.

ISSN 1581-0267



Slika 3: Zapiralno ribje dvigalo, povzeto po Thorncraft in Harris (2000).
Figure 3: A lock fishway,, adopted from Thorncraft and Harris (2000).



Slika 4: Zapiralno ribje dvigalo za manjše pregrade, povzeto po Thorncraft in Harris (2000).
Figure 4: A low level-lock fishway, adopted from Thorncraft and Harris (2000).

K slabi učinkovitosti prispeva tudi prekinjeno delovanje ribjega dvigala ter možnost, da ribe predčasno zapustijo komoro za transport pred zaprtjem z zapornico (Larinier, 2000; FAO, 2001).

V praksi se uporablja tudi zapiralno ribje dvigalo na nizkih pregradah, ponavadi v primerih, ko je gradnja drugih vrst ribjih prehodov preveč strma (slika 4; Thorncraft & Harris, 2000).

5.4 RIBJE DVIGALO SISTEMA UJEMI IN TRANSPORTIRAJ

To je tip ribjega dvigala, pri katerem se na spodnji strani pregrade privablja in zbira ribe, ki se jih nato mehansko transportira čez pregrado (slika 5). Najprej se ribe privabi s kratkim bazenskim tipom ribje steze, nato ujame v zbiralni lijak in končno transportira na zgornji nivo vode (Thorncraft & Harris 2000).

5.5 HRAPAVA DRČA

Hrapave drče so preprosti in cenovno ugodni ribji prehodi za premagovanje nižjih ovir, ki služijo tudi kot ukrep za preprečevanje erozije. Zgrajene so v naklonu 1:15 do 1:20, kjer se večje skale namestijo tako, da tvorijo majhne prečne bazene, ki si sledijo na vsaka 2 metra.

Hrapave drče so lahko zgrajene na način, da se razprostirajo čez celoten prečni profil vodotoka (slika 6) ali pa le na določenih delih (slika 7). V obdobjih majhnih pretokov preko drče migrirajo majhne ribe in mladice, v obdobju višjih pretokov pa zagotavlja prehod tudi za večje ribe. Uporablja se na vodotokih za premagovanje manjših ovir (Thorncraft & Harris, 2000).

5.6 OBTOČNI KANAL

Obtočni kanal je ribji prehod, ki se uporablja po vsem svetu (slika 8). Speljan je mimo ovire v vodotoku in je zato primeren za veliko število ribjih vrst. Sestavljen je iz naravnih materialov kot sta zemljina in kamenje, da je čim bolj podoben naravnemu vodotoku (Thorncraft & Harris, 2000).

Another factor contributing to its low effectiveness is a possible interrupted operating of the lock and the possibility that the fish leave the transport chamber before it is sealed (Larinier, 2000; FAO, 2001).

A common variation of a lock is a low–level lock fishway used on low barriers mostly in cases when the construction of other fishway designs is too steep (Fig. 4; Thorncraft & Harris, 2000).

5.4 TRAP–AND–TRANSPORT FISHWAY

This type of fishway attracts and collects the fish at the lower base of the barrier and then mechanically transports them over the barrier (slika 5). First the fish are attracted in the short section of a pool–type fishway and then they are trapped into a collection funnel and carried over to the upper water level (Thorncraft & Harris, 2000).

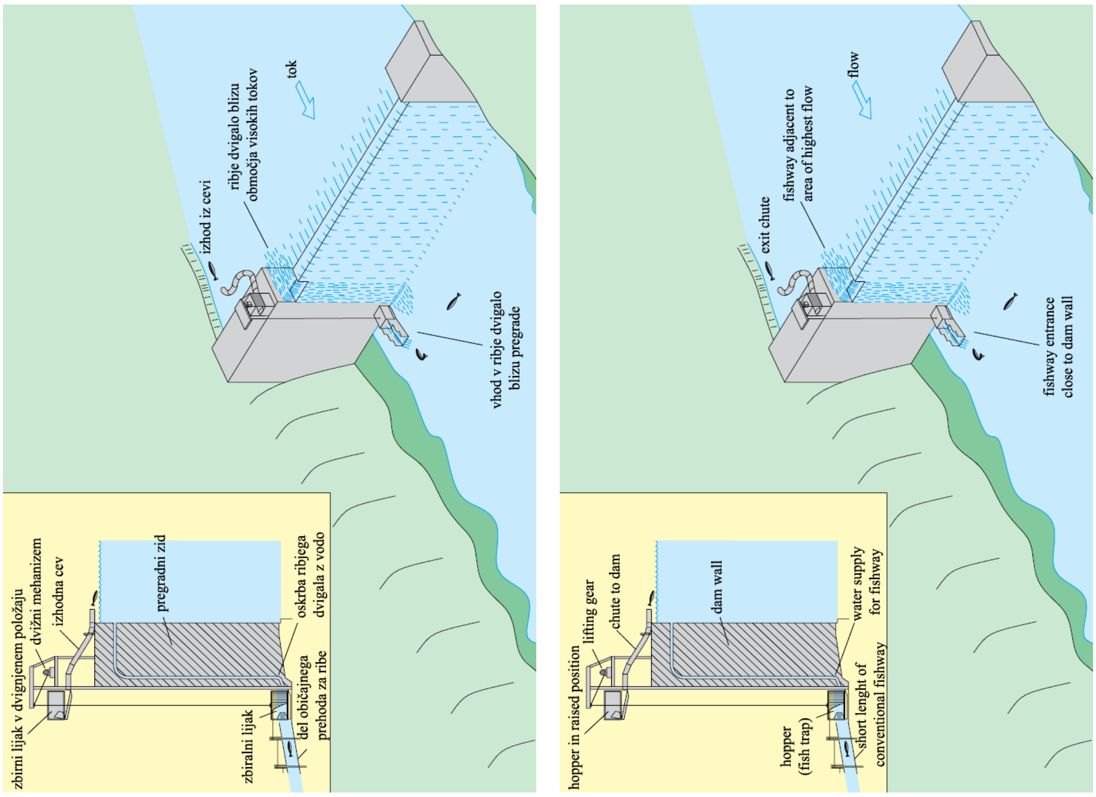
5.5 A ROCK–RAMP FISHWAY

A rock–ramp fishway is a simple and low–cost fishway design suitable for low obstructions, also serving as an erosion prevention measure. They are built on a slope of 1:15 to 1:20, with large rocks placed in a way to form small transverse pools at 2 meter intervals.

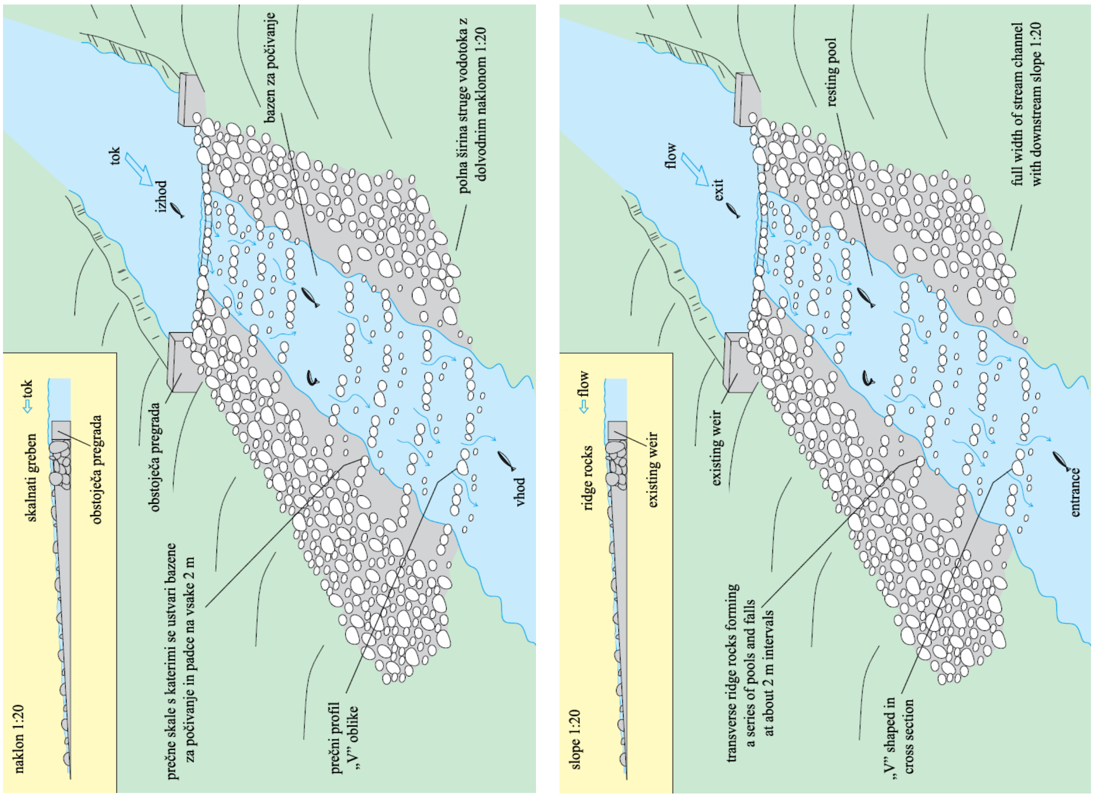
A rock–ramp fishway may be constructed across the whole transverse river–bed profile (Fig. 6) or it may extend only over a part of the profile (Fig. 7). During the period of small discharges the rock–ramp facilitates migration of small and juvenile fish, and as the flow rate increases, it becomes suitable for larger fish as well. This type of fishway is particularly useful on low obstructions (Thorncraft & Harris, 2000).

5.6 A BYPASS FISHWAY

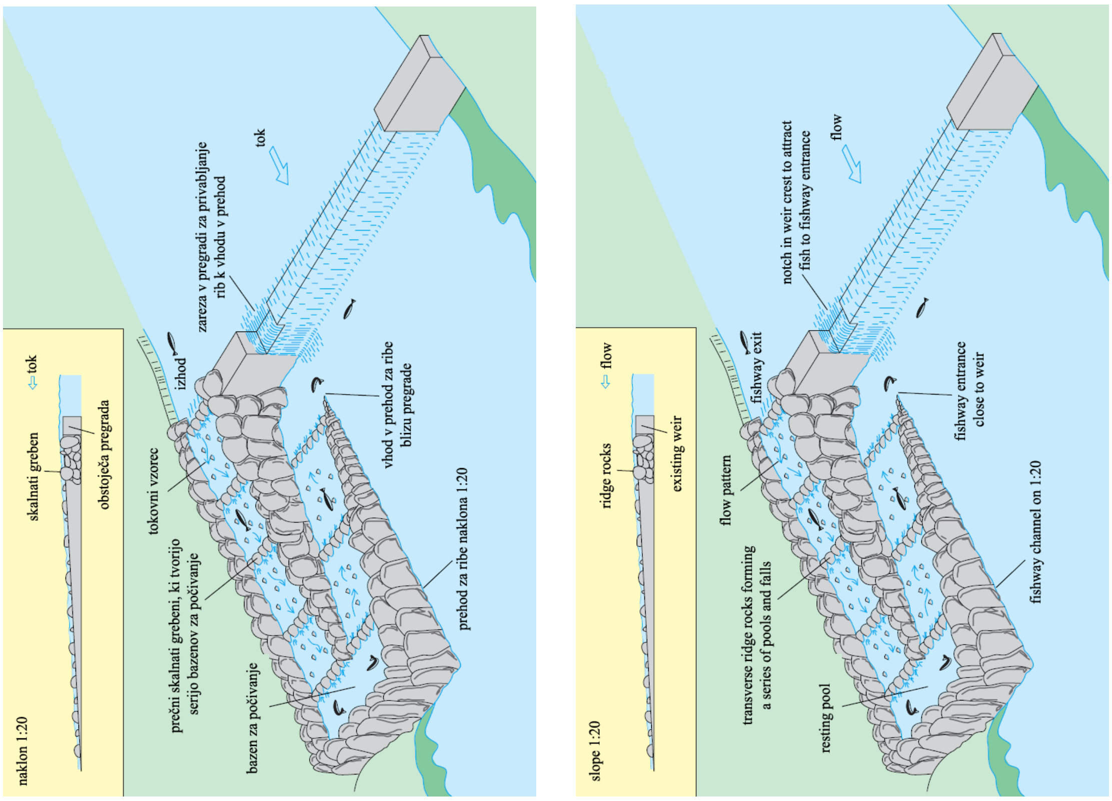
A bypass fishway is a type of fishway used worldwide (Fig. 8). It is routed around the obstruction on the watercourse and thus suitable for a large variety of fish species. It consists of natural materials such as soil and rocks, creating an appearance of a natural watercourse (Thorncraft & Harris, 2000).



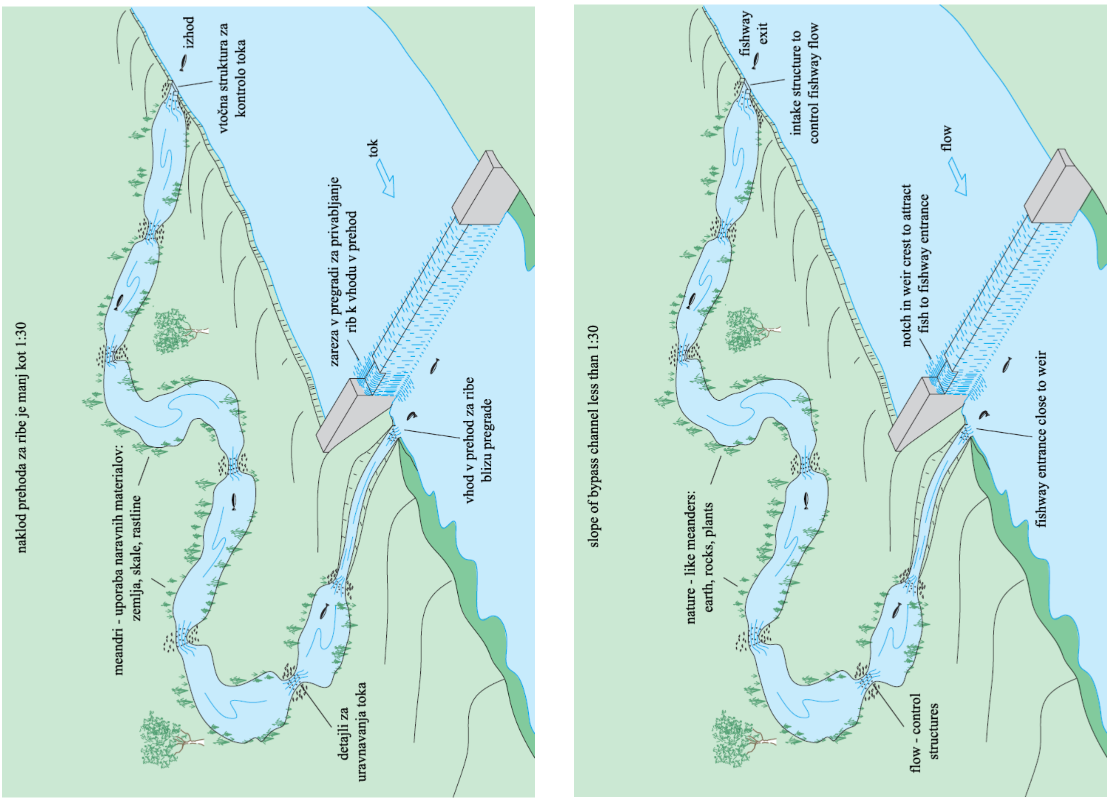
Slika 2: Ribje dvigalo sistema ujemi in transportiraj, povzeto po Thorncraft in Harris (2000).
Figure 5: A trap–and–transport fishway, adopted from Thorncraft and Harris (2000).



Slika 6: Hrapava drča čez celoten prečni profil vodotoka, povzeto po Thorncraft in Harris (2000).
Figure 6: A rock–ramp fishway across the whole transverse river–bed, adopted from Thorncraft and Harris (2000).

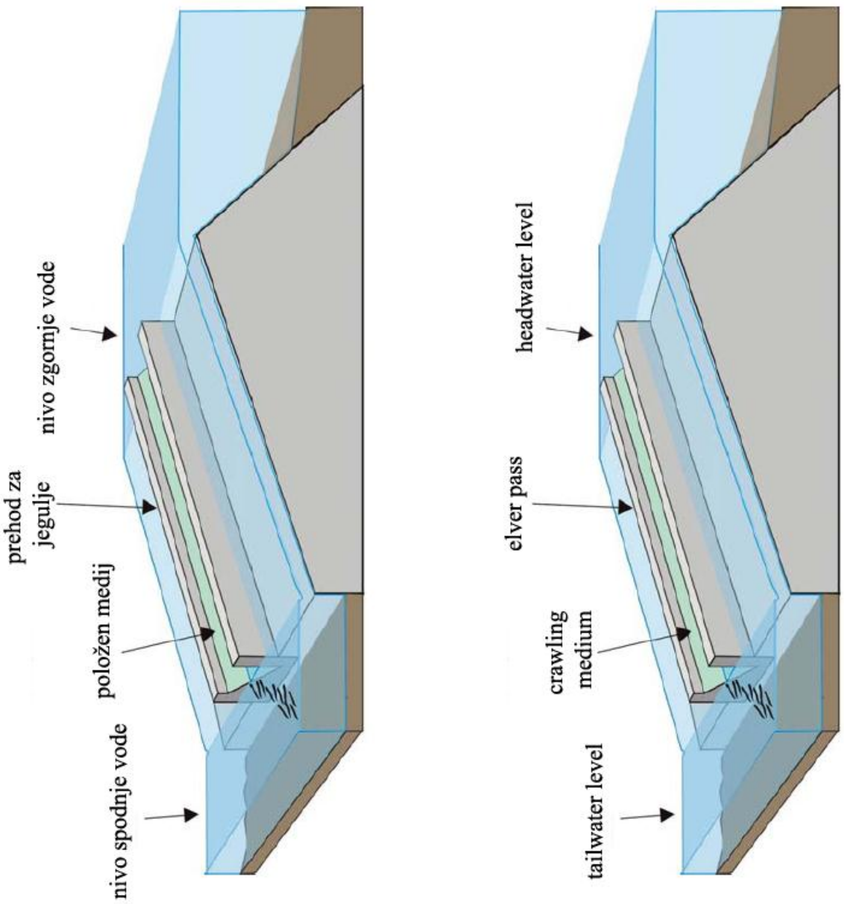


Slika 7: Hrapava drča v obrežnem prostoru, povzeto po Thorncraft in Harris (2000).
Figure 7: A rock–ramp fishway in the riparian area, adopted from Thorncraft and Harris (2000).

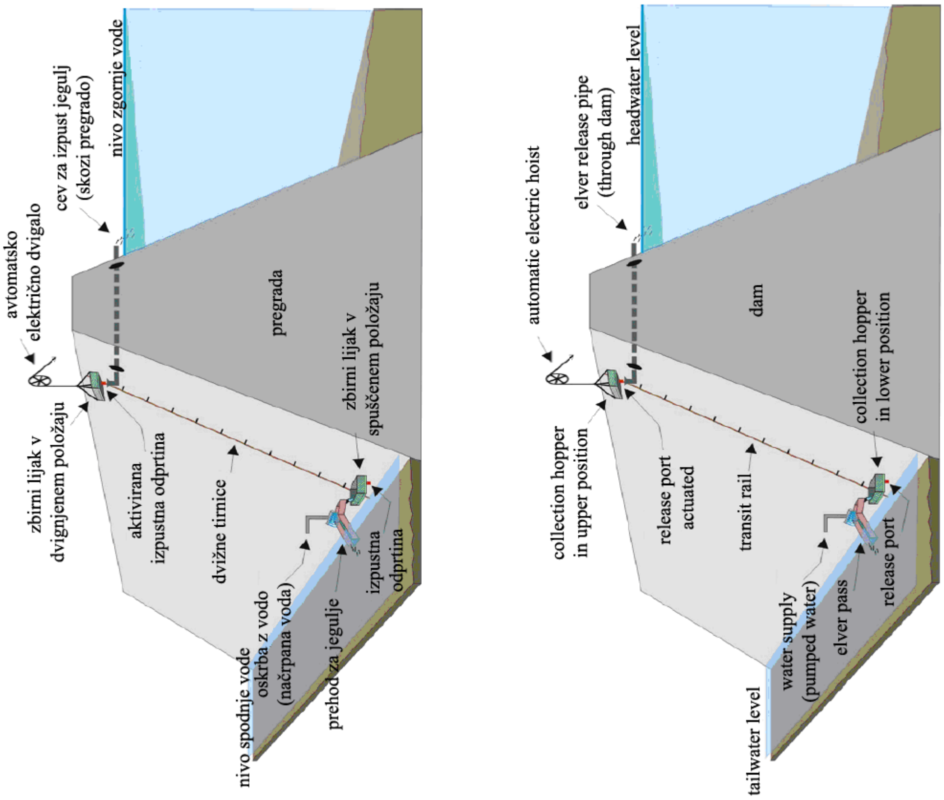


Slika 8: Obtočni kanal, povzeto po Thorncraft in Harris (2000).
Figure 8: A bypass fishway, adopted from Thorncraft and Harris (2000).

Slika 9: Ščetinast substrat, povzeto po Solomon in Beach (2004).
Figure 9: Bristle substrate, adopted from Solomon and Beach (2004).



Slika 10. Prehod za jegulje, povzeto po Solomon in Beach (2004).
Figure 10. Eel pass, adopted from Solomon and Beach (2004).



Slika 3: Dvigalo za jegulje, povzeto po Solomon in Beach (2004).
Figure 11: Eel lift, adopted from Solomon and Beach (2004).

Obtočni kanal predstavlja regulacijo vodotoka oziroma omilitveni ukrep, s katerim se nadomesti del izgubljenega habitata. Glavna značilnost je majhen padec, ki se giblje od 1 do 5% oziroma pri nižinskih rekah še manj. Energija toka se disipira skozi brzice in kaskade, ki so porazdeljene na način kot v naravnih vodotokih. Pomanjkljivost obtočnega kanala je, da rabimo prostor in tehnične objekte, kot so npr. zapornice za kontrolo nivojev zgornje vode. Tako kot pri vseh ostalih ribjih prehodih, mora biti vhod umeščen čim bližje oviri.

Zaradi majhnih padcev je včasih težko namestiti vhod za ribe v obtočni kanal pod oviro, kar pomeni, da je vhod postavljen nižje ob vodotoku. Daljša kot je oddaljenost vhoda od ovire, slabša je njegova učinkovitost, zaradi česar ni uporaben na večjih vodotokih (Larinier, 2000; FAO, 2001).

5.7 RIBJI PREHODI ZA JEGULJE IN NJIHOVE MLADICE

Za nekatere ribje vrste do sedaj našteti

A bypass fishway represents a regulation structure on a watercourse or a mitigation measure providing a substitute for the lost habitat. Its main characteristic is a low gradient, generally between 1 to 5 %, and even less in lowland rivers. The flow energy is dissipated through riffles and cascades distributed in a natural watercourse pattern. On the negative side, it requires space and technical devices such as gates to control the upstream water levels. Similar to other fishways, the entrance point needs to be installed in close vicinity of the obstruction.

Due to its low gradient, it may be difficult to position the entrance of the fishway into the bypass canal right below the obstruction; therefore it needs to be placed further down the watercourse. Long distances between the entrance and the obstruction lessen its efficiency and make it unsuitable for large watercourses (Larinier, 2000; FAO, 2001).

5.7 FISHWAY FOR EELS AND ELVERS

For some fish species, the fishways listed so far are not applicable. Such an example is a prehodi niso uporabni. Takšen primer je zagotavljanje prehodov za jegulje in njihove mladice, kjer se uporabljajo drugačni ribji prehodi. Plavalne sposobnosti jegulj so omejene in povezane s hrapavim substratom, zato je treba pri gradnji prehoda za jegulje zagotoviti majhne pretoke in hitrosti vode ter primeren substrat za ustrezno prehajanje čez prehod. Za substrat se uporabljajo šopi ščetin iz različnih materialov (slika 9).

Obstaja več izvedb prehodov za jegulje. Običajen prehod za jegulje (slika 10) se kombinira še z ribjimi dvigali (slika 11), sistemi ujemi in transportiraj ter s fizičnim premeščanjem jegulj čez oviro. Obstaja tudi možnost odstranitve ovire, ki pa v večini primerov ne pride v poštev (Solomon & Beach, 2004).

5.8 SPLAVNICE

Poseben primer so splavnice, ki lahko služijo tudi za transport rib. Splavnice nimajo vgrajenih sredstev za privabljanje rib, ker so ponavadi postavljene v mirnih območjih, primernih za manevriranje ladij. Testi, ki so jih opravili na reki Kolumbiji, so pokazali, da le 1,5% migratornih rib uporablja splavnico.

V kolikor želimo splavnico uporabljati kot pomagalo za ribje migracije, je treba zagotoviti dolvodni tok, ki ribe privablja. To se lahko omogoči z odprtjem dolvodnih zapornic. Ko je enkrat splavnica polna, je treba vzdrževati zadostno hitrost toka, da se ribe vzpodbudi h gorvodnem migriranju. Uporaba splavnic za prehajanje rib je omejena zaradi priporočil, ki morajo biti upoštevana pri plovbi (Larinier, 2000; FAO, 2001).

5.9 FIZIČNO PREMEŠČANJE RIB

Pogosto se uporablja tudi fizično premeščanje rib v primeru verige elektrarn. Ukrep je lahko začasen, oziroma se ga izvaja v času pred gradnjo ribjih prehodov, ali pa se ga uporablja, ko zaradi tehničnih razlogov ni omogočeno učinkovito migriranje rib. Ribe se ujame dolvodno od ovire in se jih fizično premesti na območja, primerna za drstenje in hranjenje (Larinier, 2000).

fishway for eels and elvers, which require other types of fishways. Swimming abilities of eels are limited and depend on a coarse substrate, therefore it is essential to ensure low flow rate and water velocity and a suitable substrate when constructing an eel pass. Bristle tufts of various materials are used as the substrate (Fig. 9).

There are several types of eel passes. An ordinary eel pass (Fig. 10) is commonly combined with an eel lift (Fig. 11), a trap–and–transport system and a physical transportation of eel over the obstruction. There is also a possibility of removal of the obstruction, which is not a likely option in most cases (Solomon & Beach, 2004).

5.8 NAVIGATION LOCKS

Navigation locks are a special type of fishway that can also serve as a means of fish transport. Navigation locks do not have facilities to attracting fish, as they are often placed in calm areas suitable for ship manoeuvring. Tests carried out on Columbia River showed that only 1.5% of all migrating fish make use of the navigation locks.

To use a navigation lock as a means of fish migration, it is necessary to provide sufficient downstream flow to attract the fish. This can be achieved by opening downstream gates of the lock. Once the navigation lock is full, sufficient water velocity needs to be maintained to encourage the fish to migrate upstream. The use of navigation locks for fish migration is limited due to navigation requirements (Larinier, 2000; FAO, 2001).

5.9 PHYSICAL TRANSPORTATION OF FISH

Physical transportation of fish is common practice in case of a chain of power plants. It may serve only as a temporary measure before the construction of fishway facilities is finished or it may be used when efficient fish migration is limited due to technical reasons. The fish are trapped below the obstruction and are then physically transported to the areas suitable for spawning and feeding (Larinier, 2000).

6. UČINKOVITOST RIBJIH PREHODOV

Učinkovitost ribjega prehoda je odvisna od tipa izvedbe, migratornih vrst rib in krajevnih značilnosti. Učinkovitost ribjega prehoda je merilo, kako dobro ribji prehod privablja selitvene ribje vrste. Nanjo vplivajo plavalne sposobnosti rib, njihovo vedenja in hidravlični pogoji. Primerni pogoji za učinkovit ribji prehod so dobro konstruirani elementi: vhod v prehod, ribja steza in izhod iz prehoda (Katapodis, 1992). Ti elementi morajo biti konstruirani tako, da so prilagojeni plavalnim sposobnostim rib. Ribe se morajo biti sposobne povzpeti po ribjem prehodu in izstopiti v območju, kjer ne bodo odplaknjene nazaj dolvodno. Takšne razmere za uspešne migracije je potrebno zagotavljati skozi celotne dnevne in sezonske cikle.

Ribje prehode je treba pregledati in vzdrževati še posebno po dogodkih, kadar nastopijo visoke vode oziroma poplave, saj je velika možnost zamašitve s sedimenti. Mehansko vodeni ribji prehodi zahtevajo poseben urnik vzdrževanja (Thorncraft & Harris, 2000).

7. STANJE V SLOVENIJI

Visoke hidroenergetske pregrade na večjih rekah Dravi, Savi in Soči in pregrade ter jezovi na ostalih vodotokih vplivajo na preživetje in obnavljanje ribjih populacij (preglednica 2). Izgradnja verig pregrad v Sloveniji, ki se ponekod nadaljujejo v sosednjih državah, vpliva na selitev rib. Pregrade povzročajo zajezitve, kar pomeni, da se rečni habitat v območju zajezitve spremeni v jezerskega, ki ni primeren za rečne ribe. Omenjeni posegi v vodotoke vplivajo na selitev na drstišča in pasišča. Omeniti je treba podust (*Chondrostoma nasus*), ki je trenutno ena najbolj ogroženih ribjih vrst v Sloveniji. Je tipična riba selivka, ki naseljuje Savo, Dravo in Muro s pritoki in se je po rekah selila več 100 km v gorvodne in dolvodne habitate, ki so sedaj prekinjeni zaradi hidroenergetskih pregrad (Povž, 2005a).

6. EFFECTIVENESS OF FISHWAYS

Fishway effectiveness varies with type of fishway, migratory fish species and site conditions. It is a measure of how well the fishway attracts emigrating fish species. Efficiency depends on fish swimming abilities and behaviour of the emigrating fish species and hydraulic conditions. Important requirements for an effective fishway are well designed components: entrance to the fishway, the fishway itself and the fishway exit (Katapodis, 1992). These components must be designed in a way to be adequate for fish swimming abilities. The fish must be able to move up the fishway and exit in the area where they will continue their way upstream without getting washed back downstream. These requirements for successful migrations must be observed constantly over daily and seasonal cycles.

Fishways also need to be regularly inspected and maintained, especially after periods of high water or flooding, in order to prevent sediment blockage. Mechanically operated fishways require special maintenance schedules (Thorncraft & Harris, 2000).

7. CURRENT SITUATION IN SLOVENIA

Large hydroelectric dams on the Drava, Sava and Soča rivers, as well as dams and weirs on other watercourses have a significant effect on survival and regeneration of fish populations (Table 2). The construction of a chain of dams in Slovenia, which continues to neigh-bouring countries, affects fish migrations. Dams are a source of water impoundment which consequently turns river habitats into lake habitats, rendering them inadequate for riverine fish species. Those interventions in watercourses have a profound impact on fish migrations to spawning and rearing areas. It's necessary to mention the Common nase (*Chondrostoma nasus*), one of the most endangered fish species in Slovenia. Nase is a typical migratory fish found in the Sava, Drava and Mura rivers with their tributaries and it used to migrate to habitats several 100 km upstream and downstream, which are now cut off by hydroelectric dams (Povž, 2005a).

Preglednica 1: Velike hidroenergetske pregrade in ribji prehodi v Sloveniji.
Table 2: Large hydroelectric dams and fishways in Slovenia.

Vodotok/ ***Watercourse***	**Hidroenergetska pregrada/** ***Hydroelectric dam***	**Ribji prehod/** ***Fishway***	**Opombe/*Notes***
Drava	HE Dravograd	+	Betoniran ribji prehod (slika 17). *Concrete wall in fishway (Fig. 17).*
	HE Vuzenica	+	Status ribjega prehoda nejasen. V kolikor ribji prehod ni porušen, obstaja verjetnost, da je nedelujoč. *Status unclear. Fishway demolished to an extent, unfit for use.*
	HE Vuhred	–	/
	HE Ožbalt	–	/
	HE Fala	+	Ob rekonstrukciji elektrarne okrog leta 1990 je bil ribji prehod porušen (slika 16) (Povž, 2005b). *Fishway was demolished at the time of the power plant reconstruction in 1990 (Fig. 16) (Povž, 2005b).*
	HE Mariborski otok	+	Ribji prehod ne deluje. V prihodnjih letih je predvidena obnova (slika 18). *Fishway unfit for use. Renovation works planned (Fig. 18).*
	Jez Melje/*Melje dam*	–	/
	Jez Markovci/*Markovci dam*	–	/
Sava	HE Moste	–	/
	HE Mavčiče	–	Drstišče (ribji prehod je bil spremenjen v drstišče) (slika 15). *Artificial spawning ground (fishway was modified to spawning ground) (Fig. 15).*
	HE Medvode	–	/
	HE Vrhovo	–	Drstišče (slika 14). *Artificial spawning ground (Fig. 14).*
	HE Boštanj	–	/
	HE Blanca	+	Obhodni kanal (sliki 12 in 13). *By–pass channel (Figs. 12 & 13).*
	HE Krško*	+	Planiran ribji prehod. *Fishway planned.*
Soča	Podsela (jez Doblar) *Podsela (Doblar dam)*	–	/
	mHE Ajba *SHHP Ajba*	–	/
	HE Solkan	–	/

*hidroelektrarna v gradnji/*hydroelectric power plant under construction*

Po kriterijih mednarodnega komiteja za velike pregrade (ICOLD), ki jih upošteva tudi Slovenija, morajo velike pregrade zadostiti naslednjim pogojem:

- biti morajo višje od 15 m, merjeno od krone do najnižje kote temeljenja ali
- biti morajo višje od 10 m in daljše od 500 m merjeno v kroni ali imeti prostornino večjo od 1.000.000 m^3 ali pa prevajati preko prelivov pretok večji od 2.000 m^3/s (Internet 2).

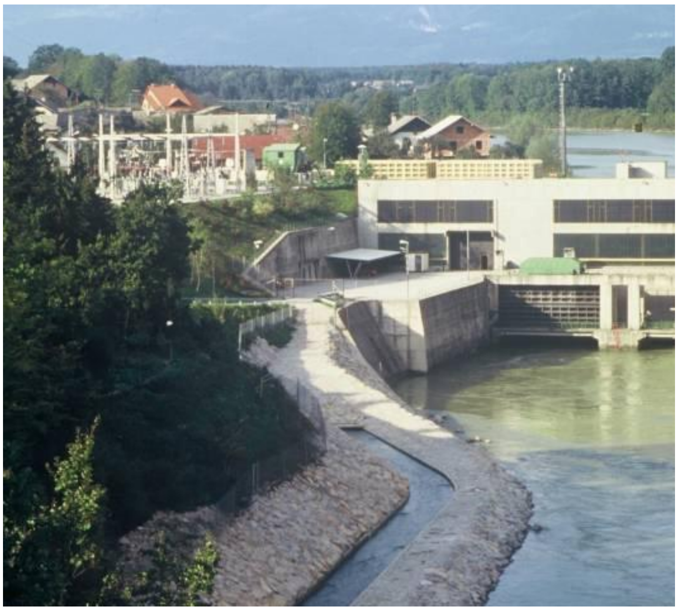
According to the criteria of the International Commission of Large Dams (ICOLD) acknowledged in Slovenia, large dams must meet the following conditions to qualify as such:

- *be over 15m tall from crown point to the foundation or*
- *be over 10m tall with crown length over 500m or have a reservoir capacity of over 1.000.000*m^3 *or have a discharge over spillways greater than 2.000* m^3*/s (Internet 2).*

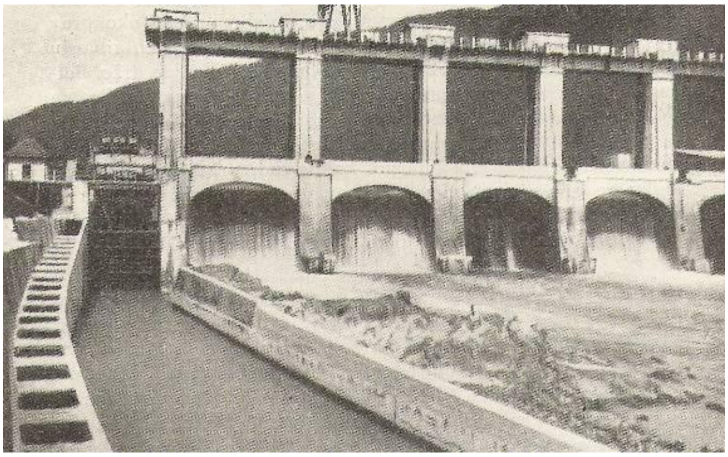
Slika 4: HE Blanca – vhod v obhodni kanal.
Figure 12: HPP Blanca – entrance to bypass fishway.

Slika 13: HE Blanca – obhodni kanal (z uravnavanjem dinamike vodnega toka).
Figure 13: HPP Blanca – bypass fishway (with levelling water flow dynamics).

Slika 14: HPP Vrhovo – vhod v drstišče.
Figure 14: HPP Vrhovo – entrance to spawning area.



Slika 15: HPP Mavčiče – drstišče.
Figure 15: HPP Mavčiče – spawning area.



Slika 16: HE Fala – izhod iz ribjega prehoda, povzeto po Munda (1928).
Figure 16: HPP Fala – fishway exit, adopted from Munda (1928).

Slika 17: HE Dravograd – vhod v ribji prehod.
Figure 17: HE Dravograd – fishway entrance.

Slika 18: HE MB otok – pogled na ribji prehod od zgoraj.
Figure 18: HPP MB otok – fishway view from the top.

Pogosto se omenja problematika prehajanja rib na velikih vodotokih, ne omenja pa se manjših neprehodnih vodotokov, ki so za ribe prav tako zelo pomembni. Trenutno ni dobro urejene baze podatkov oziroma katastra o pregradah na manjših vodotokih v Sloveniji. Januarja 2007 je bilo evidentiranih 425 malih hidroelektrarn (ARSO, 2007), ki prav tako lahko vplivajo na ribje migracije, v kolikor niso dopolnjene z ribjim prehodom oziroma ta ni delujoč ali učinkovit.

Večina velikih hidroenergetskih pregrad v Sloveniji nima zgrajenih ribjih prehodov. Hidroenergetska pregrada Mariborski otok ima ribji prehod, vendar ta ne deluje. Hidroelektrarne, ki so trenutno v gradnji, imajo predpisano izgradnjo ribjega prehoda. Takšen primer je HE Krško. HE Blanca (sliki 12 in 13), zgrajena leta 2009, ima narejen obhodni kanal. Vse bodoče hidroelektrarne bodo prav tako morale imeti vzpostavljeno vzdolžno kontinuiteto oziroma bodo morale omogočati ribje migracije.

Prvi ribji prehod na hidroenergetskih objektih v Sloveniji je bil zgrajen na HE Fala (slika 16), temu so sledile izgradnje ribjih prehodov na HE Dravograd (slika 17), HE Vuzenica in HE Mariborski otok (slika 18) (Povž, 2005b). Omenjeni ribji prehodi so bili iz različnih razlogov porušeni oziroma opuščeni. Pri gradnji verige hidroelektrarn na srednji in spodnji Savi, kjer na HE Krško gradbena dela že potekajo, bodo upoštevani zakonski predpisi. Pri izgradnji HE Blanca so bili upoštevani vsi zakonski predpisi, s

The problem of fish passage in large watercourses is a popular issue, however, smaller water bodies are often neglected despite their importance for the fish species. At the moment there is no updated data base or a register on barriers in minor watercourses in Slovenia. In January 2007, there were 435 small hydropower plants (SHPP) (ARSO, 2007), which also affect fish migrations if not complemented with a fishway or if the latter is unfit for use.

The majority of large hydroelectric barriers in Slovenia do not provide fishway structures. There is a fishway at the hydroelectric dam Mariborski otok, but it is unfit for use. Hydroelectric power plants (HPP) currently under construction are required to construct a fishway. Such example is HPP Krško. HPP Blanca (Figs. 12 & 13) constructed in 2009, has a bypass fishway. All future hydroelectric power plants will have to ensure longitudinal continuity of the stream and uninterrupted fish migrations.

The first fishway on hydroelectric barriers was constructed on HPP Fala (Fig. 16), followed by fishways on HPP Dravograd (Fig. 17), HPP Vuzenica and HPP Mariborski otok (Fig. 18) (Povž 2005b). These fishways were either demolished or abandoned for various reasons. The building of a chain of HPPs on the middle and lower Sava River, which has already started at HPP Krško, will meet all the regulations currently in place. When building katerimi je omogočena vzdolžna kontinuiteta. Po zakonu o sladkovodnem ribištvu bo moral investitor zagotoviti ustrezen ribji prehod. Funkcio-nalnost ribjega prehoda bo moral zagotavljati lastnik oziroma najemnik objekta (Ur. list RS 2006).

Z zakonom o sladkovodnem ribištvu (Ur. list RS 2006) je rešena problematika za novo grajene objekte v vodah, ta rešitev pa ne velja za vse ostale objekte, ki so bili grajeni pred sprejetjem omenjenega zakona. Po sprejetju vodne direktive je treba na vseh vodotokih doseči bodisi dobro ekološko stanje ali pa dober ekološki potencial. Pomemben element pri doseganju omenjenega cilja je, da se vzpostavi vzdolžna kontinuiteta, s čimer se omogoči transport oziroma prosto prehajanje vodnih organizmov. Nekateri posamezni lastniki mHE oziroma nekatere hidroenergetske družbe se zavedajo pomena vodne problematike in sami investirajo v ukrepe za izboljšanje stanja vodnega okolja z zagotovitvijo ribjih prehodov. Pomembno je, da se obnovijo tisti ribji prehodi, ki so v preteklosti bili zgrajeni in niso ustrezni ter da se zgradijo ribji prehodi na mestih, kjer so nujno potrebni in se določijo kot prioritetni.

Prioritetne lokacije za vzpostavitev vzdolžne kontinuitete bo treba določiti na podlagi celovitih študij povodij in porečij. Problematika gradnje ribjih prehodov zajema prečne objekte kot so pregrade, kaskade, zapornice in druge ovire. Reševanje problema se začne z inventarizacijo prečnih objektov na vodotokih, pri čemer bi se bilo najprej treba osredotočiti na vodotoke s prispevno površino večjo od 1.000 km^2 (Sava, Savinja, Krka, Kolpa, Drava, Mura in Soča) ter na ostale vodotoke, ki so ključnega pomena za razmnoževanje, razvoj, drstenje in prehranjevanje ribjih populacij. Ključnega pomena pri določevanju prioritetnih lokacij za ribje prehode bodo biološki podatki o vedenjskih vzorcih rib, migracijskih razdaljah in tipih migracij. Prioritetne bodo torejlokacije na vodotokih, ki so čim bližje izlivu, pri katerih se bodo vzpostavile čim daljše migratorne poti in kjer bo zagotovljena povezava s tistimi stranskimi pritoki, ki so pomembni za drstenje, razvoj, prehranjevanje in skrivališča.

Za rešitev problematike prehajanja rib čez

HPP Blanca, all regulations were followed to enable longitudinal connectivity. According to the Freshwater Fishery Act, the investor is required to provide a suitable fishway. Functionality of a fishway is under the domain of the owner or leaseholder (Ur. list RS 2006).

Freshwater fishery act (Ur. list RS 2006) solves the problem of new constructions on watercourse, but this solution does not apply to all other constructions that were built before the act was passed. The Water Framework Directive requires good ecological status or good ecological potential of watercourses. An important element in achieving this goal is to establish longitudinal continuity enabling the transport or free passage of aquatic organisms. Some SHPP and hydro–energy companies are well aware of the importance of water related issues and are prepared to invest into aquatic environment protection measures by providing suitable fishways. It is essential to renovate those fishways that were built in the past but do not function properly and to construct new fishways on critical locations and define them as a priority.

Priority locations for establishing longitudinal continuity will be defined on the basis of comprehensive analyses of basins and sub–basins. Fishway construction relates to transversal structures such as dams, cascades, gates and other obstructions. The solution process starts with an inventory of transverse structures on watercourses, first focusing on large watercourses with a catchment area of over 1.000 km^2 (the Sava, Savinja, Krka, Drava, Mura and Soča rivers) and other watercourses that play a key role in procreation, development, spawning and feeding of fish populations. Priority locations for fishways will be determined on the basis of biological data on fish behavioural patterns, migration distances and types of migration. To sum up, priority locations will be situated onwatercourses in the vicinity of their outfalls, with the longest possible migratory paths and connections with subsidiary streams that play an important role in spawning, development, feeding and providing shelter.

Slovenia has enough experts to address the issue of fish passage over transverse barriers.

prečne objekte je v Sloveniji dovolj znanja. Rešitev je v interdisciplinarnem pristopu reševanja problematike, pri čemer so pomembni strokovnjaki s področij biologije, hidrotehnike, varstva okolja in gradbeništva. Problem gradnje ribjih prehodov na obstoječih hidroelektrarnah ni toliko finančno narave, čeprav so stroški zelo visoki, kot nanj vplivajo interesi, bodisi posameznikov ali gospodarstva.

8. ZAKLJUČEK

Ribje populacije so močno odvisne od značilnosti vodnih habitatov, ki omogočajo njihovo biološko delovanje. Migratorne ribje vrste potrebujejo različna okolja za svoje razvojne faze. Ovire v vodotokih preprečujejo ribje migracije ter s tem povečujejo možnost izginotja ali izumrtja posameznih ribjih vrst na takšnih odsekih. Migracije rib so usmerjena gibanja med drstnimi in prehranjevalnimi habitati in se pojavljajo v obdobjih nihanja vodne gladine, poplavljanja, hrupa v vodi, turbulence, spremembe temperature vode, spremembe stopnje kisika v vodi itd. Pri ribjih prehodih se ponavadi govori o gorvodnih migracijah čez ovire. Zanemarja pa se dejstvo, da morajo ribe prehajati tudi dolvodno po vodotoku. Dolvodno migriranje vključuje diadromne vrste oziroma mladice anadromnih vrst in odrasle osebke katadromnih vrst. Dolvodno prehajanje potamodromnih ribjih vrst preko hidroelektrarn v Evropi ne smatrajo za tako pomembno (Larinier, 2000).

Pri načrtovanju in gradnji ribjih prehodov nemalokrat manjkajo ključni biološki podatki (npr. migracijsko obdobje, plavalne sposobnosti, migratorno vedenje), raziskave o dominantnih vrstah rib (gorvodno in dolvodno) pa so nezadostne. Pri ribjih prehodih je najbolj pomembna njihova učinkovitost, ki je ovrednotena z možnostjo, da vse, tudi najmanjše ciljne ribe, lahko prečkajo oviro v času migriranja. Prehajanje rib čez oviro se kontrolira na različne načine npr. vizualno, z lovljenjem in video nadzorom.

Gradnja ribjih prehodov zahteva multidisciplinaren pristop reševanja problemov. Vključeni morajo biti inženirji in biologi, ki morajo probleme reševati

The solution lies in the interdisciplinary approach to the problem, which should include experts from various fields such as biology, hydro engineering, environmental protection and civil engineering. The main problem of fishway construction on existing hydroelectric power plants is not financial, despite its high costs, but lies in the interests of individuals and the economy.

8. CONCLUSIONS

Fish populations depend highly on the characteristics of aquatic habitats enabling their biological functions. Migratory fish species require a variability of habitats at different developmental stages. Obstructions on watercourses prevent fish migration and consequently increase the chance of disappearance or extinction of certain fish species in certain parts of a watercourse. Fish migration is defined as oriented movement between spawning and feeding habitats and occurs during the periods of water surface oscillations, flooding, noise, turbulence, water temperature shifts, dissolved oxygen level changes, etc. The concept of fishways normally refers to upstream migrations over barriers. It is often forgotten that fish also migrate downstream. Downstream migrations are typical of diadromous species and juvenile anadromous fish, as well as of adult catadromous fish. Downstream migrations of potadromous fish over hydroelectric power plants in Europe are not considered important (Larinier, 2000).

The processes of design and construction of fishways often lack key biological data (e.g. migration periods, swimming abilities, migratory behaviour) and are based on incomplete analyses on dominant fish species (upstream and downstream). The main feature of fishways is their effectiveness, which is based on the presumption that even the smallest fish should be able to pass the obstruction during the migration period. The passage of fish over a barrier is controlled visually, by trapping techniques, video surveillance, etc.

Fishway construction requires a multidisciplinary approach to address all the relevant issues. The process should include engineers and biologists, who should address the problems in a systematic way. It is also sistematično. Pomembno je vedeti, da je tehnika konstruiranja empirična in je v veliki meri odvisna od izkušenj strokovnjakov. Največji napredek pri tehnologiji gradenj prehodov za ribe so naredili v državah, kjer so sistematično ocenili učinkovitost prehajanja rib.

important to acknowledge the empirical character of the construction techniques and their dependence on expertise. The biggest progress in fishway technology was made in countries where the effectiveness of fish passage over barriers was systematically assessed.

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