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DOWNSTREAM FISH MIGRATION ALONG THE LOW MEUSE RIVER



Action A2

Development of fishing capacities for stock constitution and characterization

Deliverable – Fishing protocol





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TABLE OF CONTENTS

I.	Introduction	5
II.	Global procedure.....	5
III.	Electro-fishing	6
III.1	Objectives	6
III.2	Targeted areas.....	6
III.3	Advantages	6
III.4	Constraints.....	6
III.4.1	Technical issues	6
III.4.2	Environmental issues.....	6
III.4.3	Biological issues	6
III.4.4	For operators	7
III.5	Technical procedure	7
III.5.1	Operation principle.....	7
III.5.2	The remote controller	7
III.5.3	Procedure	8
III.6	Safety and health plan.....	8
III.7	Required permits	9
III.8	Instructions.....	9
III.9	Equipment description	10
III.9.1	Power generators:	10
III.9.2	Anodes and cathodes:	10
III.9.3	Wires:.....	10
III.10	Resources.....	10
IV.	Fyke net fishing method	11
IV.1	Introduction.....	11
IV.2	Advantages	13
IV.3	Disadvantages.....	14
IV.4	Procedure	14
IV.5	Definition of capture effort	14
IV.6	Resources.....	15
V.	Estimating population size using capture–recapture encounter	16

V.1	Sampling sites:.....	16
V.2	Description.....	19
V.3	Procedure	19
V.4	Abundance estimation with Petersen (1896) method	19
VI.	Data's treatment	21
VI.1	Taxonomic determination	21
VI.2	Counting	21
VI.3	Morphometric measures.....	21
VI.4	Quality control.....	21
VII.	References and further readings	22

TABLES

Table 1: General criteria to choose the appropriate electro-fishing equipment to use in different sizes streams (Temple & Pearsons, 2007).	8
Table 2: Stations from Roland et al. (2016) infield study	18
Table 3: Data table for eel	21

FIGURES

Figure 1: Paired or double fyke net structure (http://www.filmar.qc.ca)	11
Figure 2: Paired or double fyke net (A) and single fyke net (B) (Roland et al., 2016)	11
Figure 3: 14m double fyke net (http://yvesroudier.com/verveux/)	12
Figure 4: view of one fyke net along a line of 5 fyke nets installed on the bottom of the River Meuse, facing downstream	13
Figure 5: Localisation of stations for fish capture.	16
Figure 6: Injection of PIT tag in the peritoneal cavity of an anesthetized eel (A)	19
Figure 7: Forms of fyke net installation (adapted from Tesch, 2004)	25



I. Introduction

It is necessary to develop fishing capacities to constitute a stock of migratory fish in order to:

- Establish a stock of adult eels, as close to their silver stage as possible, and Atlantic salmon at their smolt stage, collected in different stretches of the Meuse catchment basin.
- Provide relative estimates of the stock of migrating fish, either in different stretches of the Meuse itself or in the major tributaries (Ourthe, Lesse, Sambre).
- Describe the biological condition of the sampled fish to develop a detailed reference base listing their physiological and health status and their ability to migrate, both before they migrate downstream and once they reach the passes.
- Establish a stock of silver eels caught during the migration in the River Meuse available for tagging and telemetry tracking as expected by action D2.

European eel, *Anguilla anguilla* can be captured by different techniques (Tesch, 2004). However, electro-fishing and hoop net fishing techniques are the most used in Europe. A combination of these two methods exploits the eel's various needs and behaviours: periodic migration drive, avoidance of light (negative phototaxis), food seeking, affinity to physical contact (thigmotaxis) and habitat's occupation and movements between habitats. For Atlantic salmon, *Salmo salar*, electro-fishing is also one of the most widely used fishing methods due to its low cost and its relatively low impact on this species (Temple & Pearsons, 2007).

II. Global procedure

The fishing protocol describes the use of two fishing methods: electro-fishing and hoop net fishing. For Atlantic salmon, only electro-fishing is used for sampling. For European eel, a combination of the two methods is used. For the latter species, each defined area is sampled twice. In the first day, an electro-fishing session is performed followed by the laying of hoop nets (if possible). The second day (24 to 48h later), the electro-fishing is followed by the retrieval of the previously laid hoop nets.

III. Electro-fishing

III.1 Objectives

Electro-fishing is a sampling technique in order to capture fish in waterways. Only some institutions (Universities, Research Centres) are authorized to use this technique in order to conduct scientific or general interest's studies. The Public Service of Wallonia (SPW) is the only competent authority that delivers a time-limited permit for electro-fishing to these institutions.

III.2 Targeted areas

Shallow ponds, lakes and low-depth waterways for electro-fishing on feet and high-depth waterways, lakes and ponds for electro-fishing on boat.

III.3 Advantages

- Great capture's effectiveness especially for species with good swimming skills.
- Mortality's rate in populations exposed to electro-fishing is lower than 1% if good practices are respected.
- Standardized and reproducible operating conditions as sampled distances, fishing season or dates, number of anodes, considered species, adjustment of power generators allowing the acquisition of coherent results and statistical analysis for scientific purposes.

III.4 Constraints

III.4.1 Technical issues

- The length of the sampling area is dependent on the length of anode's cables.
- The weight and the clutter of the required equipment that also generates noise and smoke.

III.4.2 Environmental issues

- Water with a low conductivity (less than $100\mu\text{S}\cdot\text{cm}^{-1}$) has a higher resistance to the passage of an electric current through it.
- Because fish capture efficiency varies under different water flow conditions, it is important to perform electro-fishing under similar hydrological conditions.
- The optimum temperature for electro-fishing juvenile salmonids is 10 to 15°C as many fish go into hiding and may fail to be attracted to the anode when temperature is below 8°C.
- The efficiency of electro-fishing will decrease if the visibility of fish is reduced by one of the following factors: water turbidity, weather, water turbulences, aquatic and overhanging vegetation, undercut banks and low light levels.

III.4.3 Biological issues

- Salmonids show a greater reaction, for a given voltage, to a pulse rate of 50.s⁻¹ than one of 100.s⁻¹. Eels show the highest reaction to an electric field of around 20 pulses.s⁻¹.
- Large fish display a greater reaction to electro-fishing than small ones do. The voltage must be reduced if it is anticipated that large fish will be encountered.
- Don't use this technique when air temperature is below 0°C to avoid freezing fish when they are out of water.
- Water temperature must be recorded at every electro-fishing expedition.
- Don't expose fish to several electrical shocks
- As oxygen concentration decreases as water temperature rises, suitable aeration in the storage tank is essential.

III.4.4 For operators

- Protection against electric hazards by the use of safety equipment: fishing waders and rubber insulating gloves (1000 V of insulation).
- Protection against drowning and/or fall hazards: a life jacket should be used.
- Protection against noise and smoke caused by the electric generator. Operators have to keep themselves away from the generator by using the remote control. They also have to use protective headset against noise.
- Protection against fire hazards: never use fuel near of a running generator. Fuel cans must be kept out of the sunlight and away from fire and sparks.
- Never practice electro-fishing alone. It is recommended to be at least four persons to perform an electro-fishing expedition.
- It is recommended to perform electro-fishing under low water flow conditions.
- Field supervisors and crew members must have appropriate training and experience with electro-fishing techniques. Before an electro-fishing expedition, a training session concerning such topics as electric circuit and field theory, safety training, and fish injury awareness and minimization must be conducted to inexperienced crew.
- The crew leader must be qualified according to the applicable regulations (BA 4).
- It is prohibited to smoke during an electro-fishing expedition.

III.5 Technical procedure

III.5.1 Operation principle

Thermal power generator products a continuous electrical tension that can be set between 300 and 600 V. The engine is insulated from produced voltages but must be always kept in a dry place whatever it is running or not. Two distinct outputs are found on the generator, the first for the negative phase and the second for the positive phase. A long wire is connected to the negative phase. This wire is also connected to a grid or a large wire made in stainless steel or copper of one m length (cathode). The cathode must be placed in the water downstream of the sampled area. A marking cone must be placed near to the cathode to signalize its localization. A cable wrap system (100 m length, H07RN-F 1X4) is connected to the positive phase. The other end is connected to a fishing anode (an insulated rod that finishes with a stainless steel ring). During the electro-fishing, the operator must avoid applying any mechanical traction on the wire. The power generator is running when the safety switch is pressed. The power generator can be controlled with a remote control to ensure staff safety.

A spherical electric field appears when the power generator is running and the anode is immersed in water. This electric field radiates from the anode with decreasing intensity and affects the behaviour of any fish inside the field. As fish are sensitive to electrical stimuli, the voltage difference applied on the lateral lines of fish modifies the behaviour of fish that is attracted to the higher voltage source, the anode. The fish will swim in the direction of the anode and, when arrived, it will be exposed to a very high voltage that leads to an electrical stunning. The fainted fish can then be captured by another member of the crew using a dip net. Outside the electric field, fish recover quickly and can be measured, weighed and optionally tagged before being released when the electro-fishing session is finished.

III.5.2 The remote controller

The remote controller uses 220 volts current and is supplied by a standard power generator. It can control up to four different generators simultaneously. When the remote is on pause, the running generators do not generate any electric currents. By maintaining the contact button pushed, the

operator controls the electric field production and can easily stop it by releasing the button in case of incident.

III.5.3 Procedure

Electro-fishing is performed only on the edges by boat or on feet. The choice of backpack versus boat electro-fishing gear depends on the physical features of the stream (Table 1). In fact, stream size, discharge, temperature and conductivity determine the effectiveness of electro-fishing gear types. Generally, backpack mounted operators are used in small streams and boat mounted units can be used in larger streams and rivers. The table 1 can be used as a guide to determine the electro-fishing equipment necessary for sampling various sized streams and rivers (Temple & Pearsons, 2007).

Equipment	Temperature (°C)		Discharge (m3/s)		Stream width (m)		Conductivity (mmhos)	
	Min	Max	Min	Max	Min	Max	Min	Max
1 Backpack	6	18	0	0.3	0	7	40	250
2 Backpacks	6	18	0.3	3.3	7	15	40	250
Boat unit	6	18	11	200	15	>15	40	250

Table 1: General criteria to choose the appropriate electro-fishing equipment to use in different sizes streams (Temple & Pearsons, 2007).

Electro-fishing in boat is performed in a pneumatic boat with hard floor (4.20 m long). The power generator (EFKO FE6 7000) produces a 350 to 400 V adjusted current for an amperage about 4 to 5 A. The anode is circular with 30 cm of diameter. The cathode is placed at the back of the boat. The boat runs slowly along the edge of the sampling site from downstream to upstream, leaving about 2 meters between this edge and the boat. This allows capturing only the fish living on the edge. The fishing crew must be constituted by at least three persons. One person for the anode, one person equipped with dip net to catch fish and one person for navigation purpose. Another person may be required to use the paddle if necessary.

Less width and depth areas are explored on feet and all the width is sampled. The current is provided by a backpack power generator DEKA 3000 Lord (Copp, 2010). The cathode supplied with the generator is a copper braided wire placed behind the operator. The generated electric field have amperage of 3A and a voltage of 600 V. The power generator EFKO FE6 7000 can also be used with the cathode placed in water near the generator. The fishing crew must be constituted by at least four persons. One person per anode (normally one or two anodes are used but sometimes in larger sampling area more anodes can be used), two or three persons equipped with dip net to catch fish, one person equipped with a plastic jug containing water to keep fish immediately after their capture, one person to control the power generator and eventually another one to move the cables. The crew moves together from downstream to upstream and following the anode's holders. Each electro-fishing method is performed one time on a way of 250 m of length and 0.5 to 1m of depth.

III.6 Safety and health plan

Many parameters must be taken in account in order to ensure the safety of the crew during and after the electro-fishing session.

- Weight of the equipment: depending on the model, an electro-fishing power generator can weight about 50 to 70 kg and must be carried by four persons using the device's handles designed for this purpose, especially for long distances and if the ground is slippery or rugged.
- Equipment that exceeds 15 kg of weight, like the cable wrap system, must be carried by two persons.
- All the equipment must be checked before the electro-fishing session and defective equipment must be discarded until replacement or reparation. All wire (both defective and non-defective) must be replaced after three electro-fishing seasons.
- Electric hazards: All the operators must wear safety equipment: fishing waders and rubber insulating gloves (1000 V of insulation). Avoid being in contact with the conductive part of the anode or cathode even if you wear rubber insulating gloves.
- Drowning and/or fall hazards: the choice of the sampling area can help to control drowning and fall hazards. It is recommended to avoid, when possible, to work in high flow conditions, on mud bottoms or filled with large stones covered with slippery moss.
- For personal safety, at least one person in the crew must get a first aid certificate.
- A fast mean of communication (cell phone) must be provided to the crew. Please check the communication signal before the electro-fishing session. Call 100 for rescue and 101 for Police.

III.7 Required permits

- Displacements: a permit to use the towpaths is required. Please ask the local waterways directorate (Direction des Voies Hydrauliques) for the required authorization. As this permit is time-limited, ensure that it is renewed before the expiration date.
- Fish capture: a permit is required to capture fish and crayfish by any harmless method like electro-fishing. Please ask the SPW for authorizations and ensure that the permit is renewed before the expiration date.
- Equipment control: all the electric equipment used for electro-fishing must be checked at least once by year. A certification organisation as SGS or Vinçotte can take this control in charge.
- Crew: the crew leader must be qualified according to the applicable regulations (BA 4) and follow a specific training provided by a competent agency. A crew leader having at least 100 hours of electro-fishing experience in the field using similar equipment must train the crew. The training must include a review of these guidelines and the equipment manufacturer's recommendations, including basic gear maintenance, definitions of basic terminology (e.g. galvanotaxis, narcosis, and tetany) and an explanation of how electro-fishing attracts fish, a demonstration of the proper use of electro-fishing equipment (including an explanation of how gear can injure fish and how to recognize signs of injury) and of the role each crew member, a demonstration of proper fish handling, anesthetization, and resuscitation techniques and a field session where new individuals actually perform each role on the electro-fishing crew.
- Locations: authorizations are necessary to access to some private locations.

III.8 Instructions

- A clear signalling system of electric hazards must be established before the beginning of the electro-fishing session.

- Fill the power generators with fuel before the beginning of the electro-fishing sessions. It is forbidden to fill a running power generator with gas.
- The power generators must be ran after putting the cathode in water.
- Never put hands in water when the power generators are running. If it is necessary, please shut down the power generators before.
- Fish and debris must be transferred to a non-conductive container before handling.
- At the end of the electro-fishing session, all the equipments must be sorted and stored. Defective pieces are the discarded.

III.9 Equipment description

III.9.1 Power generators:

- Two power generators DEKA 6000 with Schaltbau IP67 connectors and a punch type emergency stop system.
- One power generator EFKO Feg 7000 with a punch type emergency stop system.

All these power generators can be used with the remote controller and produce adjustable smooth continuous currents between 300 and 600 V.

III.9.2 Anodes and cathodes:

- For DEKA generators: cathodes supplied with the power generator and anodes EFKO.
- For EFKO generator: cathodes and anodes supplied with the generator and anodes EFKO

III.9.3 Wires:

- H07RN-F (please see annexe 1), replaced every three years.

III.10 Resources

- Survey team: two persons at least in wadeable habitats, three persons at least in deeper habitats.
- A large zeppelin boat with specific security equipment for the survey team in deeper habitats.
- Drowning and fall hazards: all the crew must be equipped at least with personal flotation device in deep sites and by waders in wadeable sites.
- Electric hazards: all the crew must be equipped at least with rubber insulating gloves (1000 V of insulation).
- Electro-fishing equipment as described in paragraph III.9.
- Water quality field meter(s) to record at least water temperature and dissolved oxygen levels.

IV. Fyke net fishing method

IV.1 Introduction

Hoop nets or fyke nets are essentially a type of cylindrical fish trap. So far, they represent the best-known methods to catch eels (Tesch, 2004). They consist of cylindrical or cone-shaped netting bags mounted on rigid rings or other frameworks and fixed on the ground by anchors, ballast or stakes. One or more vertical sections of netting, called leaders, extend from the mouth of the fyke net and guide swimming fish into the net. The netting cones fitted inside the netting cylinder make entry easy and exit difficult (Figure 1). Fyke nets are considered as passive sampling gear because they rely on fish to willingly encounter and enter the net. They are adapted to demersal or benthic species and can be used to sample freshwater fish in a wide range of environments including lakes, wetlands, rivers and streams.

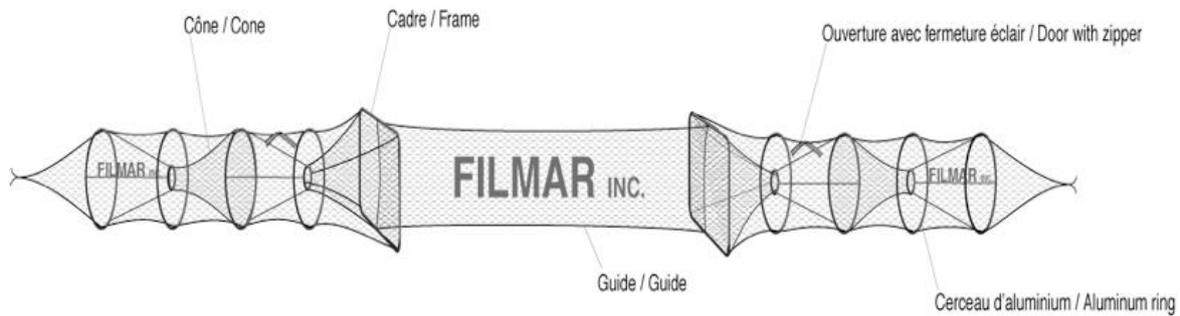


Figure 1: Paired or double fyke net structure (<http://www.filmar.qc.ca>)

The single fyke nets are constituted by two wings bound to one series of funnel-shaped throats as in two faced fyke nets (Figure 2).

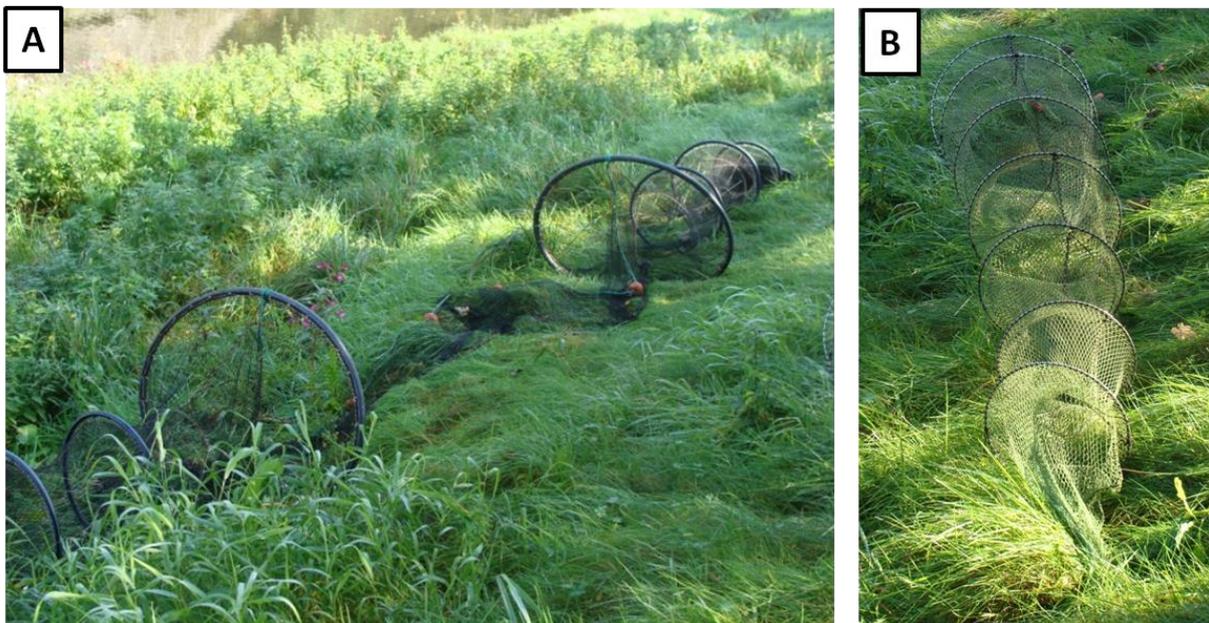


Figure 2: Paired or double fyke net (A) and single fyke net (B) (Roland et al., 2016)

The mesh size of leaders and trap bags affects strongly the size range of fish caught. The minimum size of fish caught is determined by the mesh size because if fish can pass through the mesh, they will not be retained in the trap. Mesh size affects also injury and mortality rates for captured fish. Smaller fish can become wedged in the mesh and larger mesh can also cause injury when appendages become

wedged. These effects can be minimised by using finer mesh sizes. However, fine mesh tends to reduce water flow through the net and may increase fish stress, particularly in low dissolved oxygen environments or where very large catches are made. The wings and the central net are made with a large mesh (20 mm) while the end of the net and the last rings are made in finer mesh size (10 mm) to avoid injury. The efficiency and selectivity of fyke nets are influenced by the probability that fish will encounter enter and be retained within the net until it is retrieved. Baiting can considerably increase the efficiency of this method for eel capture. Most fish can be released alive after being captured in fyke nets and the capture of non-target species, such as diving birds, is relatively rare.

In our study, for the resident eels sampling, we will use 14m double fyke nets (Yves Roudier, Brie sous Mortagne, France, Figure 3). These fyke nets have a central net of 8m long, 0.55m of height, with a large mesh size (17mm) and 7 rings in each. The two first rings (0.55 and 0.50m of diameter) are made in the same mesh size than the central net. The two second ones (0.45 and 0.40m of diameter) are made in an intermediate mesh size (14mm) and the three last rings (0.35, 0.30 and 0.25m of diameter) are made in finer mesh size (11mm). For more details, see Annexe 2.



Figure 3: 14m double fyke net (<http://yvesroudier.com/verveux/>)

For the sampling stations targeting migrating silver eels, we will use series of 5 single fyke nets along the same fishing line, attached to a heavy steel anchor and installed with the opening facing downstream, around 10-20 m upstream the screens of the hydroelectric intake (Figure 4).

This method has been selected by Profish because it is efficiently used since more than a decade in the Mosel River in Germany, in the framework of the « Eel Initiative » program. The professional fishermen of this project have developed this method as they have learned by experience that silver eels tended to develop avoidance behaviour when approaching the screens of a hydroelectric intake. This behaviour consists in swimming back upstream in the river, that's why having the fyke nets facing downstream can easily capture silver eels swimming back upstream.



Figure 4: view of one fyke net along a line of 5 fyke nets installed on the bottom of the River Meuse, facing downstream

IV.2 Advantages

- Fyke net can be easily set in complex habitat types like dense beds of aquatic vegetation.
- The selectivity for fish sizes can be adjusted by the choice of the size of mesh and funnel openings.
- Large net and capture capacity
- Less fish mortality and injury than gill nets
- Less risk to diving birds compared to gill nets
- High efficiency, especially if baited for sampling eel species (Jellyman & Graynoth, 2005).
- Good efficiency for catching fish during migration. Double-winged fykes can be used to determine the direction of migratory movement (Lyon et al., 2010).
- Compared to other fishing techniques like spotlighting or electro-fishing, sampling by fyke nets is unaffected by turbidity or electrical conductivity.
- As sampling are taken continuously over a long time period (nets can be retrieved 24 to 48 h after their setting up), using nets dampen the effects of any diurnal variations in fish behaviour (Hayes, 1989).
- Netting does not require a high level of technical expertise even if the experience of fish staff will influence catch efficiency.
- Netting causes fewer disturbances in shallow habitats than more active methods.
- Fyke net used facing downstream are not exposed to clogging with organic debris like leaves in autumn, even in stronger current near the powerhouse forebay.

IV.3 Disadvantages

- Fyke nets are not adapted for catching pelagic fish species in deep water sites. There is a bias towards benthic and demersal species and larger fish species (Hubert et al., 1996; Portt et al., 2006). Using them in combination with electro-fishing ensures that open water species are adequately sampled.
- Fyke nets can be difficult to set properly in strong currents area (Portt et al., 2006). However, they are more conducive to sampling in currents than gill nets for example.
- Predation can affect significantly capture rates, mortality and the contents of predator's stomachs.
- Catch rates are generally lower compared to those for gill nets and can present a high variability. Using a large number of sets is required to detect changes in relative abundance (Portt et al., 2006). The cross-net pattern (a lakeward-positioned main net and three smaller side nets connected by leader nets), for example, was very efficient for eel capture in north German lakes (see Annexe 3, Tesch et al., 2003).
- Like other passive netting methods, fyke netting cannot include spatial measure to define unit of effort compared to active techniques such as electro-fishing.
- Netting is biased towards more active fish.
- Netting requires a return trip to retrieve gear increasing the level of resources required to collect data.

IV.4 Procedure

The nets are disposed along the edges in the area sampled by electro-fishing. The nets are placed in areas that are attractive to eels: deep areas with low water flow in presence of some roots and stones as shelters. Fyke nets work better when water depths are roughly equal to the height of the leader but can be set in deeper water. The mouth of the net must be submerged to allow fish to enter the net and minimise the potential entry of water birds. Water levels must remain above the fyke net for the entire time that it is set to avoid fish stranding and maintain constant catch efficiencies. If baiting is used, bait quality and quantity must be standardized and controlled to avoid attracting a large number of predators and non-targeted species.

In wadeable habitats, fyke nets can easily be set by one person. However, in deeper habitats, a boat is required with a minimum of three team members to safely set fyke nets.

As fyke nets will be placed in combination with an electro-fishing session, the same constraints and safety plan will be applied.

For the lines of fyke nets used to catch silver eels, the nets are installed directly on the bottom of the river. 5 fyke nets are installed per each line, and a total of 2 to 5 lines will be used on 3 sites. No baiting is used, as the catch is made by the natural behaviour of the eels.

IV.5 Definition of capture effort

A capture effort is defined as the cycle constituted from the setup of one or more fyke nets followed by their retrieval. When possible, for resident population sampling, fyke nets should be placed for 48h, retrieved and replaced right after.

For the silver eel catches with the lines of fyke nets, the nets are controlled every 2 to 7 days, depending on the river conditions (discharge, ...) and the capture rate of eels. When eel capture rate is high, the duration of an effort of capture is reduced.



IV.6 Resources

- Survey team: two persons at least in wadeable habitats, three persons at least in deeper habitats.
- A large zeppelin boat with specific security equipment for the survey team in deeper habitats.
- Fyke nets
- Drowning and fall hazards: all the crew must be equipped at least with personal flotation device in deep sites and by waders in wadeable sites.
- Anchor weights or poles for anchoring the ends of nets.
- Shark clips to attach and detach quickly anchors and floats.
- Fish bins to hold captured fish during processing.
- Aerator if fyke nets are set for long periods to avoid sharp drop of dissolved oxygen levels.
- Water quality field meter(s) to record at least water temperature and dissolved oxygen levels.
- Aluminium large boat to handle fyke nets in the vicinity of the power house forebay with specific security equipment for the two operators.

V. Estimating population size using capture–recapture encounter

V.1 Sampling sites:

Eel will be sampled in the Meuse itself, upstream of the pilot sites. The choice is based on analysis of the SPW ichthyological database. As eel populations usually live in rock embankments, this kind of habitats will be specifically targeted.

In a previous study (Roland et al., 2016), eel captures were successful in some stations in Lesse. These stations will be included in this project. We will also prospect and try to capture eel in the Meuse River, the Lesse, the Ourthe, the Meuse, the Sambre and the Semois (Figure 5).

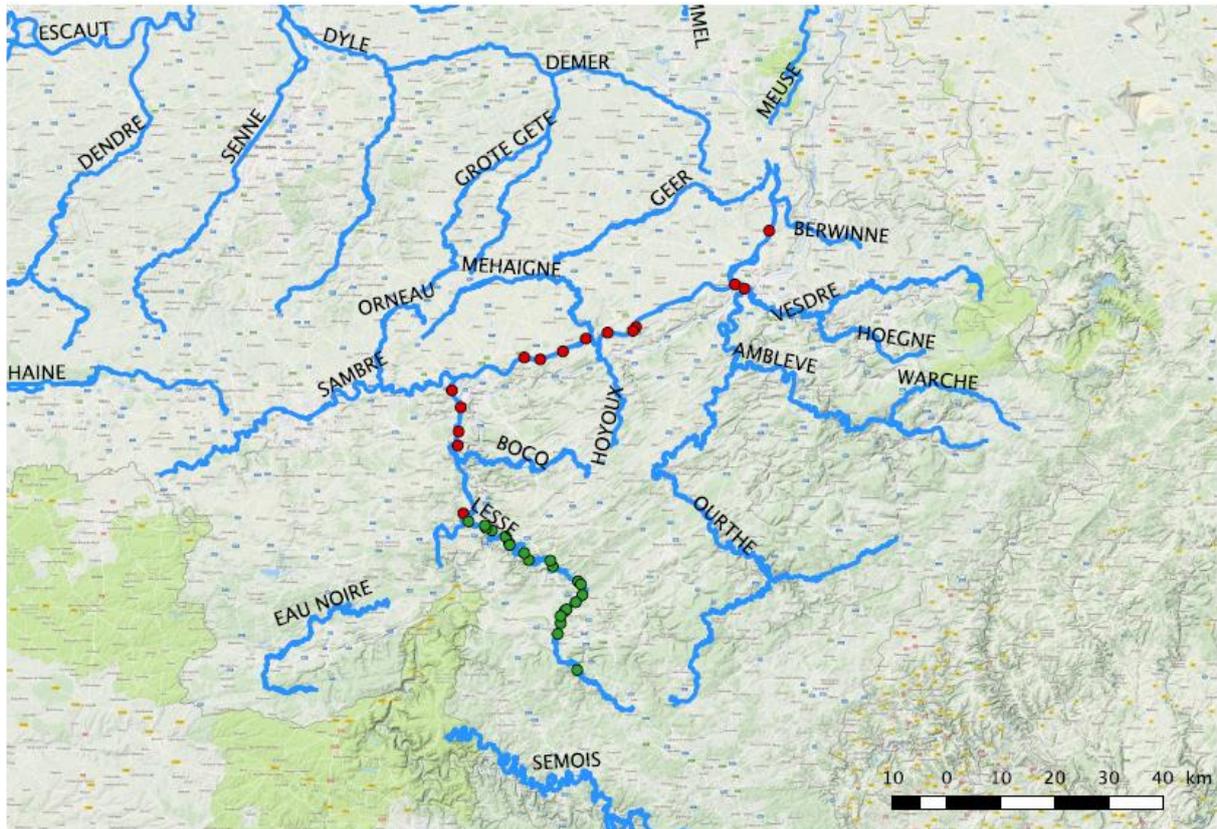


Figure 5: Localisation of stations for fish capture.
Green dots are stations from Roland et al. (2016), red dots are stations to prospect.

In these stations, we can apply one or both fishing methods in order to optimize the capture effort (Table 2).

For the silver eel fishery, the selected sampling sites are the hydropower centrals of Andenne, Ampsin-Neuville and Lixhe. During the first year 2018, only the site of Andenne will be used to validate the fishery technique with the line of fyke nets.

Station name	GPS coordinates	Altitude (m)	Waterway	Prospection mode	Prospected length (m)	Prospected width (m)	Capture method*
Aiguilles de Chaleux	Lat 50°13,151' Long 4°56,737'	100	Lesse	Boat	150	15	EF + FN (2)
Belvaux	Lat 50°06,229' Long 5°11,775'	194	Lesse	Boat	250	20	EF + FN (3)
Chanly	Lat 50°04,796' Long 5°09,317'	201	Lesse	Boat	200	10	EF + FN (2)
Chanly 2	Lat 50°04,656' Long 5°09,047'	203	Lesse	Boat	200	10	EF + FN (5)
Ferme de Mohimont	Lat 50°02,350' Long 5°07,983'	271	Lesse	Boat	120	8	EF + FN (2)
Furfooz	Lat 50°12,875' Long 4°56,934'	104	Lesse	Boat	200	15	EF + FN (3)
Han-sur-Lesse	Lat 50°07,584' Long 5°11,102'	139	Lesse	Boat	200	20	EF + FN (5)
Han-sur-Lesse	Lat 50°07,296' Long 5°11,535'	187	Lesse	Boat			FN (6)
Houyet	Lat 50°12,033' Long 4°59,933'	114	Lesse	Boat	150	25	EF + FN (1)
Houyet (kayak)	Lat 50°11,375' Long 5°00,495'	115	Lesse	Boat	120	20	EF + FN (2)
Houyet 2	Lat 50°11,202' Long 5°00,578'	115	Hileau	Feet	100	2	EF

Hulsonniaux	Lat 50°12,644' Long 4°57,824'	106	Lesse	Feet	160	15	EF + FN (4)
Maissin	Lat 49°58,766' Long 5°10,958'	303	Lesse	Feet	70	5	EF + FN (2)
Neupont	Lat 50°03,430' Long 5°08,432'	208	Lesse	Boat	240	15	EF + FN (2)
Neupont Bras de Lesse	Lat 50°04,145' Long 5°08,424'	207	Lesse	Feet	100	2	EF
Pont d'Havenne	Lat 50°10,401' Long 5°02,800'	127	Lesse	Boat	160	18	EF + FN (6)
Pont-à-Lesse	Lat 50°13,537' Long 4°54,230'	84	Lesse	Boat	180	15	EF + FN (3)
Villers-sur-Lesse	Lat 50°09,643' Long 5°06,852'	139	Lesse	Feet	120	10	EF
Wanlin	Lat 50°09,702' Long 5°03,506'	129	Lesse	Feet	250	25	EF + FN (4)
Wimbe	Lat 50°09,067' Long 5°07,192'	138	Wimbe	Boat	138	10	EF + FN (2)

Table 2: Stations from Roland et al. (2016) infield study

* EF: electro-fishing, FN: fyke net fishing method

V.2 Description

In capture-recapture encounter methods, a known number of individuals are marked using PIT tags and released into the population (population is defined here as the fish of a given species occupying the area of interest). The population is then sampled and its size is estimated from the ratio of marked to unmarked individuals. Our technique is based on the method developed by Petersen, (1896) modified by Fromont & Desouhant, (2005). This technique was used successfully at several sites in the River Lesse during previous projects conducted by UNamur (Roland et al., 2016). Recent trials were also conducted in order to estimate the quantity of catching effort needed to meet LIFE4FISH project objectives. In one catch effort covering a linear habitat of one km, we succeeded to catch around 43 eels and among them 17 fish were close or larger than 70 cm which is the usual size for silver eels (or yellow eels evolving to the silver stage). On this basis, we estimated that 15 to 20 catching efforts are needed to reach an approximate quantity of 250 eels of adequate size/stage.

V.3 Procedure

Electro-fishing and fyke nets will be used conjointly to catch fish. Fyke nets will be set up along the edges in the area sampled by electro-fishing. For each sampling area, information as sampling dates, the length and the width of the prospected area, the number of fyke nets set up in this area must be recorded.

Eels will be anesthetized by immersion into a clove oil solution (0.2 mL/L, Sigma). Fish will be measured (cm), weighed (g) and tagged with a passive integrated transponder PIT Tag (ID-100B implantable transponder, diameter. 2.12 mm; length 11.5 mm, Trovan[®], Dorset Identification b.v., Netherlands, Annexe 3). The PIT tag will be injected in the peritoneal cavity with an implanter (IID100E, Trovan[®], Dorset Identification b.v., Netherlands). The use of PIT Tag allows us permanently and easily marking fish. The identification code is internal rather than external, and the code will always be unmistakable as it is composed of 10 characters (letters and numbers) that can be read with the portable reader (GR-250 High Performance Portable Reader, Trovan[®], Dorset Identification b.v., Netherlands) (Figure 6). The injection site will be then disinfected with iodine solution and the PIT tag will be read in order to verify its activity. Fish will be placed in a fish tank filled with the river water and equipped with an aerator to recover from the anaesthesia before the releasing in the upstream of the next capture area. For eel, the silvering degree will also be determined by measuring the height and width of each eye and the length of each pectoral fin.



Figure 6: Injection of PIT tag in the peritoneal cavity of an anesthetized eel (A)
GR-250 High Performance Portable Reader (B) (Roland et al., 2016)

V.4 Abundance estimation with Petersen (1896) method

Several methods are commonly used for stocks assessment in marine or freshwater habitats: estimating density by using statistical approaches and estimating abundance and dynamic by using mathematical models. While estimating abundance is applied to the entire population and requires data from the whole area occupied by the targeted population, estimating density is applied to a defined area at a particular time.



Many mathematical models allow the analysis of data provided by capture-recapture encounter methods. They are based on two important assumptions:

- Samplings are independent and all individuals have the same probability to be captured.
- The used tag is permanent and did not affect the marked fish.

Marking individuals is used to distinguish individuals caught in the samples, and allows that the recapture information (overlap information) can be used to estimate the number of missing animals in the sampling session. In case of independent samples, when recaptures are few, we can suppose that the population size is much larger than the number of distinct captures while when the recapture rate is high, we suppose that we caught most of the animals (Chao, 2001).

Models can be classified into two types: models for closed populations such as Lincoln – Peterson – Bailey model, with the assumption that there is no birth, no migration and no death between samplings and models for open populations such as Jolly – Seber model with the assumption that individual survival is the same between the different samplings (Fromont & Desouhant, 2005).

In this study, we will use the Petersen, (1896) method to estimate population density. This method is easy to conduct because each capture and marking is followed by one sampling time for recapture. Assume that the true population size is N , which is our parameter of interest and all animals act independently. The formula for the Peterson indicator is:

$$N = \frac{m \times n}{r}$$

With N : the number of individuals in the population, m : the number of tagged fish, n : the number of all the captured fish in the station during the two samplings and r : the number of recaptured fish.

The density is calculated by the ratio between the population size and the surface (m^2) of the sampled area. The biomass is calculated by the multiplication of the density and the mean weight. Calculated density and biomass are representatives of the sampling period only.

VI. Data's treatment

VI.1 Taxonomic determination

All captured organisms must be classified according to their species immediately after the capture. Only the targeted species have to be kept for measures or brought to the laboratory facilities, all other organisms must be released right after the electro-fishing session.

VI.2 Counting

Individual counting must be performed. If necessary and when data are available, counting can be performed on the basis of mean weight: Number of individuals = total weight / mean weight.

VI.3 Morphometric measures

All morphometric measures as total and standard length, weight,... must be done in the field, or in laboratory facilities only if fish are brought to.

VI.4 Quality control

- All the measurement equipments must be calibrated before use.
- One person will be in charge of reporting data on the dedicated tables (e.g. table 3 for eel).
- Acquired data have to be encoded in excel tables and verified twice by two different persons to ensure that there is no error in the encoded data.
- Descriptive statistics and box-plot graphics have to be done on raw data in order to check the potential outliers.

Date	Fishing method	Code	Total length (mm)	weight (g)	Eye height (mm)	Eye width (mm)	Pectoral fins length (mm)	Silvering stage
X/X/XX	Electro-fishing	Tag code	855	1158	R: 8,03 L: 6,74	R: 8,12 L: 7,49	R: 37,29 L:36,72	FIII
X/X/XX	Fyke net	Tag code	820	1806	R: 10,01 L: 10	R: 10,06 G: 10,1	R: 42 L: 42,5	FIII

Table 3: Data table for eel

VII. References and further readings

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Annexe 1: Rubber insulated cable characteristics



DATA SHEET	1600xxx
RUBBER INSULATED CABLE H07RN-F	valid from : 12.01.2007

Application

H07RN-F is a heavy duty rubber sheathed cable for use on heavy appliance such as tool and agricultural machinery subject to high levels of stress in premises exposed to dry and damp conditions as well as in the open air and wet industrial environments. Continuous, busy movements, usage of these cables in moving cable carriers, respectively on motor drum guidance or under a strain of more than 15 N/mm² is not allowed. Assembly of rubber insulated cables (only the **single core** cable H07RN-F) in acc. to VDE 0282 part 4 they are recognized as short-circuit and earth-fault proof in acc. to VDE 0100 part 520.

Design

	in acc. to HD 22.4 S4 that is VDE 0282 part 4
Conductor	copper, fine wire strand in accordance to IEC 60228 that is VDE 0295, class 5
Core insulation	rubber compound EI4 in acc. to HD 22.1 that is VDE 0282 part 1
Identification	in acc. to VDE 0293-1, with up to 5 cores are coloured-coded in acc. to HD 308 S2 that is VDE 0293-308; cables with more than 7 cores black cores with white numbers with gn/ye ground conductor in acc. to DIN EN 50334 that is VDE 0293 part 334
Outer sheath	rubber compound EM2 in acc. to HD 22.1 that is VDE 0282 part 1
Colour outer sheath	black

Electrical properties at 20 ° C

Nominal voltage	450 / 750 V
Test voltage	2500 V AC

Mechanical and thermal properties

Temp. range	for fixed installation and handling: -25 up to + 60 ° C max. conductor temperature
Min. bending radius	for flexible use: 6 x cable diameter
Flame retardant	in acc. to IEC 60332-1-2 resp. VDE 0482 part 332-1-2
Approvals	H07RN-F in acc. to HD 22.4 S4 that is VDE 0282 part 4
Tests	in acc. to VDE 0472 and IEC 60811-x.x that is VDE 0473

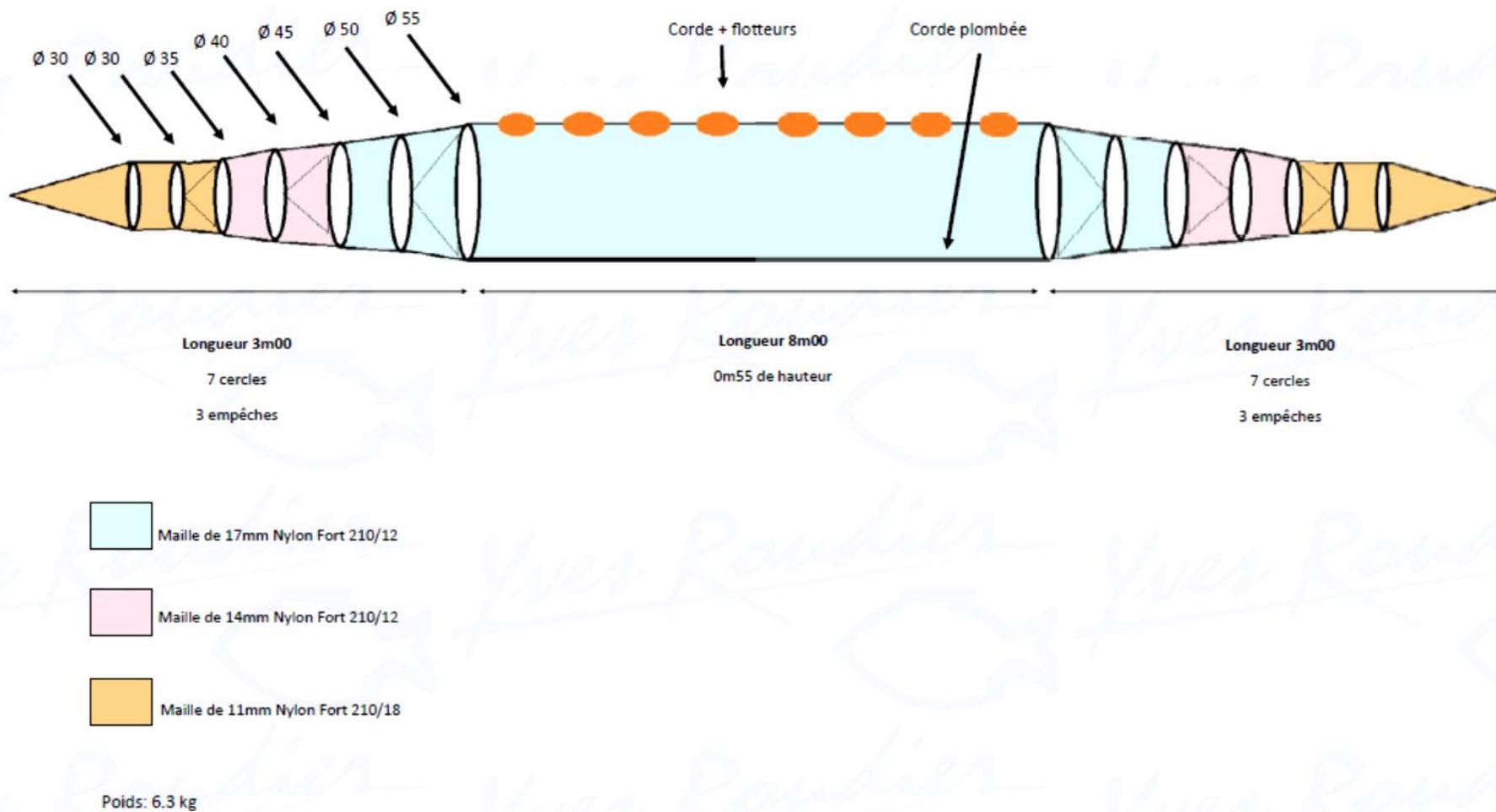
The cable is indicated with the ◁ HAR ▷ sign or a tracer thread.

EC directive this cable confirms to ECD 73/23/EEC (low voltage directive).

elaborated by: TE-K: H.Schillinger / M. Herb	Document: DB1600199EN	page 1 of 1
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Nr.: 0019/0894

Annexe 2: 14m Double fyke net characteristics



Date: 19-Feb-19	Deliverable	 UNIVERSITÉ DE NAMUR
Project: Life4Fish project	University of Namur Research Unit in Environmental and Evolutionary Biology Profish	
Version: V2	UNamur, Research Unit in Environmental and Evolutionary Biology (URBE) Postal address: rue de Bruxelles 61, B-5000 Namur, Belgium Profish Rue des scabieuses, 18, 5100 Naninne, Belgium	Contact name: Imen Ben Ammar Damien Sonny

Annexe 3: Different types of fyke net installation

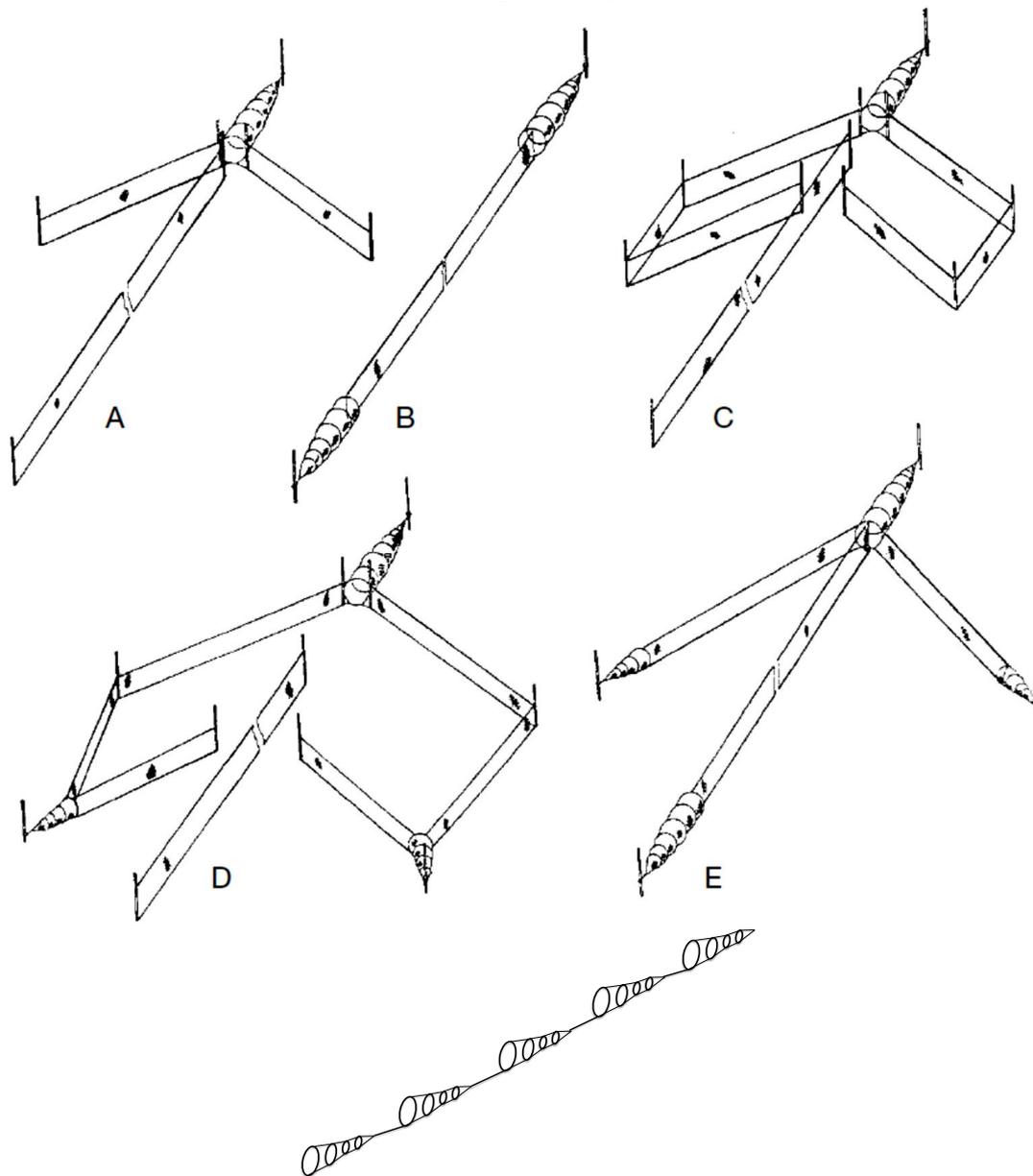


Figure 7: Forms of fyke net installation (adapted from Tesch, 2004)

- | | | | |
|---|---------------------------|---|---------------------------------|
| A | Simple fyke net | D | Triple bag |
| B | Paired or double fyke net | E | Cross-net: Kreuzsack or Kossack |
| C | Bocksack | F | Lines of fyke nets |