IFISH

Fish and Habitats: Science and Management

Vol. 1

Manual for Ageing Common Freshwater Fish Species in Ireland

Iascach Intíre Éireann
Inland Fisheries Ireland

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Manual for Ageing Common Freshwater Fish Species in Ireland

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Foreword

Determining the age of fish is a core tool for fishery scientists. Age determination is essential for knowledge of recruitment frequency and hence population trends and stability. Fish growth rates can vary considerably between geographically separated populations of a species and also within an individual population where there can be varying life history strategies. Managing fishing activity for both recreationally and commercially targeted species and protecting rare species under conservation concern is practically impossible without the ability to determine age.

This manual is aimed as a starter for scientists setting out to determine the age of individual Irish fresh water fish, and sets out the methods, from fish in the hand to the measured age, with worked examples of 10 of the common species routinely handled by Inland Fisheries Ireland staff, specifying equipment requirements, nomenclature, and age recording formats.

The examples are deliberately chosen for clarity and have been verified by a panel of experienced staff. Practitioners know fish ageing is not always this straightforward – there will always be protracted discussion over the difficult examples and sometimes there will be no absolutely agreed definitive answer for the age of a fish from a scale or bone reading such that experts will agree to differ. For those who wish to dig deeper into the history and background there is appended a comprehensive reference list of classic and more recent papers and texts against which to refer such arguments.

For the core function, however, of ageing most specimens passing through the laboratory and supplying management information, this manual is a new and significantly valuable collection of information and should stand in good stead as training and reference material for years to come.

Robert Rosell (Guest Editor)

Agri-Food and biosciences Institute Northern Ireland

Preface

Fish ageing is a fundamental element of fisheries research. The structures used for fish ageing capture vital information on factors influencing populations such as age and growth, population dynamics and life history characteristics.

This manual describes the procedures used by fisheries scientists when ageing many of the most common fish species recorded in the Irish freshwater environment and guides the reader through the collection, preparation and interpretation of different ageing structures. Included is a chapter presenting ageing structure images (scales, opercular bones and otoliths), classified by age, with notes on life history features for ten fish species (i.e. brown trout, salmon, arctic char, pollan, pike, perch, roach, rudd, bream and dace). The chapter also includes images from sea trout and roach x bream hybrids.

1. Introduction

Age determination is an important element in the study of fish population dynamics and forms the basis for calculations leading to knowledge on growth, mortality, recruitment and other important parameters of their populations (FAO, 1974). Fishery biologists use structures such as scales, bone (e.g. cleithra, vertebrae or opercular bones) or calcified structures (e.g. otoliths) to determine the age of many fish species. These structures produce periodic growth increments (in a manner similar to the rings of a tree) useful for age determination in fish (Campana, 2001). Scales and otoliths are the most widely used because they are easy to collect and store (FAO, 1974).

The history of fish age determination has been explained by numerous authors (e.g. Dahl, 1909; Ricker, 1975; Jackson, 2007). The earliest references to rings on hard structures of fish date to the 17^{th} and 18^{th} centuries. Scientific validation of fish scales began in the late 1800's (Jackson, 2007). Scales were the first source of determining fish age (Sigler and Sigler, 1990; Jackson, 2007). Difficulties with accurately identifying fish age using scales alone, however, led to investigations into other structures. Otoliths were first used as an accurate and reliable method in 1899 (Jackson, 2007; Tzadik *et al.,* 2017). The first reference to the use of opercular bones, vertebrae, and several bones in the pectoral girdle for ageing appears in 1905 (Jackson, 2007).

In addition to providing information on age, growth, mortality and recruitment, these structures can provide information on age at maturity, population structure, life span, mortality and reproduction (Bagenal and Tesch, 1978). Additionally, with the advances of technology such as digital cameras and laser ablation inductively coupled plasma mass spectrometry (LA ICP-MS) some of the above structures are being used to determine occurrences of spawning events, freshwater and sea age, extent of fresh and marine residence, movement and migratory habits (e.g. Secor, 2004; Ryan *et al*., 2016).

While various publications have provided information on specific species (e.g. sea trout, CSTP, 2010; salmon, ICES, 2011), this manual aims to guide the reader through the collection, preparation and interpretation of different ageing structures for many of the most common Irish freshwater fish species in one publication. The ageing structures described here are scales, otoliths and opercular bones. Brief instructions are presented on how to take and prepare structures and age various fish species. Additionally the manual provides a catalogue of reference images for these species. Note that eel (*Anguilla anguilla*) age determination is not covered by this manual and the prospective eel age reader is referred to ICES, 2009.

This manual is aimed at new and existing Inland Fisheries Ireland staff, fisheries scientists, fishery science students, and those with an interest in fish ageing and fish ecology. It is also hoped that the catalogue of images will be a valuable comparative reference source for international colleagues.

2. Methodology

The following provides a brief description of three of the most common structures (scales, otoliths and opercular bones) used for ageing fish. Brief instructions detailing how to remove, store, prepare/mount and image the structures for ageing and other analyses are also provided.

2.1 Scales

The skin of most fish is covered with scales. These structures are "flexible, calcified plates lying within shallow envelopes, or scale pockets, in the upper layers of the dermis" (Bullock and Roberts, 1974 as cited in Able and Lamonica, 2006) (Fig. 2.1). These structures are covered with a very thin, outer layer of skin called the epidermis (Taylor, 2012).

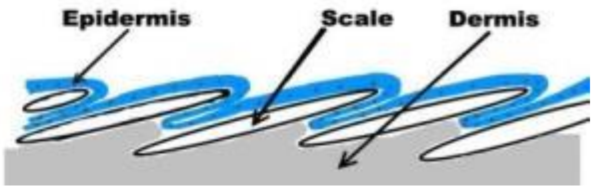


Fig. 2.1: The skin of a fish (source IFI)

2.1.1 Scale types

Fish scales can be divided into four main types, i.e. cosmoid, placoid, ganoid and elasmoid (Patterson, *et al.,* 2002). Cosmoid scales are present on lungfishes and some extinct fossil fishes. Placoid scales are found on cartilaginous fish such as sharks and rays. These scales do not grow in size as the fish increases, instead more scales are added. Ganoid scales are found on lower order fish species such as sturgeons and gar and are composed of bone. Bony fish (teleosts) have elasmoid scales and these are further subdivided into two types: cycloid and ctenoid (Bräger and Mortitz, 2016). All species described in this document have either cycloid (Fig. 2.2) or ctenoid scales (Fig. 2.3). The main difference between these two scale types is their shape.

Cycloid scales: these have a smooth rounded posterior edge and are most common on fish with soft fin rays, such as Atlantic salmon, brown trout and roach (Bagenal and Tesch, 1978) (Fig. 2.2).

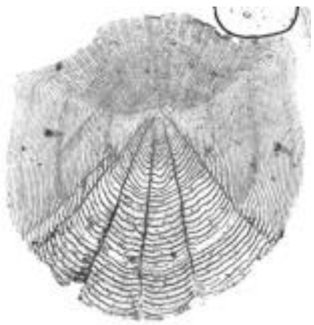


Fig. 2.2: Example of a cycloid scale: Roach (*Rutilus rutilus*) (source IFI)

Ctenoid scales: These are similar to cycloid scales but have a toothed outer edge, and are found on fish with spiny fin rays such as perch (Bagenal and Tesch, 1978) (see Fig. 2.3).

Fig. 2.3: Example of a ctenoid scale: Perch (*Perca fluviatilus*) (source IFI)

2.1.2 How to remove scales from a fish

To provide a level of consistency in the ageing and growth analysis process, it is important that scales are removed from specific locations on each fish species; this can vary per species (Table 3.2). Note that carefully handled and live fish returned to the water have the capacity to replace lost or removed scales. Gently scrape scales from the recommended location. A blunt knife or forceps is sufficient for this process. From dead specimens, the scales can be lifted by working the blade against the grain and more scales can be taken. If handling live specimens in the field the scale sample take should be taken quickly, a minimum number of scales removed (5-6 for small scaled fish, down to 2-3 for large scaled fish with forceps recommended for larger scaled fish. The knife should be cleaned after each fish sample is taken to prevent contamination.

2.1.3 Scale storage

Scale samples should be stored in scale envelopes. Ideally samples should not be left in a clump, but spread out to dry in the envelope. Details such as species name, river or lake name, site number, fork length, weight, capture method and date of capture should be recorded on each scale envelope. It is recommended that individual small scale envelopes from a river site or lake should be stored loosely in a large brown labelled envelope in a dry location to prevent fungal growth. Once thoroughly dried these envelopes should be stored in dry conditions in the office or laboratory.

2.1.4 Preparation for ageing (cleaning and mounting)

It is important to select scales with clearly readable centres for age analysis (CSTP, 2010). Replacement (re-grown or regenerated) scales, where portions of the centre of the scale lack a record of growth previous to the scale loss event are not suitable for ageing (See section 3.1.1).

Replacement scales selected should be retained and returned uncontaminated to the scale envelope for any future analysis (e.g. genetics). The steps for removing, preparing and mounting of fish scales are described in Table 2.1. If samples are to be used for microchemistry/LA ICP-MS analyses, plastic knives and disposable nitrile gloves must be utilised to avoid zinc powder contamination (CSTP, 2016). Carefully remove a selection of scales from the envelope and place in embryo dishes/small petri dishes (a separate dish should be used for each fish) filled with contact lens solution/soapy water/distilled water (depending on the tests being carried out on the scales) and allow to soak. Scales heavily soiled with dried slime can be effectively cleaned by holding forceps, washing in 0.1M Sodium Hydroxide, rinsing distilled water and drying off with a tissue before handling.

Table 2.1: Summary of equipment required and methodology for removing, preparing and mounting of fish scales

Step	Procedure	Equipment used by IFI
1. Removal	Non-lethal procedure. Remove minimum of 5-6 scales from fish. Ensure knife is cleaned before next sample to avoid contamination. Remove gently from specified area (Table 3.2)	Blunt knife, tweezers or forceps
2. Storage	Spread evenly in envelope to avoid clumping. Air dry individual envelopes if damp. Store scale envelopes loosely in large brown envelopes in a dry location	Labelled scale envelope Pencil/marker
3. Cleaning	Clean with water/contact lens fluid/washing up liquid. Remove dirt/mucus material from posterior of scales. Rub between fingers or use a damp fine glasses cloth	Petri dish/embryo dish Pipette/Forceps/Fine glasses cloth Contact lens solution/distilled water/washing-up liquid/0.1M Sodium Hydroxide
4. Mounting	Position several scales concave side down on a glass slide with cover slip or between two glass slides. Select scales with complete centres and with little erosion, take care not to tear or damage scales. Wet or dry mount (allow scales to dry for dry mount). If wet mounting add a drop of water to the glass slide, try to avoid air bubbles under the second slide/cover slip	Glass slides (and cover slip) Sticky tape to fix slides Water bottle
5. Imaging/ Ageing, Electronic	Aged using a manual or electronic microfiche/scanner. Imaged by an electronic scanner. Scale indicated by a bar (e.g. 1mm or 1000 microns). Magnification setting is specified on image to aid with further growth analysis. See Fig 2.4. Image preference are: (a) Jpeg image – ageing/publications (b) TIF image –ageing/growth analysis	**Hardware**: 300dpi Microfilm Scanner **Magnification**: Range of lens from x1-x55 **Software**: Use suitable imaging software
6. Imaging/ Ageing, Manual	Manual Microfiche. Growth is calculated using pencil, ruler (or paper) to an image projected on a screen. See Fig 2.5 & 2.6. Length at age data is retained on a paper strip, measured using a ruler to the nearest mm and inputted directly to the ageing database. In contrast to the electronic microscope images, scales often are easier to read when dry mounted. Large scales are sometimes best examined under a binocular microscope (set up as for opercular bones below)	**Hardware**: Microfiche **Magnification/lens size (mm)/** x21/32mm Large cyprinids/pike/salmon x24/29mm Large cyprinids/pike/salmon x42/17mm (Salmonids/small cyprinids/pike) x48/15mm Salmonids/small cyprinids/pike) Ruler/Paper strips/pencil

2.1.5 Equipment used in scale ageing

A) Digital imaging of scales

Magnification: Range of lens from x1-x55

Software: Imaging software

Fig. 2.4: Example of digital microfiche setup used in IFI

B) Manual ageing of scales

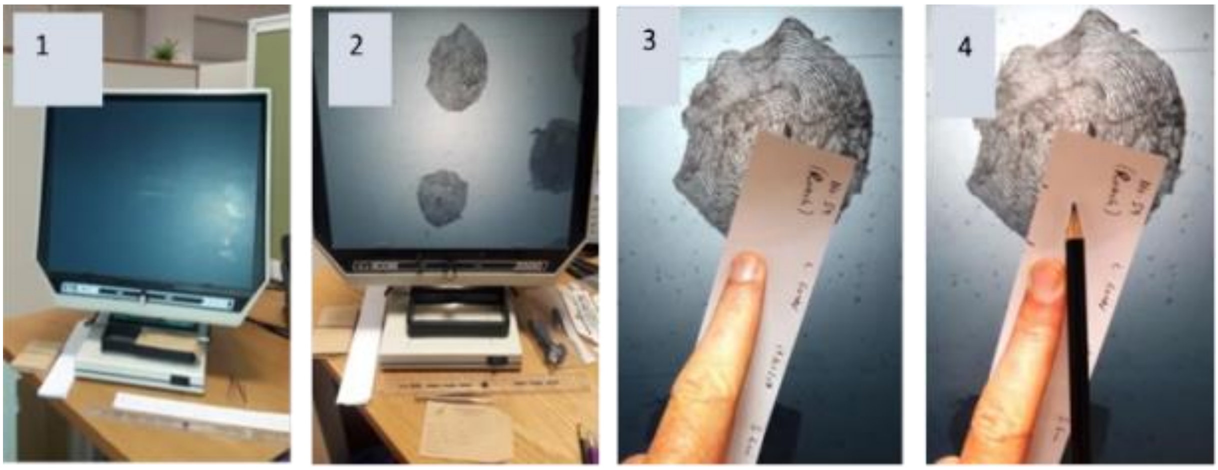


Fig. 2.5: Steps 1-4 illustrate how scales are aged using manual microfiches. 1) Preparation (see Table 2.1) 2) Place several scales on slide and select best scale. 3) Using edge of paper strip or ruler at focus, place at appropriate angle of measurement. 4) Mark all annuli and the scale edge

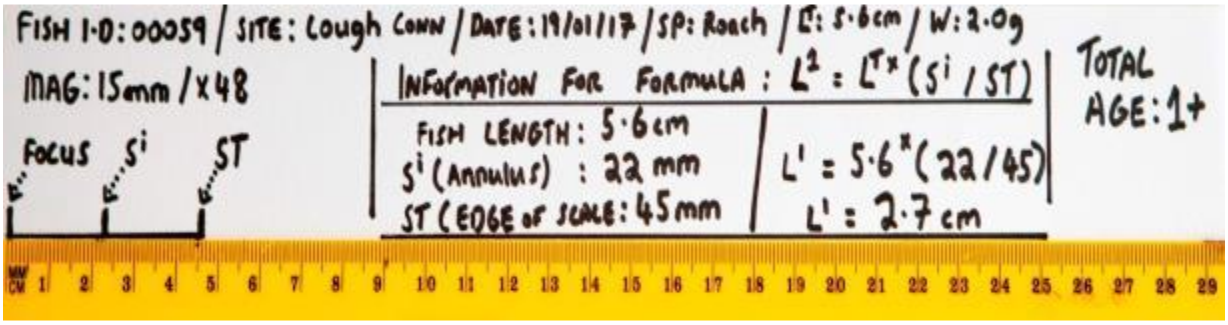


Fig. 2.6: Example of details on paper strip showing fish ID/ species/ fish length/weight/date of capture/site name/total scale length/each annulus length from focus/ magnification settings and total age. In this example the fish is aged 1+

2.1.6 Lighting options

A high quality binocular microscope, with optional digital camera attachment, can offer lighting options additional to the conventional transmitted /underlit arrangement, including surface view illumination, single or cross polarised light, or dark field with angled light. These latter lighting options can be particularly useful when looking for annuli in one-off scales of large, old or specimen fish where scale thickening is an issue. In this thicker age determination material (scales or opercular and cleithral bones) the internal structure of the annulus is not perpendicular to the outside faces of the specimen. This can lead to a double line visible where the annulus meets the near and far sides of the specimen. In large and/or older fish this can lead to double counting of an annulus. Panning the focus through such structures can clarify the issue. Under a binocular microscope, switching to a surface view without transmitted light may also help.

A calibrated eyepiece graticule and stage micrometer can be used for absolute measurement of material. For field or public display use, digital microscopes with means to capture images to laptop computers or project to screen are also available.

2.2 Opercular bones

The determination of age and growth from opercular bones is a well-established method and has been found to be more effective, than scales in some fish species, where fish are available as dead specimens, e.g. perch (*Perca fluviatilis)* (Shafi and Maitland, 1971) and pike (*Esox Lucius)* (Frost and Kipling, 1959). Currently perch is the only fish species that IFI fisheries scientist's age using opercular bones.

2.2.1 Opercular bone types

The opercular bone or operculum is the hard bony flap covering and protecting the gills of fish (Roberts *et al.*, 2000) (Fig. 2.7). In most fish the rear edge of the operculum roughly marks the division between the head and the body.

The operculum is composed of four fused bones; the interopercular, preoperclular, subopercular and opercular. Of these four bones, the opercular bone (Fig 2.7d) is primarily used for ageing purposes.

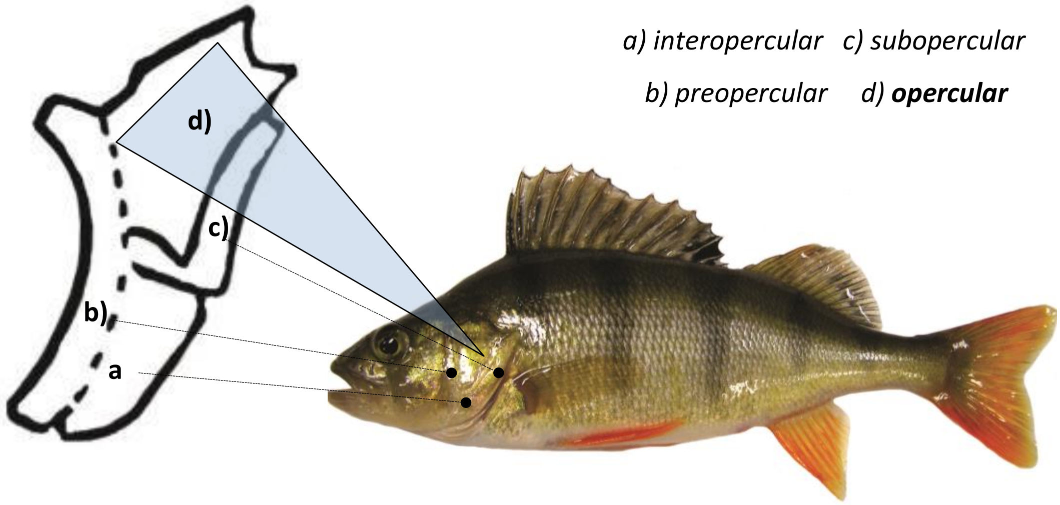


Fig. 2.7: The four fused bones (a-d) of the operculum in European perch (*Perca fluviatilis*) including the location of the opercular bone (highlighted by blue arrow) which is used in the ageing process

2.2.2 How to remove opercular bones

Fish are euthanised prior to removal of opercular bones. A downward incision is made along the posterior edge between the opercular and the subopercular bones (Fig. 2.7). Twist, lift and pull away opercular bone with fingers/tweezers. For larger fish the incision is made with a sharp scalpel in front of the opercular bone before twisting it off. This will avoid breakages (Table 2.2).

2.2.3 Preparation for ageing (cleaning)

Paired opercular bones from each fish are placed in a labelled glass beaker (separate beaker for each fish) half-filled with water. Glass beakers are placed in a water bath (heated close to 70^{0}C) for approximately 35 to 40 minutes to allow skin/residue to soften. Remove beakers from the water bath and clean each opercular bone with running cold water and dab with tissue paper to remove skin/residue. Allow to dry. The identification of annuli is enhanced by drying for an extended period (Table 2.2).

2.2.4 Opercular bone storage

Dry opercular bone samples should be stored in labelled scale envelopes provided. Details such as species name, river or lake name, site number, fork length, weight, capture method and date of capture should be recorded on each scale envelope. Store scale envelopes loosely in large brown envelopes to prevent fungal growth. These envelopes should be stored in dry conditions in the office or laboratory (Table 2.2).

Table 2.2: Summary of equipment required and methodology for taking, preparing and ageing of fish using opercular bones

Step	Procedure	Equipment used by IFI
1. Removal	• Fish are euthanised prior to removal • Make a downward incision under posterior edge between the opercular and the subopercular bones (Fig. 2.7) • Twist, lift and pull away opercular bone with fingers/tweezers • For larger fish make a cut with a scalpel between the preopercular and the opercular bones to remove skin before twisting it off. This will avoid breakages	• Scalpel • Forceps • Tweezers
2. Cleaning	• Add operculum to glass beaker with some water • Place glass beaker in water bath (heated close to 70 degrees). • Allow 35-40min for skin/residue to soften • Clean with running cold water and dab with paper tissue to remove skin/residue	• Glass beaker • Water bath • Paper towel
3. Storage	• Place opercular bones in labelled scale envelopes. • Allow to dry for a few days. Do not seal envelope. The identification of annuli is enhanced by drying for an extended period. • Keep in dry location	• Scale envelope
4. Mounting	• None required	• N/A
5. Imaging/Ageing	• Place operculum under microscope. Fine tweezers can be used to adjust for best image position • Maintain magnification at 0.63x • Focus for image preference • Save image as: • TIF - image for ageing/growth analysis • JPEG – reports and publications	• Hardware: Binocular microscope with • video attachment • Lighting: e.g. • Magnification: fixed at 0.63 • Software: Imaging software • See Fig. 2.8

Fig. 2.8: Example of a PC, microscope and lighting unit setup for ageing (opercular bones and otoliths)

2.3 Otoliths

An otolith is a hard calcium carbonate structure located directly behind the brain of bony fishes (Fig. 2.9). Otoliths are generally more accurate than scales for ageing fish. With their internal location, they do not incur the same damage from stressors such as spawning, migration and reabsorption that appear in scales. These processes can cause circuli loss, overlapping and "cutting over" (i.e. disruption of circuli development from erosion and/or resorption) in scales and are often the cause of underestimating fish age, particularly in older age classes of all Irish fish species but in particular spawning salmonids. Drawbacks with otoliths include the retention and euthanizing of fish to remove them and a greater amount of time/effort must be undertaken to prepare otoliths for the ageing process.

2.3.1 Otolith types

Otoliths exist as paired structures (Campana and Neilson, 1985). There are three types (sagittae, asteriscus and lapillus), all of which aid fish in balance and hearing. The sagittae are the most frequently used otolith for ageing (Chilton, 1982). The size and shape of otoliths varies widely depending on each fish species (Kerr and Campana, 2014).

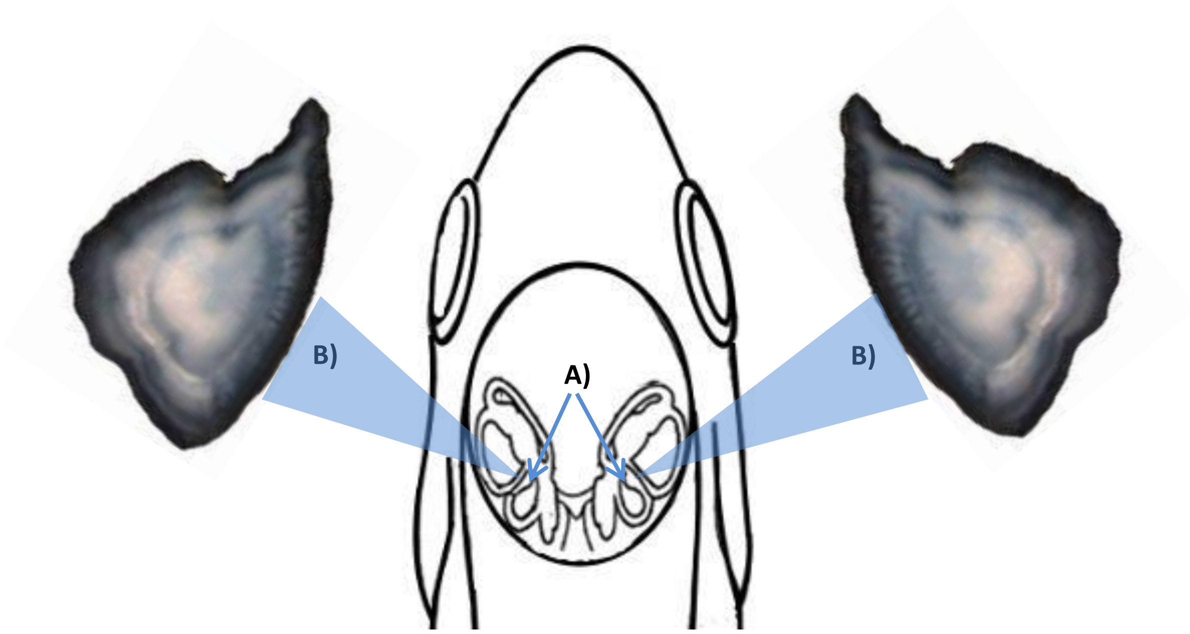


Fig. 2.9: A) Location of otoliths and B) image of otoliths in Arctic char (*Salvelinus alpinus*) (source IFI)

2.3.2 How to remove otoliths from a fish

A number of methods are used for extracting otoliths from fish and the technique is usually dependent on the shape of the head. The methods used for otolith removal (i.e. Arctic char) in IFI are based on factors such as fish size and operator preference. Three methods commonly used are the "Right between the eyes", the "Guillotine" and "Open the hatch" method as described in Table 2.3 (Secor *et al.*, 1992).

2.3.3 Otolith storage

Pairs of otoliths should be stored in appropriately labelled numbered trays, vials, capsules or multi-celled plastic boxes (Butler, 1992). Scale envelopes are not recommended as otoliths can be crushed when packed together.

Table 2.3: Otolith removal techniques (from Secor *et al.,* 1992)

"Right between the eyes" method	"Guillotine" method	"Open-the-hatch" method
• Otolith removal for deep bodied fishes and large (Total Length>200mm) fishes • Use this method for new species and where staff have had no previous experience	• A good technique for removing large sagittae (>3mm) from big, adult fish (>100mm). Some experience is required before attempting this technique to avoid otolith damage/loss	• Make a dorso-ventral transverse cut using a sharp instrument (knife/scalpel)
• In larger fish, cut away the head from the rest of the body • Position the head squarely and securely on the cutting surface to make the cut • A vertical cut is made centrally through the top of the skull to split the skull in half • The brain is exposed underneath (cut horizontally/transversely) without damaging the otoliths	• Make a transverse cut from the top of the head • Hinge the fish's head away from the body • Locate the exposed butterfly-shaped capsules that house the otolith	• Grip the otolith with forceps/tweezers and remove
• Push the brain to one side; the otoliths are usually resting inside hollows at the base of the skull • Grasp the otolith with forceps/tweezers and remove	• Grasp the otolith and work it back and forth so that the otolith is "backed out" of the fish	• In fishes with partially encapsulated otoliths, gently shift the otolith back and forth within the capsule and gradually angle it out of the capsule

2.3.4 Preparation for ageing

Otolith preparation techniques depends on research needs, life stage of the fish, otolith size and shape and reading techniques (Morales-Nin, 1992). The following table summarises the stages followed by IFI scientists during the preparation of otoliths for ageing of Arctic char (Table 2.4).

Table 2.4: Summary of equipment required and methodology for taking, preparing and ageing of fish using otoliths bones

Step (1-5)	Procedure	Equipment
1. Removal	• See Table 2.3 above	• Sharp knife/scalpel • Safety gloves • Forceps/tweezers • Plastic equipment if conducting microchemistry analysis
2. Cleaning	• Clean with paper between fingers to remove material. Rotate on paper towel removing fibrous tissue	• Paper tissue • Water (distilled if conducting microchemistry analysis)
3. Mounting	• If otolith is <300 µm then it can be analysed intact (most Arctic char otoliths in Ireland are below this size limit) • If otoliths are >300 µm they contain too much three-dimensional material and must be embedded in medium, sectioned and polished to remove excess medium. This will expose the core for ageing and obtain a flat surface parallel to the desired section plane From Secor *et al*., 1992	• For otoliths <300µm. Keep intact in storage. The most common method used in IFI. • For otoliths >300µm the following procedure is undertaken • Embedded medium (low viscosity and transparent) • Sectioning using a Isomet saw to cut at desired plane/angle • Polish using otoliths are polished on grinding stones, wet-dry sandpaper, lapping wheels, polishing cloths, and various other abrasives From Secor *et al*, 1992
4. Storage	• Store in a dry/dark location • Place pairs of otoliths in labelled storage • Adult otoliths are often stored dry in numbered trays, in labelled vials, capsules or multi celled plastic boxes (Butler, 1992) • Scale envelopes are not recommended as curved otoliths can be crushed when packed together	• Numbered trays, labelled vials, capsules or multi celled plastic boxes
5. Imaging/Ageing	• Place otoliths in ethanol for 20 minutes • Use 2-oxypropenol in a camera film lid or similar small container. Place otolith in lid using black background for imaging • Illuminated from above • Save image as JPEG	• Hardware: Microscope video attachment • Lighting • Magnification: x0.63 -x6.3 • Software: Imaging software

3. Age and growth determination

3.1 Common ageing conventions/nomenclature

Annual growth cycles for fish in a temperate climate can be "divided into warm "growing" and cold "non-growing" seasons" (Conover, 1992 cited in Griffiths and Kirkwood, 1995). Scales, otoliths and opercular bones show the life history of the fish in a manner similar to rings of a tree. These rings, also known as circuli, form out from the centre/focus or core of these hard structures (Fig. 3.1). These structures increase in size as the fish grows by adding circuli to the structure edge. Like a tree the fish normally grows faster in the summer when temperatures are warmer and there is more food available and the circuli are spaced farther apart. During the winter, growth slows down and the circuli are closer together, forming a dark ring or annulus (Fig. 3.1). Each annulus represents a year's growth and by counting the annuli it is possible to estimate the age of a fish.

Table 3.1: General ageing guidelines (I-VI) for all fish species

I.	A fish in its first growing season is categorised to the age group 0 (fry, young of the year (YOY), etc.). There will be no annulus visible on the ageing structures for these fish
II.	A fish in its second growing season is categorised to the age group 1. A fish in this group will only have one annual mark (annulus) on its scale, otolith or operculum
III.	A fish in its third growing season is categorised to the age group 2 or 2 years old (two annuli). This continues up to the outer edge of the ageing material
IV.	"Plus" growth: Growth after the last annulus at the outer edge of the scale is recorded as "plus" growth and added to the recorded age, e.g. "0+""1+", etc.
V.	Fish that migrate between fresh and salt water, e.g. salmon and sea trout have special naming designations to show the period(s) spent in both environments (e.g. CSTP, 2010; ICES, 2011)
VI.	Knowledge of initial scale development in juvenile fish is important in fish ageing. The initial process of scale development in juvenile fish is known as squamation (Taylor, 2012). This process begins at different times of the year, locations on the fish and at various lengths during larval development depending on the species. This information is used to establish an arbitrary birth date and provide an optimum scale removal location for each species for ageing purposes
VII.	There can be a wide range of other factors that influence the development of an annulus. Therefore, all fish in this document are aged "as seen". Scales are aged based on the features displayed on the image no matter the time of year in which the scale was recorded

3.1.1 Scales

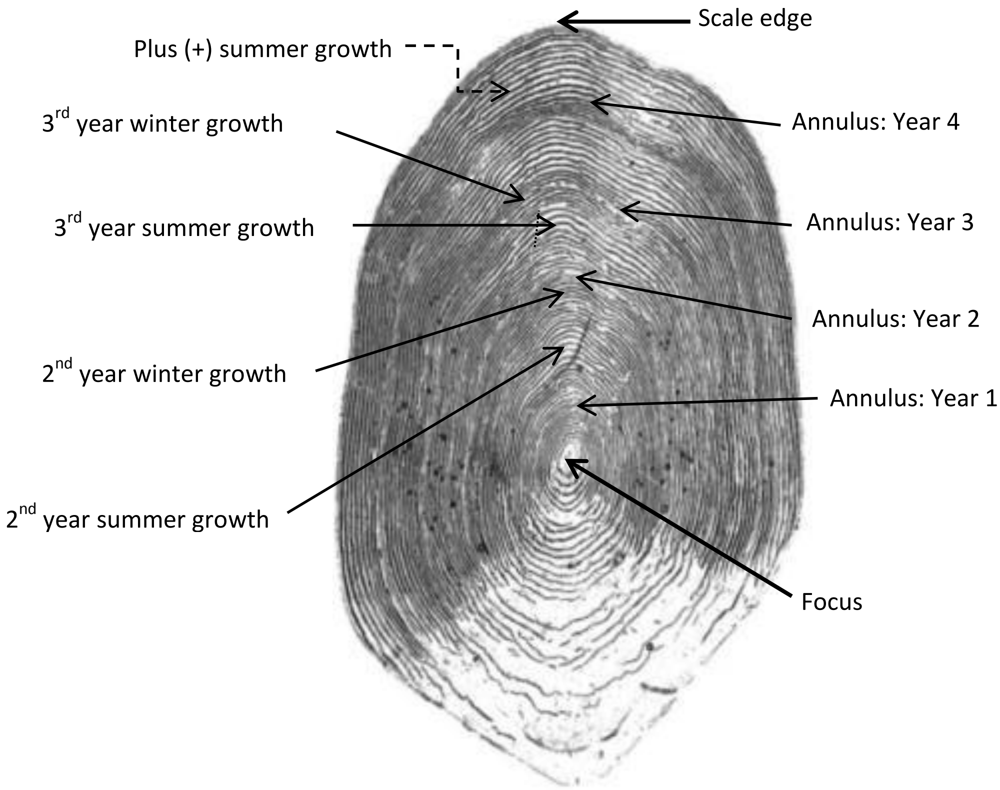


Fig. 3.1: A typical salmonid scale (4+ years) showing key ageing characteristics

3.1.2 Maturity marks and the underestimation of age (scales)

Spawning marks are laid down in scales when the outer growing edge of the scale erodes, leaving a ring or partial ring of missing, partly missing, or cross cutting circuli after which the scale returns to normal growth. Note that growth interruptions (=Checks) in fish through any cause , e.g. surviving pollution incidents, movement between different environments, or extreme temperature events can also produce similar marks.

The ageing of fish with significant spawning marks should be treated with caution, and interpretations should be kept to a minimum (Allan and Ritter, 1977). Beyond the age of maturity, the age of fish may be underestimated (Chilton, 1982).

Salmonids in particular, appear to incur significant cutting over/erosion and reabsorption of circuli during the gonad development/spawning process compared to other families. Note when circuli do not complete a full circumference of the scale (see Plates No. 10, 11, 13, 18, 19, 23, 24, 31).

Studies by the Celtic Sea Trout Project suggested that fish with spawning marks should be aged at length only with no back calculation performed (CSTP, 2010; CSTP, 2016).

3.1.3 Regenerated (replacement) scales

All species may have regenerated (replacement) scales. These scales have formed at a later stage in fish development. They fill gaps in the scale coat quickly after the loss of a previous scale and do not include all circuli or relevant ageing information. Examples of these will be displayed in plates throughout the document. These should not be used for ageing purposes. However, it can be worth noting where there is a consistent pattern of scale loss at a particular time in a sample of fish from a particular area or site – as this can indicate an environmental stressor event that has occurred, but otherwise gone unnoticed.

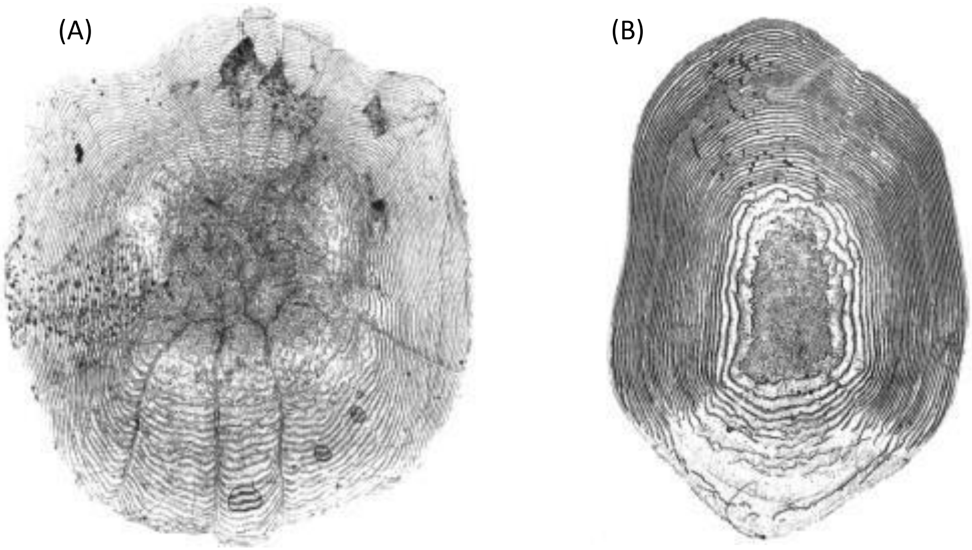


Fig. 3.2: Examples of regenerated (replacement) cycloid scales. (A) cyprinid (B) salmonid

3.1.4 Otoliths

Using current imaging methodology the colour of the growth zones in otoliths results in alternating opaque (annulus/winter growth) and translucent/hyaline (summer growth) bands (Ashford *et al.*, 2001). The centre of the otolith used for ageing is known as the core (Klumb *et al.*, 2001) (see Fig. 3.3).

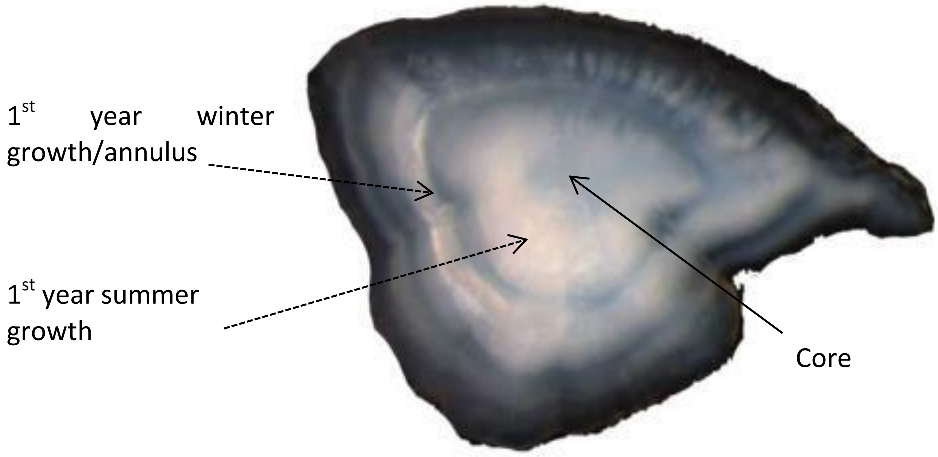


Fig. 3.3: Example of an otolith of an Arctic char (*Salvelinus alpinus*)

3.1.5 Opercular bones

Using current imaging methodology, the colour of the growth zones results in opaque (summer growth) bands and translucent (annulus/winter growth) bands (Bagenal and Tesch, 1978) (see Fig. 3.4).

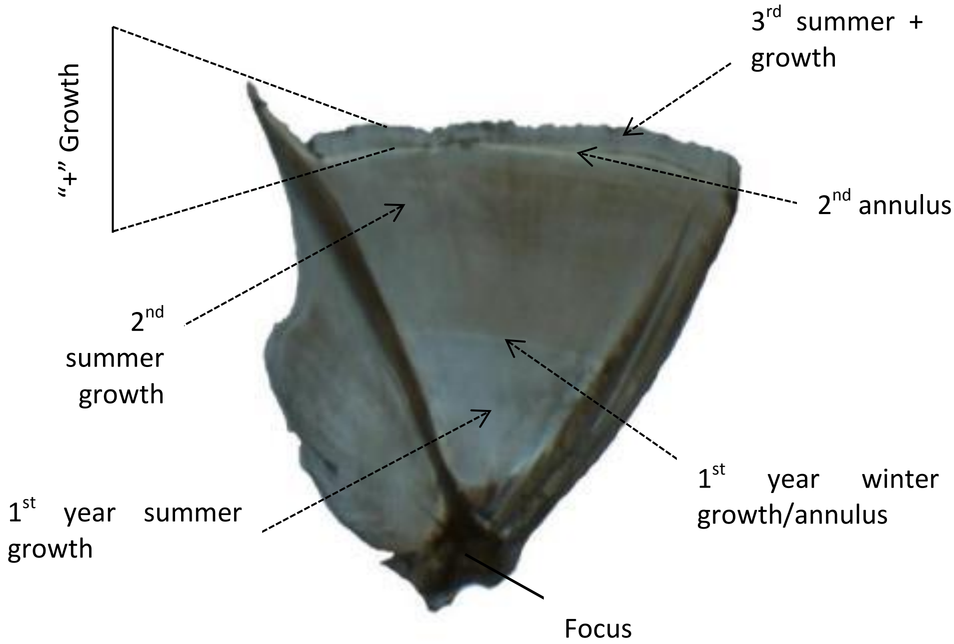


Fig. 3.4: Example of an opercular bone of a perch (*Perca fluviatilis*) indicating key ageing features

3.2 Growth rate calculation

The length of fish at each age can be calculated from the body length scale radius relationship and measurement of annuli radii (Bagenal and Tesch (1978). This is known as back calculation. IFI staff normally estimate growth of fish using back-calculation of fish scales and opercular bones. No back calculation is performed on otoliths. Francis (1990) defined back-calculation as "a technique that uses a set of measurements made on a fish at one time to infer its length at an earlier time or times".

Lea's (Lea, 1910) formula for back calculation is presented here. This method assumes that when the body:scale relationship is linear and passes through the origin, scale growth is directly proportional to body growth (i.e. isometric growth) (Kennedy and Fitzmaurice, 1971; Bagenal and Tesch, 1978). Other methods are available for non-linear growth (Bagenal and Tesch, 1978). All fish lengths displayed in this document are fork length and have been measured to the nearest millimetre. Lea's formula is described as follows:

$$Li = LT*(Si / ST)$$

Where:

Li = length of fish when annulus 'i' was formed

LT = length of fish at capture (fork length)

*****ST (total scale length)*** = Total scale radius at capture

Si (annulus)= scale radius at time of annulus 'I' formation

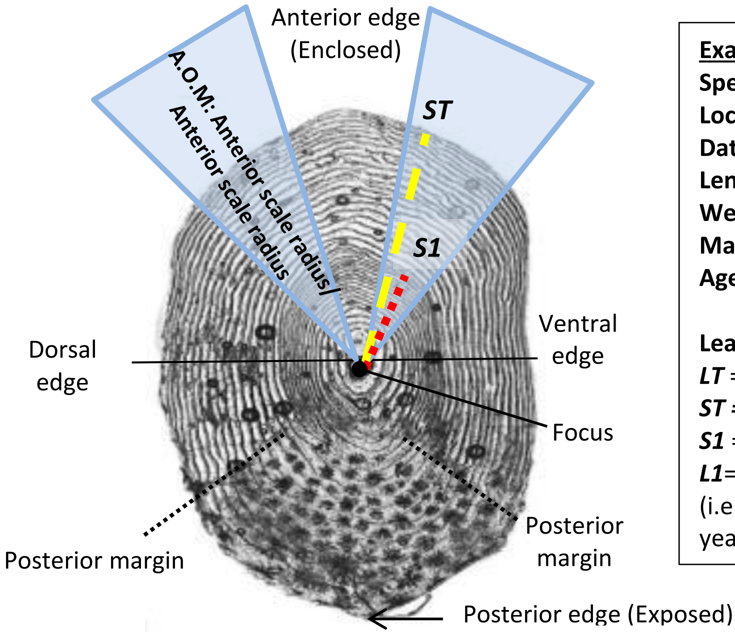
****ST= total scale length as measured along the angle of measurement (AOM) for each fish of that species**

3.3 Angle of measurement

The above formula is used to calculate growth (length at age) of the majority of fish species documented in this manual. However, there are differences between species as to where the scale radius measurement should be taken (angle of measurement (AOM)). The following section illustrates the appropriate angles of measurement (A.O.M.) used for ageing salmonids, cyprinids and pike scales; perch operculum and Arctic char otoliths. The examples shown will demonstrate how Lea's back-calculation formula is used to generate length at age.

3.3.1 Recommended angle of measurement for salmonids (scales)

Angle of measurement: Salmon and trout: traditional line/anterior-lateral axis (ICES, 1984; Martinson *et al.*, 2000; Ogle, 2013). Pollan: anterior scale radius (Wilson and Pitcher, 1983).



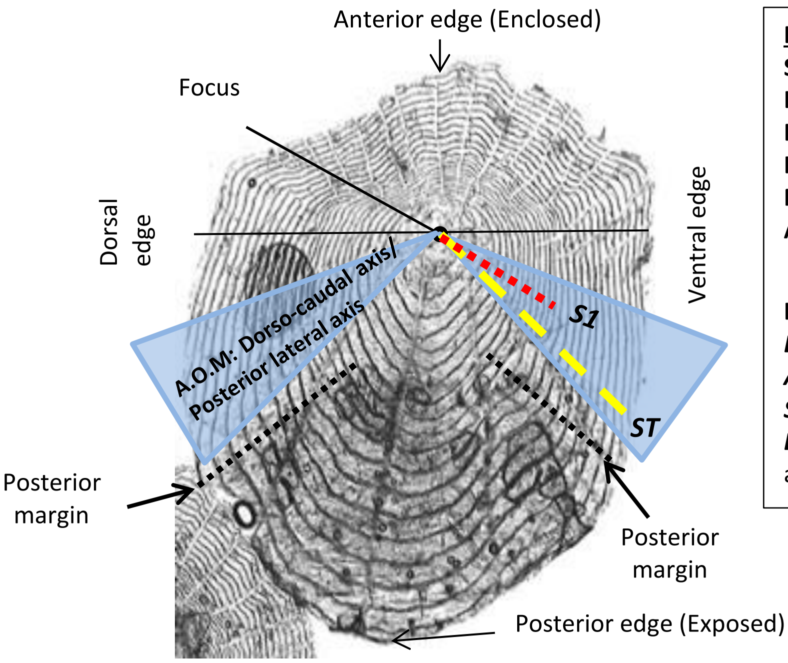
Example:
Species: Salmon (*Salmo salar*)
Location:River Dee, Co. Meath
Date of capture: 07/08/2014
Length: 14.7 cm
Weight: 45g
Magnification: n/a
Age: 1+

Lea's Formula
LT = 14.7cm
ST **=** 4.3cm
S1 = 1.9cm
L1= 14.7*(1.9 / 4.3) =6.5cm
(i.e. L1 = length at the end of 1st year)

Fig. 3.5: Recommended angle of measurement (A.O.M) for scale radius measurement and terminology for salmonid scales

3.3.2 Recommended angle of measurement for cyprinids (scales)

Angle of measurement*:* Approximate posterior lateral axis above dorso-caudal (posterior) axis (McCarthy and Kennedy, 1965), posterior margin (Ibàñez *et al.*, 2008).



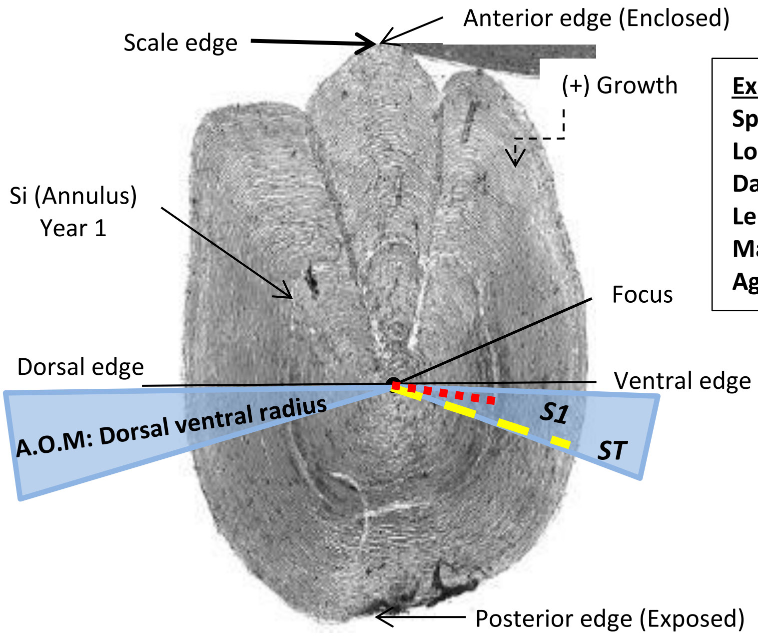
Example:
Species: Dace (*Leciscus leuciscus)*
Location: River Barrow, Co. Kilkenny
Date: 22/07/2015
Length: 7.2 cm
Magnification: n/a
Age: 1+

Lea's Formula
LT = 7.2cm
A.O.M = 3.0cm
S1 = 1.7cm
L1 = 7.2*(1.8 / 3.0) = 4.3cm (length at end of 1st year)

Fig. 3.6: Recommended angle of measurement (A.O.M) and terminology for cyprinid scales

3.3.3 Recommended angle of measurement for pike (scales)

Angle of measurement: Dorsal-ventral radius (Frost and Kipling, 1959; Bracken, 1973).

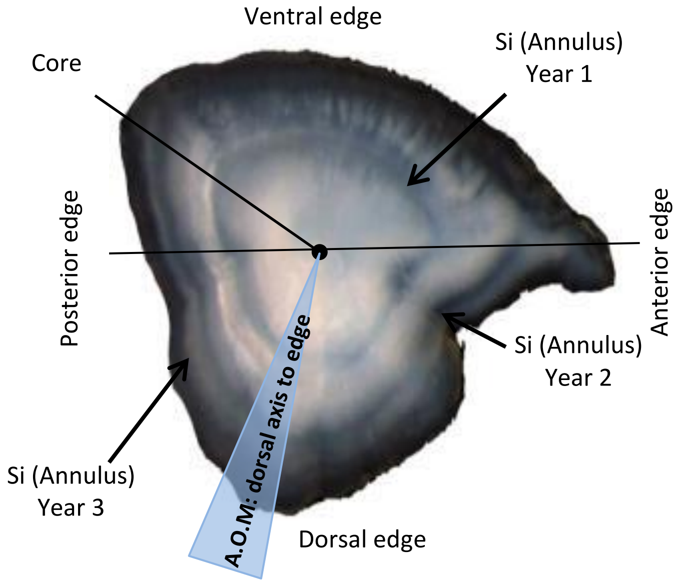


Example:
Species: Pike (*Esox lucius*)
Location: Atedaun Lough, Co. Clare
Date: 10/09/2010
Length: 26.4cm
Magnification: x32
Age: 1+

Fig. 3.7: Recommended angle of measurement (A.O.M) and terminology for pike scales

3.3.4 Recommended angle of measurement for Arctic char (otoliths)

Angle of measurement: Dorsal axis to edge (Klumb *et al.*, 2001; Aymes *et al.*, 2015)

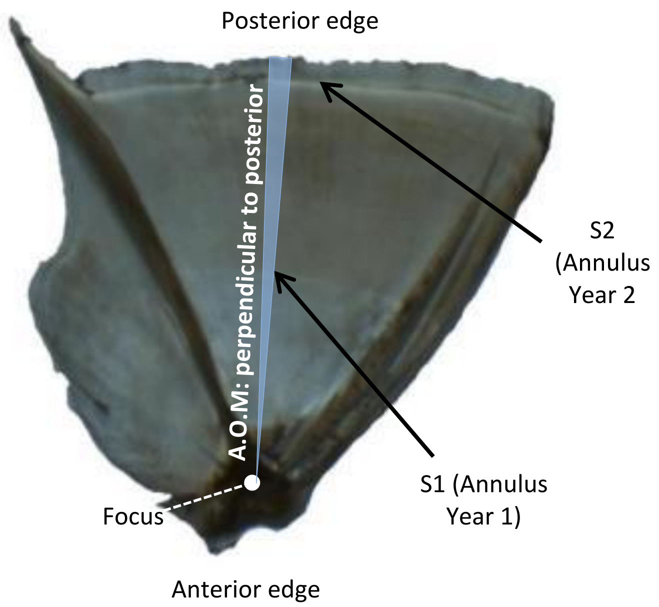


Example
Species: Arctic char (*Salvelinus alpinus*)
Location: Shindilla Lough, Co. Galway
Date: 07/09/2010
Length: 20cm
Back calculation: n/a
Magnification: n/a
Age: 3+

Fig. 3.8: Recommended angle of measurement and terminology for Arctic char otoliths

3.3.5 Recommended angle of measurement for perch (opercular bone)

Angle of measurement: Approximate perpendicular to its posterior edge (Le Cren, 1947; Shafi and Maitland, 1971; Mann, 1973).



Example
Species: Perch (*Perca fluviatilis*)
Location: Lough Derg
Date: 14/06/2016
Length: 14.3cm
Weight: 40g
Magnification: n/a
***Age:** 2+*

Lea's Formula
LT = 14.3cm
A.O.M = 8.0cm
Si (^{1}) = 3.9cm
Si (^{2}) =7.6cm
Li (^{1}): 14.3*(3.9/8.0) =7cm
Li (^{2}): 14.3*(7.6/8.0) =13.5cm

Fig. 3.9: Recommended angle of measurement and terminology for perch opercular bones

3.3.6 Cyprinid scales – comparison of key features

Scales of three common cyprinid species and one cyprinid hybrid found in Irish waters are displayed in Figure 3.10. To demonstrate some key morphological traits, all scales imaged are from fish of a similar size (to nearest 0.5cm) and where possible captured at the same time and location. If unsure of identification in the field, observing these features in the lab during the ageing process can be useful for species verification.

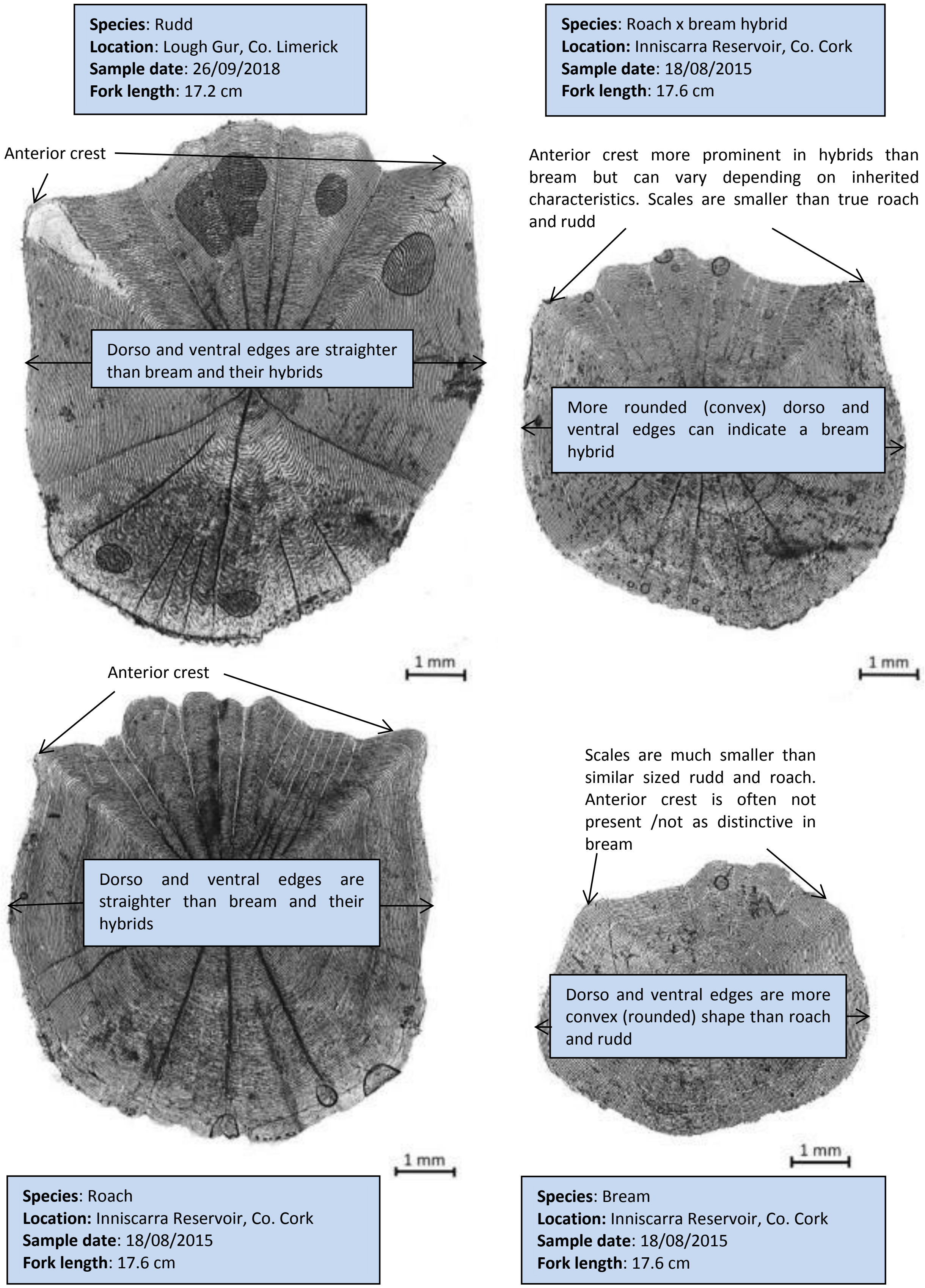
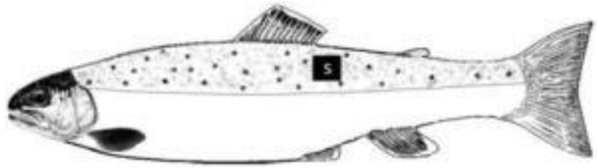


Fig. 3.10 Comparison of cyprinid scales from similar sized cyprinid species (all images recorded at x55 magnification)

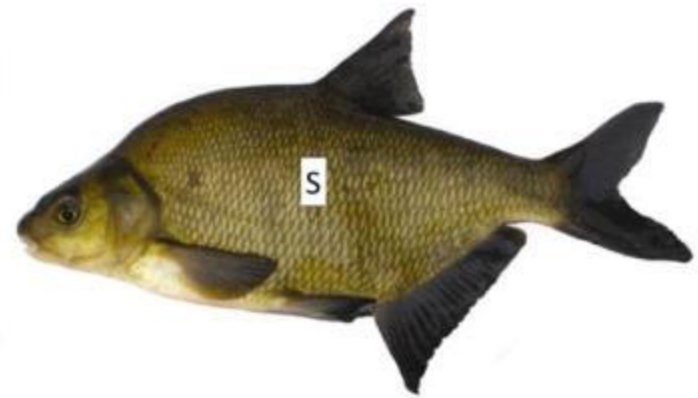
3.3.7 Summary of ageing information

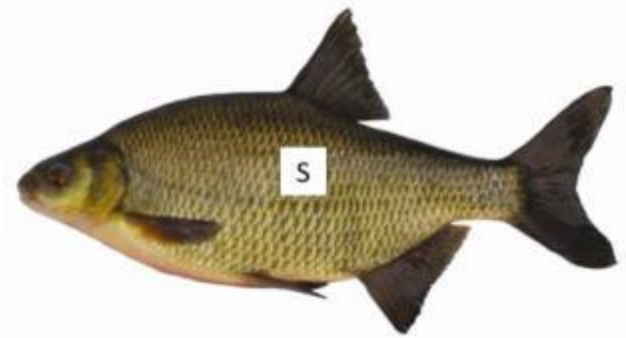
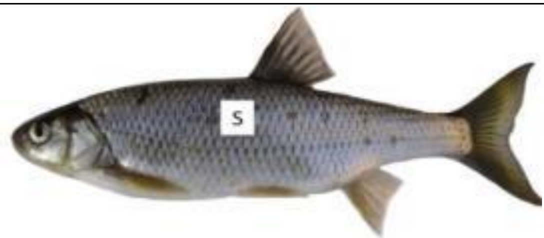
The following table (Table 3.2) provides a synopsis of important information for each species described in this document. This includes species name, arbitrary birth date, length at squamation (1st scale development), suitable ageing structures and appropriate location for removing such ageing structures.

Table 3.2: Approximate first scale (squamation) length, arbitrary birth date, most suitable ageing structure and removal locations for common Irish freshwater fish species

Species	1st scale (mm)	Ref.	Birth date	Ref.	Most suitable ageing structure	Removal location	Removal location (Image)	Ref.
Family: *Salmonidae*								
Brown trout *(Salmo trutta)*	30-35mm	Parrott, (1934) Jensen & Johnsen, (1981)	Spring	Kaeding (1976) Bardonnet *et al.,* (1993)	Scales	Scales (S): 3-6 rows above the lateral line, just behind the dorsal fin		Shearer (1992)
Sea trout (*Salmo trutta*)	n/a	-	Late April	Elliot (2009)	Scales	Scales (S):Refer to image		Shearer (1992)
Atlantic salmon (*Salmo salar*)	30mm (total length)	Jensen & Johnsen, (1981)	1st April	Allan and Ritter (1977) ICES (2011)	Scales	Scales (S):Refer to image		Shearer (1992)
Arctic char (*Salvelinus alpinus*)	38mm	Frost (1978)	Autumn and Spring spawning	Frost (1978) Baroudy (1995)	Otoliths	Scales (S):Refer to image Otoliths (Oth): Located directly behind the brain of bony fishes		Otoliths: Baroudy (1995) Scales: Shearer (1992)

Species	1st scale (mm)	Ref.	Birth date	Ref.	Most suitable ageing structure	Removal location	Removal locatiom (Image)	Ref.
Family: *Salmonidae* (Continued)								
Pollan (*Coregonus autumnalis*)	17 mm	IFI/AFBI NI Pollan ageing workshop (2017)	1st April	IFI/AFBI NI Pollan ageing workshop notes (unpublished, 2017)	Scales	Scales (S): remove from an area just above the lateral line, between the dorsal and adipose fin		Wilson and Pitcher (1983)
Family: *Esocidae*								
Pike (*Esox lucius*)	32-35 mm	Raat (1988)	1st April	Schneider (2001) Clark & Steinbach (1959)	Scales (other structures e.g. cleithra or opercular bones: when dead specimens available:	Scales (S) : those located in middle above lateral line easiest to interpret		(Williams, 1955) Steinmetz and Muller (1991) Schneider (2001), Casselman (1973)
Family: *Percidae*								
Perch (*Perca fluviatilis*)	18-28 mm	Spanovskaya & Grygorash (1977)	1st May	Shafi & Maitland (1970)	Operular bone	Opercular bone (Op): part of the gill cover on bony fish (Section 2.3) Scales (S): the second row above the lateral line below the insertion of the first dorsal spine		Opercular bone: Le Cren (1947) Scales: Kornilovs, (2015)

Species	**1st scale (mm)**	**Ref.**	**Birth date**	**Ref.**	**Most suitable ageing structure**	**Removal location**	**Removal locatiom (Image)**	**Ref.**
						Family: *Cyprinidae*		
Roach *(Rutilus rutilus)*	18.5 mm	Bagenal & Tesch, (1978)	1st June	Cragg-Hine and Jones (1969) Mann 1973	Scales	Scales (S): those above the lateral line below the insertion of the dorsal fin		Mann (1973) Steinmetz and Muller (1991)
Bream *(Abramis brama)*	17 mm	Kucharczyk *et al.*, (1998)	1st June	Cowx (1983)	Scales	Scales (S): those above the lateral line, anterior to the dorsal fin		Treer *et al.*, (2003)

Species	1st scale (mm)	Ref.	Birth date	Ref.	Most suitable ageing structure	Removal location	Removal locatiom (Image)	Ref.
Family: *Cyprinidae* (Continued)								
Rudd *(Scardinius erythrophthalmus)*	21 mm	Kennedy and Fitzmaurice (1974)	1st June	Kennedy & Fitzmaurice (1974)	Scales	Scales (S): ideal location is above lateral line anterior to dorsal fin		Kennedy and Fitzmaurice (1974)
Roach x bream hybrid	n/a	-	1st June	Cowx (1983)	Scales	Scales (S): above lateral line under the dorsal fin		Steinmetz and Muller (1991)
Dace *(Leuciscus leuciscus)*	19 mm	Kennedy (1969)	1st March	Kennedy (1969) Caffrey *et al.,* (2007)	Scales	Scales (S): above lateral line anterior to dorsal fin		Kennedy, (1969)

4.0 Catalogue of Fish Ageing Images

This chapter presents images of ageing structure (scales, opercular bones and otoliths) from ten of the most common Irish freshwater fish species. Images of scales from sea trout and roach x bream hybrids are also included. Notes on life history features for each species are provided and each image is classified by age.

Table 4.1: List of plates of age read material

Plate No.	Species	Location	Length (cm)	Age (yrs.)	Capture date
1	Brown trout	Dodder, River	6	0+	15/07/2014
2	Brown trout	Vartry, River	9	1+	11/08/2014
3	Brown trout	Lettercraffroe Lough	15.1	1+	04/09/2013
4	Brown trout	Shindilla, Lough	20	2+	07/08/2013
5	Brown trout	Clare River	27.2	2+	29/07/2014
6	Brown trout	Owel, Lough	37	2+	27/04/2013
7	Brown trout	Blackwater (Mon), River	25.6	3+	09/07/2014
8	Brown trout	Kylemore Lough	24	3+	21/08/2013
9	Brown trout	Ennell, Lough	37.1	4+	20/09/2017
10	Brown trout	Gara, Lough	47	6+	04/09/2015
11	Brown trout	Ree, Lough	57	6+	04/03/2014
12	Brown trout (Ferox)	Melvin, Lough	36.1	6+	19/07/2014
13	Brown trout (Ferox)	Lough Corrib	85 (est.)	10+	17/08/2000
14	Sea trout	Vartry, River	28	2.0+	30/08/2011
15	Sea trout	Castletown River	28	2.0+	29/08/2011
16	Sea trout	Kylemore Lough	27.5	3.0+	21/08/2011
17	Sea trout	Castletown River	34.5	2.1+	16/08/2011
18	Sea trout	Dungloe Lough	37.5	2.1+	23/07/2015
19	Sea trout	Dargle, River	51.7	2.1.1SM+	27/09/2011
20	Sea trout	Currane, Lough	71	3.4SM+	19/07/2010
21	Atlantic salmon	Kylemore Lough	12	1+	21/08/2013
22	Atlantic salmon	Vartry River	14.9	1+	12/08/2014
23	Atlantic salmon	Bandon River	55.5	2.1+	19/07/2015
24	Atlantic salmon	Caragh (Kerry), Lough	84	2.2+	22/08/2017
25	Atlantic salmon	Suir, River	117	2.3+.2SM+	01/02/2013
26	Arctic char	Glen Lough	15.3	2+	30/07/2014
27	Arctic char	Shindilla Lough	20	3+	07/09/2010
28	Arctic char	Kindrum, Lough	27.7	5+	17/07/2009
29	Pollan	Allen, Lough	9.1	0+	01/09/2015
30	Pollan	Ree, Lough	16.1	1+	01/07/2016
31	Pollan	Ree, Lough	26.5	3+	01/07/2016
32	Pollan	Ree, Lough	28.8	4+	01/07/2016
33	Pike	Barrow, River	16.5	0+	20/07/2015

34	Pike	Atedaun Lough	26.4	1+	10/09/2013
35	Pike	Barrow, River	41.6	2+	20/07/2015
36	Pike	Lene, Lough	58	3+	02/10/2013
37	Perch	Templehouse Lough	7	0+	01/10/2014
38	Perch	Derg, Lough	10	1+	15/06/2016
39	Perch	Derg, Lough	14.3	2+	14/06/2016
40	Perch	Derg, Lough	15.4	3+	21/06/2016
41	Perch	Derrybrick Lough	23.8	5+	11/10/2011
42	Roach	Muckno, Lough	4	0+	08/09/2015
43	Roach	Cullin, Lough	6.5	1+	11/08/2015
44	Roach	Gara, Lough	10	2+	04/09/2015
45	Roach	Glenade Lough	12.1	3+	27/08/2013
46	Roach	Ross Lake	14.8	3+	14/08/2013
47	Roach	Urlaur Lough	17.1	4+	25/07/2013
48	Roach	Glenade Lough	17.9	4+	27/08/2013
49	Roach	Glenade Lough	20.6	5+	27/08/2013
50	Rudd	Cullaun, Lough	7.2	1+	27/08/2015
51	Rudd	Cullaun, Lough	12	2+	27/08/2015
52	Rudd	Atedaun, Lough	16.8	3+	10/09/2015
53	Rudd	Aughrusbeg Lough	13.8	6+	31/07/2013
54	Bream	Stonemans Lake	6	0+	24/06/2015
55	Bream	Stonemans Lake	8.5	1+	24/06/2015
56	Bream	Inniscarra Reservoir	12.2	2+	18/08/2015
57	Bream	Inniscarra Reservoir	19.1	4+	18/08/2015
58	Roach x bream hybrid	Muckno, Lough	4.8	0+	23/09/2015
59	Roach x bream hybrid	MacNean (Lwr), Lough	7.1	1+	28/06/2013
60	Roach x bream hybrid	Barrow, River	8.8	2+	20/07/2015
61	Roach x bream hybrid	MacNean (Lwr), Lough	19.5	7+	28/06/2013
62	Dace	Barrow, River	4.2	0+	20/07/2015
63	Dace	Barrow, River	7.2	1+	22/07/2015
64	Dace	Barrow, River	14.3	2+	21/07/2015
65	Dace	Barrow, River	18.1	3+	21/07/2015

4.1 Brown trout (Salmo trutta)

4.1.1 Identifying features

Brown trout usually have a pale belly with greenish grey/olive brown/golden flanks and a darker back with a reddish-brown/orange adipose fin. Brown trout are pigmented with spots, mostly blackish but sometimes with reddish spots (fisheriesireland.ie) (Plate 6.1). Late 0+ and 1+ fish have up to 8 "parr marks" – greyish vertical bars on the flanks. Brown trout colouration is highly variable and has been documented by O' Grady (2008).

4.2.2 Distribution and biological information

Brown trout are a member of the salmonidae family. They are indigenous to Europe, North Africa and western Asia (Klemetsen *et al.,* 2003).

Table 4.1: Brown trout life stages (I-III)

I.	**Fry**: Following hatching, absorbing their yolk sac as alevins and emerging from gravels, young trout start feeding and developing territorial behaviour in shallow waters in their natal streams. Approximate size range for 0+ fry: 4-10cm (see Plate No. 1).
II.	**Parr**: After a year's growth as fry, brown trout become parr. Parr often remain in their natal river but may expand their territory to deeper areas. Approximate size range for 1+ parr: 9-15cm (see Plates No. 2-3).
III.	**Adult:** After year 2 brown trout become classified as adults. At this stage brown trout can often move to lakes or deep, slower pools in main river channels in catchments where there lakes are absent. They will return to tributary streams and rivers to spawn in the winter months.

Plate 4.1: Brown trout (*Salmo trutta*) (source IFI)

The lifespan of Irish brown trout, like many aspects of its biology is varied (O'Grady *et al*., 2008). Listed below are some of the most common life stage information to be aware of when ageing brown trout.

Table 4.2: Common variations in the brown trout life-cycle (I-V)

I.	Brown trout reside their entire life in the natal river (Elliott, 1994) (see Plate No. 5).
II.	Brown trout migrates at an age of 1+ or 2+ to a main river and the adult fish only return to the natal river for spawning (Elliott, 1994) (see Plate No. 7).
III.	Brown trout migrates at an age of 1+ to 2+ (3+ do occur but are rare) to a lake (see Plate No. 3, 4, 8, 9, 10, 11). The spawning population consists of iteroparous (spawning several times during their life) males and females from the lake, returning to their natal river for spawning. A portion of the male population do not migrate to the lake and become sexually mature in their natal river (Elliott, 1994).
IV.	Ferox are a long lived piscivorous form of brown trout (O' Grady *et al*., 2008). Specimens have been recorded up to 12 years old (Gargan, P. 2019 *pers. comm.*). While they share the same scientific name as brown trout, they appear to be reproductively isolated and genetically distinct (Thorne *et al.,* 2016). They are present in lakes in Ireland which share a large area, deep refuges and historic/existing populations of Arctic char. Examples of this variation are present in the document (see Plate No. 12 & 13). Other genetically distinct varieties of trout with separate spawning habits are present in some large Irish lakes, including Gillaroo and Sonaghen (Ferguson and Taggart, 1991).
V.	In addition to this list a number of systems in Ireland are stocked with adult brown trout. A reference scale from an artificially reared, pond on-grown brown trout is included in this document (see Plate No. 6).

4.1.3 Ageing notes

Historical (angling reports, life history data) and environmental information (survey site info, water chemistry) are important tools for biologists when ageing brown trout and other salmonid species. The recording of fish colour/condition of brown trout as well as time of capture can also be informative. Brown trout recorded during the early summer typically show no narrowing circuli at the scale edge (see Plate No. 5). In contrast a fish captured in late August/September may begin to show narrowing of the circuli at the edge of the scale (see Plate No. 3, 8). This can be mistaken for an annulus (see Plate No. 5). Factors that may affect this include a drop in temperature, a lack of feeding, and/or a switch from feeding to gonad development prior to spawning later in winter.

Plate No: 1

Species: Brown trout (*Salmo trutta*)
Location: River Dodder, Dublin 16
Capture date: 15/07/2014
Fork length: 6.0cm
Age: 0+
Magnification: x 55

Comments: There is no annulus formed on this scale, only plus (+) growth. Fish age is 0+.

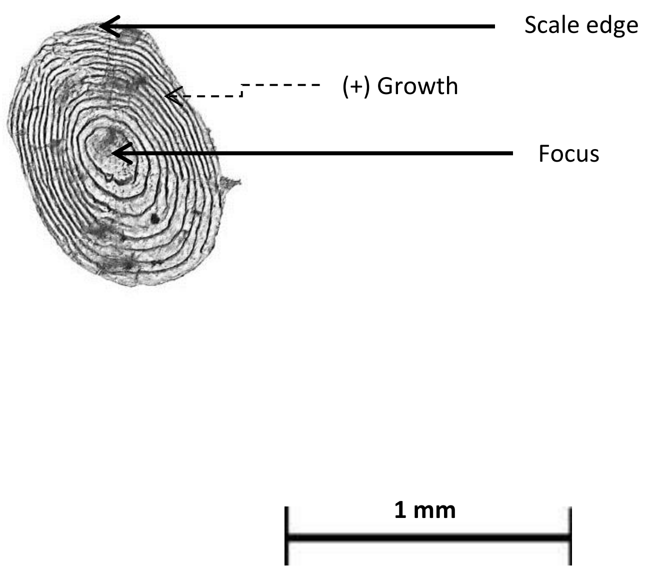
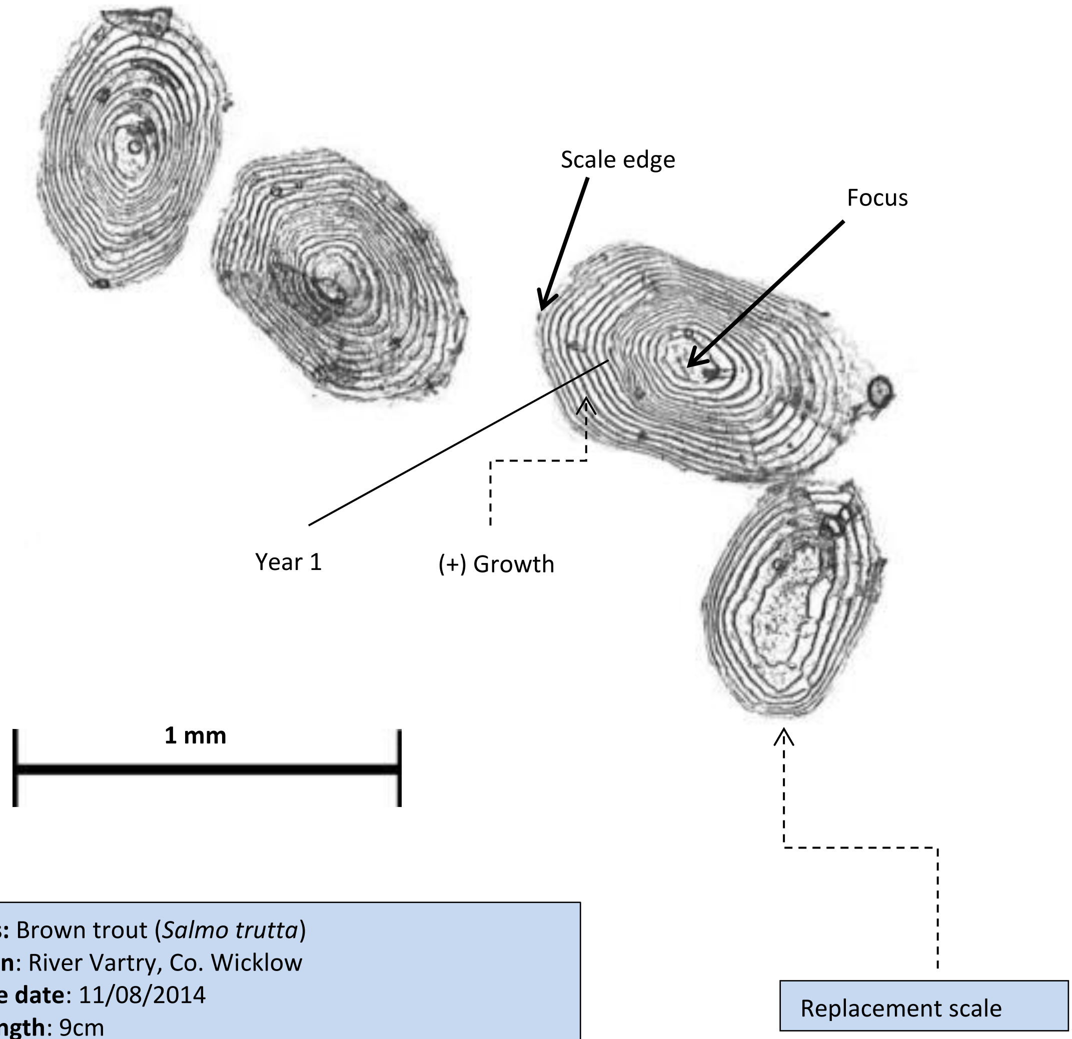


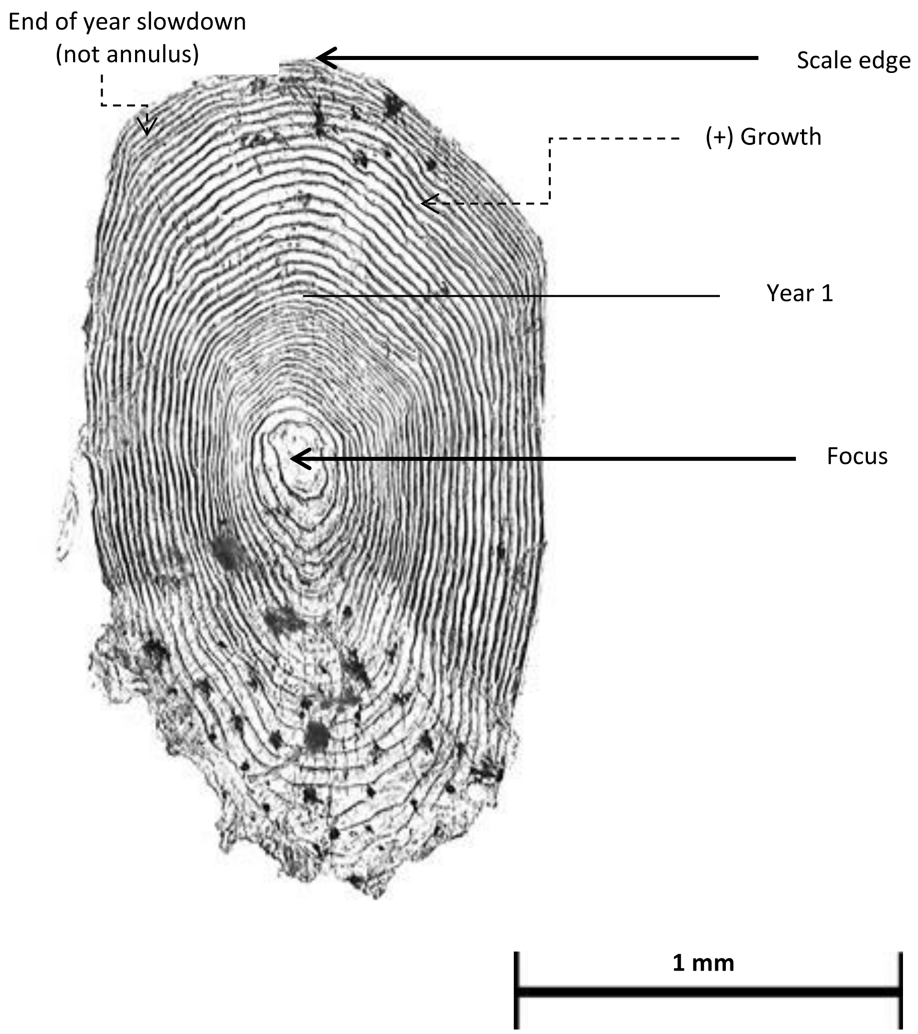
Plate No. 2



Species: Brown trout (*Salmo trutta*)
Location: River Vartry, Co. Wicklow
Capture date: 11/08/2014
Fork length: 9cm
Age: 1+
Magnification: x 55

Comments: This example shows the variation in growth that can occur in Irish waters. This fish resided in the River Vartry, an oligotrophic river. While the river contains large numbers of resident brown trout, they display a slow growth rate in this nutrient poor environment. The scale at right of the image is a replacement scale. This is evident by the larger uneven focus. These scales are not used during the ageing process.

Plate No: 3



Species: Brown trout (*Salmo trutta*)
Location: Lettercraffoe Lough, County Galway
Capture date: 04/09/2013
Fork length: 15.1cm
Age: 1+
Magnification: x 55

Comments: From the image we can see that the circuli are beginning to narrow at the outer edge of the scale. This is attributable to the summer growth (wider circuli) slowing down and autumnal growth (narrowing circuli) beginning to appear. This growth pattern is very common in salmonids captured in the later part of the fieldwork season (late August/September). It is not an annulus; it is a slowing down of the current year's growth rate.

Plate No. 4

Location: Shindilla Lough, County Galway
Sample date: 07/08/2013
Fork length: 20cm
Age: 2+
Magnification: x 55

Comments: This fish is aged as 2+. A replacement scale is shown at the top of the image.

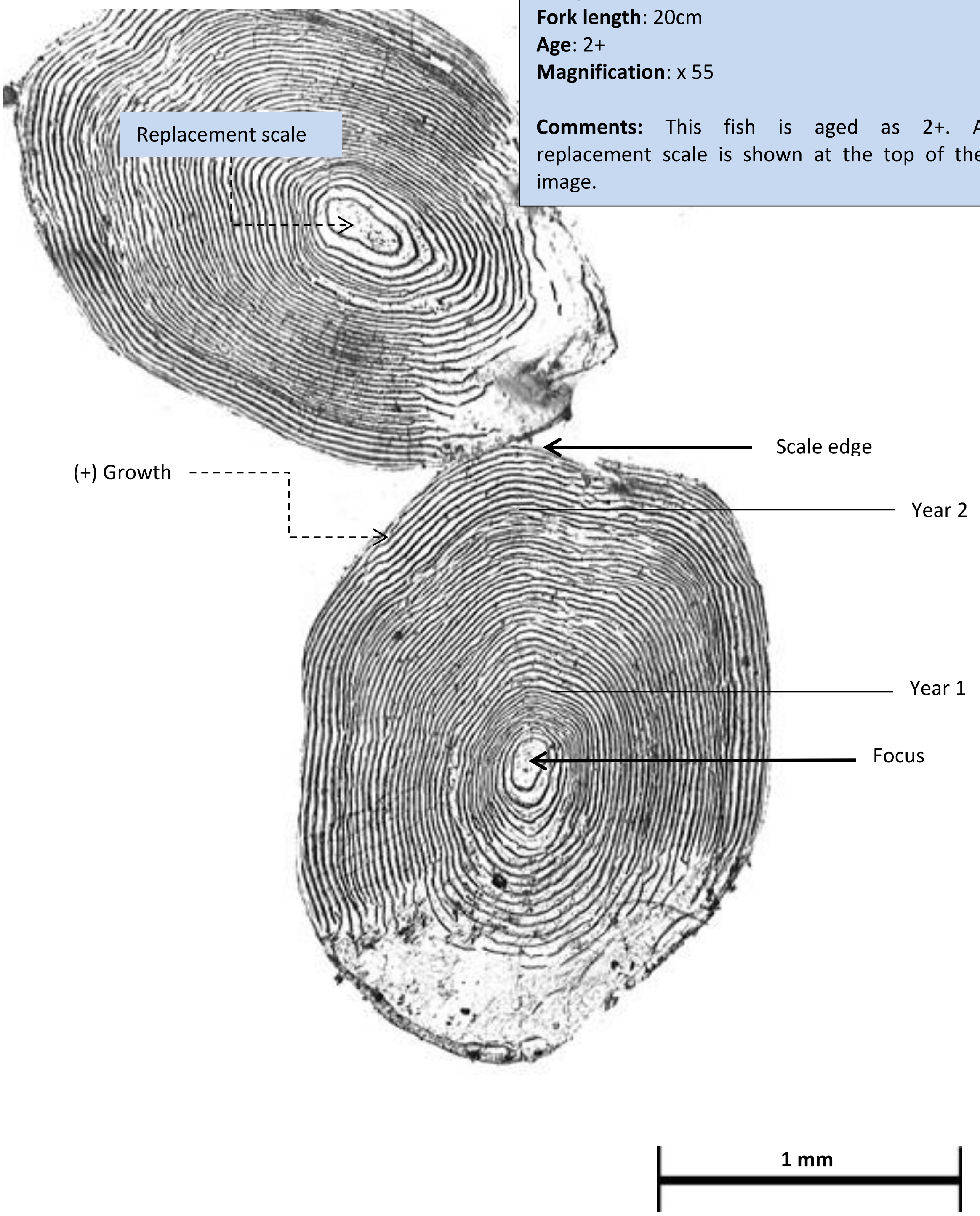
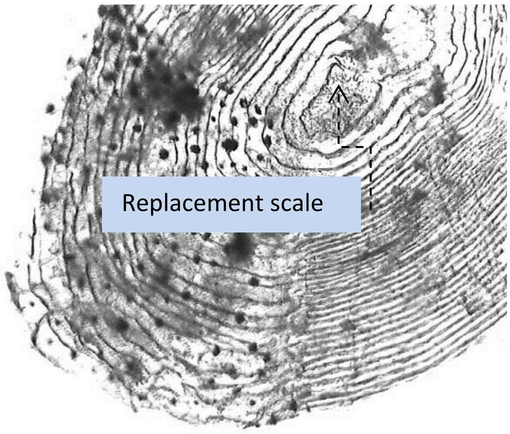
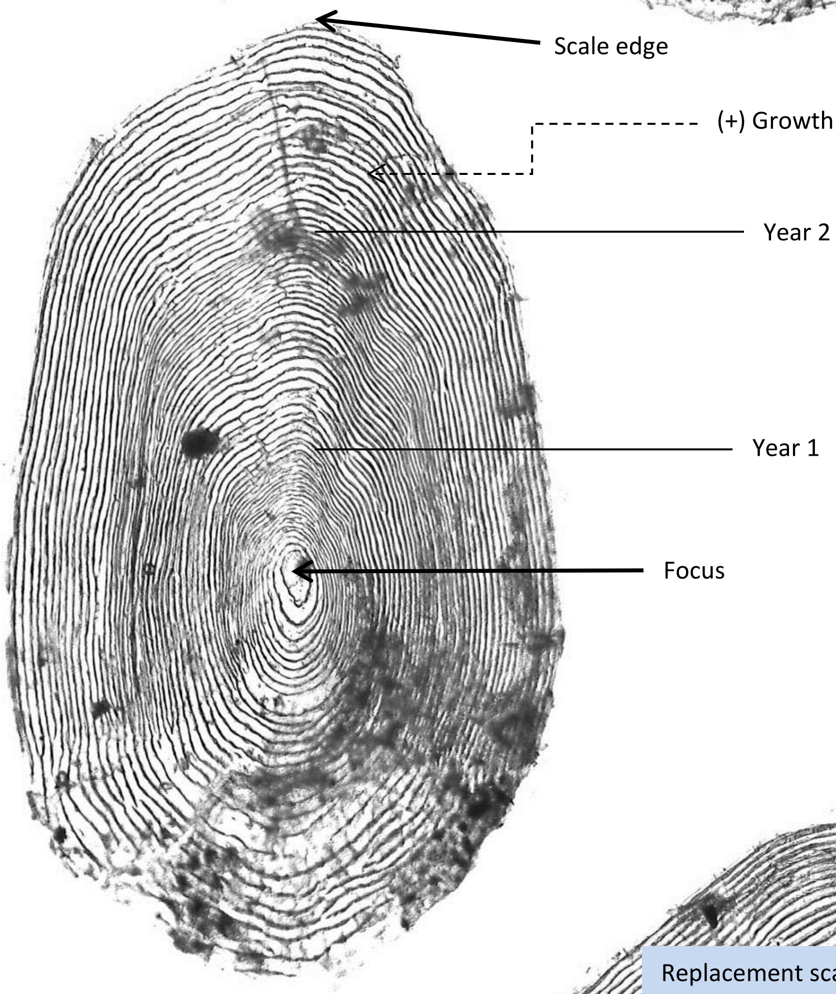
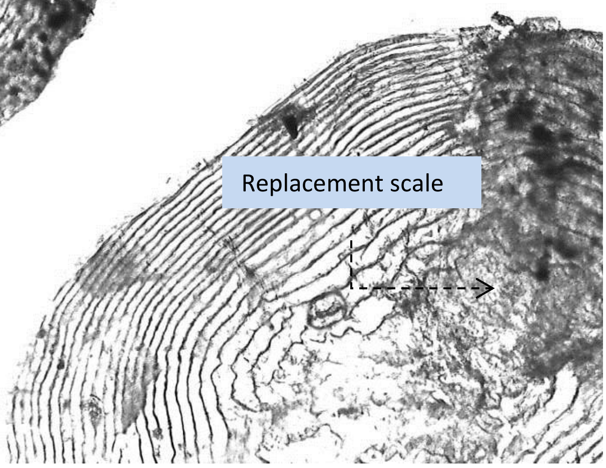


Plate No: 5

Species: Brown trout (*Salmo trutta*)
Location: Clare River, County Galway
Sample date: 29/07/2014
Fork length: 27.2cm
Age: 2+
Magnification: x 45
Comments: The Clare River is a major contributor of adult trout to Lough Corrib but contains some very large resident trout in its own right. This fish displays resident river growth with no major growth contrasts throughout its life. It is aged as 2 years old (2+) and displays a fast growth rate. Replacement scales can be seen in the right hand corners.







1 mm

Plate No: 6

Species: Brown trout (*Salmo trutta*) (Stocked)
Location: Lough Owel, Co. Westmeath
Sample date: 27/04/2014
Fork length: 37.0cm
Age: 2+
Magnification: x35

Comments: IFI brown trout stocking programmes primarily consists of 2 year old fish ongrown at IFI fish farm facilities (Cowen, J. 2017 *pers. comm.*). Note the even growth rate as a result of a precise feeding regime and a lack of seasonal growth variations (summer vs. winter) in comparison to a wild fish. This particular fish appears to have derived from stock propagated in November 2011. It is likely to have been introduced into Lough Owel as part of a stocking programme in March 2014.

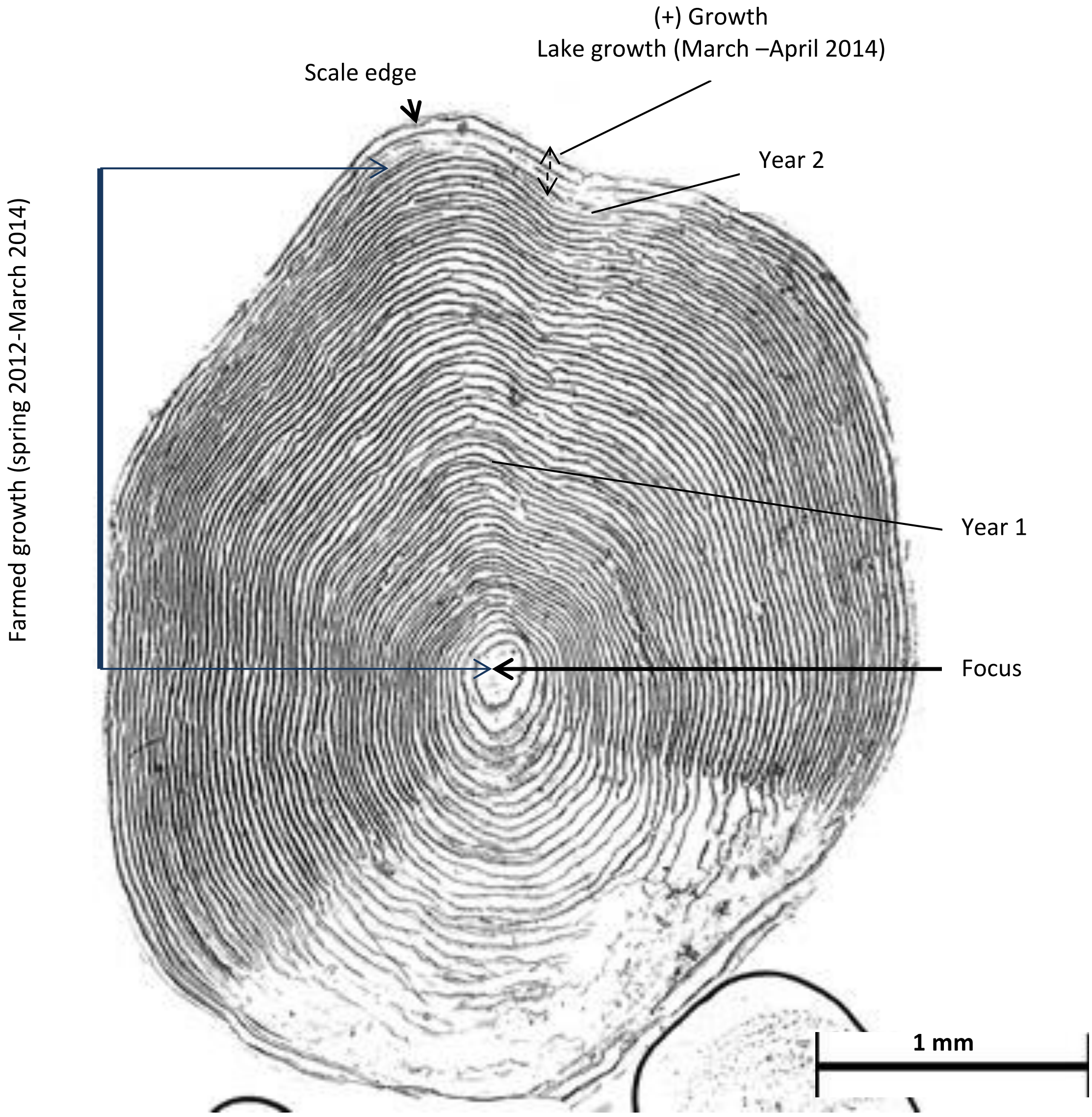
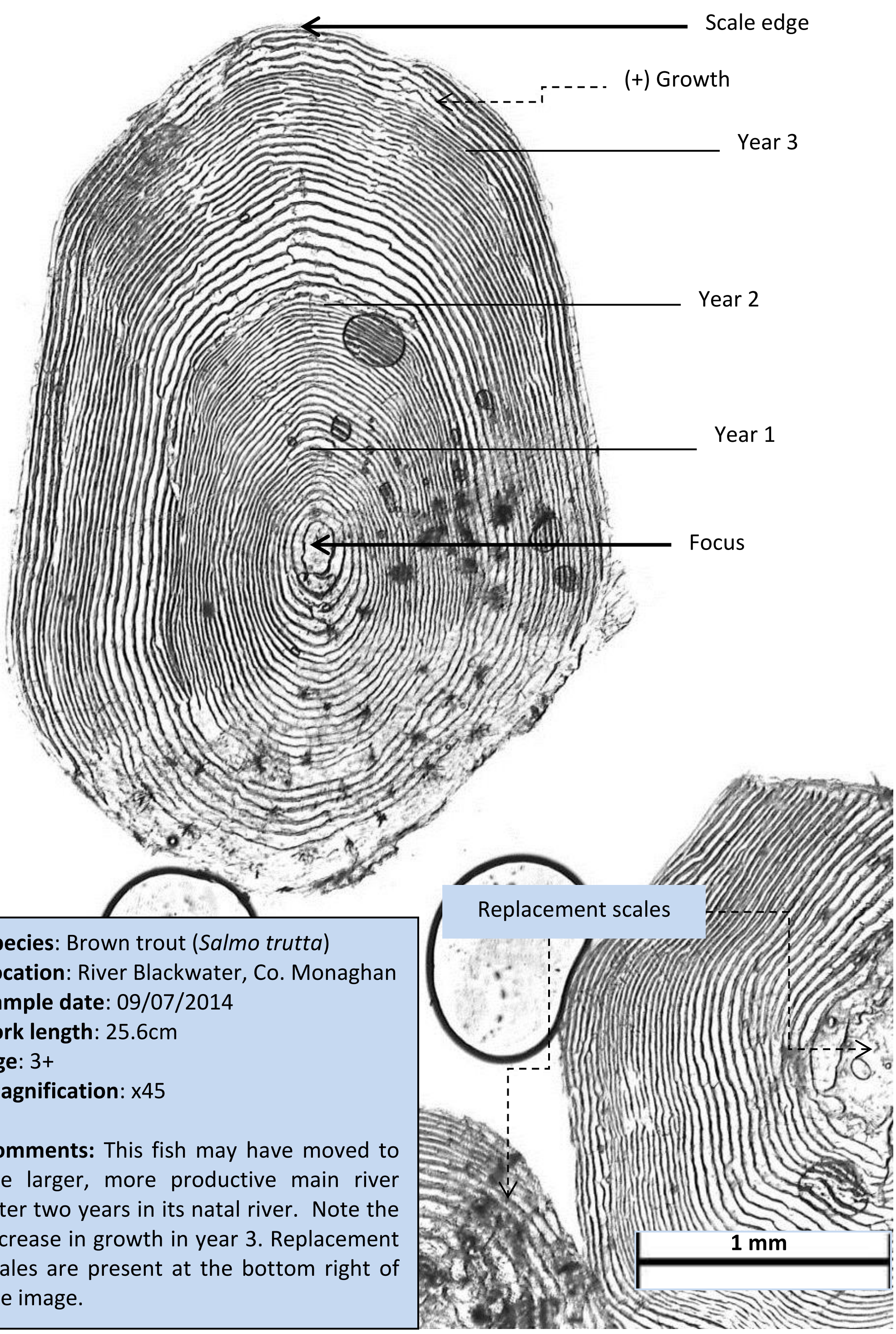


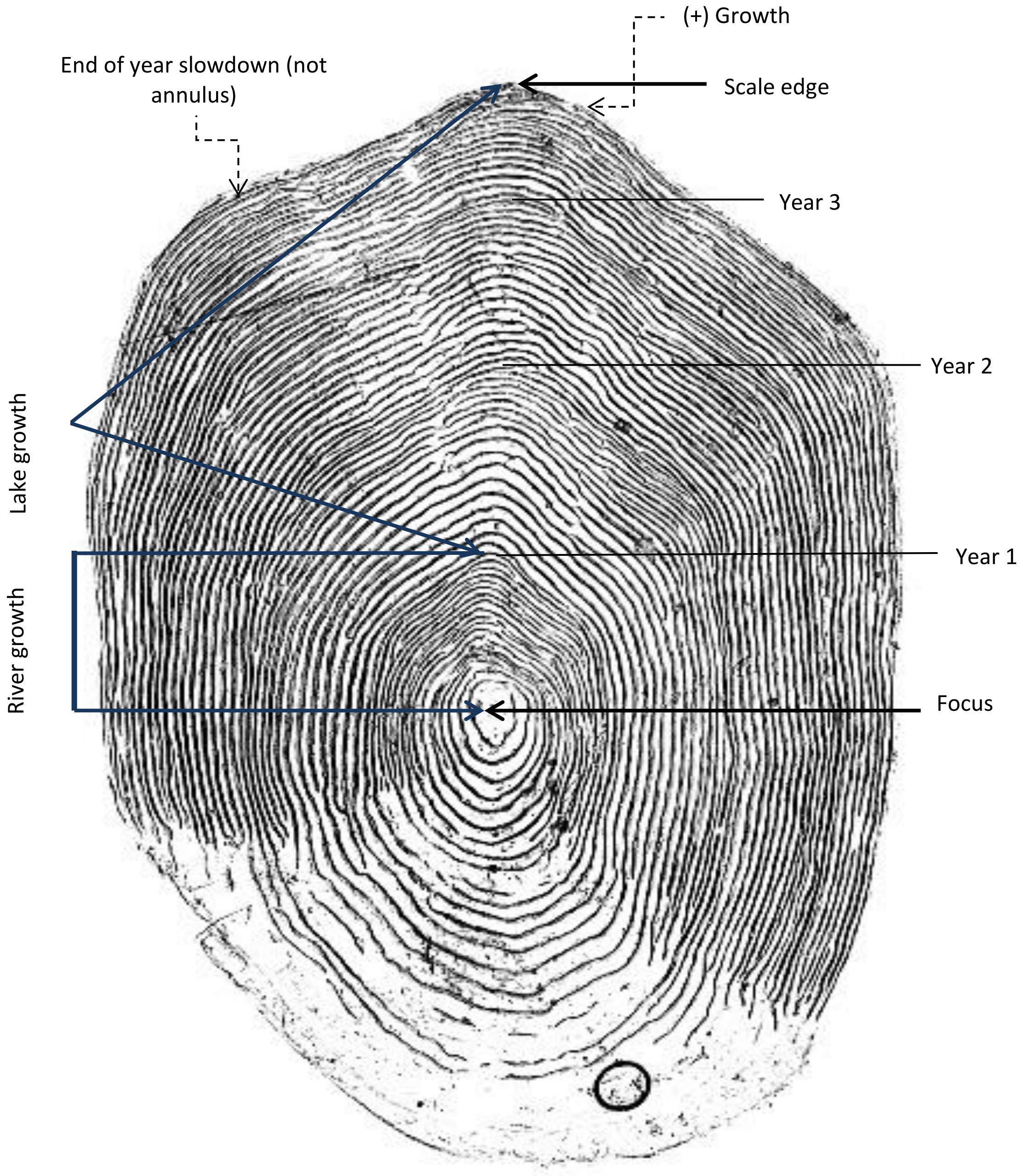
Plate No: 7



Species: Brown trout (*Salmo trutta*)
Location: River Blackwater, Co. Monaghan
Sample date: 09/07/2014
Fork length: 25.6cm
Age: 3+
Magnification: x45

Comments: This fish may have moved to the larger, more productive main river after two years in its natal river. Note the increase in growth in year 3. Replacement scales are present at the bottom right of the image.

Plate No. 8



Species: Brown trout (*Salmo trutta)*
Location: Kylemore Lough, County Galway
Sample date: 21/08/2013
Fork length: 24cm
Age: 3+
Magnification: x 45

Comments: Evidence of a slowdown in growth at the outer end of the scale in year 3 (fish was captured in late August 2013).

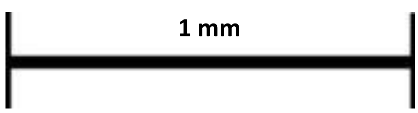
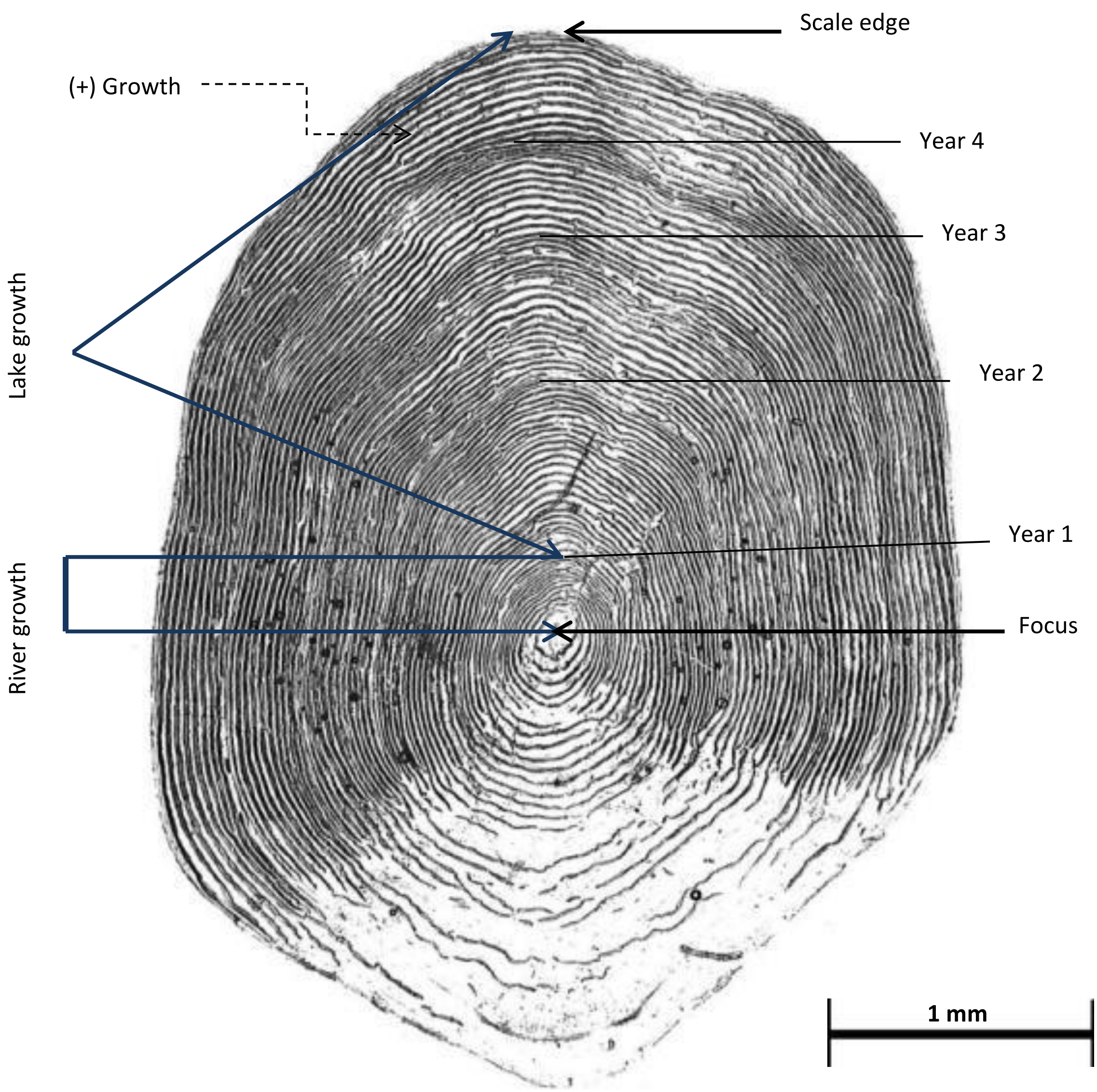


Plate No: 9



Species: Brown trout (*Salmo trutta*)
Location: Lough Ennell, Co. Westmeath
Sample date: 20/09/2017
Fork length: 37.1cm
Weight: 600g
Age: 4+
Magnification: x 32

Comments: A notable increase in growth after year 1 suggests an entry to a more productive lake environment.

Plate No: 10

Species: Brown trout (*Salmo trutta*)
Location: Lough Gara, County Sligo
Sample date: 04/09/2015
Fork length: 47cm
Weight: 1.55kg
Age: 6+
Magnification: x40

Comments: An example of where to avoid back-calculation. As described in Section 6.1.3, age can be underestimated when spawning marks/erosion occurs, particularly in salmonids. This fish could be aged as 5+ with year 4 and 5 counted as one annulus. Note how year 4 and 5 merge on the dorso and ventral edges of the scale due to this cutting over of circuli.

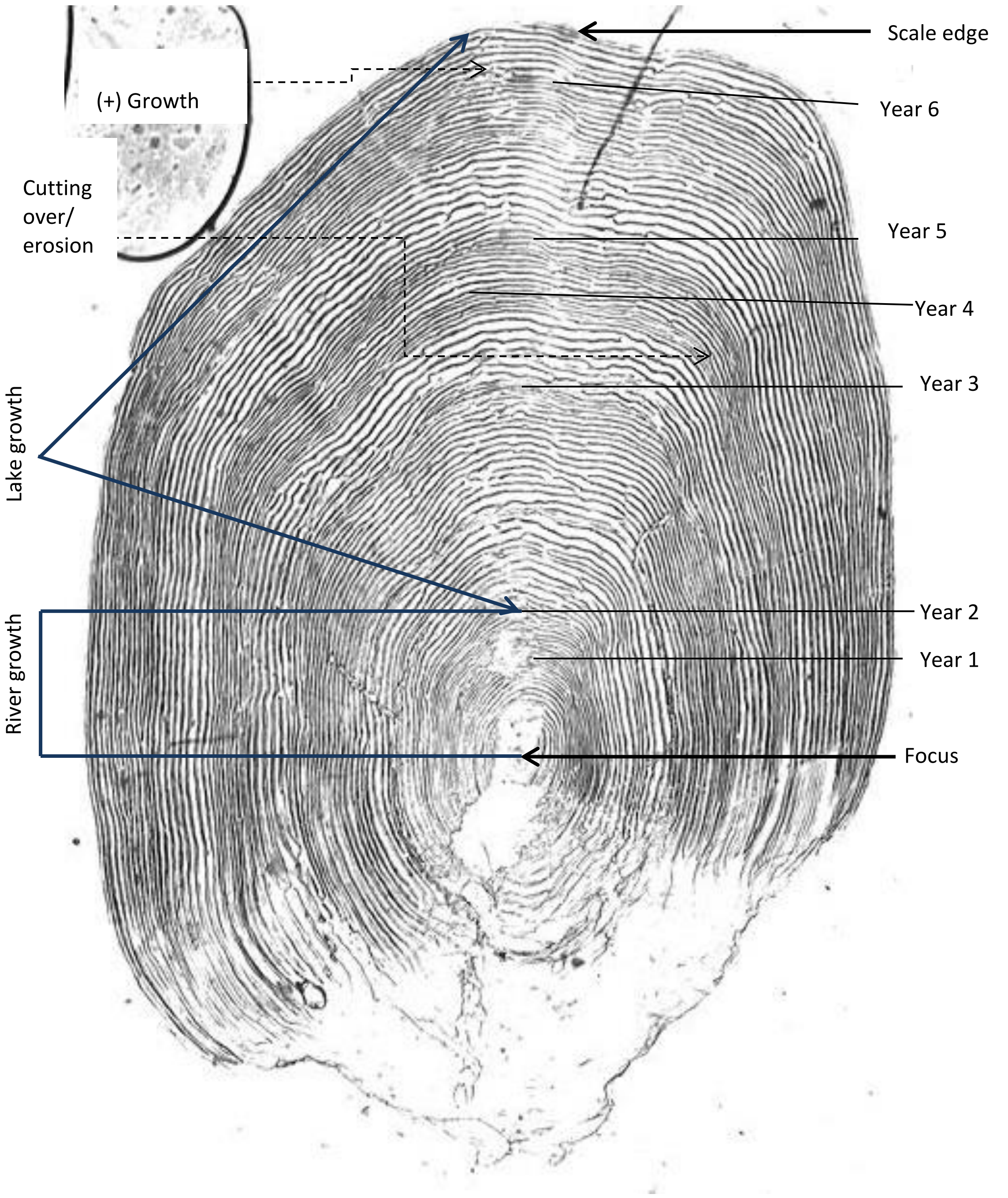
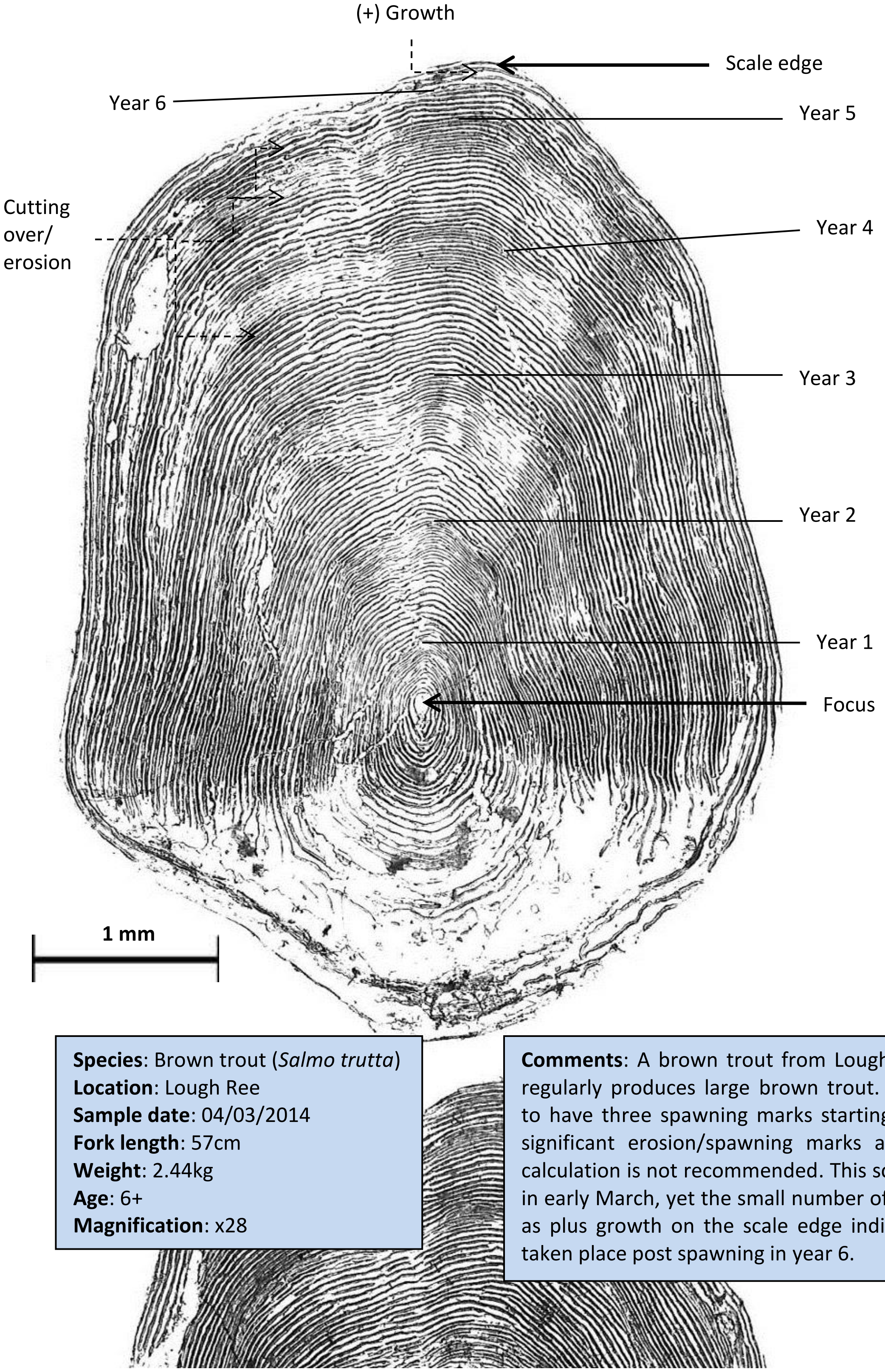


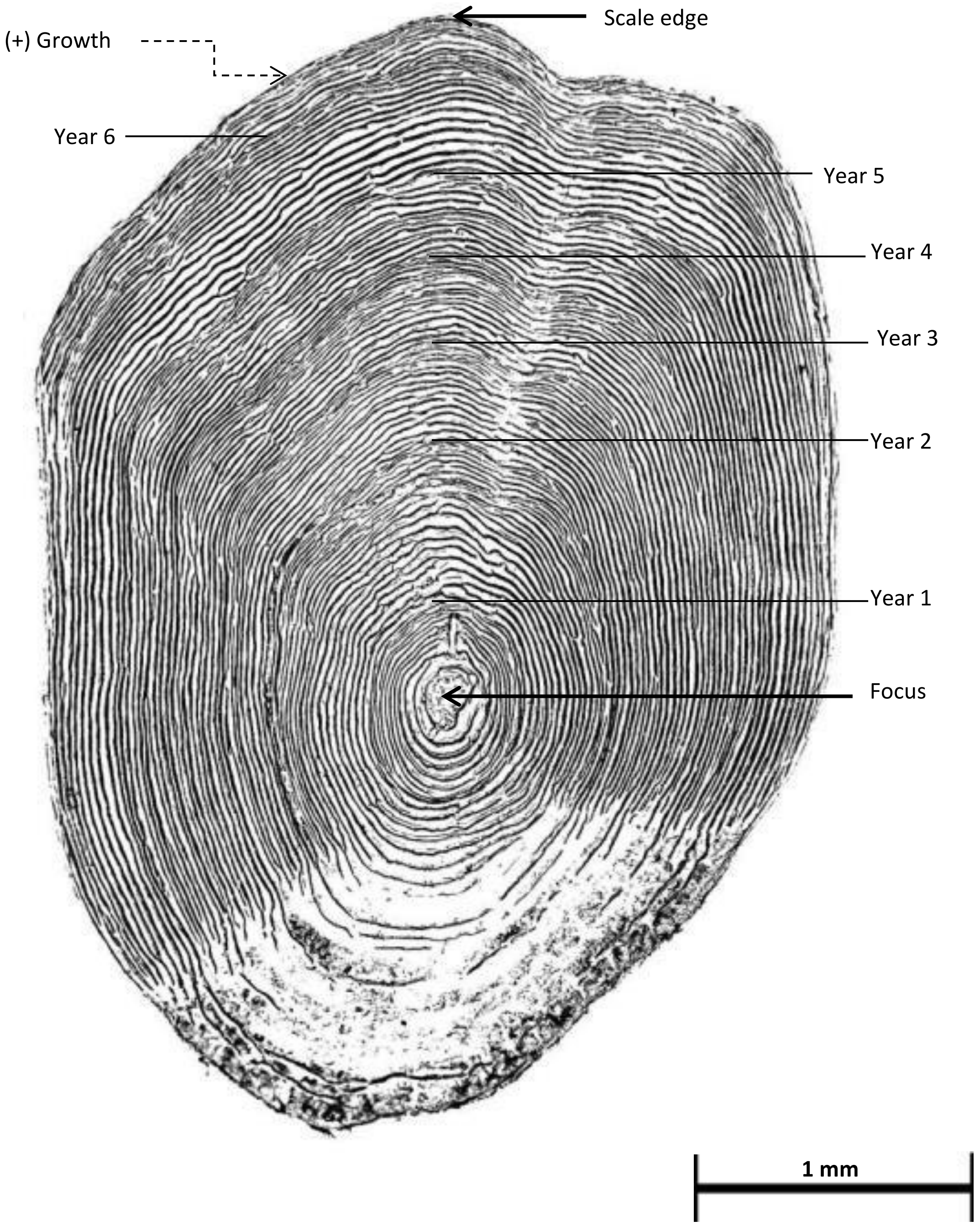
Plate No: 11



Species: Brown trout (*Salmo trutta*)
Location: Lough Ree
Sample date: 04/03/2014
Fork length: 57cm
Weight: 2.44kg
Age: 6+
Magnification: x28

Comments: A brown trout from Lough Ree, a lake that regularly produces large brown trout. This fish appears to have three spawning marks starting in year four. As significant erosion/spawning marks are present, back calculation is not recommended. This scale was recorded in early March, yet the small number of circuli presented as plus growth on the scale edge indicates growth has taken place post spawning in year 6.

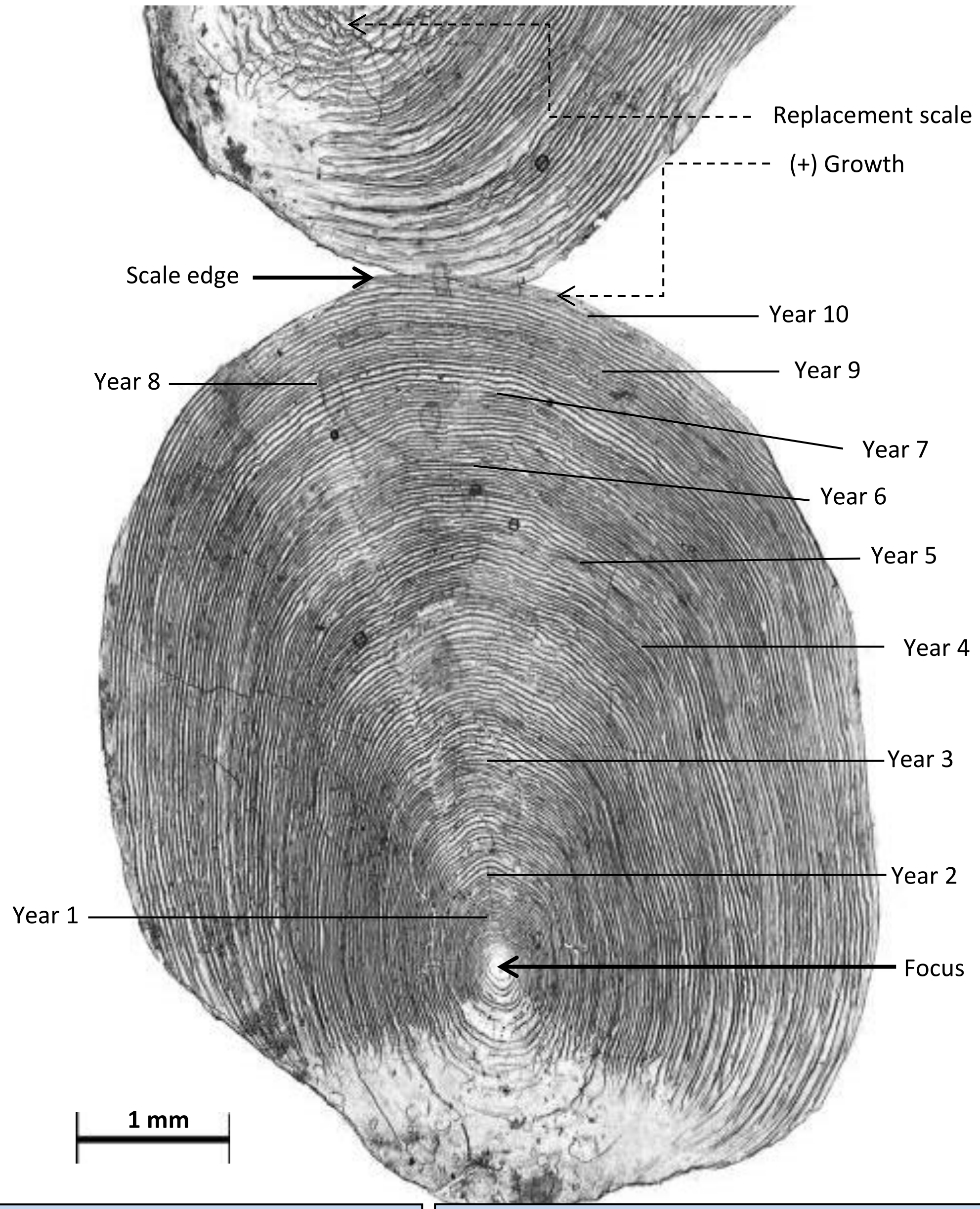
Plate No: 12



Species: Brown trout (Ferox) (*Salmo trutta*)
Location: Lough Melvin
Sample date: 19/07/2017
Fork length: 36.1cm
Age: 6+
Magnification: x50

Comments: A Ferox brown trout from Lough Melvin. Ferox have been shown to be genetically distinct from other brown trout populations in Lough Melvin (Ferguson and Taggart, 1991). While this fish displays a clear and steady growth pattern, a slow growth rate can be observed.

Plate No: 13



Species: Brown trout (Ferox) (*Salmo trutta*)
Location: Lough Corrib
Sample date: 17/08/2000
Fork length: est. 85cm
Weight: 7966g (17lb 9oz)
Age: 10+
Magnification: x30

Comments: A ferox brown trout from Lough Corrib. Scales were recorded as part of an IFI project investigating ferox populations in Lough Corrib. Subsequent telemetry studies revealed that these unique fish are vulnerable to exploitation due to their relatively small populations and reliance on a limited number of spawning locations. Since 2008 measures have been implemented to protect spawning and post-spawning populations of ferox in Lough Corrib and Lough Mask. This fish displays fast growth rate in years 3 and 4 but has maintained its growth at a slower rate in later years. A replacement scale is present in upper part of the image. As significant erosion/spawning marks are present, back calculation is not recommended. Thanks to Paddy Gargan (IFI) for the ageing of this fish.

4.2 Sea trout (Salmo trutta)

4.2.1 Identifying features

Adult fish: eyes are above the level of a horizontal line through the tip of the snout; the "wrist" of the tail does not narrow in and then expand again as distinctly as in the salmon; fresh-run sea trout are blue or green and silver with small, x-shaped black spots; sea run fish which have been in fresh water for a long period will become dark and heavily spotted like brown trout (fisheriesireland.ie).

4.2.2 Distribution and biological information

Sea trout are the anadromous variation of the species *Salmo trutta*. The parr of sea trout smoltifies and migrates to the estuary or to the sea and remains there to develop or grow. After a period, from less than one year to several years, the adult fish returns to freshwater (Elliott *et al*., 1994).

Plate 4.2: Sea trout (*Salmo trutta*) (source IFI)

Table 4.3: Sea trout life stages (I-VI) with ageing examples (from ICES, 2011)

I.	**Fry and Parr**: See brown trout (Table 4.1, Plates No. 1-3).
II.	**Smolts**: This life stage describes the downstream migration and adjustment for living at sea. Sea trout smolts typically run to sea from March to June each year. The transition from parr to smolt is known as smoltification. The most common age recorded in Irish smolts is 2+. In productive rivers large 1+ parr will smoltify and in less productive rivers smolts have been recorded as old as 4 years.
III.	**Finnock**: Finnock migrate; spend a short period (3-5 months) at sea, before returning to freshwater within the same year (see Fig. 4.1, Plates No. 14-16). Varying between regions, finnock may mature and spawn in their year of first return from the sea or return to sea without spawning and mature in a subsequent year.
IV.	**Maiden**: Maidens migrate and spend an entire year at sea before returning to freshwater (see Plates No. 17-18).
V.	**Multi sea-winter maiden**: Multi sea-winter maiden (MSW) sea trout are fish which remained at sea for the duration of two winters or more before migrating to freshwater. A rare occurrence but has been observed on some large sea trout on the east coast of Ireland.

VI.	**Multi spawners**: A smaller proportion of sea trout stocks are often multiple spawners that migrate back to sea after spawning on several occasions. Multi-spawners are commonly larger fish (>45cm). Large sea trout have been documented to complete the yearly cycle of spawning and sea migration up to ten times in their lifetime (see Plate No. 20).

4.2.3 Ageing notes

Shearer (1992) described the following as the standard for notating anadromous salmonids.

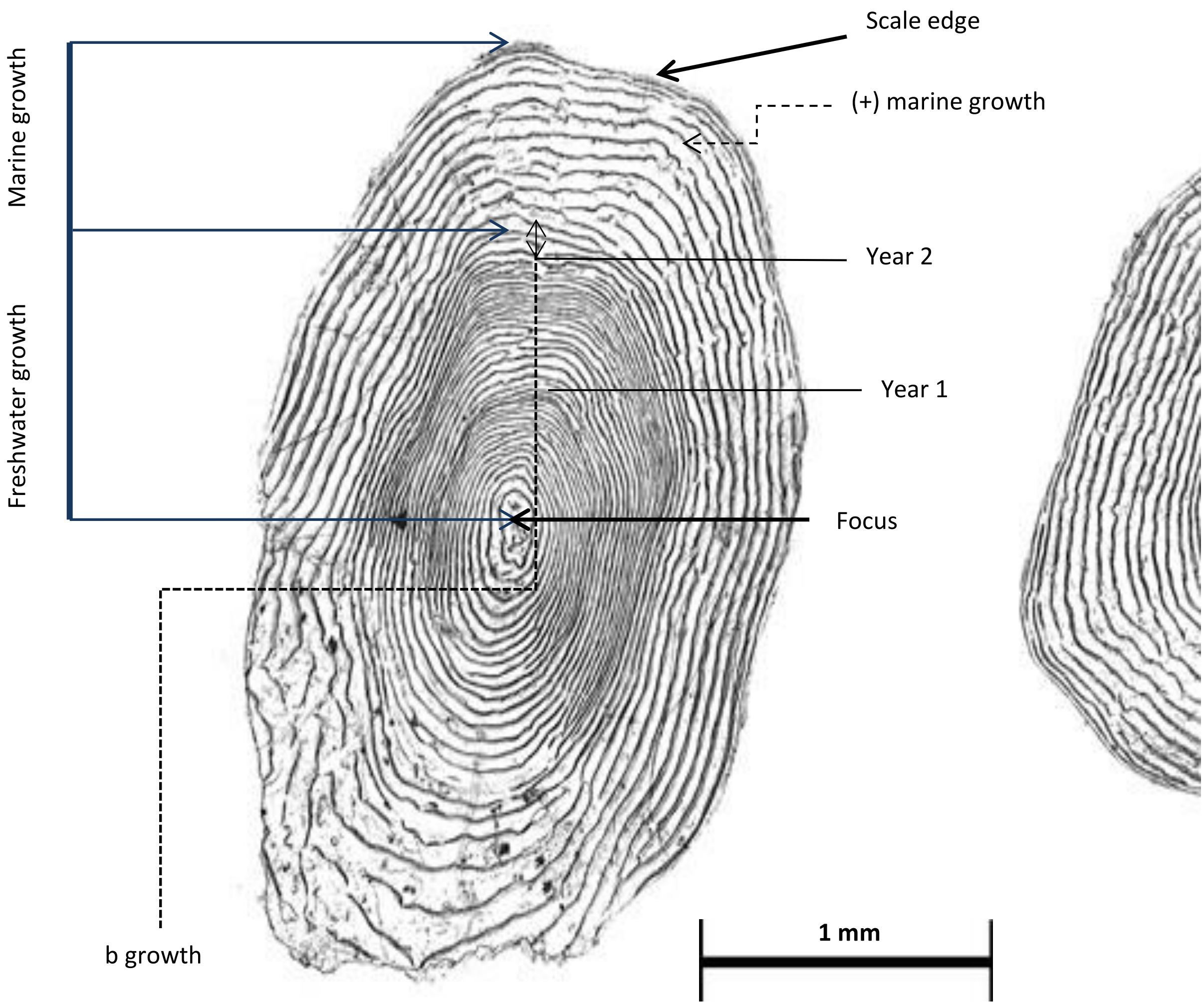
Table 4.4: Ageing notation order (1-3) for the ageing of anadromous salmonids

1.	A single digit (e.g. 2) indicates freshwater age prior to smolting followed by a decimal point (.) which separates marine and freshwater growth (e.g. 2.).
2.	Following this decimal point, a number to illustrate life history is added. This can vary from less than a year's growth (e.g. .0+ for finnock)/ one sea winter maidens (e.g. .1+) / one year spawners (e.g. .1sm)/ multiyear spawners (e.g. .2sm) and upwards).
3.	A plus (+) is added at the end of the notation to describe the current year's growth (see Table 6.3).

4.2.4 Additional information (anadromous salmonid scales)

Recording fish colour/condition of anadromous salmonids at time of capture can be informative. Recently returned fish (immature or maturing adults) typically show no narrowing circuli at the scale edge. In contrast a stale fish may begin to show narrowing of the circuli at the edge of the scale. This would indicate a lack of feeding in anadromous fish residing in the freshwater environment for an extended period of time, and/or a switch from feeding to gonad development prior to spawning. Although not calibrated, these observations will contribute to interpretation.

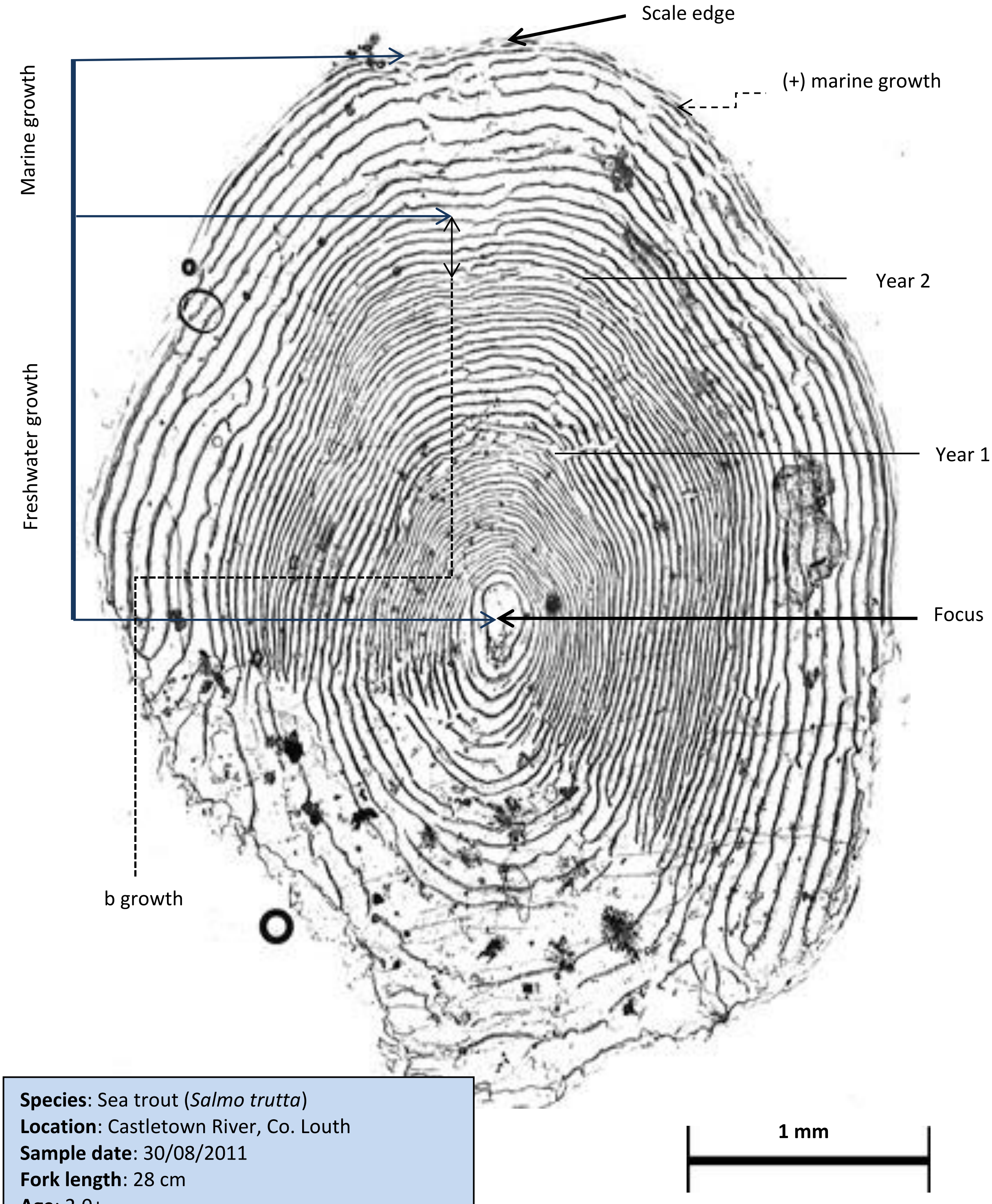
Plate No: 14



Species: Sea trout (*Salmo trutta*)
Location: River Vartry, Co. Wicklow
Sample date: 29/08/2011
Fork length: 28 cm
Age: 2.0+
Magnification: x 32

Comments: Two year old finnock (see Table 6.3). Two years of freshwater growth. Following year 2 smolt migrates to sea to feed for less than 1 year before returning to the river. b growth also present (see Section 5.0).

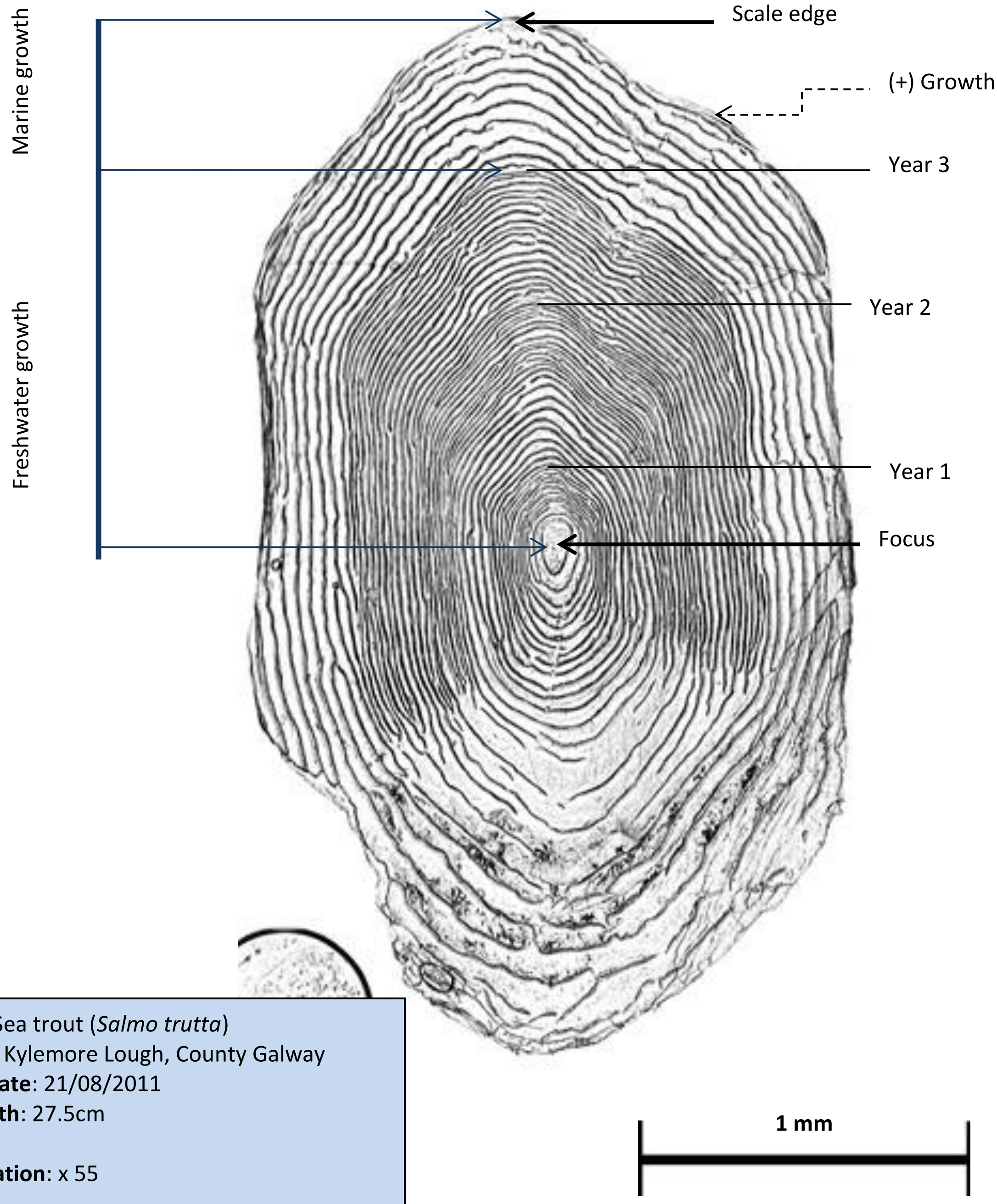
Plate No: 15



Species: Sea trout (*Salmo trutta*)
Location: Castletown River, Co. Louth
Sample date: 30/08/2011
Fork length: 28 cm
Age: 2.0+
Magnification: x 45

Comments: Two year old finnock (see Table 6.3). b growth present and highlighted (see Section 5.0).

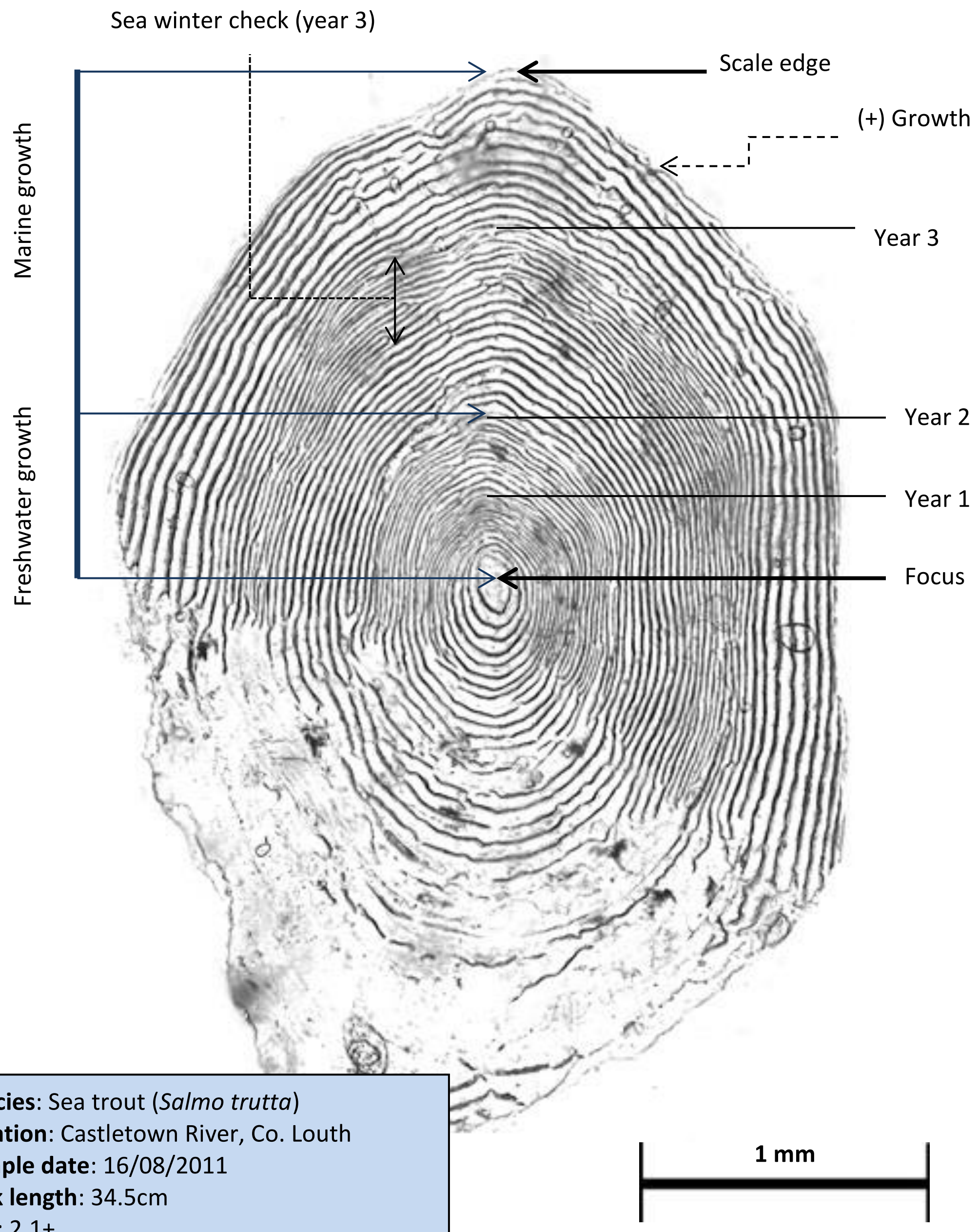
Plate No: 16



Species: Sea trout (*Salmo trutta*)
Location: Kylemore Lough, County Galway
Sample date: 21/08/2011
Fork length: 27.5cm
Age: 3.0+
Magnification: x 55

Comments: A three year old finnock (see Table 4.3). The transition to the marine environment at the end of year 3 is clearly defined.

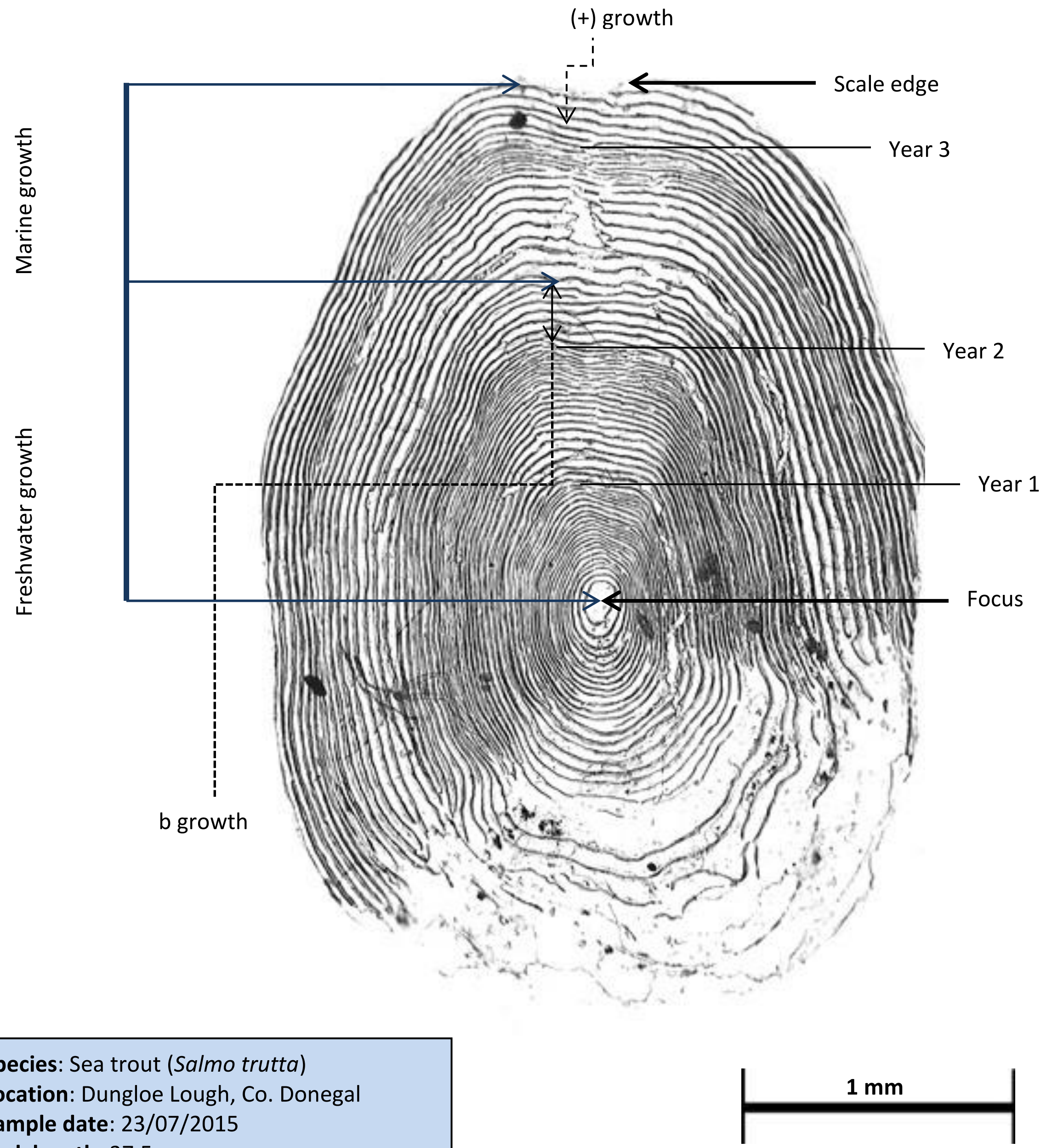
Plate No: 17



Species: Sea trout (*Salmo trutta*)
Location: Castletown River, Co. Louth
Sample date: 16/08/2011
Fork length: 34.5cm
Age: 2.1+
Magnification: x 45

Comments: One sea winter maiden (see Table 4.3). This fish has spent an entire year at sea before returning the following year. Maidens are predominantly larger than finnock with specimens generally greater than 30cm in length, a benefit of a full years feeding at sea. Total age is 3+ years.

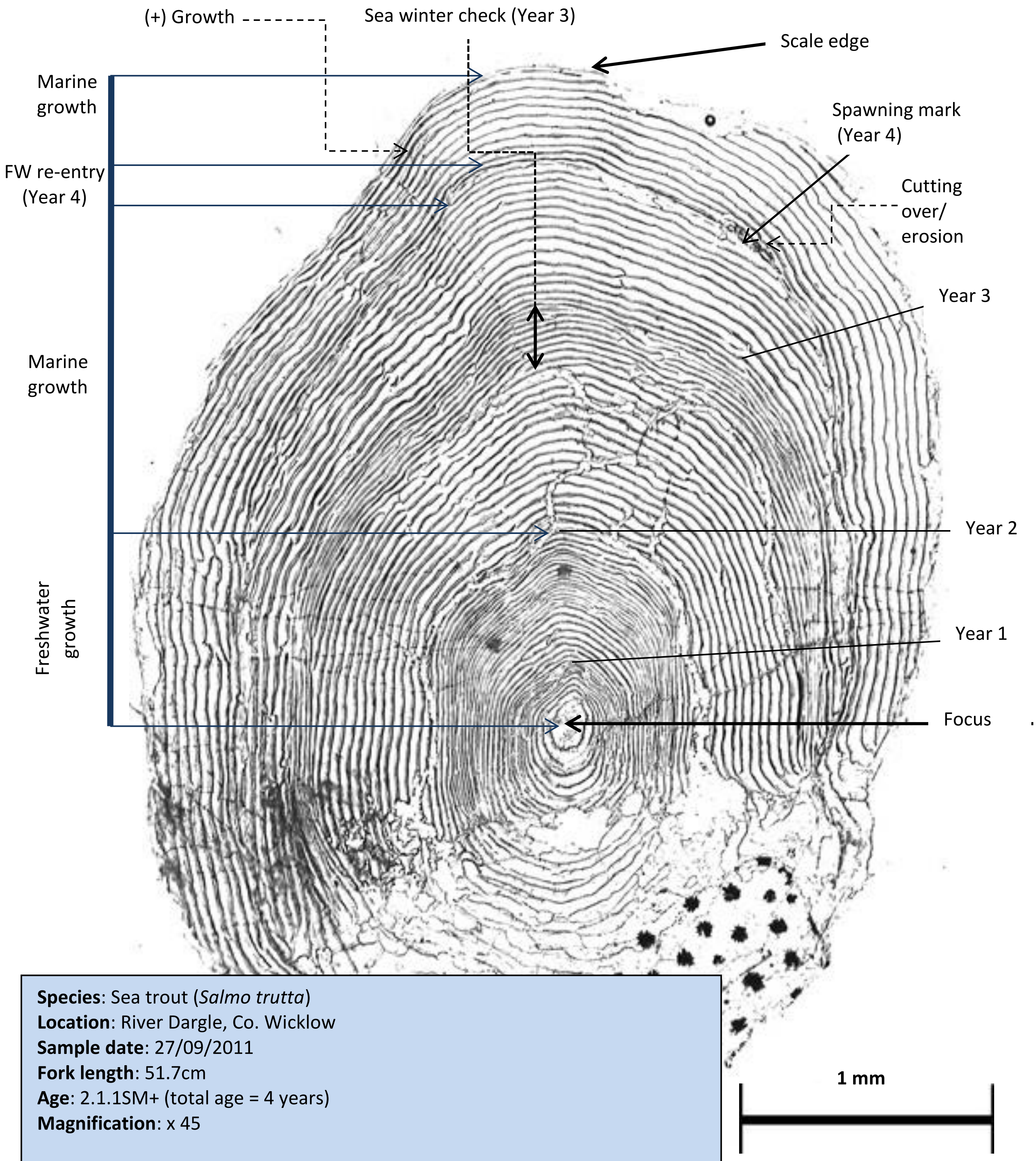
Plate No: 18



Species: Sea trout (*Salmo trutta*)
Location: Dungloe Lough, Co. Donegal
Sample date: 23/07/2015
Fork length: 37.5cm
Age: 2.1+
Magnification: x 45

Comments: One sea winter maiden (see Table 4.3). b growth also present (see Section 5.0).

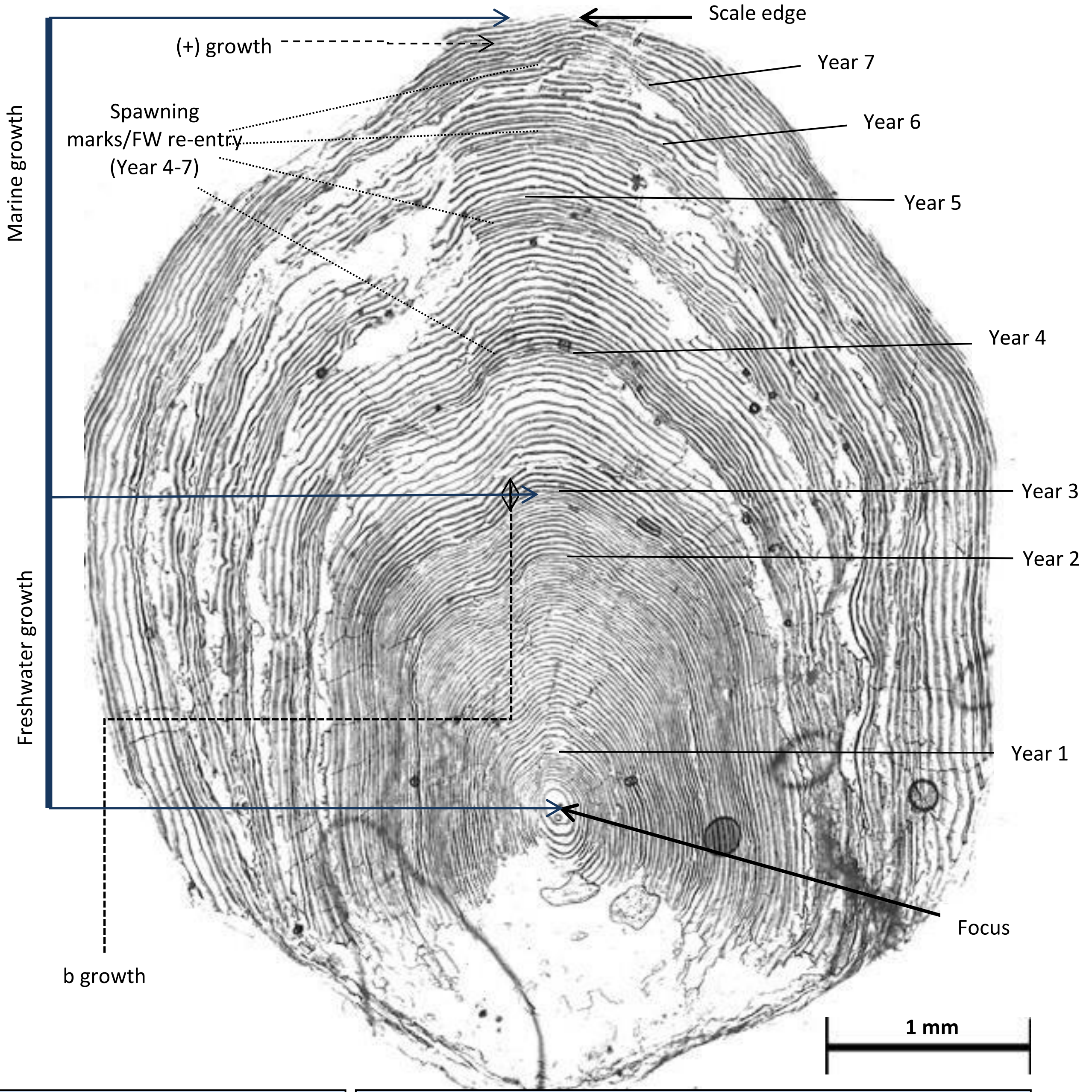
Plate No: 19



Species: Sea trout (*Salmo trutta*)
Location: River Dargle, Co. Wicklow
Sample date: 27/09/2011
Fork length: 51.7cm
Age: 2.1.1SM+ (total age = 4 years)
Magnification: x 45

Comments: The River Dargle in Co. Wicklow has some of the largest sea trout in Ireland. This fish resided in the river for 2 years. After smoltifying, the fish spent a full year at sea (year 3) before returning to spawn (SM) in year 4. There is evidence of "cutting over" and significant loss of circuli in year 4, an indication of spawning (see Section 5.0). The scale was recorded from this fish in September of the following year (+) during its return to freshwater.

Plate No: 20



Species: Sea trout (*Salmo trutta)*
Location: Lough Currane, Co. Kerry
Sample date: 19/07/2010
Fork length: 71cm
Age: 3.4SM+ (total age = 7 years)
Magnification: x32

Comments: Lough Currane in Co. Kerry is one of the premier sea trout fisheries in Ireland. Specimen sea trout are regularly captured in this venue. The Currane system produces large smolts up to 25-26cm (*Fahy, 1980;* Roche, W. 2018 *pers. comm.*). Juvenile trout benefit from migrating from unproductive tributaries to the lake, which leads to faster growth rates prior to smoltification. This fish spent 3 years in freshwater. It appears to have entered Lough Currane in Year 2 (note the dramatic increase in growth in year 2). Following smoltification after year 3, it appears to have spawned as a finnock and continued this pattern of spawning each successive year. b growth is also shown in the image(see Section 5.0). Note the cutting over of the spawning marks (see Section 5.0). Therefore, this specimen is not suitable for accurate back calculations.

4.3 Atlantic salmon (Salmo salar)

4.3.1 Identifying features

Adult Atlantic salmon have a small head and blunt nose adult salmon are steel-blue and silver in colour when fresh (just returned to freshwater) (see Plate 4.3). The caudal peduncle, or "wrist" of the tail narrows in and then swells out again at the base of the tail-fin. At spawning time, the females are dull leaden coloured; the males, which develop a hook in the lower jaw, become mottled with red and orange (fisheriesireland.ie).

Plate 4.3: Atlantic salmon (*Salmo salar*) (source IFI)

4.3.2 Distribution and biological information

Atlantic salmon occur naturally along both east and west coasts of the North Atlantic Ocean (Klemetsen *et al*., 2003). The following table displays the different life stages of Atlantic salmon (*Salmo salar*).

Table 4.5: Life stages of Atlantic salmon (I-IV)

I.	**Fry and Parr**: Juvenile salmon display similar growth patterns to brown trout (see Plates No. 20-21).
II.	**Smolt**: Refer to sea trout (see Table 4.3). Irish Atlantic salmon migrate to sea in spring mostly as 2+ year old smolts. While some fisheries produce 1+ or 3+ year old smolts, all scales of adult Atlantic salmon displayed in this document are from fish which migrated as 2+ year old smolts.
III.	**Grilse** (adult salmon): A salmon that returns to freshwater after one full year at sea. This is the youngest and most common life-stage of the adult Atlantic salmon stock in Irish waters. The peak run for grilse is from late May to August. Grilse are aged as X.1+ (X = age of smolt).

IV.	**Multi sea winter** (adult MSW salmon): MSW salmon are fish which remained at sea for the duration of two or more winters, before migrating to freshwater (see Plates No. 23-24). These fish often return in the early part of the season hence they are commonly known as a "springers". However, these large fish can also return to freshwater later in the year, with runs in summer and at the back end of the season also occurring in some systems.

4.3.3 Ageing notes

Unlike brown trout, adult Atlantic salmon life history always comprises time spent in the marine environment. While ageing notations are the same as sea trout (see Table 4.4), there are few notable differences when assigning an age to Atlantic salmon (see Table 4.6).

Table 4.6: Ageing notes for Atlantic salmon

•	Marine growth notations same as sea trout (see Table 4.4)
•	Marine growth in adult Atlantic salmon is notated as .1+ and upwards (see Plates No. 23-25). It is highly unlikely that 0+ occurs in adult Atlantic salmon
•	Summer checks: The first sea-annulus occurs between 40 and 60 cm estimated by a linear back calculation. When there is doubt about the identification of the first sea-winter band, any band occurring at a back-calculated length of less than 35cm is assumed to be a summer check and NOT an annulus (ICES, 1984) (see Fig. 4.1, Plate No. 24)

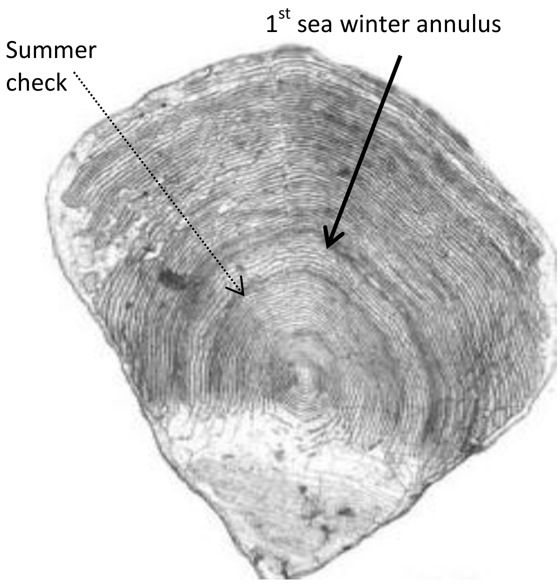
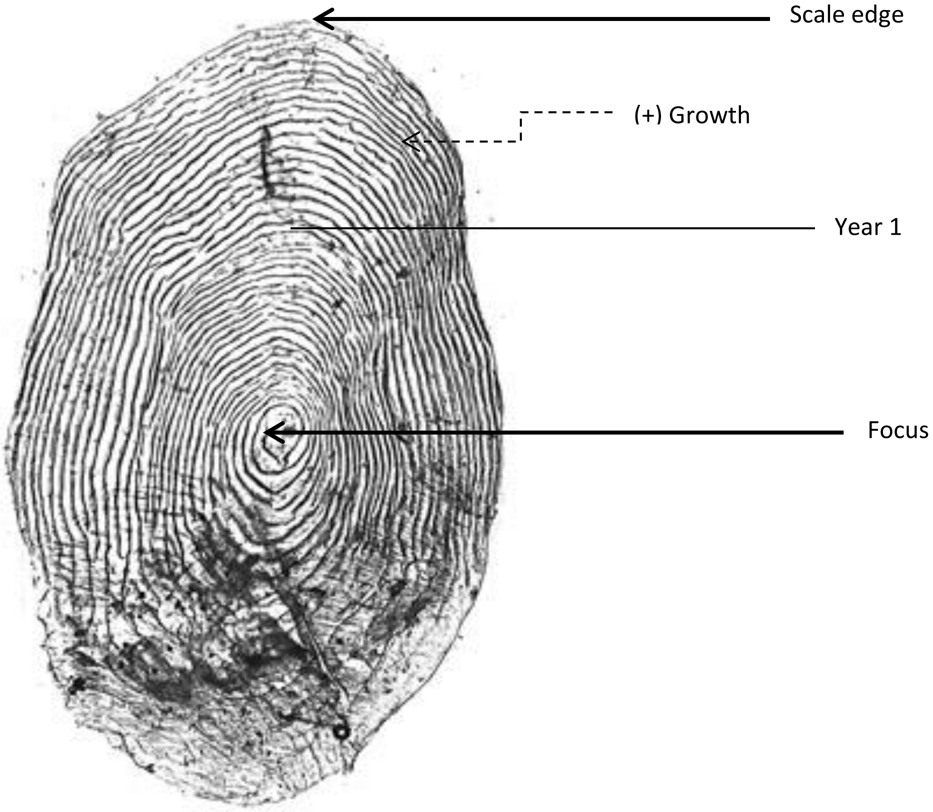


Fig. 4.1: Example of a summer check vs. a true annulus on an adult Atlantic salmon (*Salmo salar*) (source IFI)

4.3.4 Additional information (anadromous salmonid scales)

Refer to sea trout: Section 4.2.4

Plate No. 21



Species: Atlantic salmon (*Salmo salar)*
Location: Kylemore Lough, County Galway
Sample date: 21/08/2013
Fork length: 12.0 cm
Age: 1+
Magnification: x 55

Comments: 1 year old salmon parr (see Table 6.1).

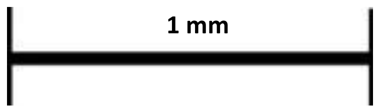
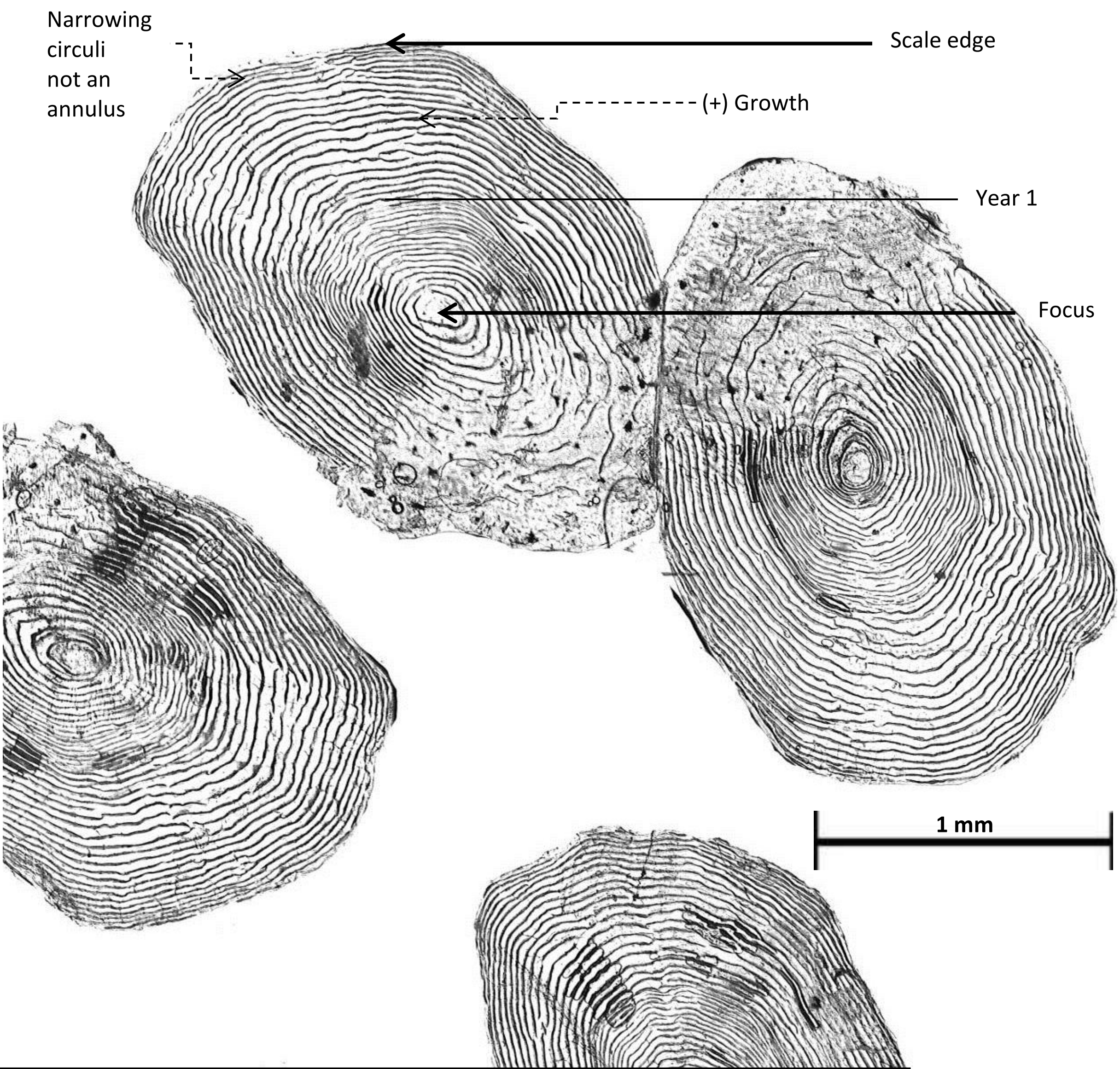


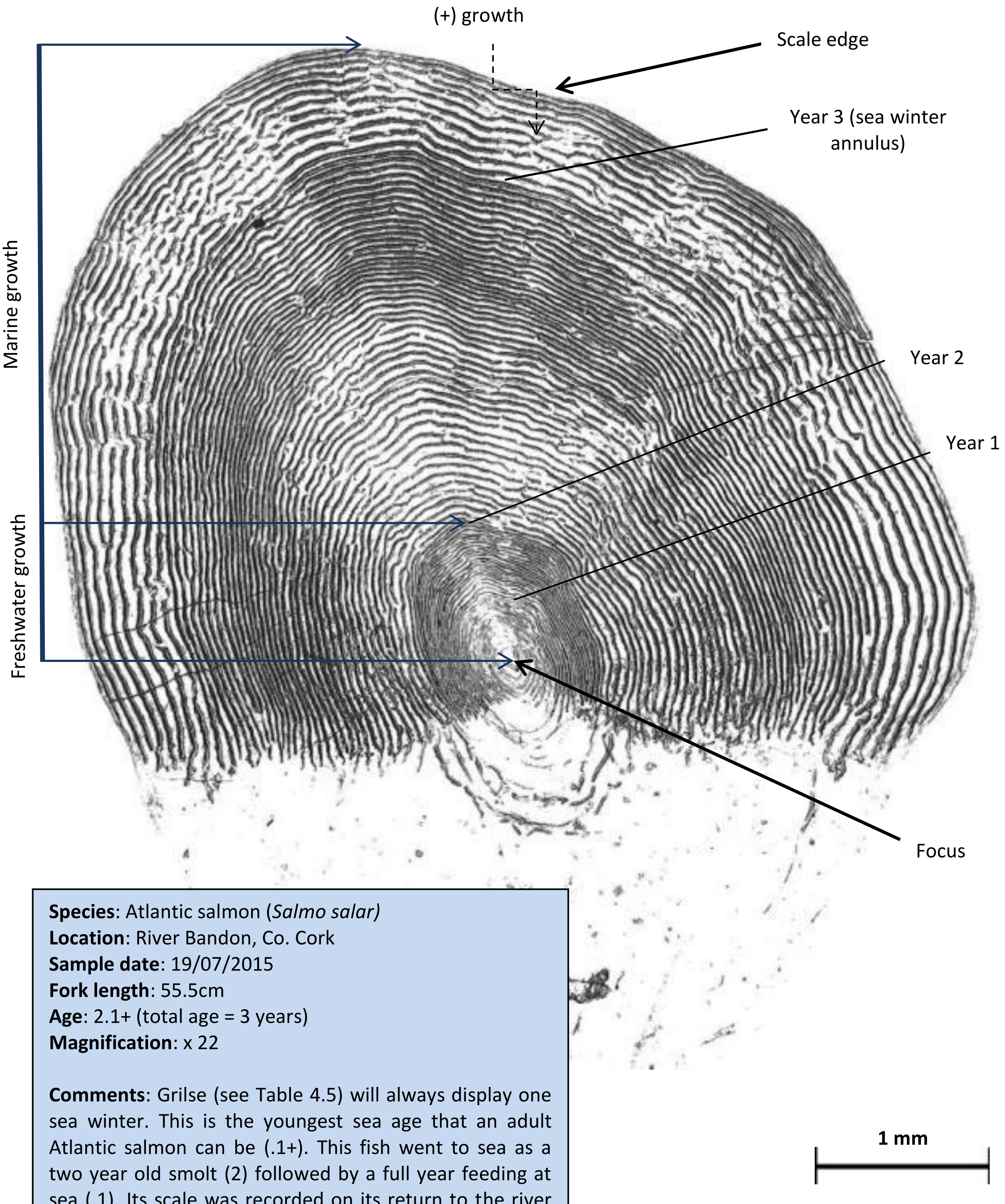
Plate No. 22



Species: Atlantic salmon (*Salmo salar)*
Location: Vartry River, Co. Wicklow
Sample date: 12/08/2014
Fork length: 14.9 cm
Weight: 44g
Age: 1+
Magnification: x 55

Comments: 1 year old salmon parr (See Table 4.1). Capture date was mid-August 2014. Note narrowing circuli beginning to appear at scale edge. This is not an annulus, only a slowdown of growth in the same year.

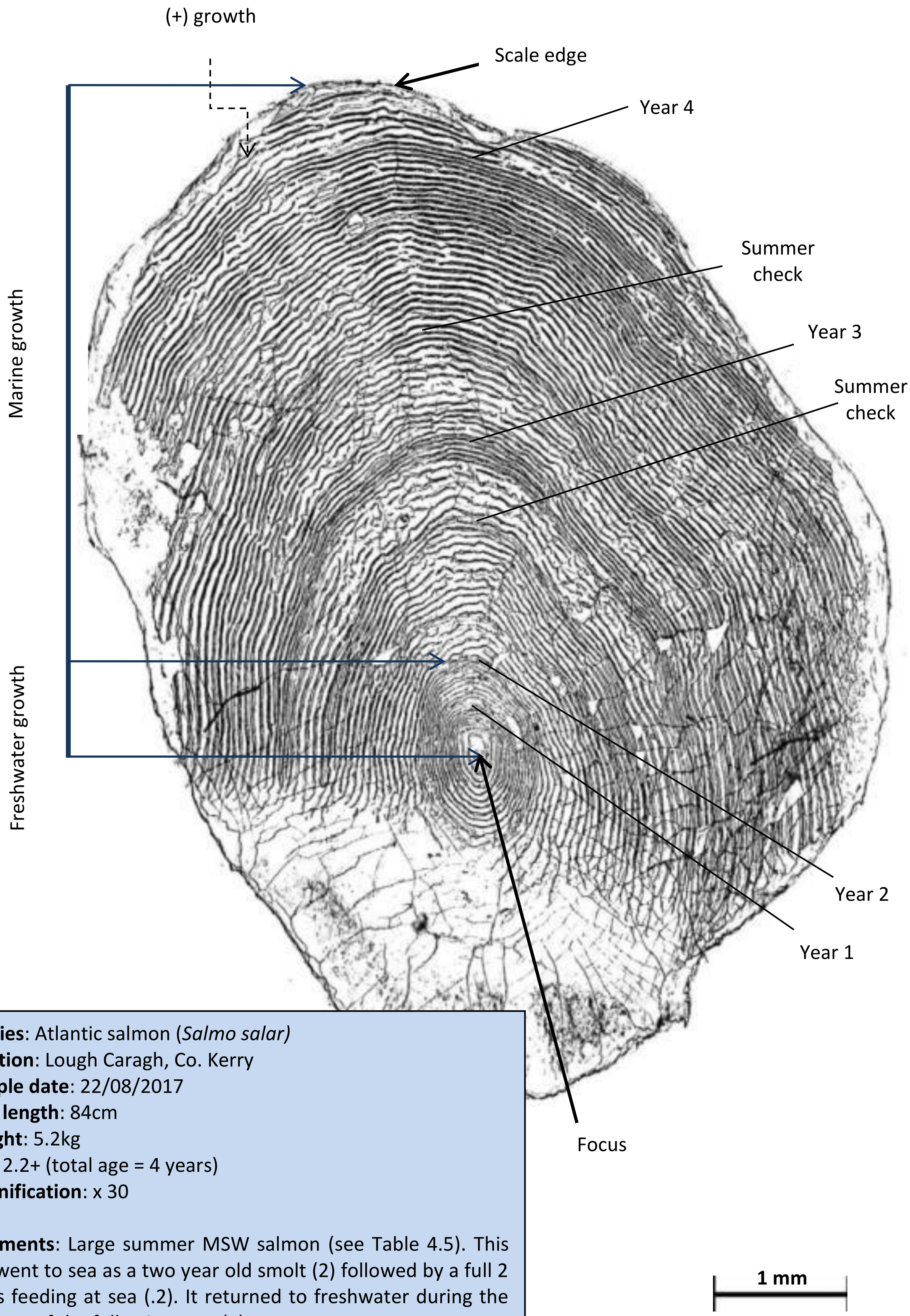
Plate No: 23



Species: Atlantic salmon (*Salmo salar)*
Location: River Bandon, Co. Cork
Sample date: 19/07/2015
Fork length: 55.5cm
Age: 2.1+ (total age = 3 years)
Magnification: x 22

Comments: Grilse (see Table 4.5) will always display one sea winter. This is the youngest sea age that an adult Atlantic salmon can be (.1+). This fish went to sea as a two year old smolt (2) followed by a full year feeding at sea (.1). Its scale was recorded on its return to the river the following year (+).

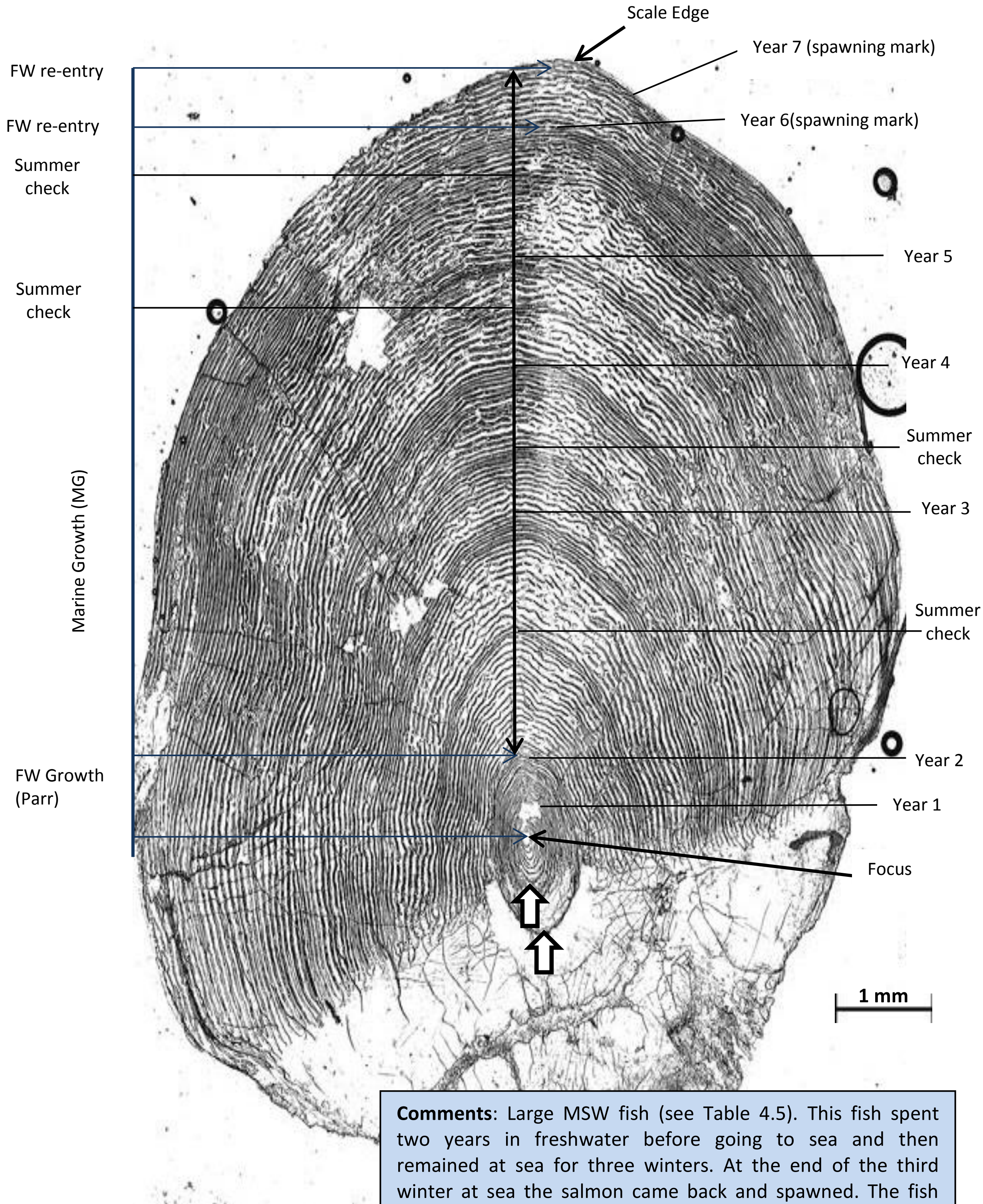
Plate No. 24



Species: Atlantic salmon (*Salmo salar)*
Location: Lough Caragh, Co. Kerry
Sample date: 22/08/2017
Fork length: 84cm
Weight: 5.2kg
Age: 2.2+ (total age = 4 years)
Magnification: x 30

Comments: Large summer MSW salmon (see Table 4.5). This fish went to sea as a two year old smolt (2) followed by a full 2 years feeding at sea (.2). It returned to freshwater during the summer of the following year (+).

Plate No. 25



Species: Atlantic salmon (*Salmo salar)*
Location: River Suir, Co. Waterford
Sample date: Found early February 2013 (Post spawning mortality)
Fork length: 117cm
Age: Multi sea winter salmon (2.3+.2SM) (Total age =7 years)
Magnification: x 22

Comments: Large MSW fish (see Table 4.5). This fish spent two years in freshwater before going to sea and then remained at sea for three winters. At the end of the third winter at sea the salmon came back and spawned. The fish then went back to sea and remained for another winter before returning to spawn a second time. After spawning for a second time the fish was found dead in February along the River Suir. The age determination can be described as 2.3+2SM. There is no notated "+" growth as the fish was found dead post-spawning. The total age is 7 years. Thanks to Paddy Gargan (IFI) and to Peder Fiske and Gunnell Ostborg of the Norwegian Institute for Nature Research for ageing this fish.

4.4 Arctic char (Salvelinus alpinus)

4.4.1 Identifying features

Body shape is trout-like, coloration variable according to habitat, sex and breeding conditions; olive or blue-grey above (Plate 4.4), becoming lighter on the sides; some fish, especially breeding males, become red or orange on the belly and have the lower fins pink or red, with cream or white edges; Arctic char have pale spots on a dark ground, whereas trout and salmon have dark spots on a light background; in Irish waters, Arctic char grow to about 0.7kg but are often much smaller (fisheriesireland.ie).

4.4.2 Distribution and biological information

Historically, Arctic char have been recorded in 84 lakes in Ireland but, due to the stresses of pollution, eutrophication, acidification, climate change, invasive species etc., approximately one third of these populations are now deemed extinct (Igoe and Hammer, 2004; Ferguson *et al*., 2019). In more northerly latitudes, chars are anadromous in nature. Arctic char in Britain and Ireland do not migrate to sea. While most authorities agree that these stocks belong to a single polymorphic species complex, isolation between separate lake systems has led to the development of several phenotypic characteristics (Maitland *et al.*, 2007). An example of this in Ireland is in Lough Coomsaharn in County Kerry where Arctic char have a higher gill raker count than most other European populations (Igoe and Hammar, 2004).

Plate 4.4: Arctic char (*Salvelinus alpinus*) (source IFI)

4.4.3 Ageing notes

The following table describes some biological data useful for the ageing process of Arctic char.

Table 4.7: Ageing notes for Arctic char

i.	Otoliths contain the best permanent pattern of fish growth as bone reabsorption is not known to occur unlike scales (Barbour and Einarsson, 1987). When marking an annulus for an image, mark at outer edge of winter (dark) band (see Plates No. 26-28).
ii.	Arctic char scales can be extremely difficult to age. Due to their small size and erosion, ageing scales can often underestimate age. This is particularly apparent after year 3 (Morrissey, E. 2016 *pers. comm.*).
iii.	Arctic char scales are very useful for other scientific research programmes such as population genetics and microchemistry analysis.

Plate No: 26

Species: Arctic char (*Salvelinus alpinus*)
Location: Glen Lough, Co. Donegal
Sample date: 30/07/14
Fork length: 15.3cm
Weight: 40g
Age: 2+

Comments: Annuli marked on outer edge of dark lines following image settings (see Table 4.7, Table 2.4).

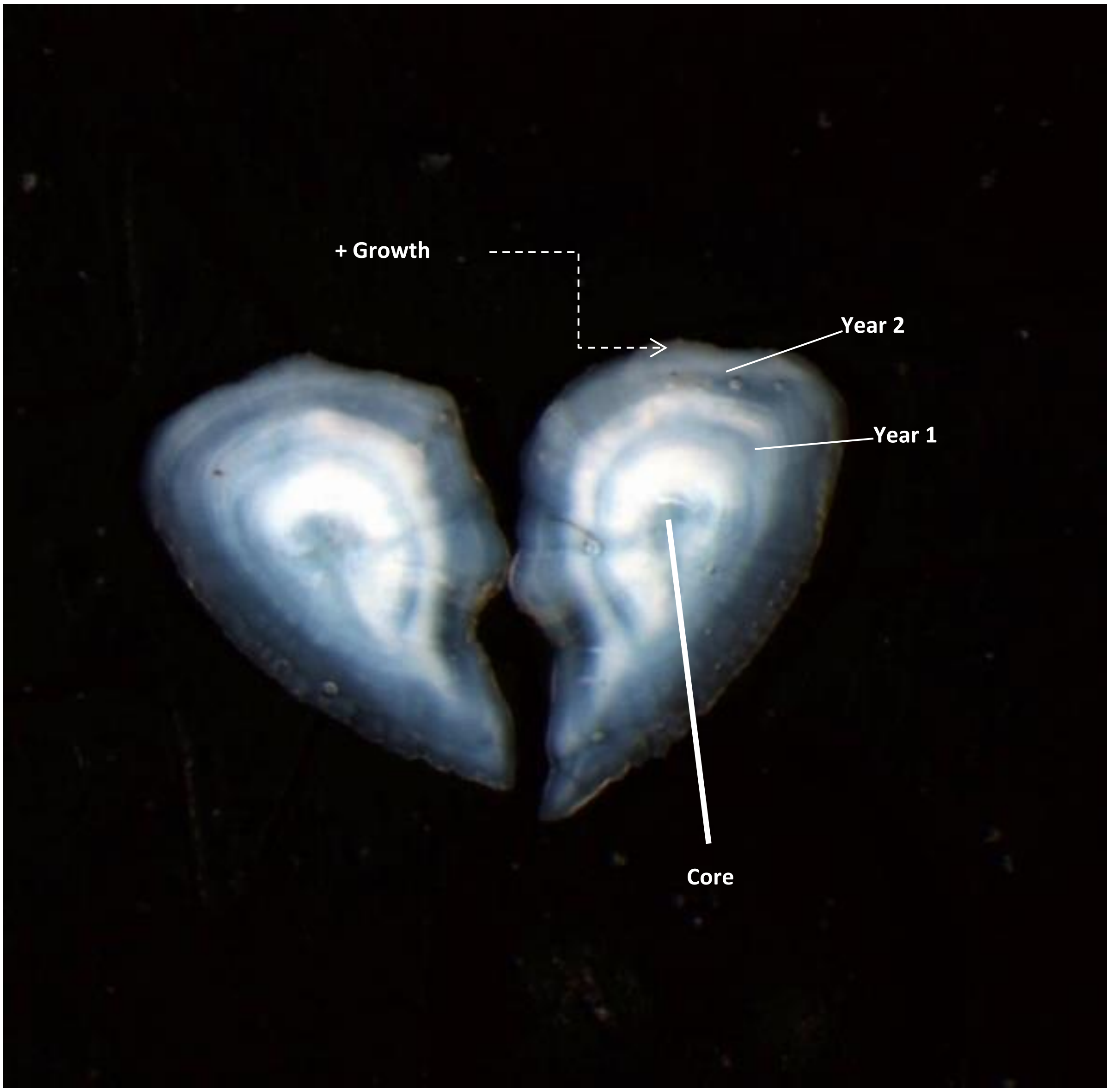


Plate No: 27

Species: Arctic char (*Salvelinus alpinus*)
Location: Shindilla Lough, Co. Galway
Sample date: 07/09/2010
Fork length: 20cm
Weight: 86g
Age: 3+

Comments: Annuli marked on outer edge of dark lines following image settings (see Table 4.7, Table 2.4).

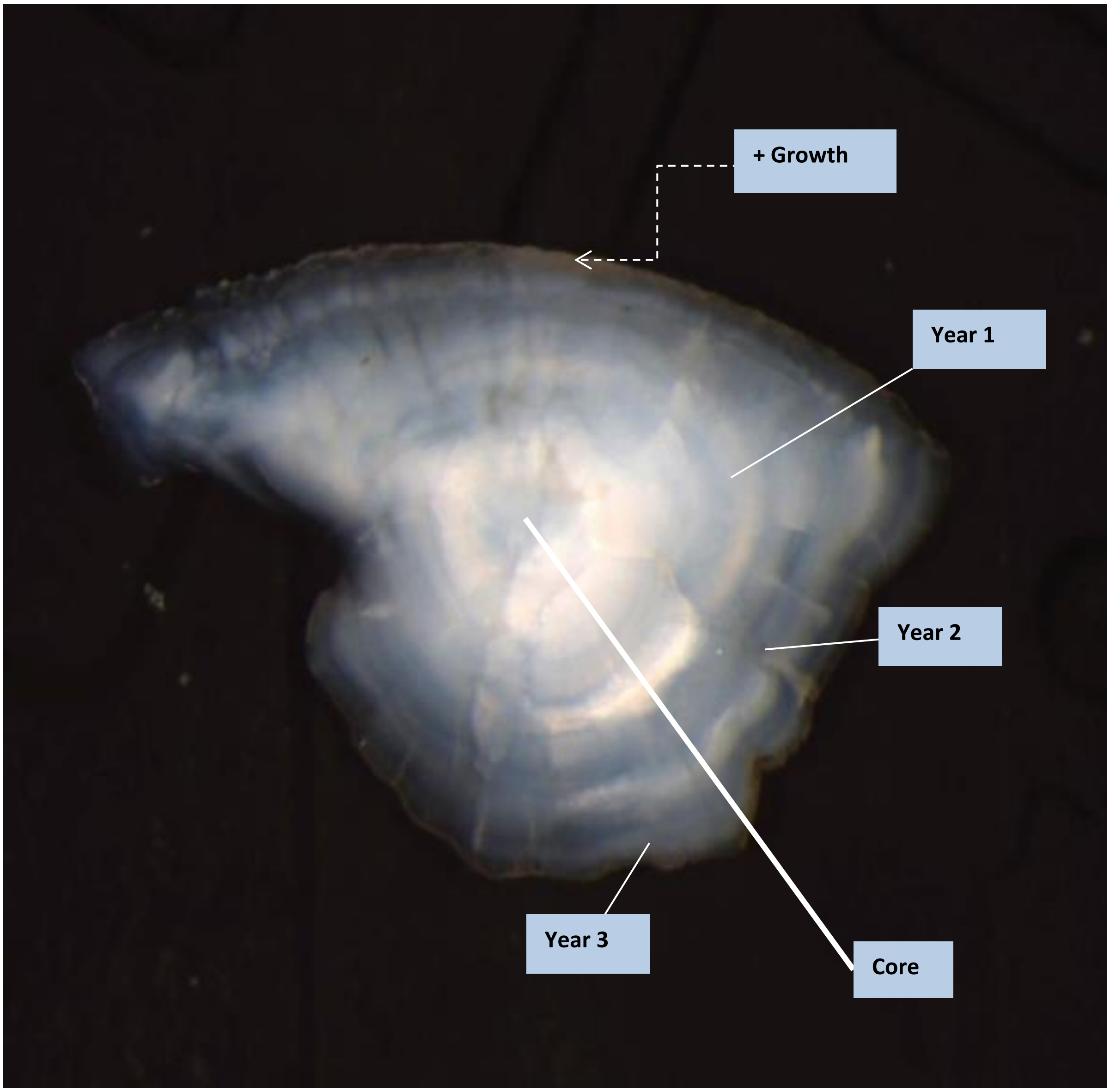
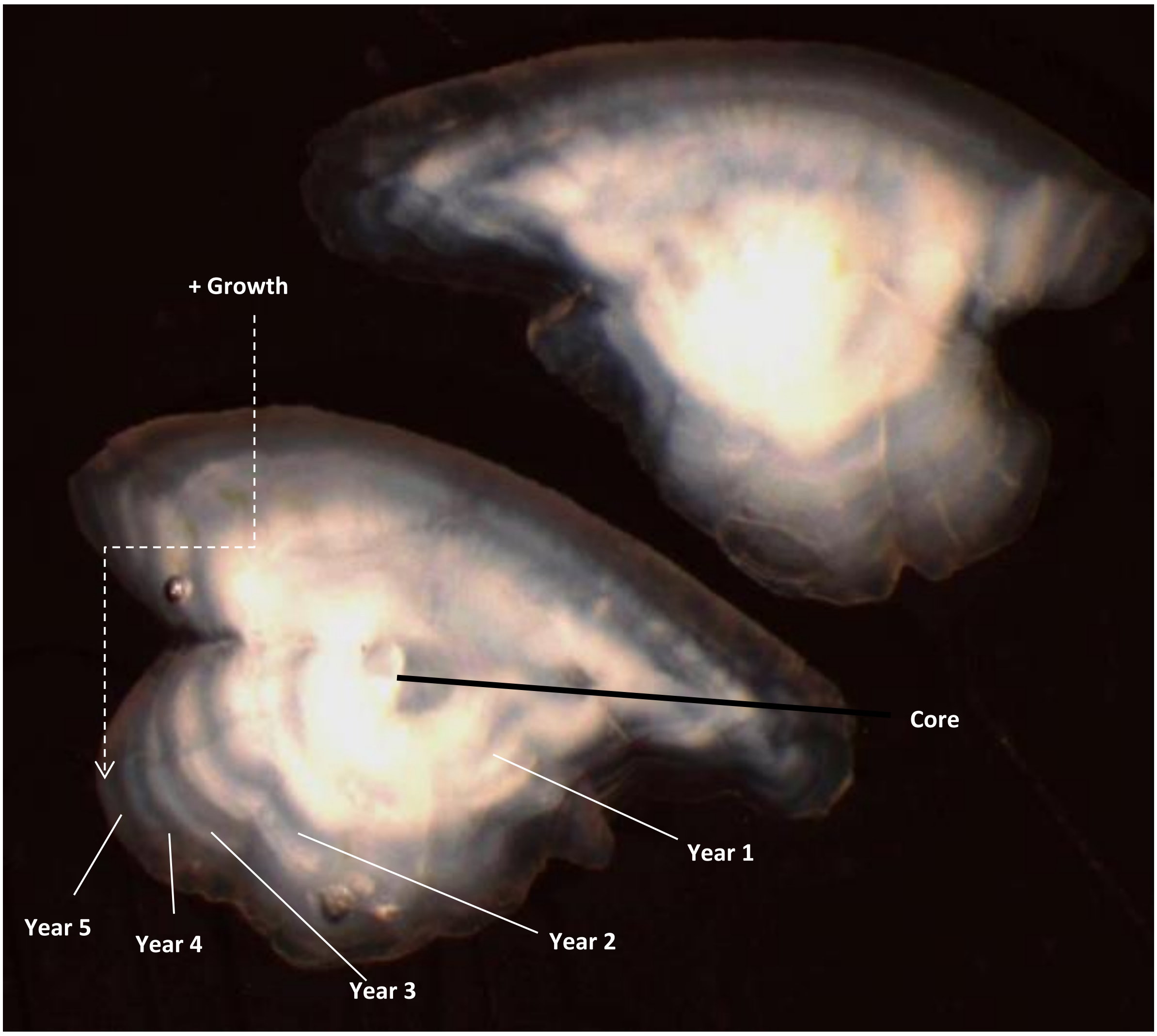


Plate No: 28

Species: Arctic char (*Salvelinus alpinus*)
Location: Lough Kindrum, Co. Donegal
Sample date: 17/07/2009
Fork length: 27.7cm
Weight: 233g
Age: 5+

Comments: Annuli are marked on outer edge of dark lines following image settings (see Table 4.7, Table 2.4).



4.5 Pollan (Coregonus autumnalis)

4.5.1 Identifying features

Blue-backed, silvery, fork-tailed, herring-like fish; a salmonid it has an adipose fin, but no spots; grows to about 0.7kg (fisheriesireland.ie) (Plate 4.5). Terminal mouth, 74-86 lateral line scales, 41-48 gill rakers (Maitland and Herdson, 2009).

Plate 4.5: Pollan *(Coregonus autumnalis)* (source IFI)

4.5.2 Distribution and biological information

The pollan is a unique and threatened freshwater fish species endemic to the island of Ireland. There are extant populations of pollan in Lough Neagh, Lower Lough Erne and Loughs Allen, Ree and Derg on the Shannon system (Ferguson *et al*., 1978; Rosell *et al.*, 2004, Harrison *et al*., 2010).

As with Arctic char, pollan in northern latitudes are anadromous (Harrod *et al.*, 2001). The only non-arctic populations occur in Ireland and these are landlocked relics of postglacial colonisation (Rosell *et al*, 2004). The Irish pollan is relatively short-lived with cohorts often not exceeding five years old (Wilson and Pitcher, 1983; Harrod *et al.*, 2001, Rosell *et al.*, 2004). Occurring in shoals, pollan are primarily zooplankton feeders (Wilson, 1984 cited in Rosell *et al.,* 2004). Most populations in Ireland attain a maximum length of 30cm (Rosell *et al.,* 2004) with some specimens in Lower Lough Erne recorded at 38cm (Rosell*,* 1997).

4.5.3 Ageing notes

Table 4.8: Ageing notes for pollan (I-V)

I.	Pollan achieve fast growth rates in their first year. Lengths up to 14-15cm have been recorded in their first year (Wilson and Pitcher, 1983). The first annulus can be quite clear to read with wide winter bands present (see Plate No. 30).
II.	The majority of growth in 0+ pollan is generated in the early part of the growing season with slowing growth rates being displayed between September and February.
III.	1+ pollan also display this growth pattern from September to February. Later (subsequent) years involve a lower number of circuli (see Plate No. 31).
IV.	Spawning marks (normally year 2 onwards) are defined by “cutting over”/posterior seam loss of circuli (see Plate No. 32).
V.	As with all salmonids, back-calculation with caution once these patterns occur.

Note: Pollan (in Lough Neagh) can show summer checks in growth which can confuse age determination (Wilson and Pitcher 1983), possibly linked to thermal stress.

Plate No. 29

Species: Pollan (*Coregonus autumnalis*)
Location: Lough Allen
Sample date: 01/09/15
Fork length: 9.1cm
Weight: 8.5g
Age: 0+

Comments: Fast growth generated post hatching (see Table 4.8). Fish age is 0+.

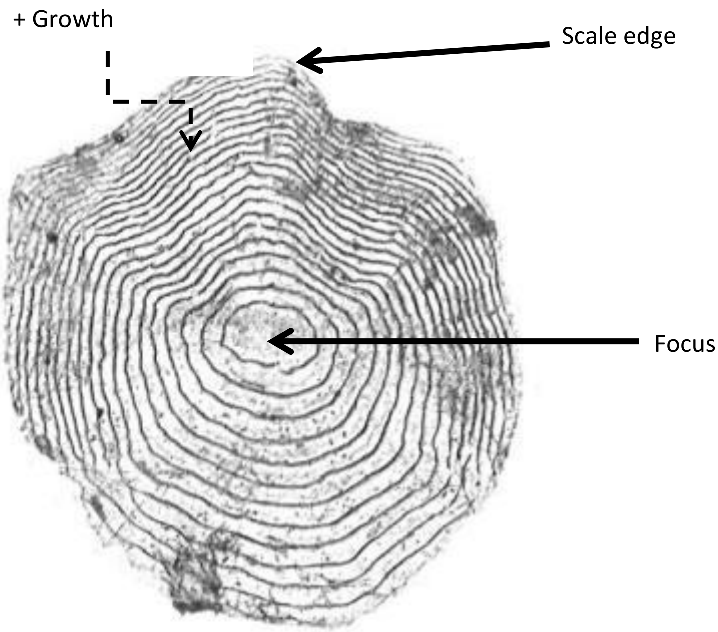


Plate No: 30

Species: Pollan (*Coregonus autumnalis*)
Location: Lough Ree
Sample date: 01/07/16
Fork length: 16.1cm
Weight: 56.8cm
Age: 1+

Comments: Fast growth continues into year 1 (see Table 4.8).

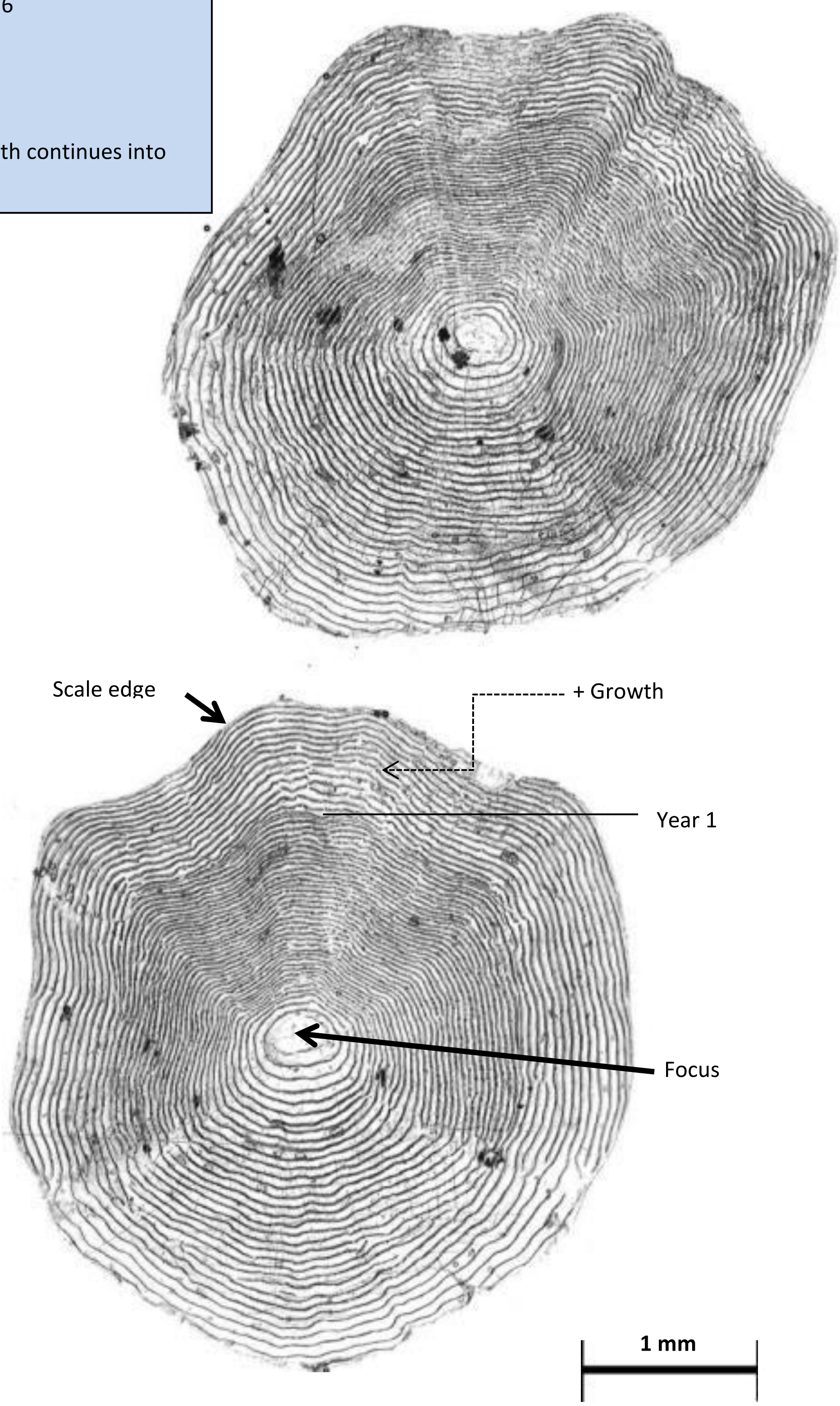
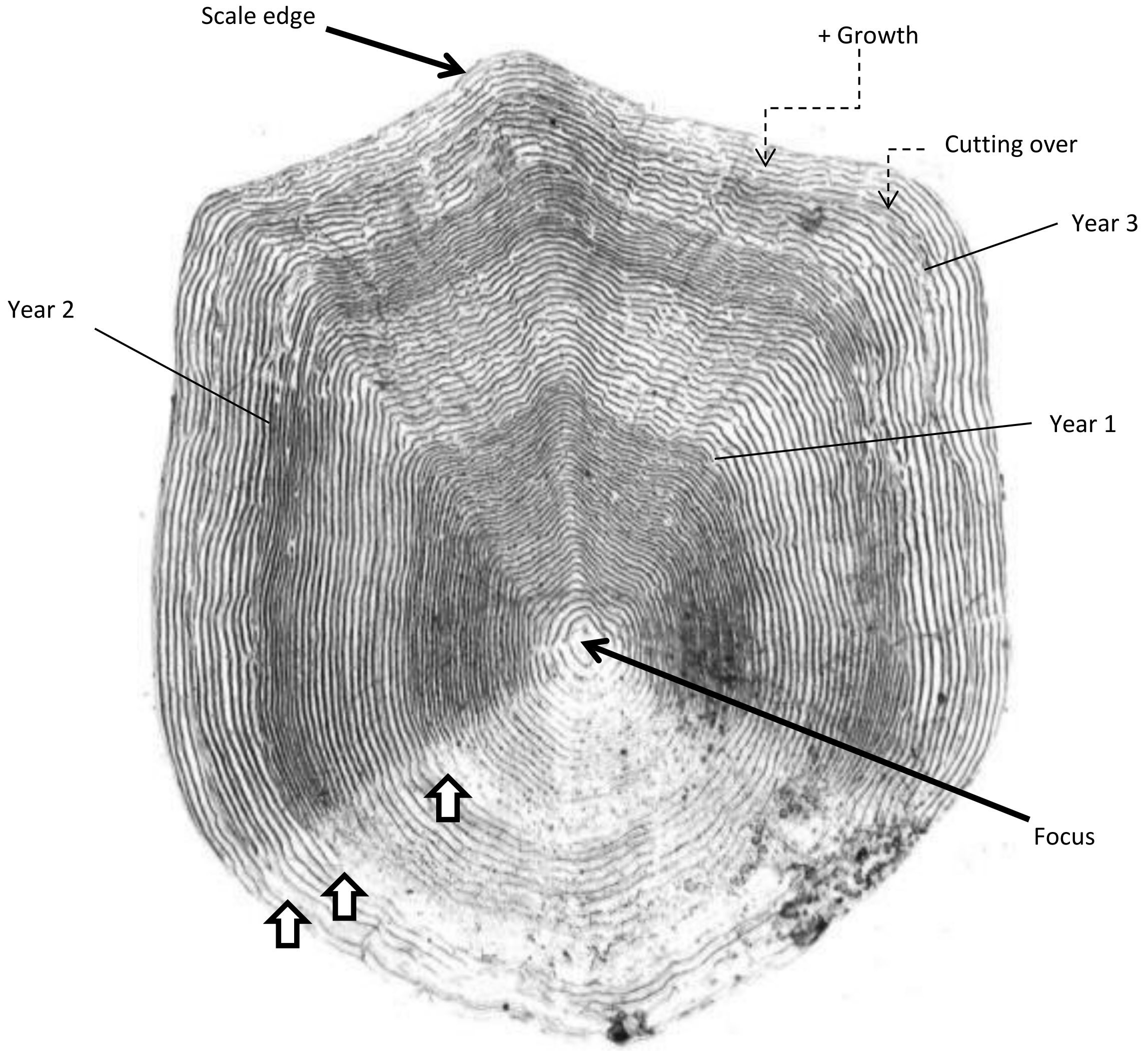


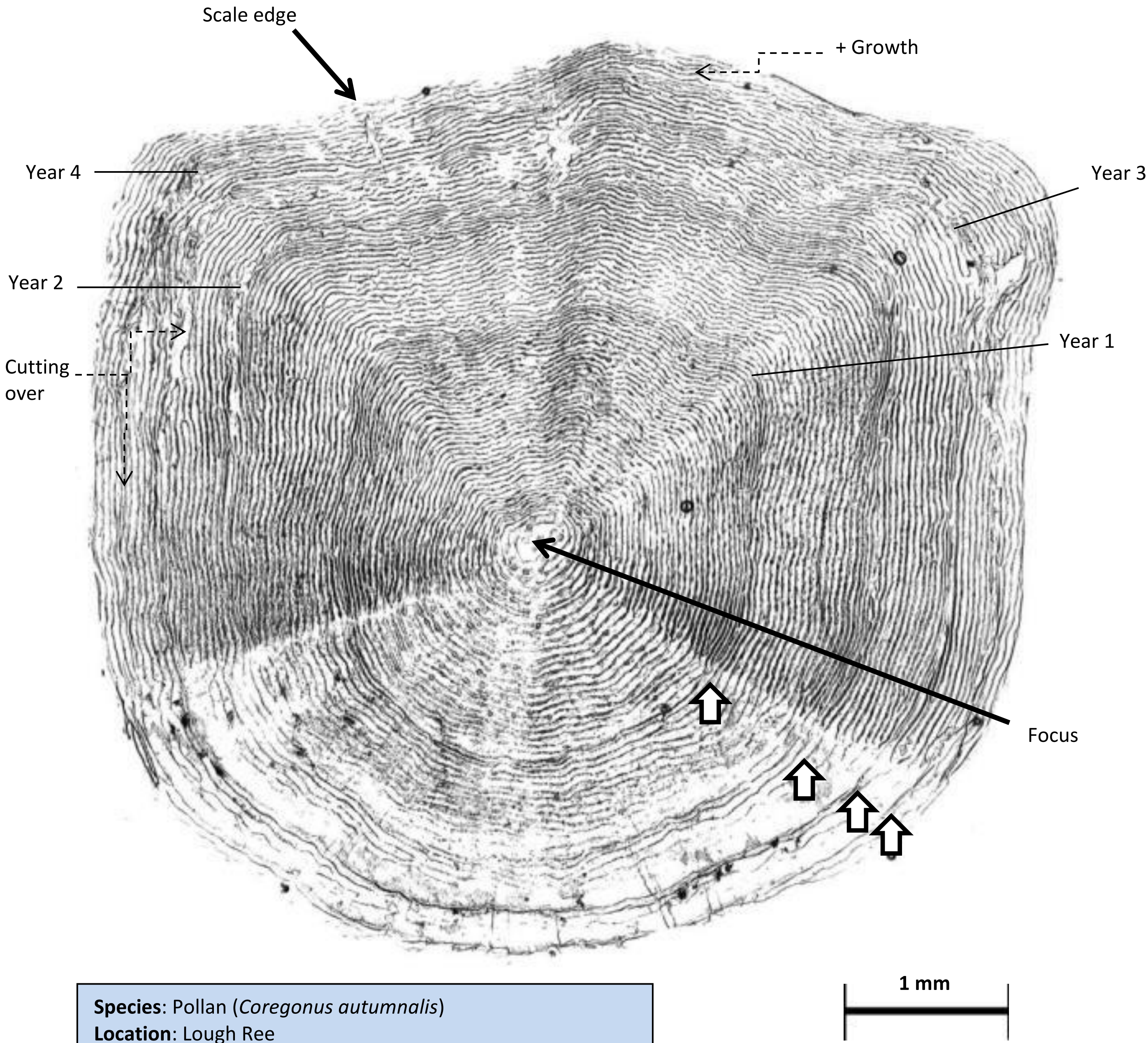
Plate No: 31



Species: Pollan (*Coregonus autumnalis*)
Location: Lough Ree
Sample date: 01/07/16
Fork length: 26.5cm
Weight: 308.8g
Age: 3+

Comment: Significant cutting over appears in year 3. Posterior seams (white arrows) indicate presence of an annulus (see Table 4.8, Section 5.0).

Plate No: 32



Species: Pollan (*Coregonus autumnalis*)
Location: Lough Ree
Sample date: 01/07/16
Fork length: 28.8cm
Weight: 429.4g
Age: 4+

Comments: Spawning marks evident with cutting over present from year 3 onwards. Posterior seams (white arrows) are also indicative of an annulus (see Table 4.8, Section 5.0).

4.6 Pike (Esox lucius)

4.6.1 Identifying features

Torpedo shaped body; shovel like snout; large mouth with many sharp teeth; single dorsal fin set far back, over the anal fin; greenish olive, mottled with lighter patches; the young have a more barred coloration (inlandfisheriesireland.ie).

4.6.2 Distribution and biological information

Pike are present in many systems throughout Ireland. Spawning has been observed in pike in Irish waters in February-March in conjunction with water temperatures reaching 9-10^{o}C (Kennedy, 1969). Onset of sexual maturity is dependent on growth rate with faster growing specimens maturing after 2 years (Billard, 1996).

Plate 4.6: Pike (*Esox lucius*) (source IFI)

4.6.3 Ageing notes

Temperature appears to be the main driver in the formation of an annulus in immature pike. In more mature fish, gonad development and the interruption of growth during spawning are take over as drivers in annulus formation (Casselman, 1967, as cited in Craig, 1996).

Table 4.9: Ageing notes for Pike

I.	High variation in growth is characteristic in pike. This can cause difficulties for scale reading (Mann and Beaumont, 1990). Males usually grow slower than females and males may stop growing after they reach sexual maturity.
II.	The first annulus is usually unique in that the extremely rapid growth following it is characterised by irregular or incomplete circuli, often chain-like in pattern with wide spacing. It may also consist of several close, irregular or discontinuous circuli. It is seldom represented by a hyaline area (white line or blank stripe) on the scale (see Plate No. 35) (Schneider, 2001).
III.	The second annulus is usually indicated by several close, discontinuous circuli. It may be indicated by a white line at the lateral region, but is seldom indicated by the chainlike pattern of the first annulus (see Plate No. 36) (Schneider, 2001).
IV.	Annuli of the third and later years are usually represented by a white line of bunched circuli (see Plate No. 35) (Schneider, 2000).
V.	Be aware of double bands in an annulus. Only age one (see Plate No. 35) (Schneider, 2001).
VI.	Age estimated from scales tends to be less than true age. Reliability of scale ageing often declines after age 4. Variance increases as age increases, with underestimation bias developing in older fish at 8-10 years (Billard, 1996).

Note: While all the examples of pike age determination in this document are from scales, opercular (metapterygoid) bones or cleithra are considered to be more reliable, (Casselman 1973, Frost 1959) but clearly only usable when a dead specimen is available. If cleithra are available, prepare them for ageing as for perch operculars.

Plate No: 33

Species: Pike (*Esox lucius*)
Location: River Barrow, Belview, Co. Kildare
Sample date: 20/07/2015
Fork length: 16.5cm
Age: 0+
Magnification: x55

Comments: No evidence of an annulus formed. Based on approximate hatching time, this fish has benefited from several months growing time (see Table 3.2).

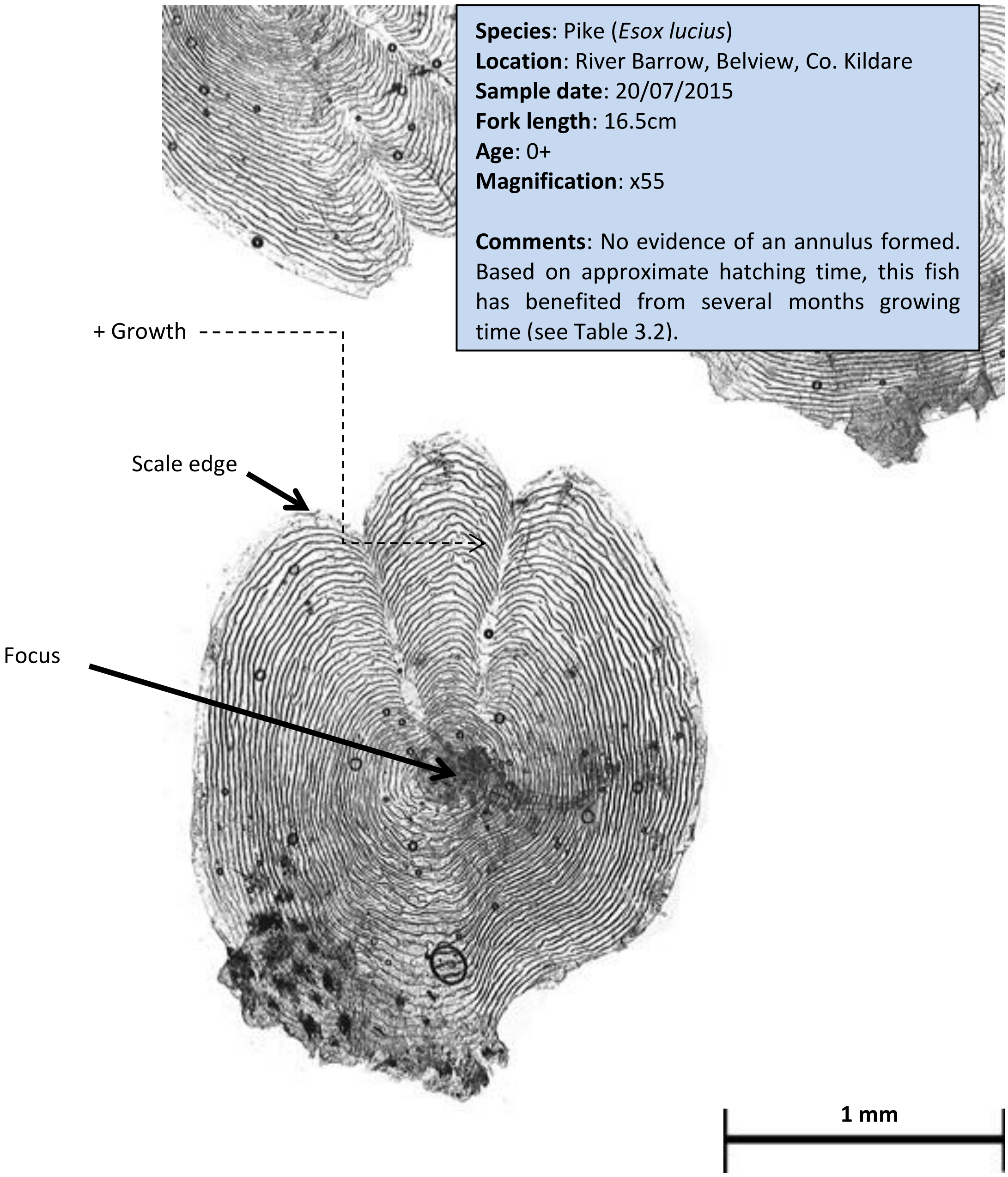


Plate No: 34

Species: Pike (*Esox lucius*)
Location: Atedaun Lough, Co. Clare
Sample date: 10/09/2010
Fork length: 26.4cm
Age: 1+
Magnification: x 32

Comments: An annulus is indicated by a white line (see white arrow). This pattern seldom occurs in year 1 (see Table 4.9).

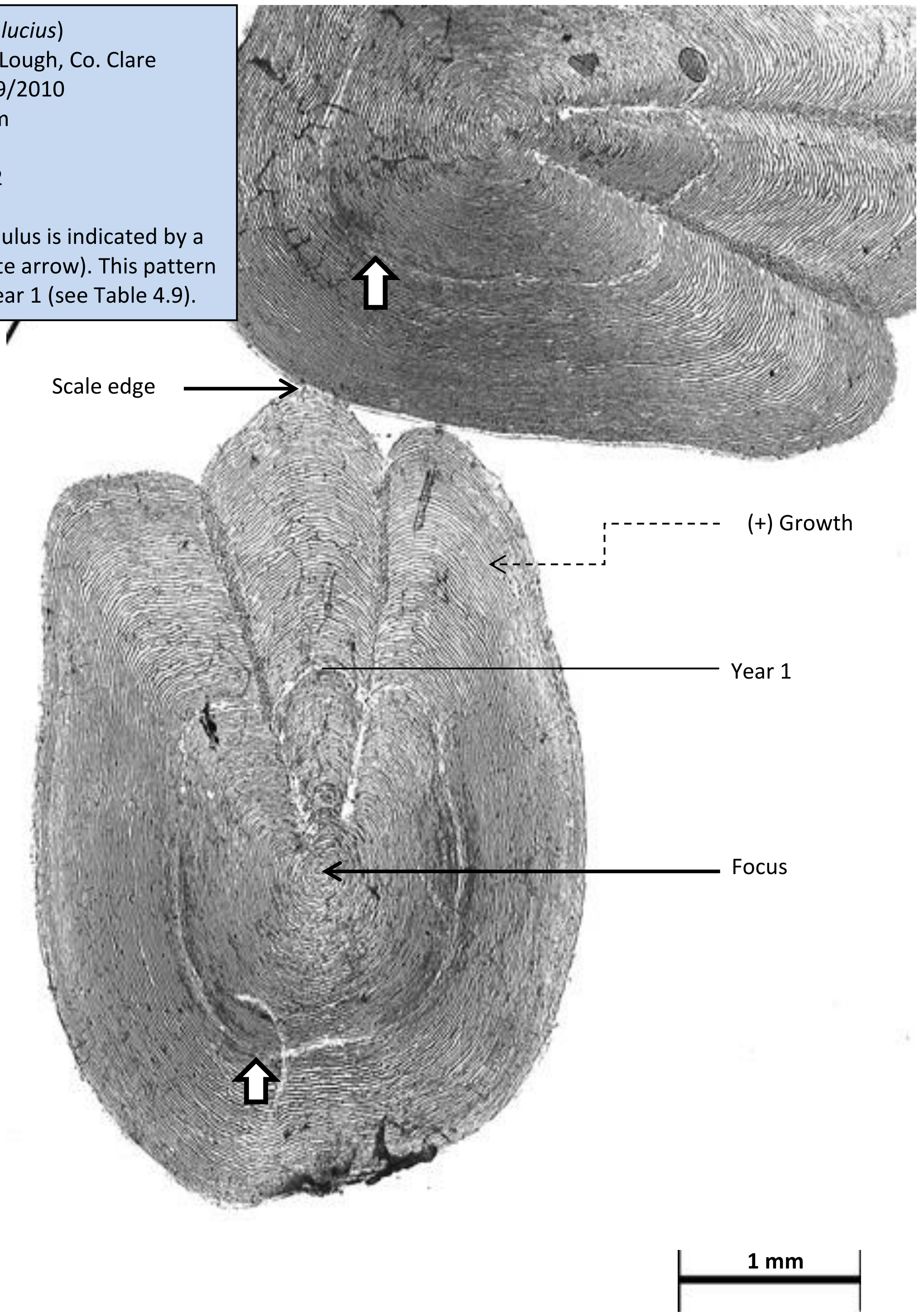
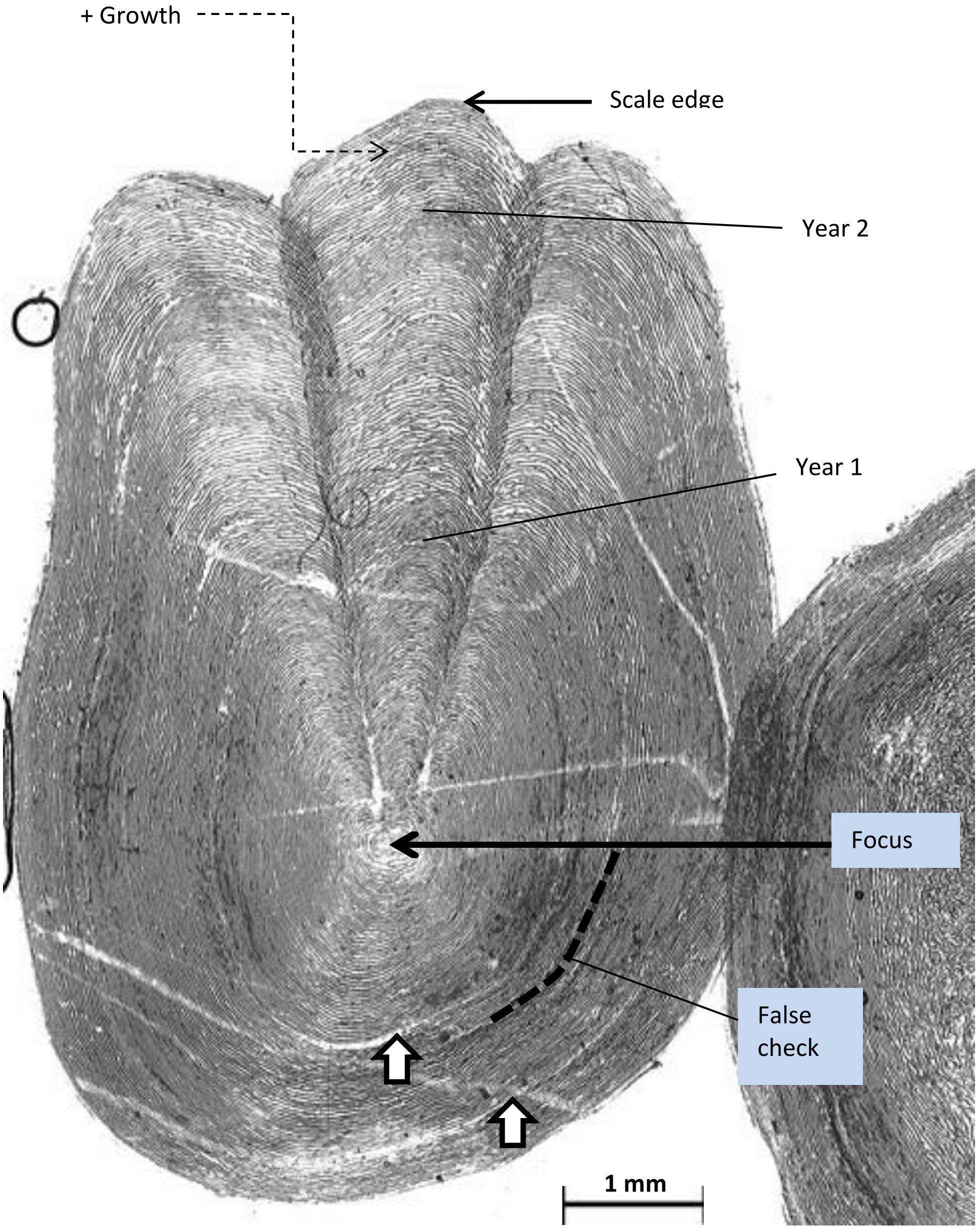


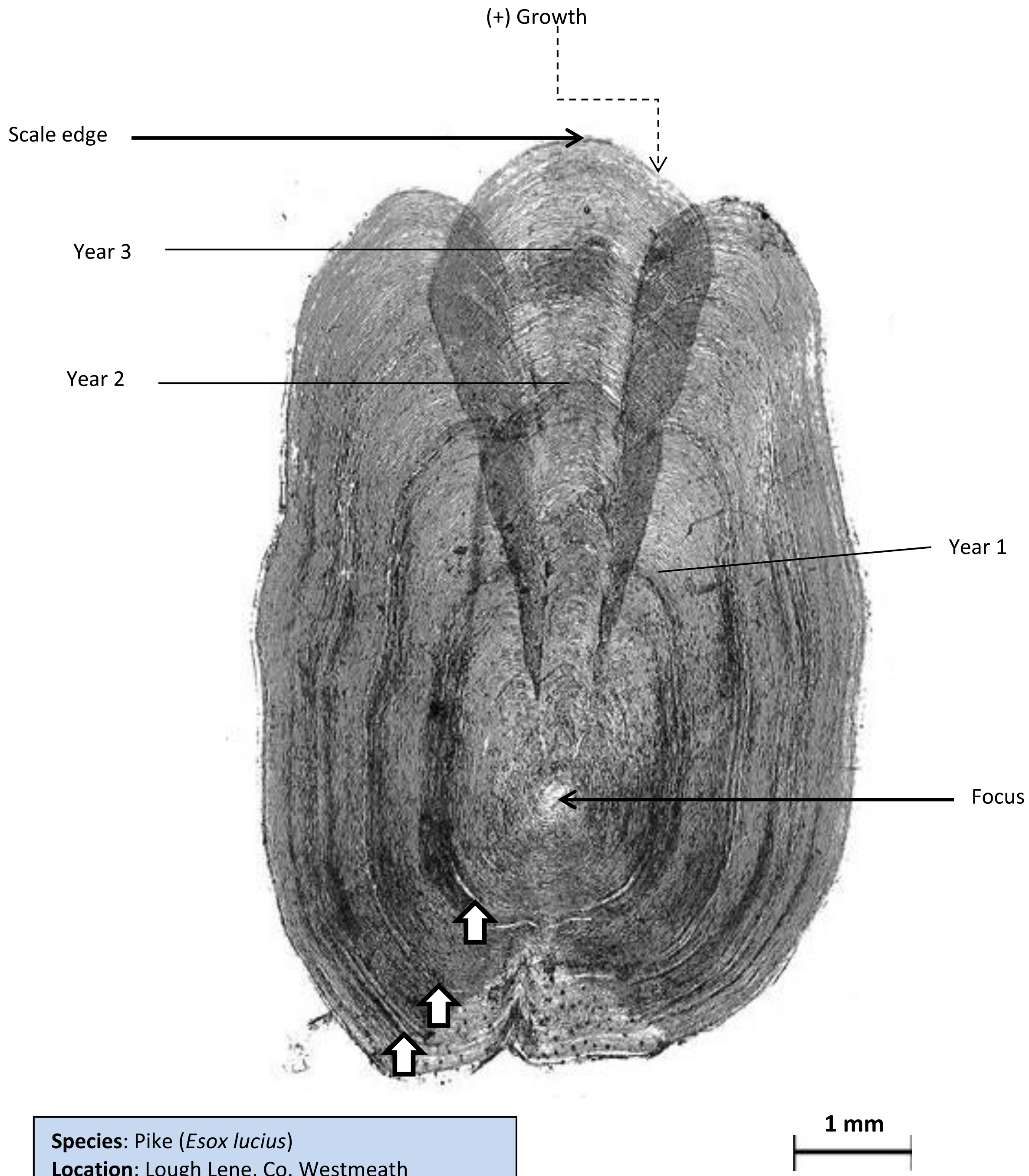
Plate No: 35



Species: Pike (*Esox lucius*)
Location: River Barrow, Bagenalstown, Co. Carlow
Sample date: 20/07/2015
Fork length: 41.6cm
Age: 2+
Magnification: x30

Comments: Evidence of a false check (see Section 5.0) (double band) after year 1. This is highlighted by checked line (see Table 4.9).

Plate No: 36



Species: Pike (*Esox lucius*)
Location: Lough Lene, Co. Westmeath
Sample date: 02/10/2013
Fork length: 58 cm
Age: 3+
Magnification: x24

Comments: White lines at posterior end indicate an annulus (see white arrows) (see Table 4.9).

4.7 Perch (Perca fluviatilis)

4.7.1 Identifying features

Two dorsal fins set close together, the first with sharp spines; spines also in the origin of the anal fin and in the origin of the pelvic fins, which are placed under the pectorals; Greenish-olive, with black bars on the sides; pelvics, anal and tail-fin red or orange.

4.7.2 Distribution and biological information

Perch tolerate a wide range of environments, but prefer shallow and moderately productive freshwaters. Young larvae consume algae and zooplankton (rotifers, cladocerans and copepods) but adult perch can continue this dietary pattern in unproductive waters. Adults are primarily piscivorous in habit. Larvae and young juveniles congregate in shoals whilst adults are more solitary in nature. Spawning in Irish waters occurs in April and May when temperatures reach 9-14 degrees (www.fisheriesireland.ie).

Plate 4.7: Perch (*Perca fluviatilis*) (source IFI)

4.7.3 Ageing notes

Perch populations are characterised by a large variance in weight and size heterogeneity resulting from feeding competition (Toner and Rougeot, 2008). This variation is often characterised by slow growing zooplankton and invertebrate feeders or fast growing piscivores (Kornilovs, 2015).

Table 4.10: Ageing notes for perch

I.	When ageing perch, treat each individual as a separate entity and do not look for patterns among age classes (Morrissey, E., 2016, *pers. comm*.).
II.	Year 1 can be extremely faint in opercular bones, less so with scales which can be useful for observing the first years growth (Kornilovs, 2015). When ageing opercular bones look for a difference in shade rather than a classic white line that appears in later years (see Plates No. 39-41) (Morrissey, E., 2016, *pers. comm*.).
III.	Sampling perch scales is easy and quick, but the use of scales in the determination of perch age has its limits. If the details hampering the ageing of perch (e.g. the formation of false rings) are known and the growth of the perch is fast and steady, the use of scale is justified.

Plate No: 37

Species: Perch (*Perca fluviatilis*)
Location: Templehouse Lake, Co. Sligo
Sample date: 01/10/14
Fork length: 7cm
Age: 0+
Magnification: n/a

Comments: No change in shade suggests a lack of an annulus (see Table 4.10).

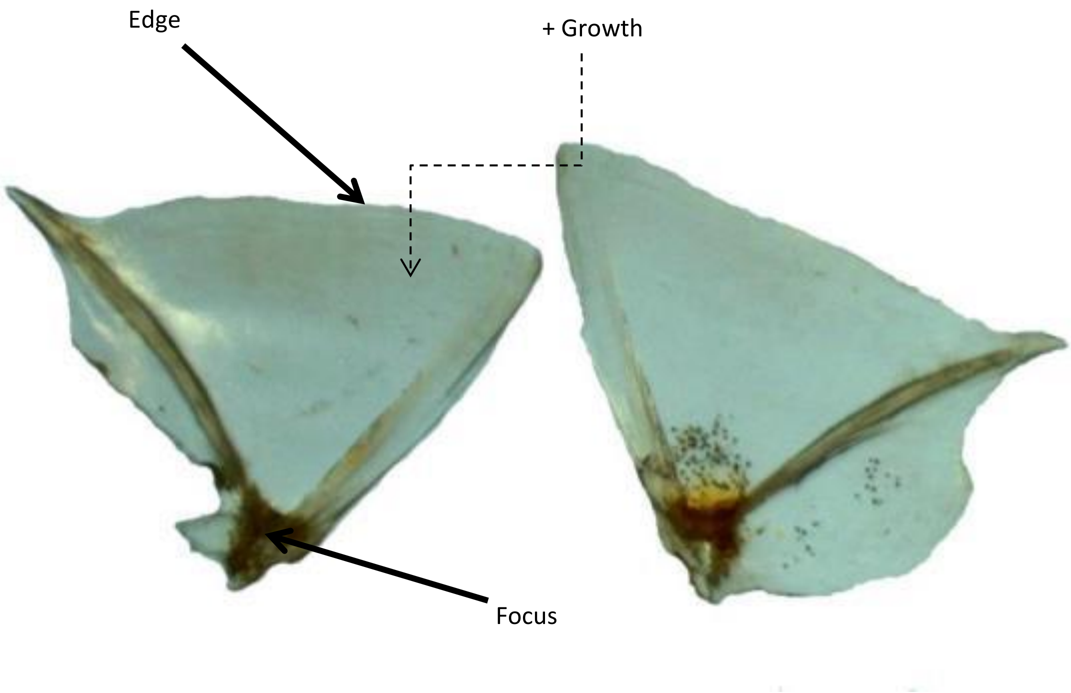


Plate No: 38

Species: Perch (*Perca fluviatilis*)
Location: Lough Derg, Co. Tipperary
Sample date: 15/06/16
Fork length: 10cm
Weight: 10g
Age: 1+
Magnification: x 0.63

Comments: A change in shade indicates the first annulus (see Table 4.10).

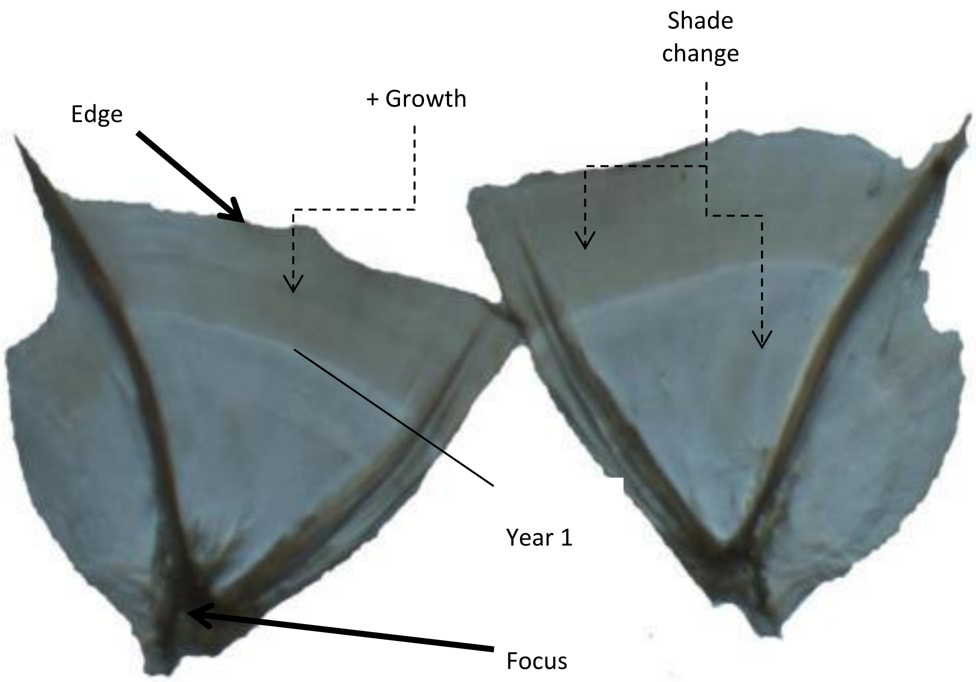


Plate No: 39

Species: Perch (*Perca fluviatilis*)
Location: Lough Derg, Co. Tipperary
Sample date: 14/06/16
Fork length: 14.3cm
Weight: 40
Age: 2+
Magnification: x0.63

Comments: A change in shade indicates the first annulus (see Table 4.10). Note the contrast between the first and second annulus, which displays more prominent lines.

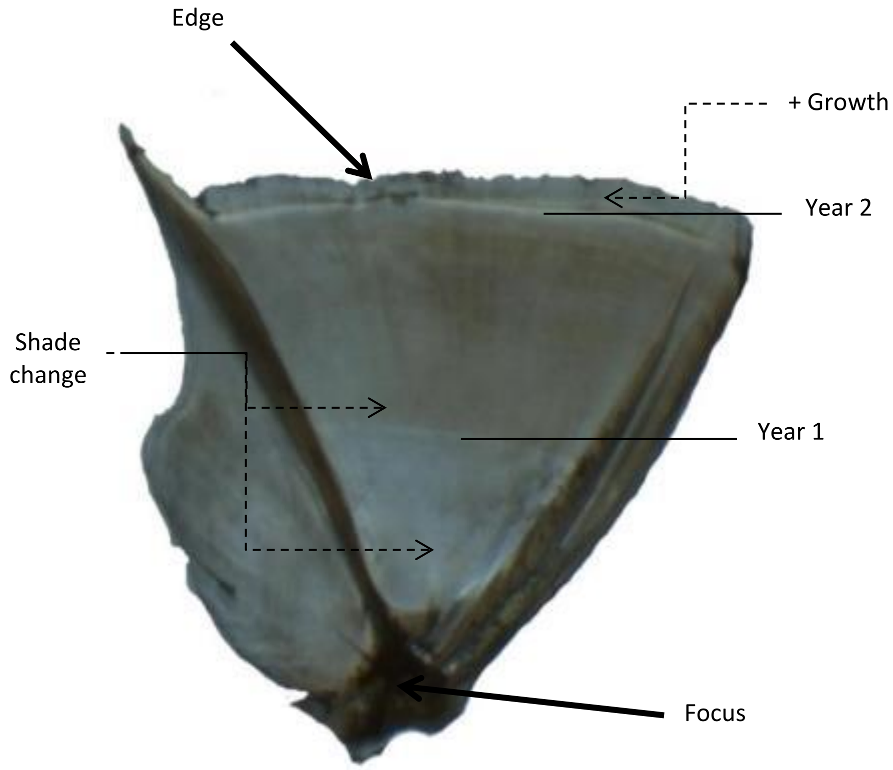


Plate No: 40

Species: Perch (*Perca fluviatilis*)
Location: Lough Derg, Co. Tipperary
Sample date: 21/06/16
Fork length: 15.4cm
Weight: 44g
Age: 3+
Magnification: x 0.63

Comments: A change in shade indicates the first annulus (see Table 410). Note the contrast between the first annulus and years 2 and 3.

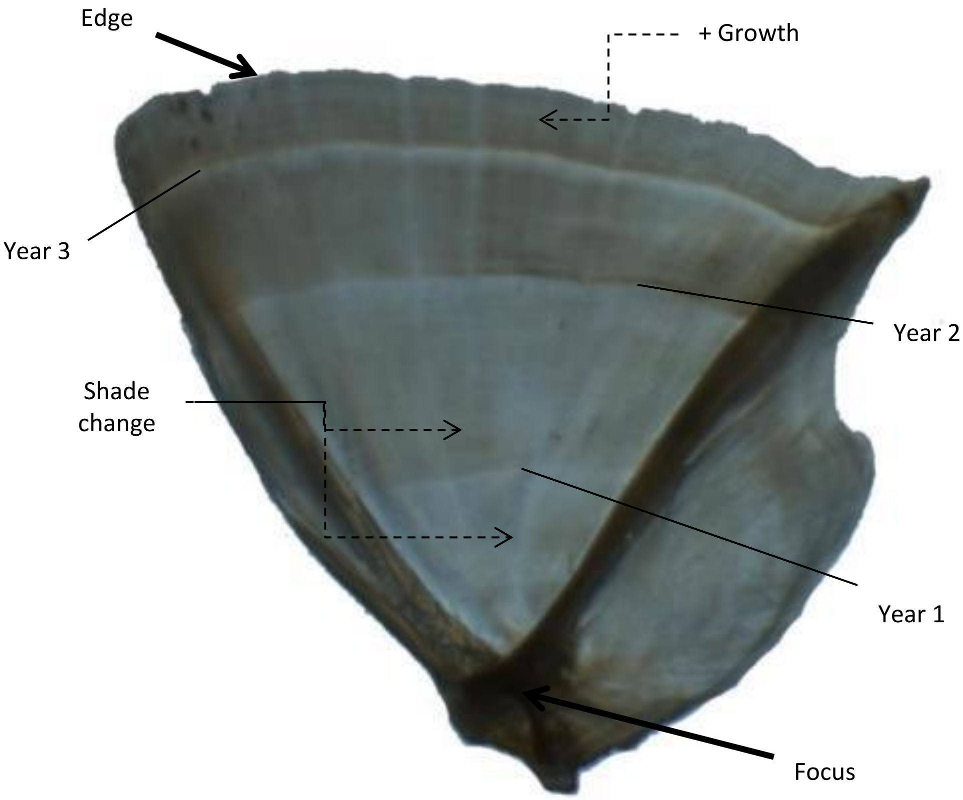
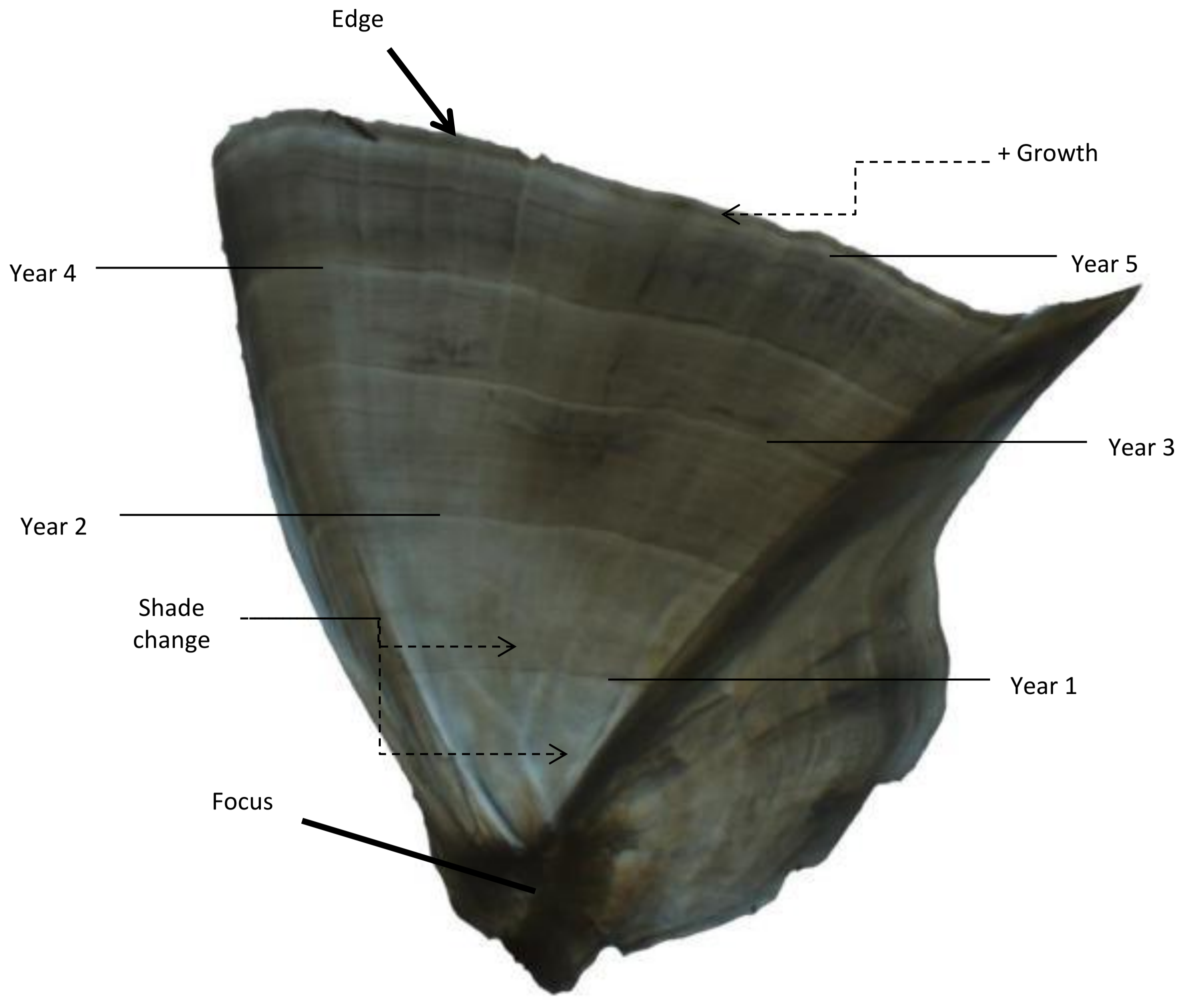


Plate No: 41

Species: Perch (*Perca fluviatilis*)
Location: Derrybrick Lough, Co. Cavan
Sample date: 11/10/11
Fork length: 23.8cm
Weight: 208g
Age: 5+
Magnification: x 0.63

Comments: A change in shade indicates the first annulus (see Table 4.10).



4.8 Roach (Rutilus rutilus)

4.8.1 Identifying features

Mouth inferior; dorsal fin noticeably large, with its origin over the insertion of the pelvic fins; Anal fin short, with 9-12 branched rays, 41-44 scales along lateral line; blue on the back, silvery on the sides (sometimes with a bronze lustre in big fish); dorsal fin brownish red; pelvics and anal fins and tail red; (fisheriesireland.ie).

4.8.2 Distribution and biological information

The first introduction of roach in Ireland occurred in 1889 in the River Blackwater in County Cork (Caffrey *et al.*, 2007). Between the 1960's and early 1980's roach rapidly spread to colonise many catchments throughout the country. A highly successful species, roach spawn in large numbers, can utilise a wide variety of spawning media and can tolerate a wide variety of environmental conditions.

Plate 4.8: Roach (*Rutilus rutilus*) (source IFI)

4.8.3 Ageing notes

Table 4.11: Ageing notes for roach

I.	The first annulus can be difficult to observe, particularly in larger specimens (McCarthy and Kennedy, 1965), obscured by thickening of the centre of the scale.
II.	Closely spaced circuli at winter bands; well defined annuli, suggestive of the winter bands of trout and salmon (McCarthy and Kennedy, 1965) (see Plates No. 44-45). Scale erosion in cyprinid scales is known as chaining (Kennedy and Fitzmaurice, 1974). Posterior seam is a good indicator of an annulus (McCarthy and Kennedy, 1965).
III.	Scales of roach also display straighter dorsal and ventral edges, and often display a distinctive crest on each side of its anterior edge (see Fig. 3.10).
IV.	Scales in roach are significantly larger than similar sized bream (see Fig. 3.10).

Plate No: 42

Species: Roach (*Rutilus rutilius L.*)
Location: Lough Muckno, Co. Monaghan
Sample date: 08/09/2015
Fork length: 4.0 cm
Age: 0+
Magnification: x 55

Comments: This fish displays no annulus, only summer growth post hatching in the same year. Fish age is 0+.

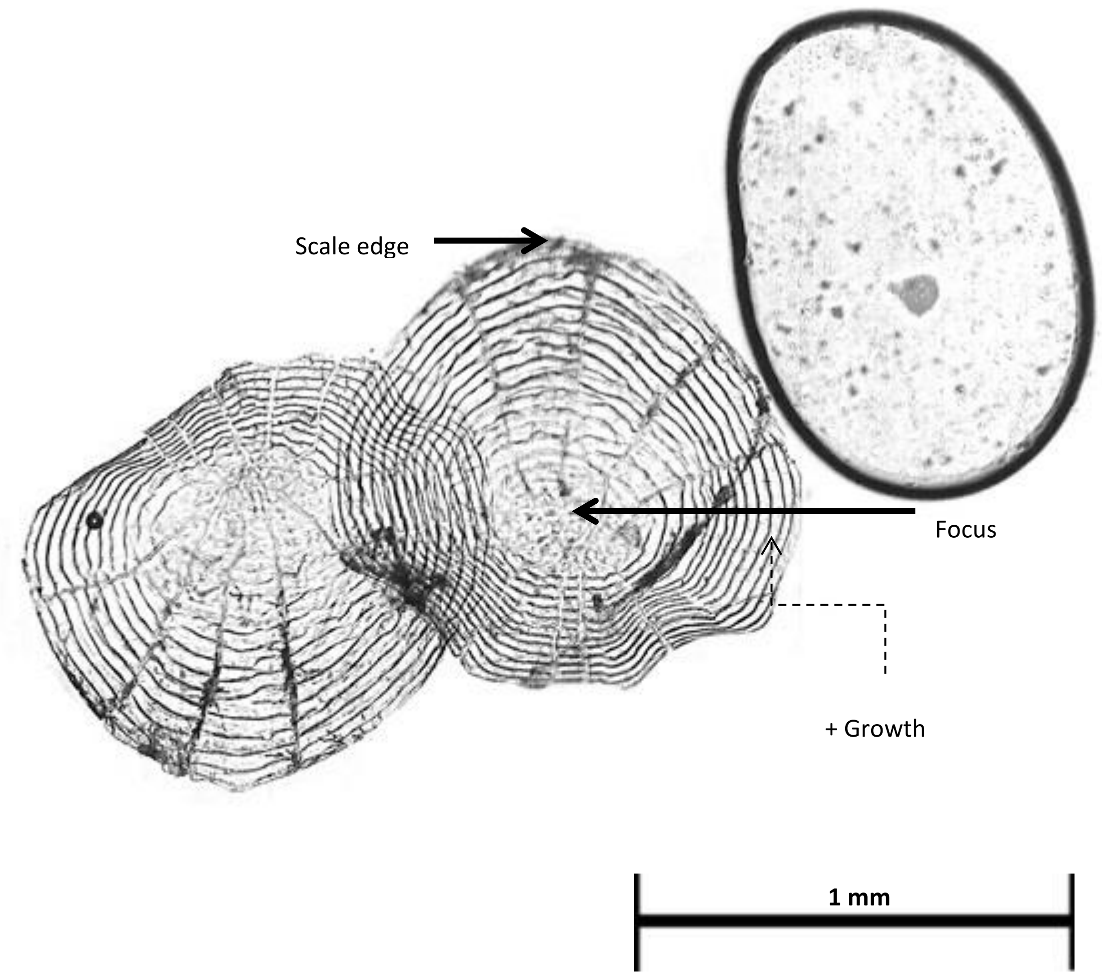


Plate No: 43

Species: Roach (*Rutilus rutilius L.*)
Location: Lough Cullin, Co. Mayo
Sample date: 11/08/2015
Fork length: 6.5 cm
Age: 1+
Magnification: x 55

Comments: Posterior seam is indicative of an annulus (see white arrow) (see Section 5.0, Table 4.11).

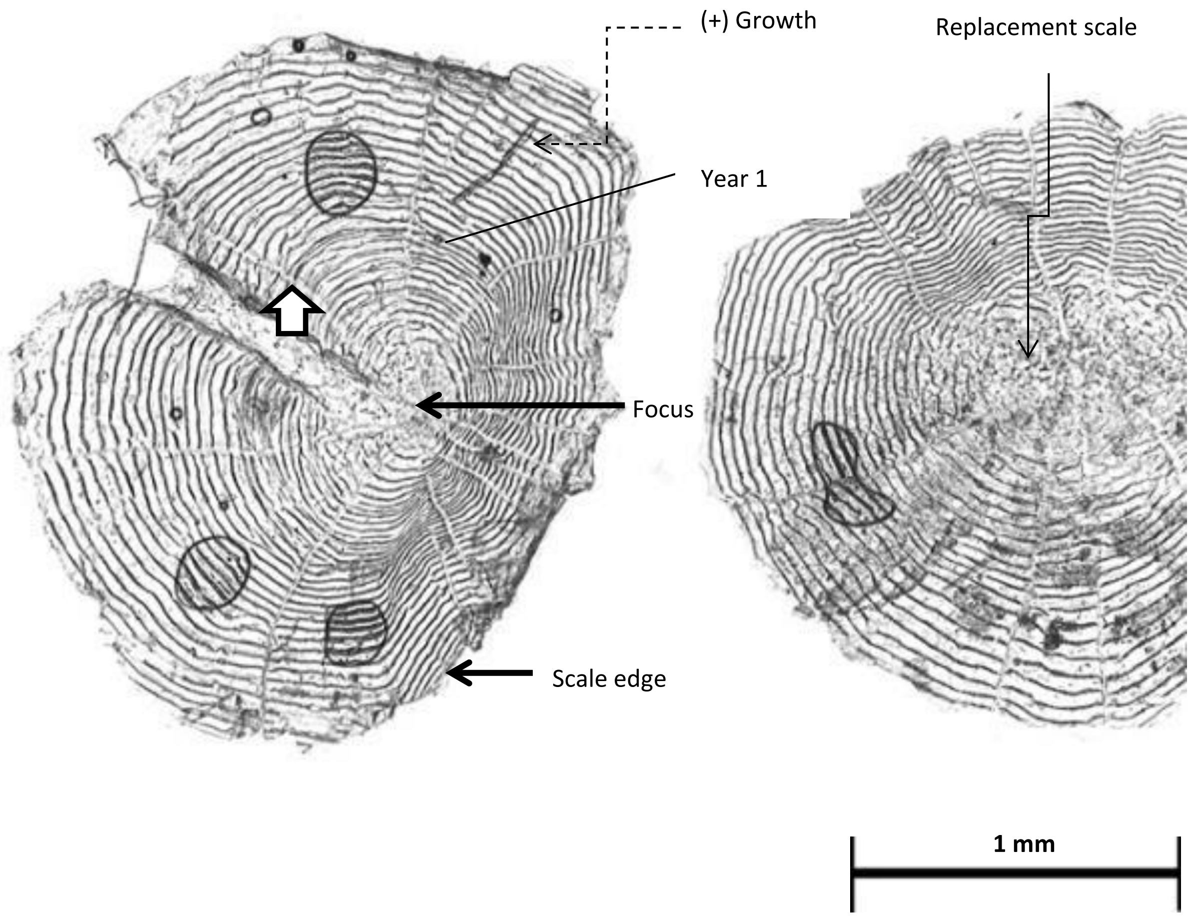


Plate No: 44

Species: Roach (*Rutilus rutilius L.*)
Location: Lough Gara, Co. Sligo
Sample date: 04/09/2015
Fork length: 10 cm
Age: 2+
Magnification: x 30

Comments: Posterior seams are indicative of an annulus (see white arrows) (see Section 5.0, Table 4.11).

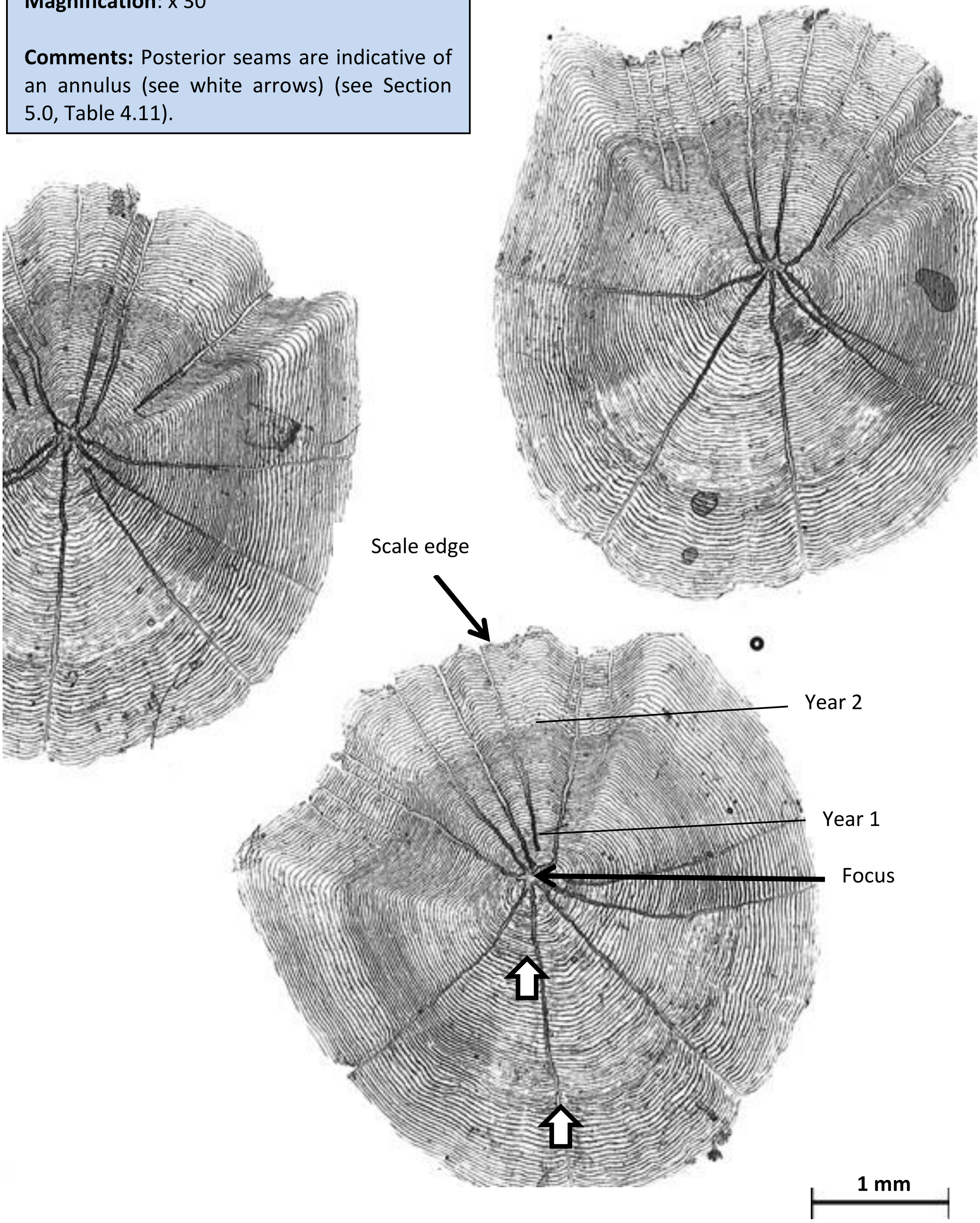


Plate No: 45

Species: Roach (*Rutilus rutilius L.*)
Location: Glenade Lough, Co. Letrim
Sample date: 27/08/2013
Fork length: 12.1 cm
Age: 3+
Magnification: x 26

Comments: Posterior seams are indicative of an annulus (see white arrows). Chaining also occurs in year 3, indicating a potential spawning event (see Section 5.0, Table 4.11).

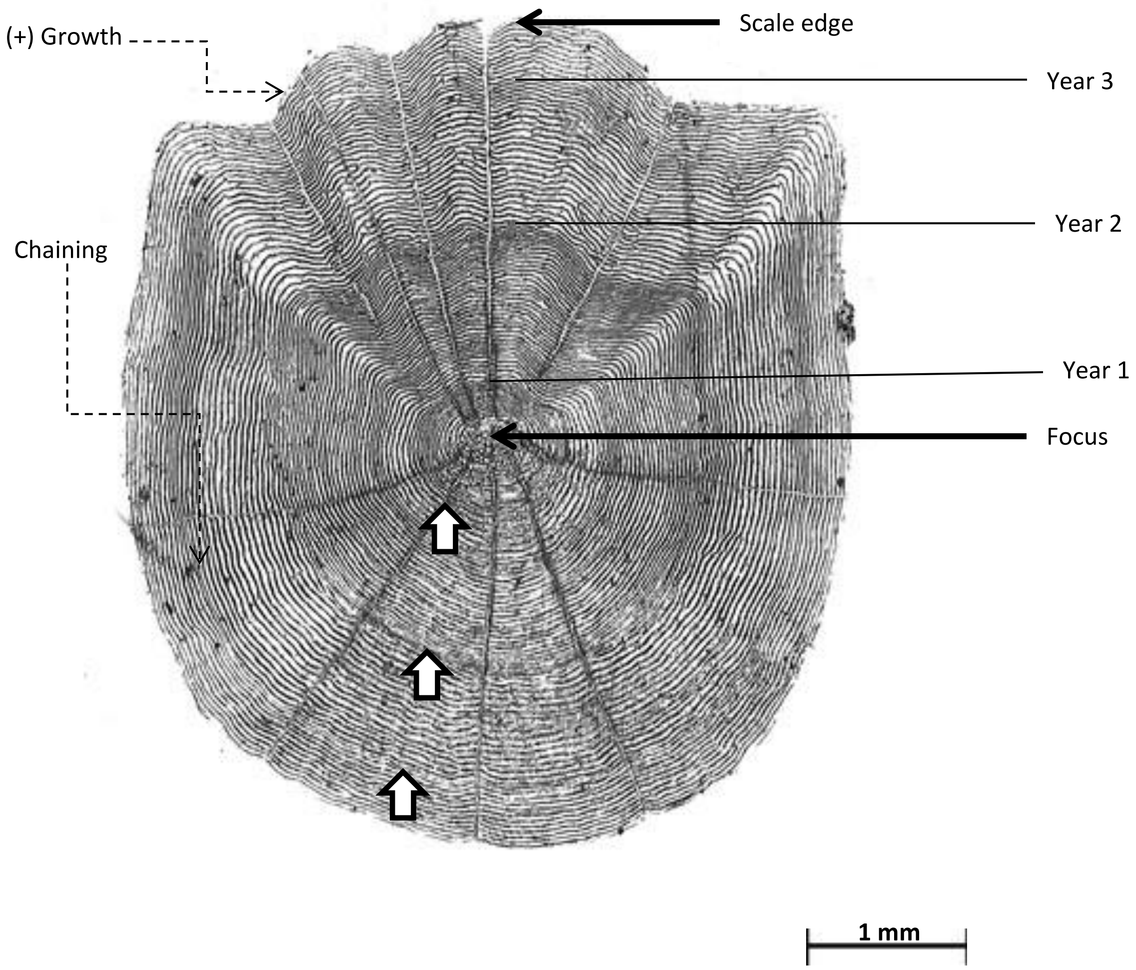


Plate No: 46

Species: Roach (*Rutilus rutilius L.*)
Location: Ross Lake, Co. Galway
Sample date: 14/08/2013
Fork length: 14.8cm
Age: 3+
Magnification: x 24

Comments: Posterior seams are indicative of an annulus (see white arrows). Chaining occurs in year 3 (see Section 5.0, Table 4.11).

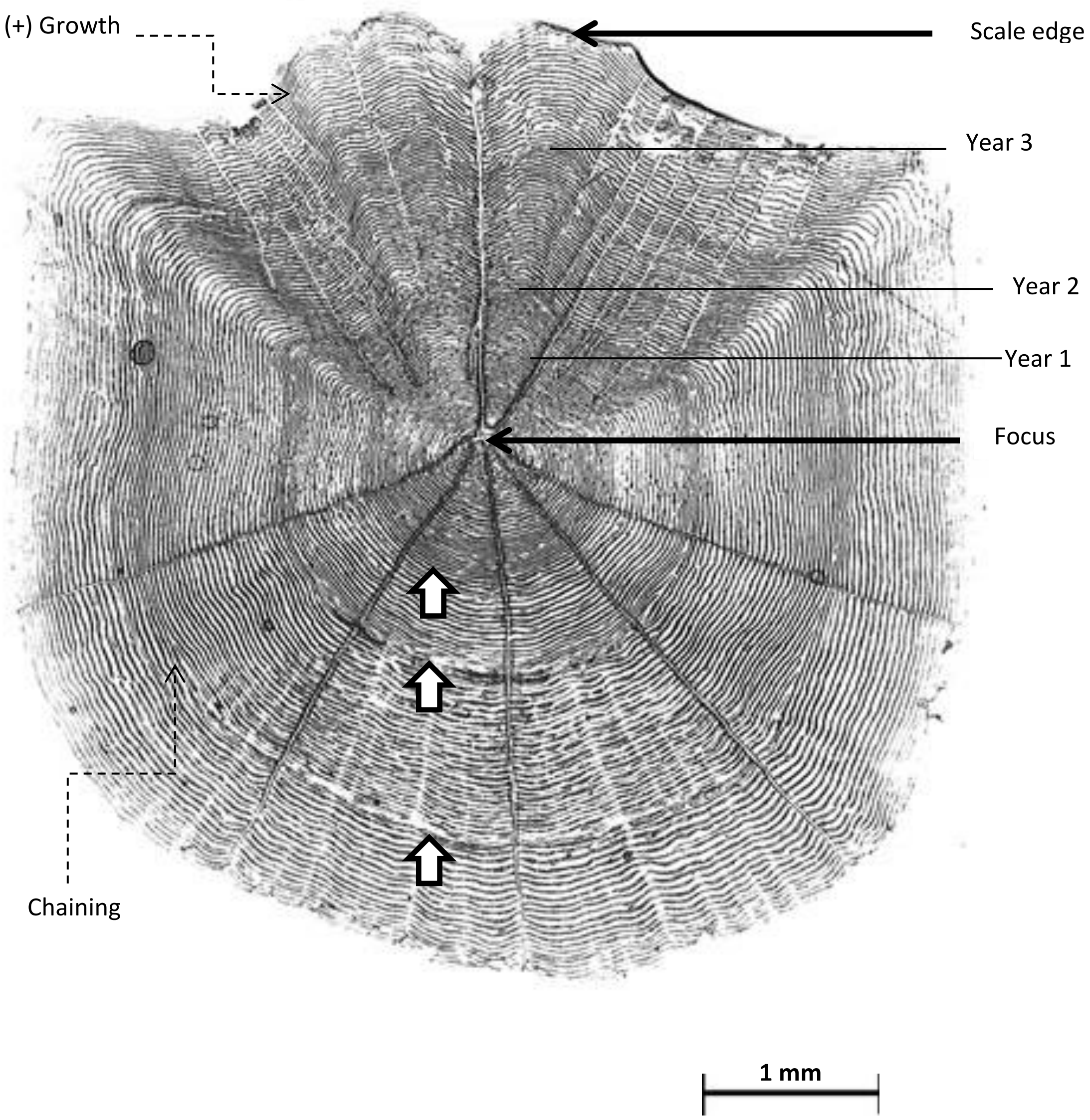


Plate No: 47

Species: Roach (*Rutilus rutilius L.*)
Location: Urlaur Lough, Co. Mayo
Sample date: 25/07/2013
Fork length: 17.1cm
Age: 4+
Magnification: x 24

Comments: Posterior seams are indicative of an annulus (see white arrows). Chaining occurs onwards from year 3 (see Section 5.0, Table 4.11).

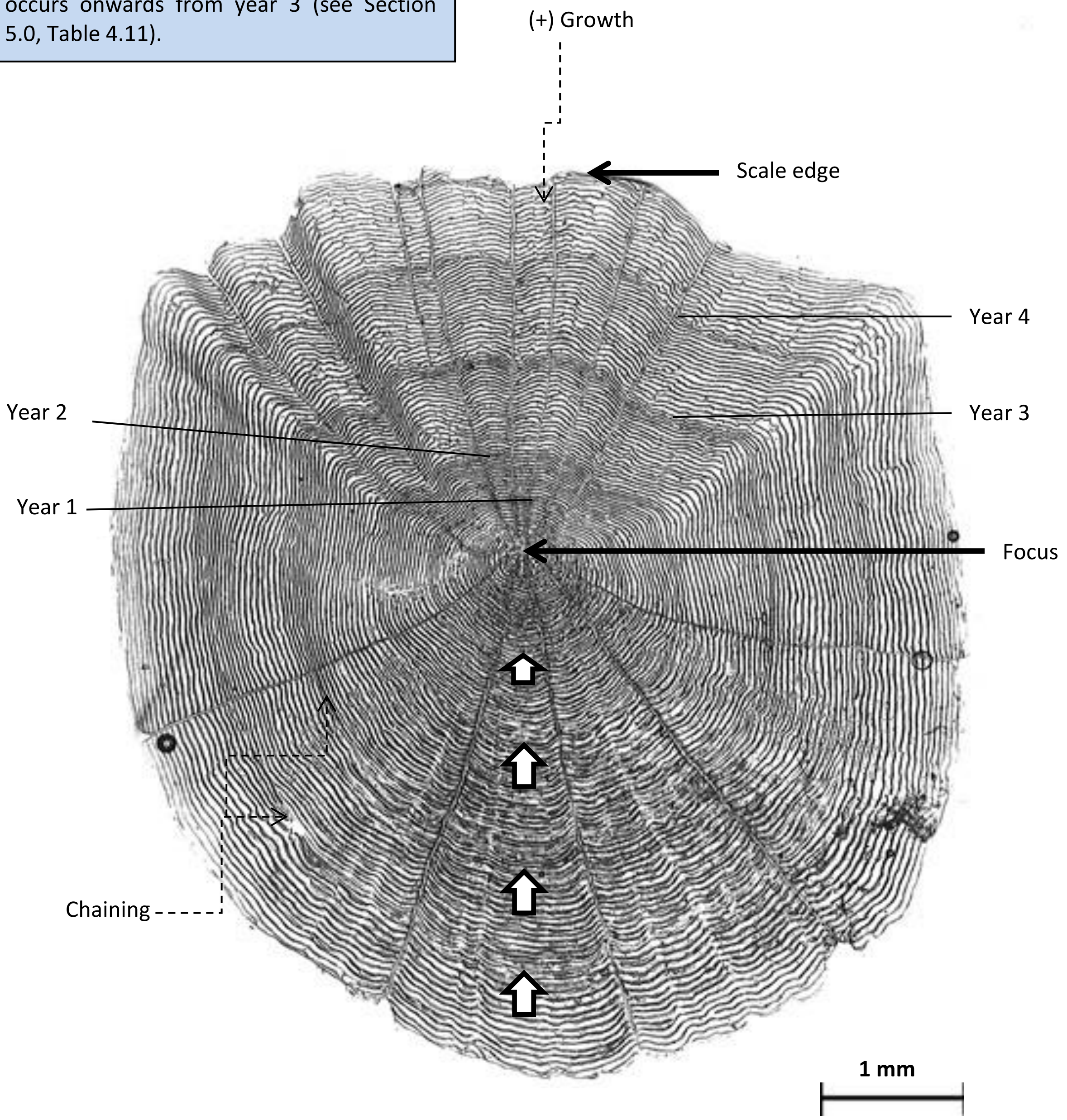


Plate No: 48

Species: Roach (*Rutilus rutilius L.*)
Location: Glenade Lough, Co. Letrim
Sample date: 27/08/2013
Fork length: 17.9 cm
Age: 4+
Magnification: x 22

Comments: Posterior seams are indicative of an annulus (see white arrows). Chaining occurs from year 3 (see Section 5.0, Table 4.11).

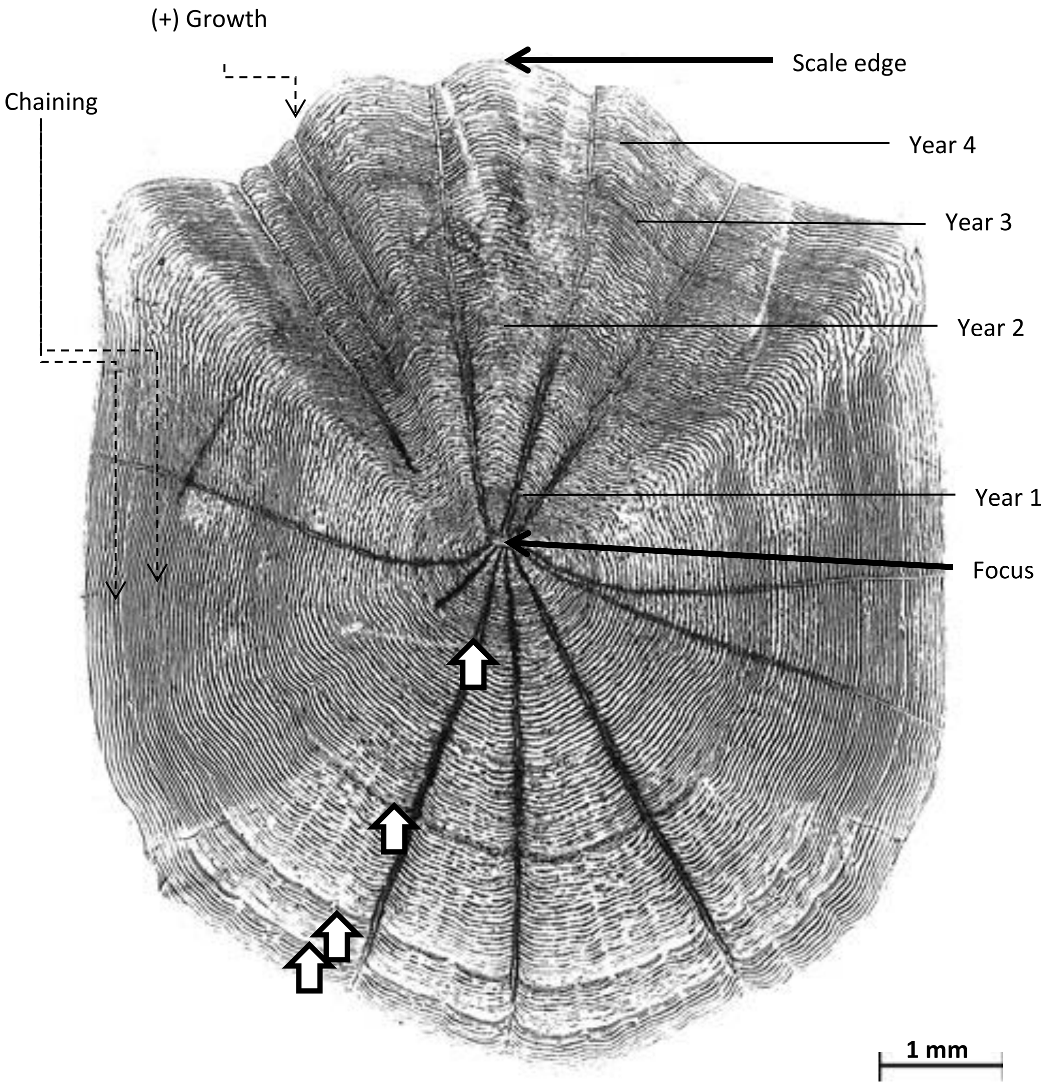
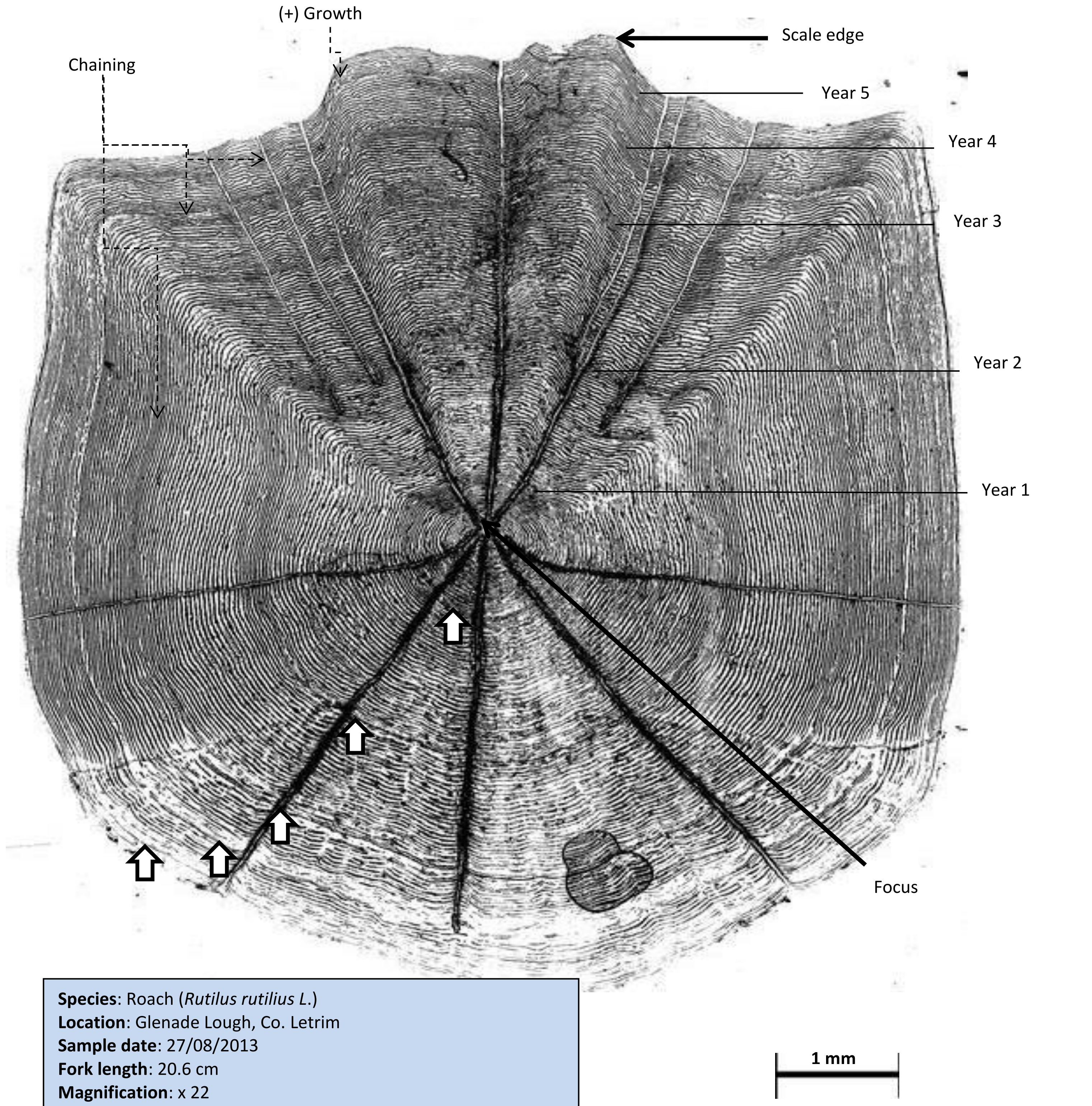


Plate 49



Species: Roach (*Rutilus rutilius L.*)
Location: Glenade Lough, Co. Letrim
Sample date: 27/08/2013
Fork length: 20.6 cm
Magnification: x 22
Age: 5+

Comments: Posterior seams are indicative of an annulus (see white arrows). Chaining occurs from year 3 (see Section 5.0, Table 4.11).

4.9 Rudd (Scardinius erythrophthalmus)

4.9.1 Identifying features

A key feature is the cleft mouth directed obliquely upwards. The dorsal fin is small, its origin well behind insertion of pelvic fins; anal fin short, with 10-13 branched rays. 39-42 scales are present along lateral line; young fish are blue and silver in colour; large fish are green-backed, with a golden lustre (fisheriesireland.ie).

4.9.2 Distribution and biological information

Rudd are present in a number of large systems such as the Shannon, Erne, Lee and the Corrib as well as being distributed in small lakes, ponds and both the Royal and Grand canals (McCarthy and Kennedy, 1965).

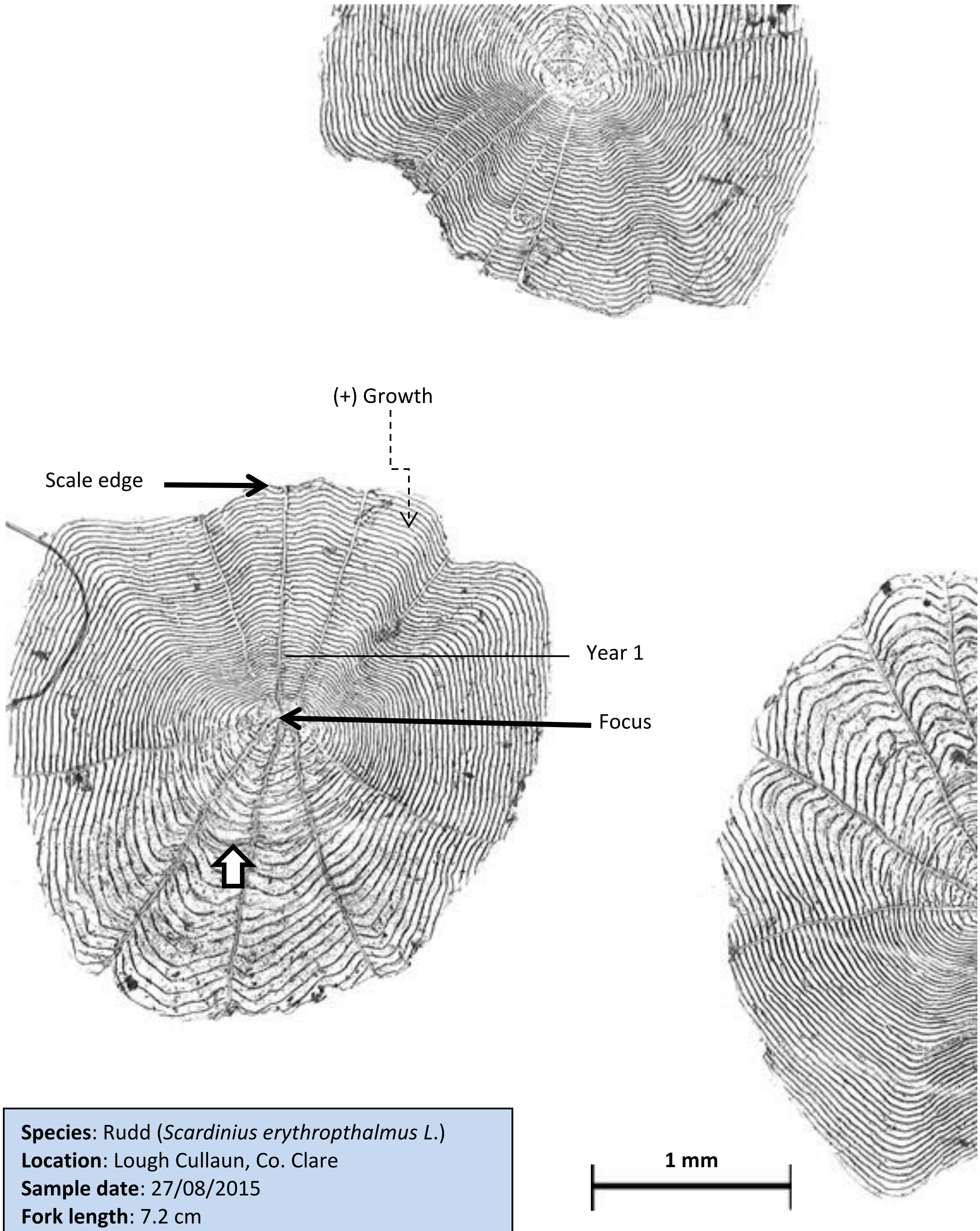
Plate 4.9: Rudd (*Scardinius erythrophthalmus*) (source IFI)

4.9.3 Ageing notes

Table 4.12: Ageing notes for rudd

I.	The first annulus is more distinctive in rudd than roach (McCarthy and Kennedy, 1965).
II.	Winter bands are clearer and wider than bream (Kennedy and Fitzmaurice, 1974). Posterior seam is a good indicator of an annulus (McCarthy and Kennedy, 1965) (see Plate No. 51). Scale erosion in cyprinid scales is known as chaining (Kennedy and Fitzmaurice, 1974) (see Section 5.0).
III.	Age at length varies in different rudd populations. Rudd are a long lived fish and appear to incur more stunted populations than other cyprinids in Irish waters (see Plate No. 53).
IV.	Scales of rudd also display straighter dorsal and ventral edges, and often display a more distinctive (less rounded) crest on each side of their anterior edge. Scales are similar in size to roach but larger than similar sized bream (see Fig. 3.10).

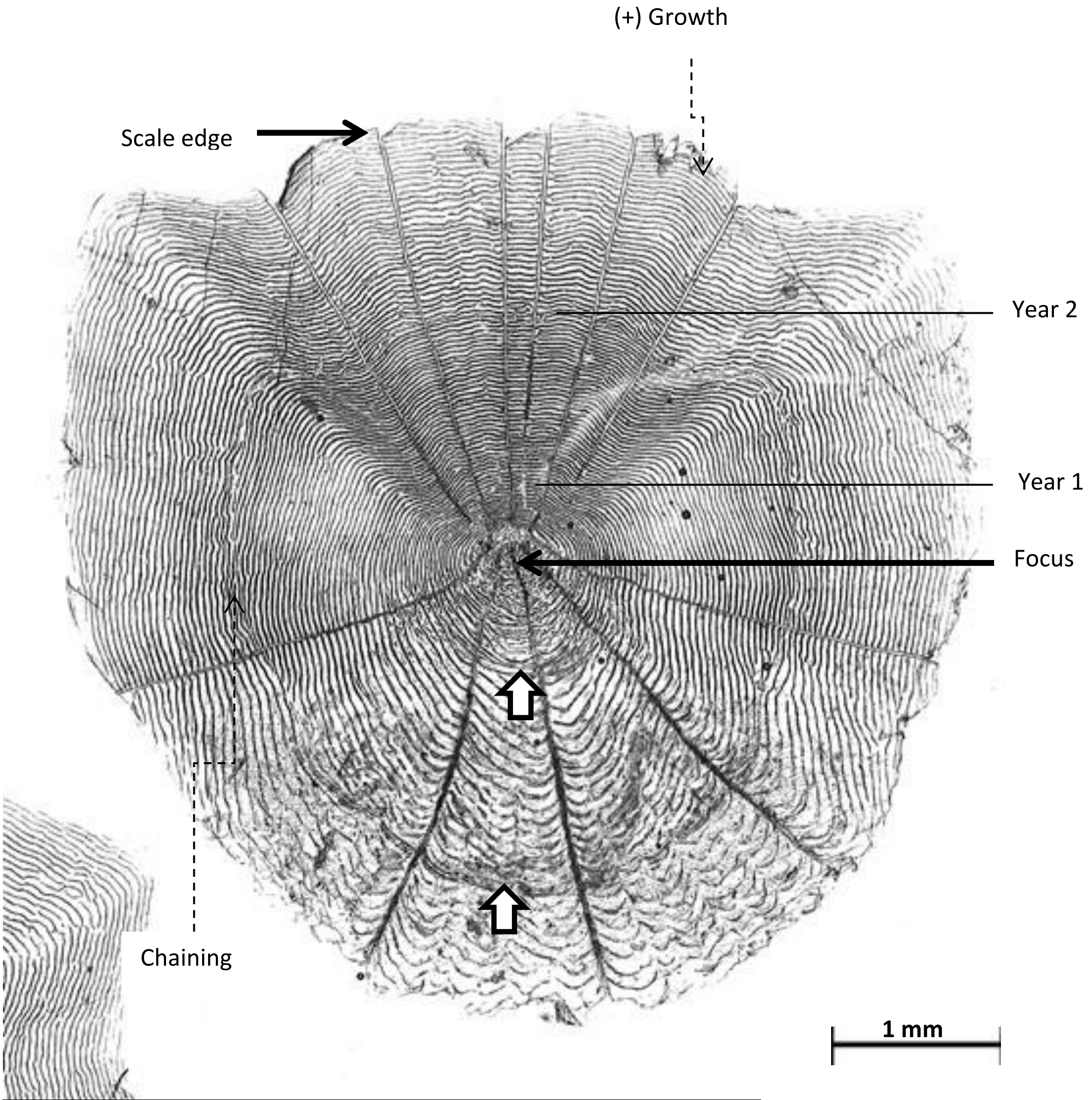
Plate No: 50



Species: Rudd (*Scardinius erythropthalmus L.*)
Location: Lough Cullaun, Co. Clare
Sample date: 27/08/2015
Fork length: 7.2 cm
Age: 1+
Magnification: x 40

Comments: Posterior seam is indicative of an annulus (see white arrow) (see Section 5.0, Table 4.12).

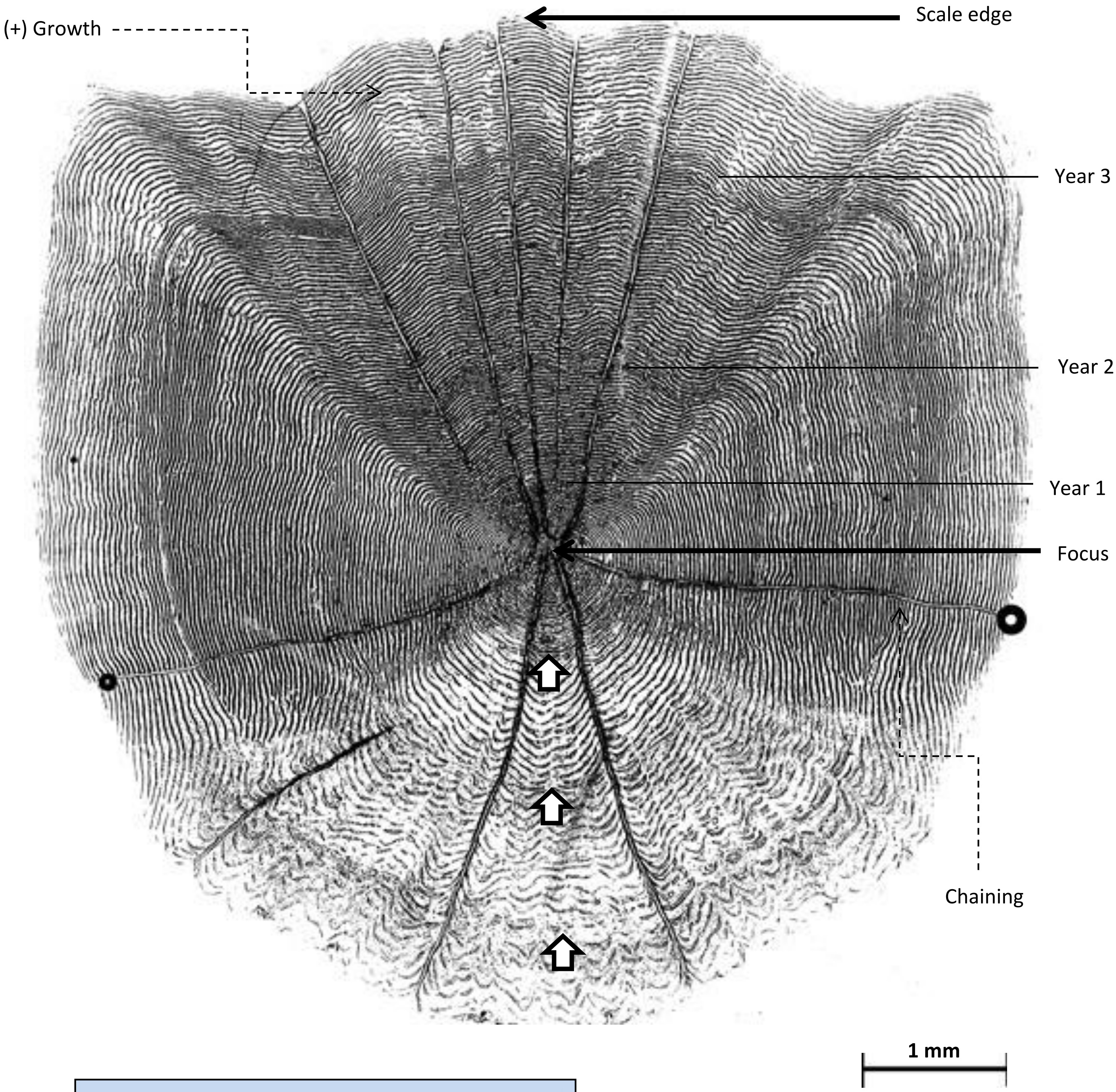
Plate No: 51



Species: Rudd (*Scardinius erythropthalmus L.*)
Location: Lough Cullaun, Co. Clare
Sample date: 27/08/2015
Fork length: 12 cm
Age: 2+
Magnification: x 30

Comments: Posterior seam indicates an annulus (see white arrows). Significant chaining visible in year 2 (see Section 5.0, Table 4.12).

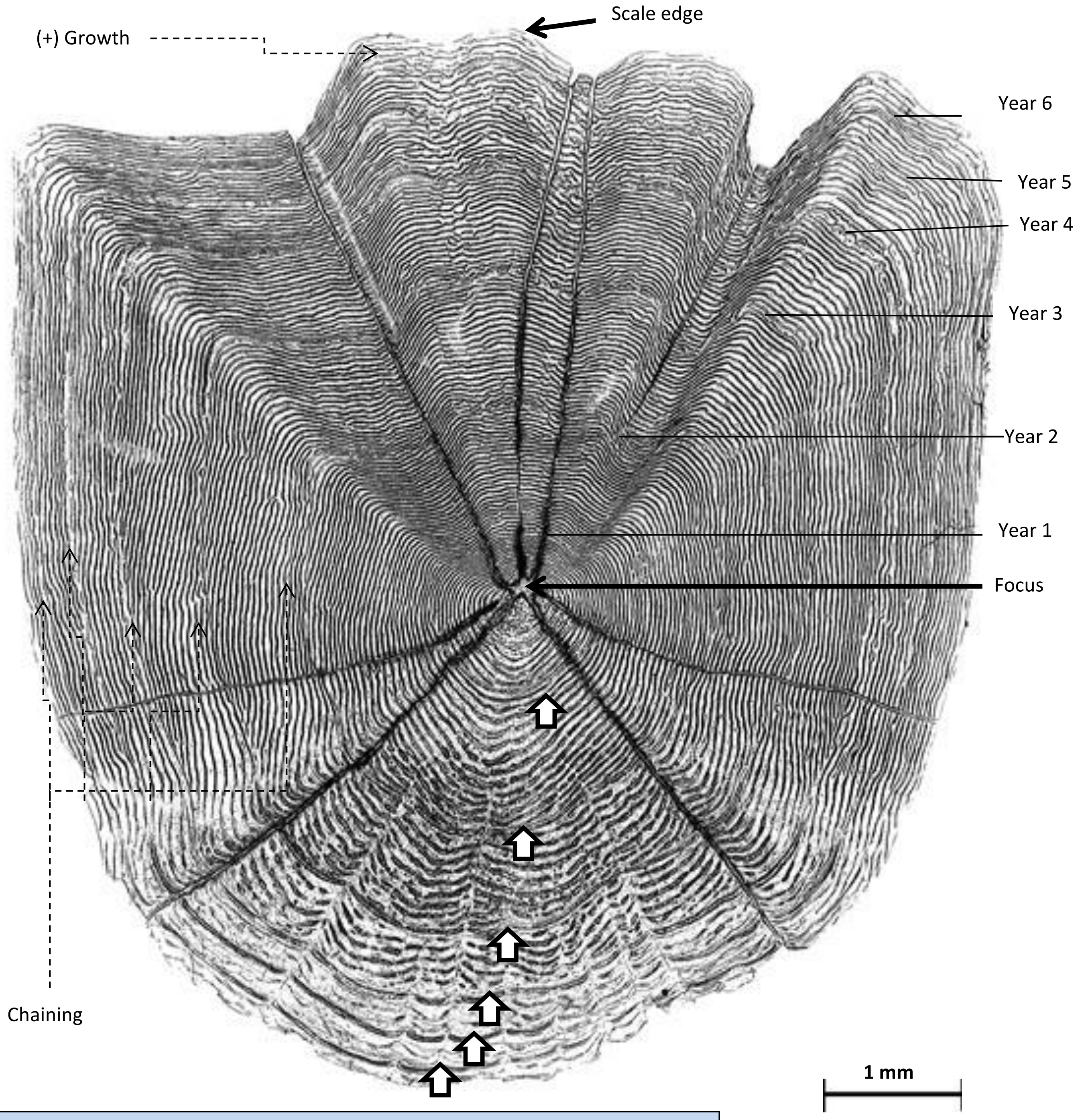
Plate No: 52



Species: Rudd (*Scardinius erythropthalmus L.*)
Location: Atedaun Lough, Co. Clare
Sample date: 10/09/2015
Fork length: 16.8 cm
Age: 3+
Magnification: x 22

Comments: Posterior seam indicates an annulus (see white arrows). Chaining occurs in year 3 (see Section 5.0, Table 4.12).

Plate No: 53



Species: Rudd (*Scardinius erythropthalmus L.*)
Location: Aughrusbeg Lough, Co. Galway
Sample date: 31/07/2013
Fork length: 13.8 cm
Age: 6+
Magnification: x 22

Comments: Posterior seam indicates an annulus (see white arrows). Prominent chaining occurs from year 3 (see Section 5.0, Table 4.12). Very slow growth rate displayed, which can occur in rudd populations (see Table 4.12).

4.10 Bream (Abramis brama)

4.10.1 Identifying features

Mouth inferior; dorsal short-based, but high and 'peaked'; its origin some distance behind insertion of pelvic fins; anal fin very long, with 23-29 branched rays; tail-fin large, deeply forked, the lower lobe the longer; 51-60 scales along the lateral line. Young fish greyish above, silvery on the sides, fins grey often known as skimmers or silver bream. Large fish darken to a bronze colour, with very dark fins (fisheriesireland.ie).

4.10.2 Distribution and biological information

In Ireland, bream are present in a number of major river systems and lakes such as the Shannon, Erne, Corrib and the two main canal systems (Kennedy and Fitzmaurice, 1968). Spawning in Irish waters takes place when water temperatures are around 15^{o}C between mid-May and June (Kennedy and Fitzmaurice, 1968).

Plate 4.10: Bream (*Abramis brama*) (source IFI)

4.10.3 Ageing notes

Table 4.13: Ageing notes for bream

I.	Young bream can have less defined annuli than other cyprinids (see Plates No. 54-55). In older bream the first annulus can be missed entirely during ageing (Kennedy and Fitzmaurice, 1968) (see Plate No. 57).
II.	Scale erosion in cyprinid scales is known as chaining (Kennedy and Fitzmaurice, 1974). This occurs in particularly older fish and is indicative of an annulus (see Plates No. 57). While less defined than in roach and rudd, it can assist in recording an annulus (McCarthy and Kennedy, 1965). Later annuli can also be indicated with prominent white lines (Corcoran W., 2017, *pers. comm.*) (See Plates No. 56-57). Posterior seams also suggest an annulus in bream scales (see Section 5.0).
III.	Scales of bream are smaller than similar sized rudd and roach and also display a more convex shape on its dorsal and ventral edges. Bream scales often do not display a distinctive crest on each side of its anterior edge (see Fig. 3.10).

Plate No: 54

Species: Bream *(Abramis brama)*
Location: Stonemans Lake, Co. Roscommon
Sample date: 24/06/2015
Fork length: 6cm
Age: 1+
Magnification: x55

Comments: Year 1 annulus is highlighted (see white arrow) Difficult to spot an annulus. Fish is aged as 1+. This fish has possibly laid down its annulus earlier in this year (see Table 3.2) and is only displaying several weeks growth in year 2.

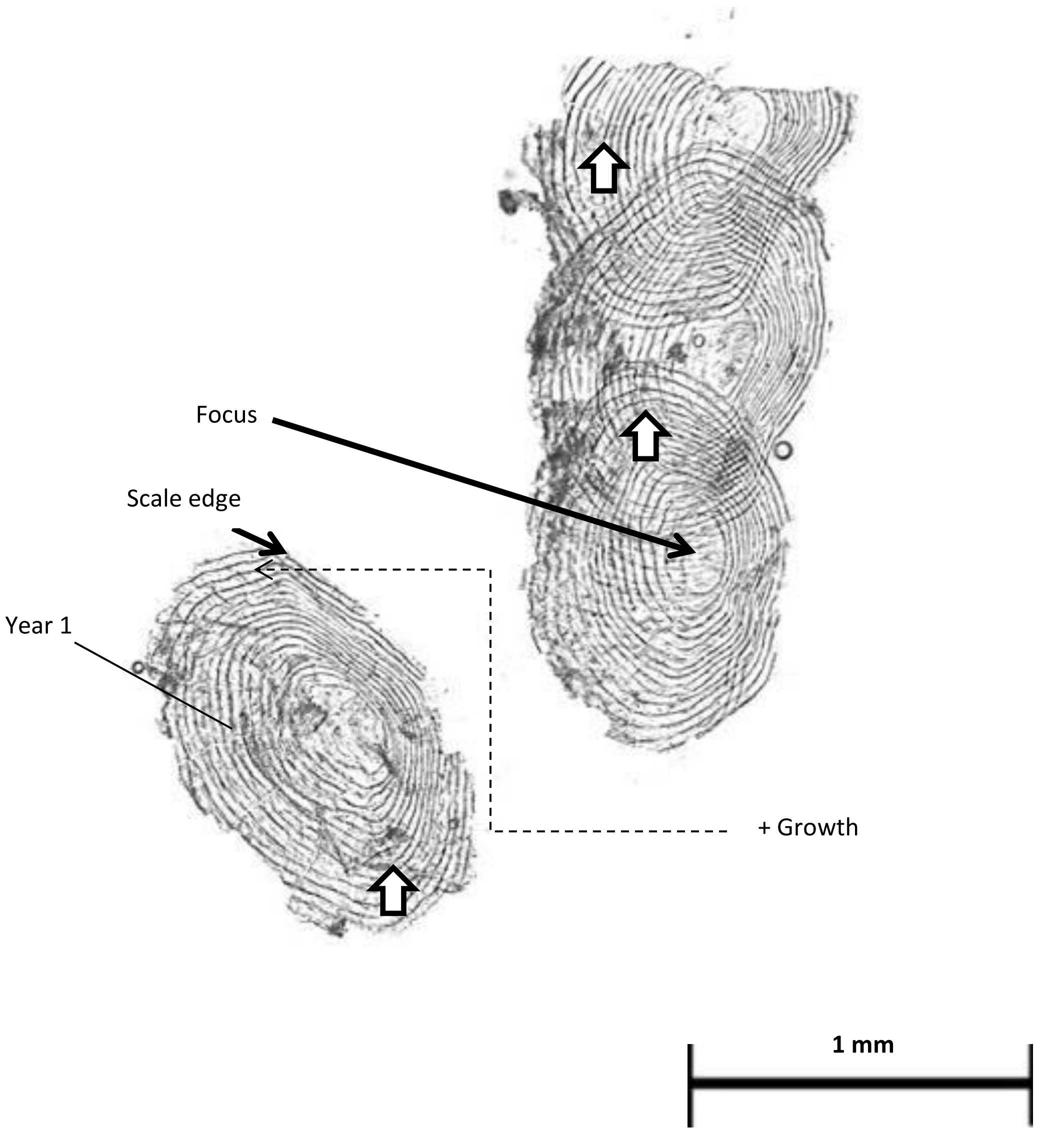
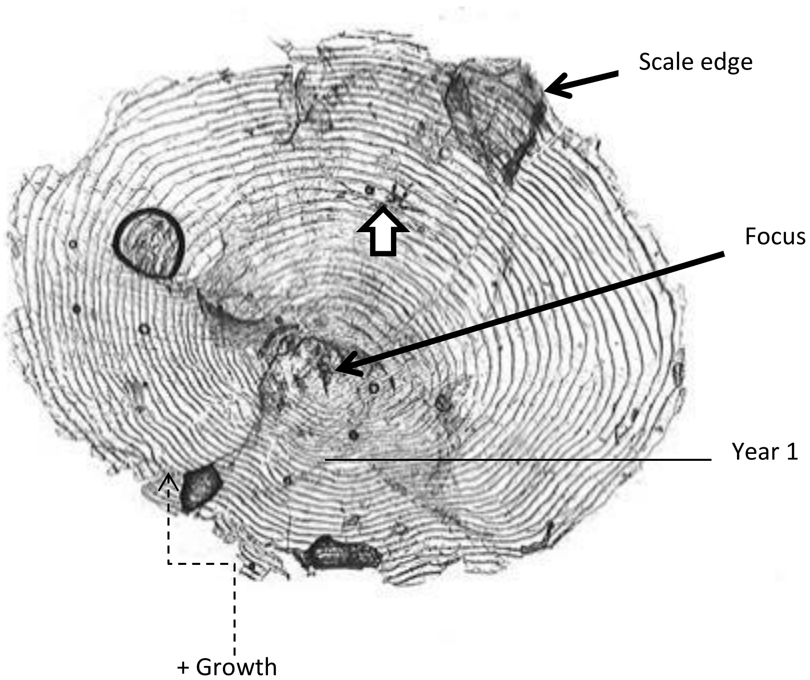
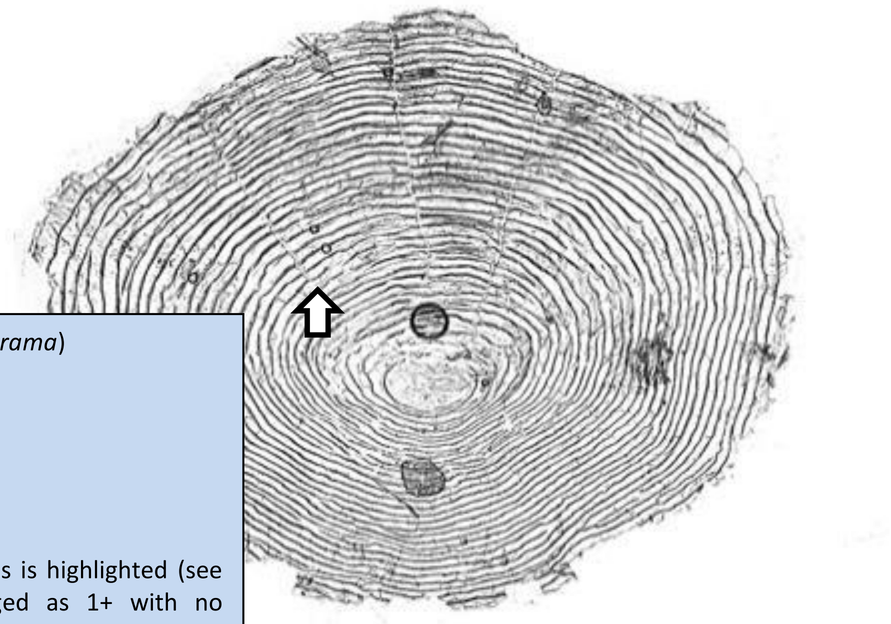


Plate No: 55





Species: Bream (*Abramis brama*)
Location: Stonemans Lake
Sample date: 24/06/2015
Fork length: 8.5cm
Age: 1+
Magnification: x55

Comments: Year 1 annulus is highlighted (see white arrow). Fish is aged as 1+ with no evidence of 2nd annulus. However, the time of year would suggest an imminent occurrence of the 2nd annulus (see Table 3.2).

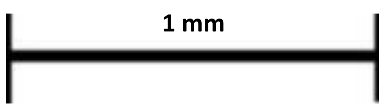


Plate No: 56

Species: Bream (*Abramis brama*)
Location: Inniscarra Reservoir, Co. Cork
Sample date: 18/08/2015
Fork length: 12.2cm
Age: 2+
Magnification: x 35

Comments: Posterior seams are indicative of an annulus (see white arrows) (see Section 5.0, Table 4.13).

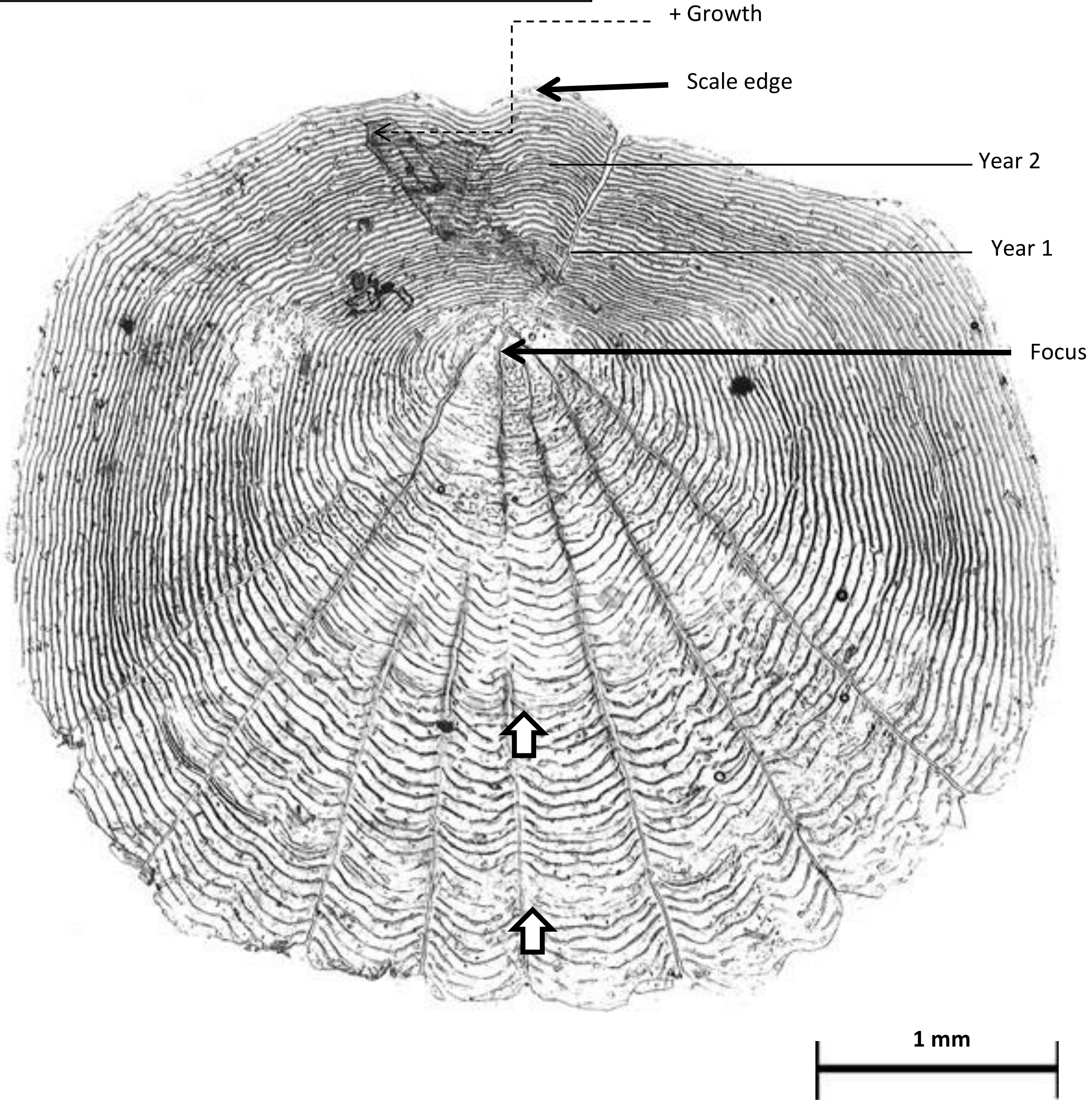
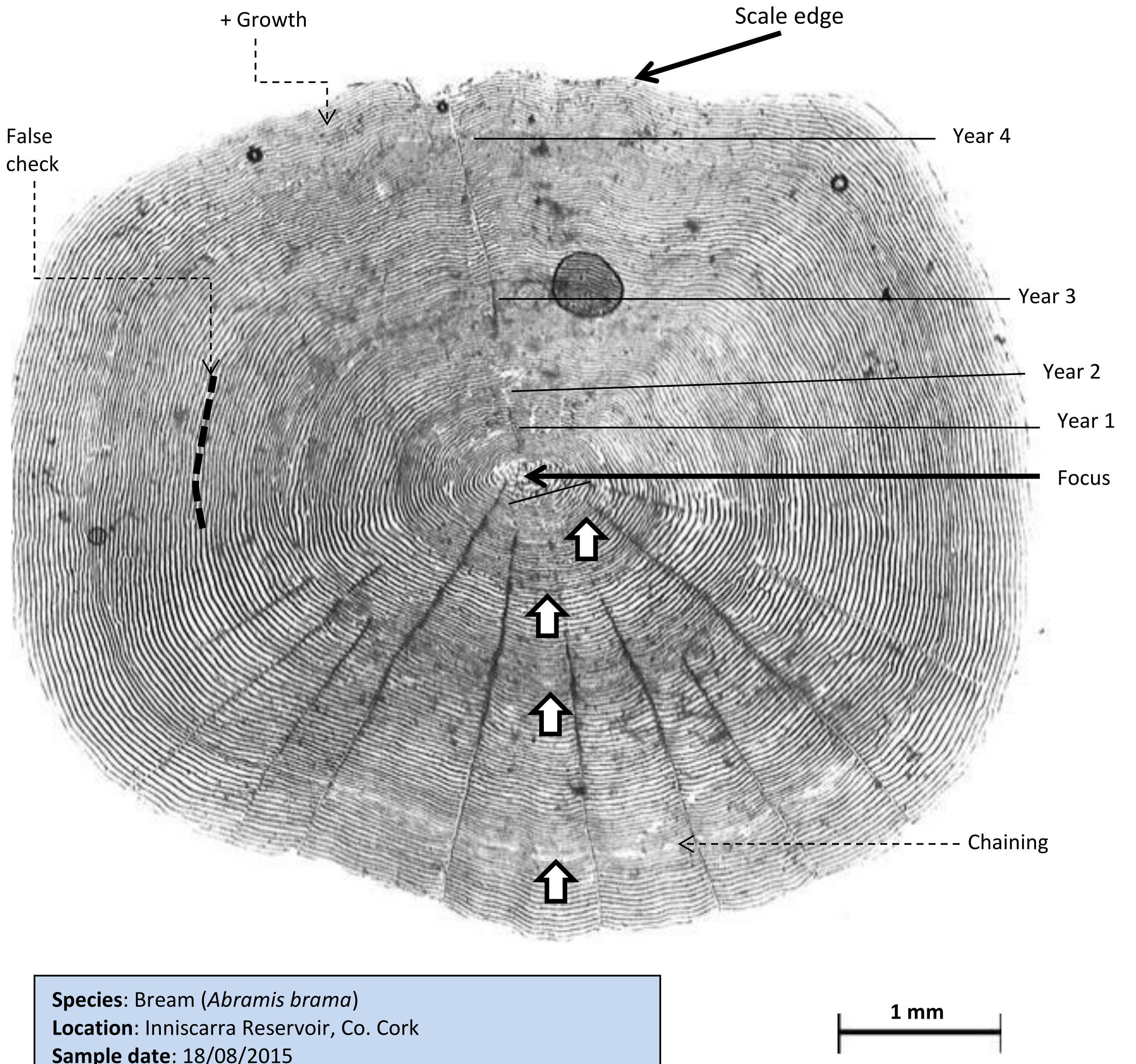


Plate No: 57



Species: Bream (*Abramis brama*)
Location: Inniscarra Reservoir, Co. Cork
Sample date: 18/08/2015
Fork length: 19.1cm
Age: 4+
Magnification: x30

Comments: Posterior seams are indicative of an annulus (see white arrows). Chaining also occurs in year 4 (see Section 5.0, Table 4.13). Note the presence of a false check (see Section 5.0) between year 3 and 4.

4.11 Roach x Bream hybrid (Rutilus rutilus x Abramis brama)

4.11.1 Identifying features

Roach x bream hybrids take on the characteristics of both parents. There are 16-21 anal ray fins and 46-50 lateral line scales (Klein *et al.*, 2012). The anal fin does not "fan" out when extended having up to 10 less anal fin rays than true bream.

4.11.2 Distribution and biological information

Since the introduction of roach to Irish river and lake systems (from 1889) where bream previously existed, populations of roach x bream hybrids are a common occurrence. In the unstable Irish climate the spawning period for roach and bream may be considerably short, consequently the opportunity for overlap in the spawning of both species and resulting hybridisation is increased (Hayden *et al.*, 2010). It is not unusual for hybrids to outnumber true bream in mixed cyprinid fish populations in Irish waters.

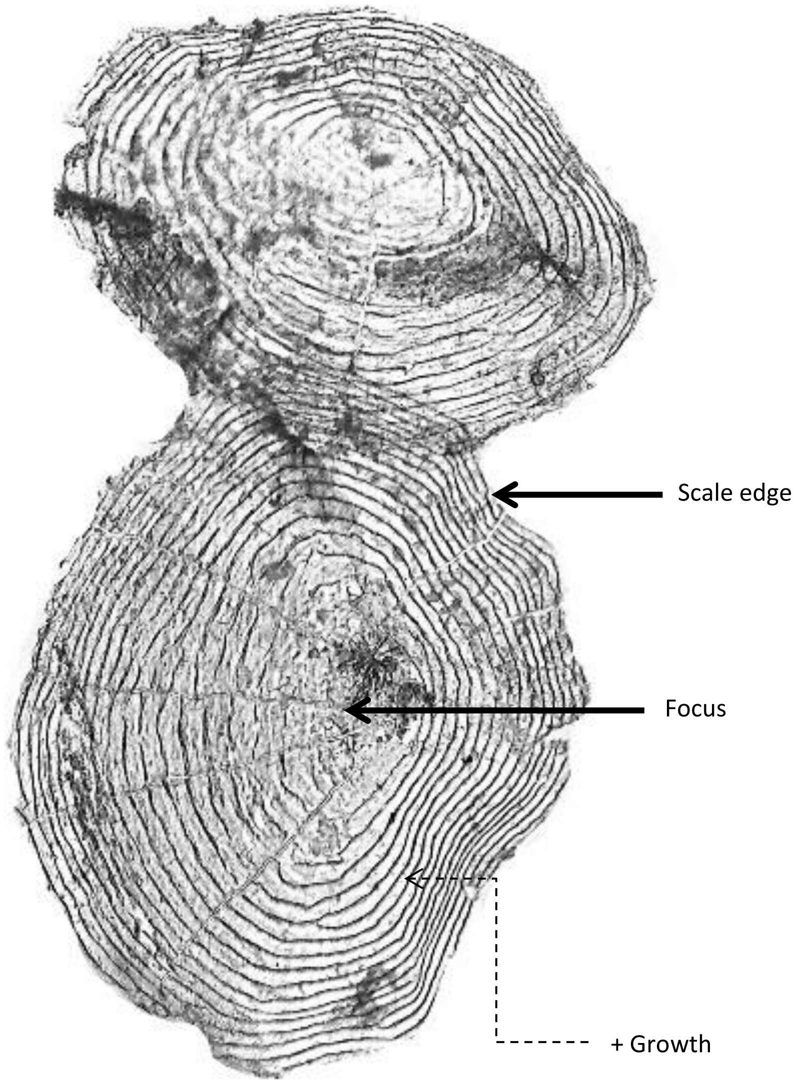
Plate 4.11: Roach x bream hybrid (*Rutilus rutilus x Abramis brama*) (source IFI)

4.11.3 Ageing notes

Table 4.14: Ageing notes for roach x bream hybrid (I-IV)

I.	Roach x bream hybrids scales are often larger than true bream scales but are smaller than true roach scales of a similar size (see Fig. 3.10).
II.	Scales of roach x bream hybrids also display straighter dorsal and ventral edges, and may display a more distinctive anterior crest on each side of the scale than true bream (see Fig. 3.10, Plate No. 61).
III.	Roach x bream hybrid populations are often dominated by intermittent year classes and are long lived. Large specimens can reach 20 or more years old.
IV.	Posterior seams also occur in hybrid scales and can suggest an annulus (see Plates No. 60-61).

Plate No: 58



Species: Roach x bream hybrid
Location: Lough Muckno, Co. Monaghan
Sample date: 23/09/2015
Age: 0+
Magnification: x 55
Fork length: 4.8cm

Comments: This fish displays no annulus, only summer growth post hatching the same year. Age is 0+.

1 mm

Plate No: 59

Species: Roach x bream hybrid
Location: Lough MacNean Lower, Co. Fermanagh
Sample date: 28/06/2013
Age: 1+
Magnification: x 50
Fork length: 7.1cm

Comments: Annulus for year 2 not yet formed. Fish is aged as seen (1+).

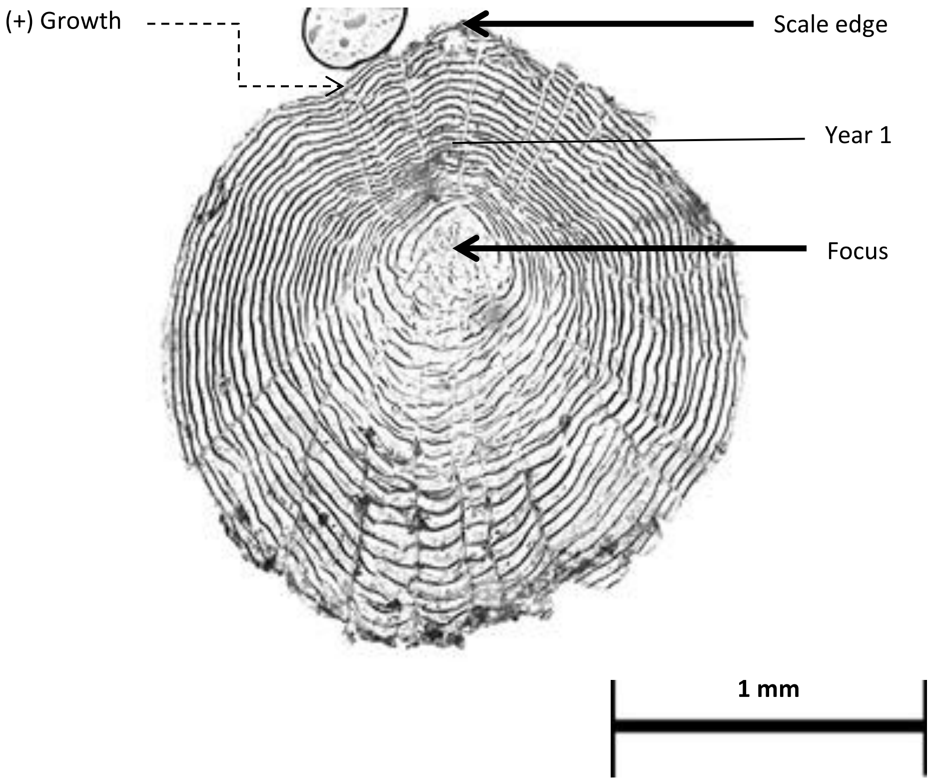
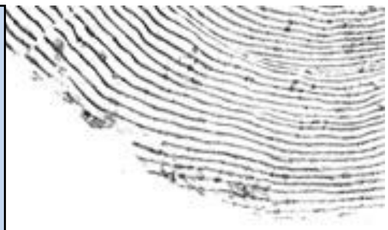


Plate No: 60

Species: Roach x bream hybrid
Location: River Barrow, Bagenalstown, Co. Carlow
Sample date: 20/07/15
Age: 2+
Magnification: x40
Fork length: 8.8cm

Comments: Posterior seams are indicative of an annulus (see white arrow) (see Section 5.0, Table 4.14).



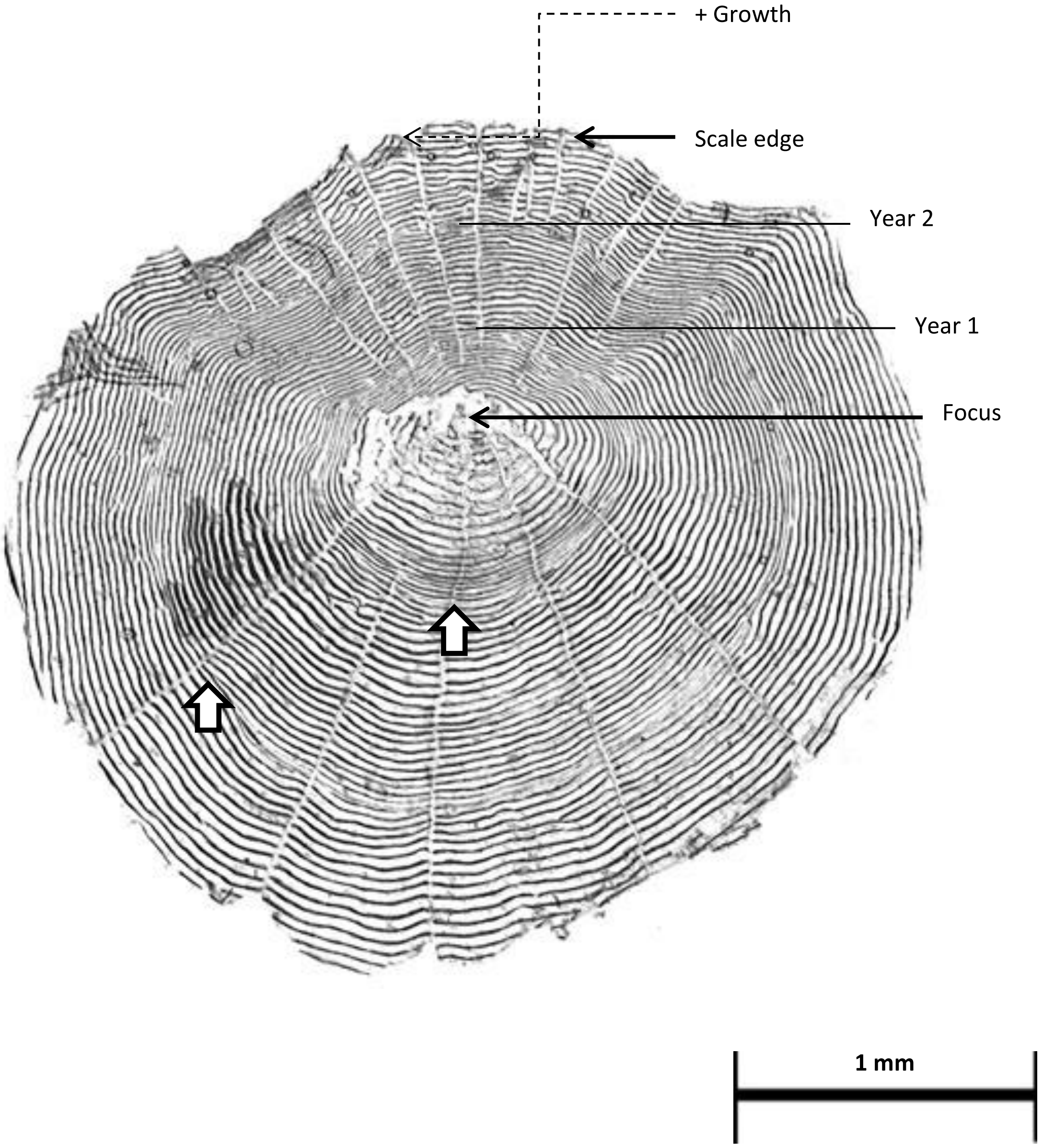
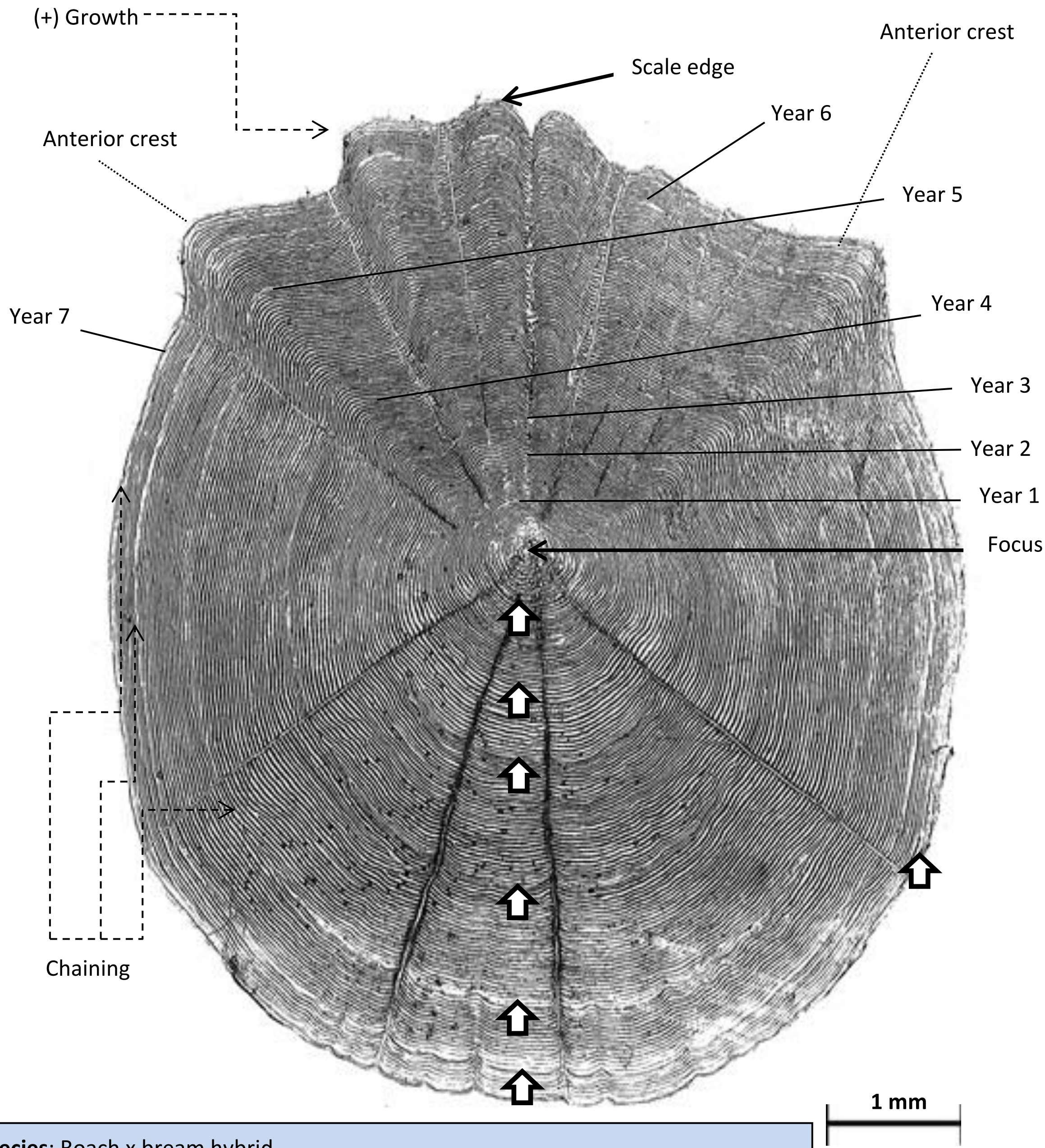


Plate No: 61



Species: Roach x bream hybrid
Location: Lough MacNean Lower, Co. Fermanagh
Sample date: 28/06/2013
Fork length: 19.5cm
Age: 7+
Magnification: x 24

Comments: A more prominent anterior crest can be indicative of hybrid vs. a true bream (see Figure 3.10). The chaining of circuli is a common occurrence in older cyprinids but can show an annulus (Kennedy and Fitzmaurice, 1974). The first year in large cyprinids is also more difficult to spot and can be missed. Look for posterior seams as these can assist in locating an annulus (see white arrows) (see Section 5.0, Table 4.14).

4.12 Dace (Leuciscus leuciscus)

4.12.1 Identifying features

Sub-inferior mouth; sub-equal jaw, upper jaw slightly longer; upper lip tip about level with centre of eye. Rarely longer than 30 cm TL; normally 47-52 scales in lateral line; anal fin concave; caudal fin forked with 19 rays (www.Fishbase.org).

4.12.2 Distribution and biological information

The dace (*Leuciscus leuciscus*.) has a European-wide distribution ranging from Scandinavia to the South of France and eastwards into the former Soviet Union (Wheeler, 1969). Dace were originally introduced into the River Blackwater in County Cork in 1889 and it was almost 100 years before dace populations began to appear on the Ahaclare River in County Clare, ultimately appearing on the River Maigue, River Mulkear and the River Shannon (Kennedy, 1969). Populations are also present in the Rivers Nore and Barrow since the early 1990's, and were first recorded in the River Suir during IFI fish monitoring surveys in 2010 (O' Briain, R., 2019 *pers. comm.*). Dace spawn in gravels and utilise other debris in flowing water when water temperatures are between 8-11^{o}C (Kennedy, 1969, Caffrey *et al.*, 2007). Spawning occurs earlier than other cyprinids, with spawning observed as early as late February depending on water temperature (Kennedy, 1969).

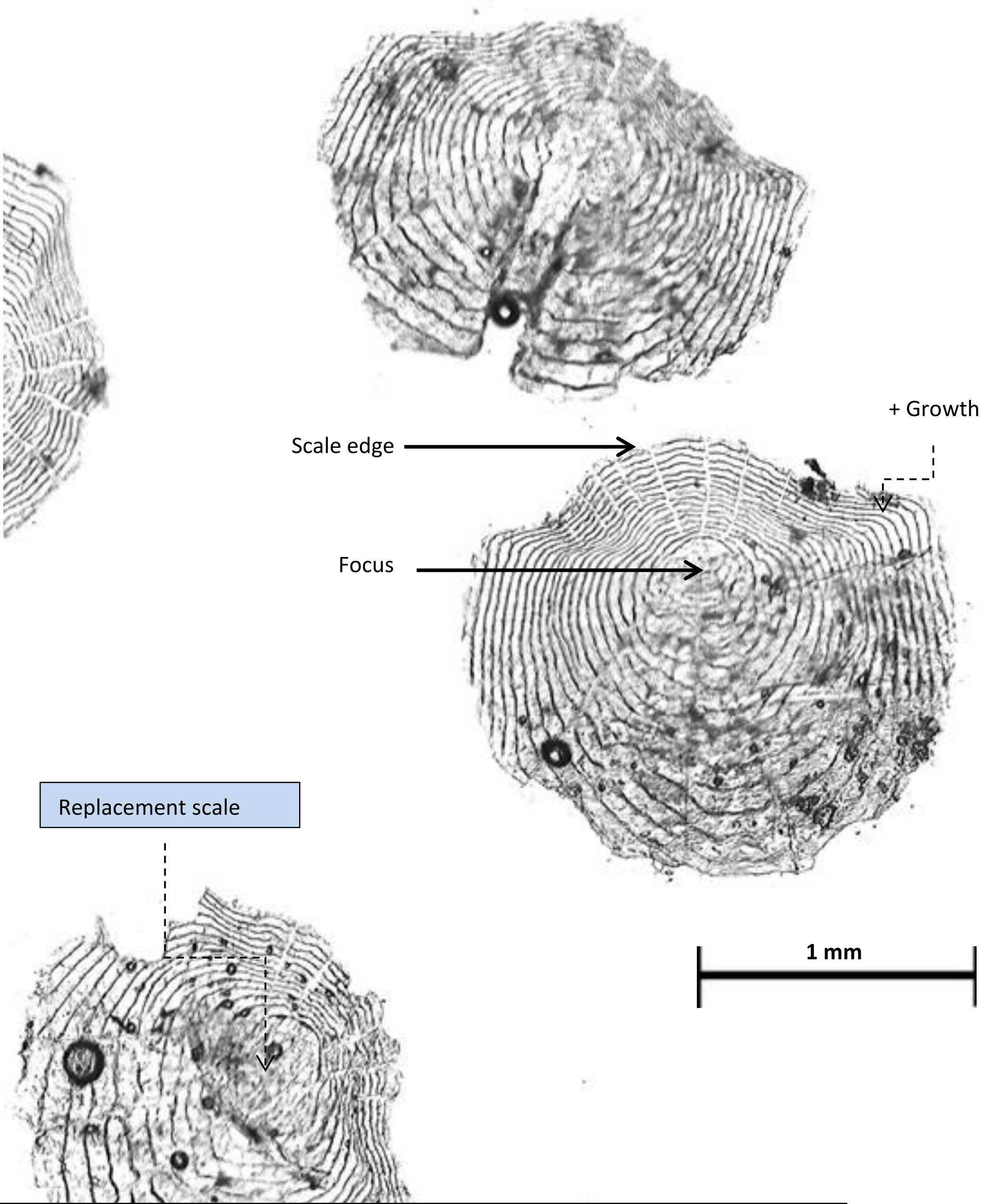
Plate 4.12: Dace (*Leuciscus leuciscus*) (source IFI)

4.12.3 Ageing notes

Table 4.15: Ageing notes for dace (I-III)

I.	Dace have larger eggs, emerging larvae and display faster growth than other cyprinids, particularly in year 1 (Kennedy, 1969). In early years, dace make much bigger length increments than roach, even though roach become, ultimately, the larger fish (Hartley, 1947).
II.	The first annulus of dace is well defined in comparison to other cyprinids. The first annulus often forms between 4 and 5cm (Kennedy, 1969) (see Plate No. 62).
III.	"Cutting over" of circuli on the posterior end of scales is more evident in dace than other cyprinids (Mcloone, P., 2016 *pers. comm.*). This is a feature that also appears on salmonid scales, particularly in older age classes. These scars on the posterior end of the scale (posterior seam) are also observed to be a good indicator of an annulus (Kennedy (1969) (see Plates No. 64-65).

Plate No: 62



Species: Dace (*Leuciscus leuciscus)*
Location: River Barrow, Strawhall, Co. Carlow
Sample date: 20/07/15
Fork length: 4.2cm
Age: 0+
Magnification: x55

Comments: Knowledge of species biology is very important when looking at growth patterns (see Table 3.2). Dace emerge some months earlier than other cyprinids and generate faster year 1 growth (see Table 4.15). Replacement scale is positioned in the bottom left of plate.

Plate No: 63

Species: Dace (*Leuciscus leuciscus)*
Location: River Barrow, Graiguenamanagh, Co. Kilkenny
Sample date: 22/07/2015
Fork length: 7.2cm
Age: 1+
Magnification: x45

Comments: Dace aged 1+. This fish displays significant growth in year 2, based on formation of annulus in March (see Table 3.2).

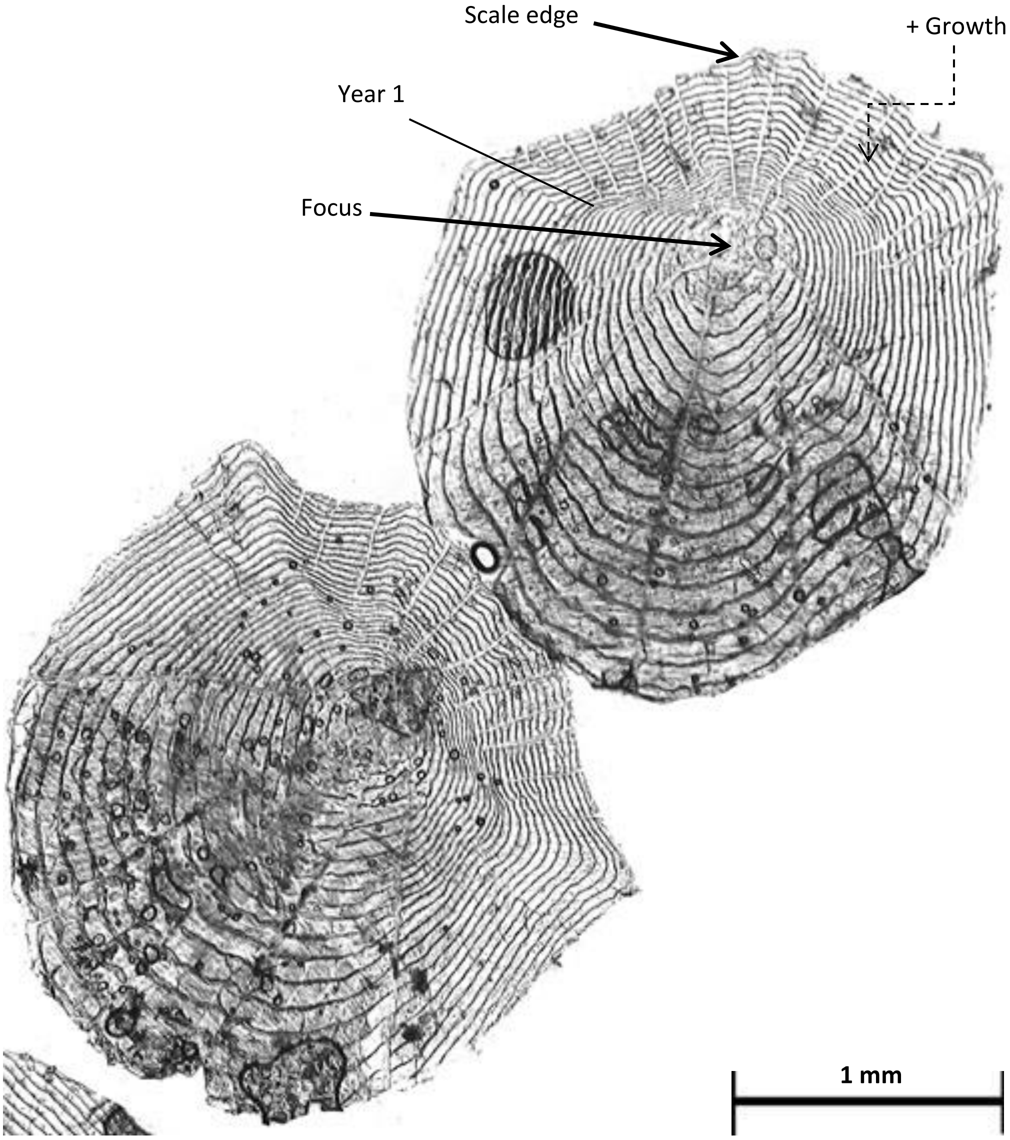


Plate No: 64

Species: Dace (*Leuciscus leuciscus)*
Location: River Barrow, near Ballinkillen, Co. Carlow
Sample date: 21/07/2015
Fork length: 14.3cm
Age: 2+
Magnification: x35

Comments: Significant cutting over appears in year 2. Posterior seams (white arrows) indicate presence of an annulus (see Section 5.0, Table 4.15).

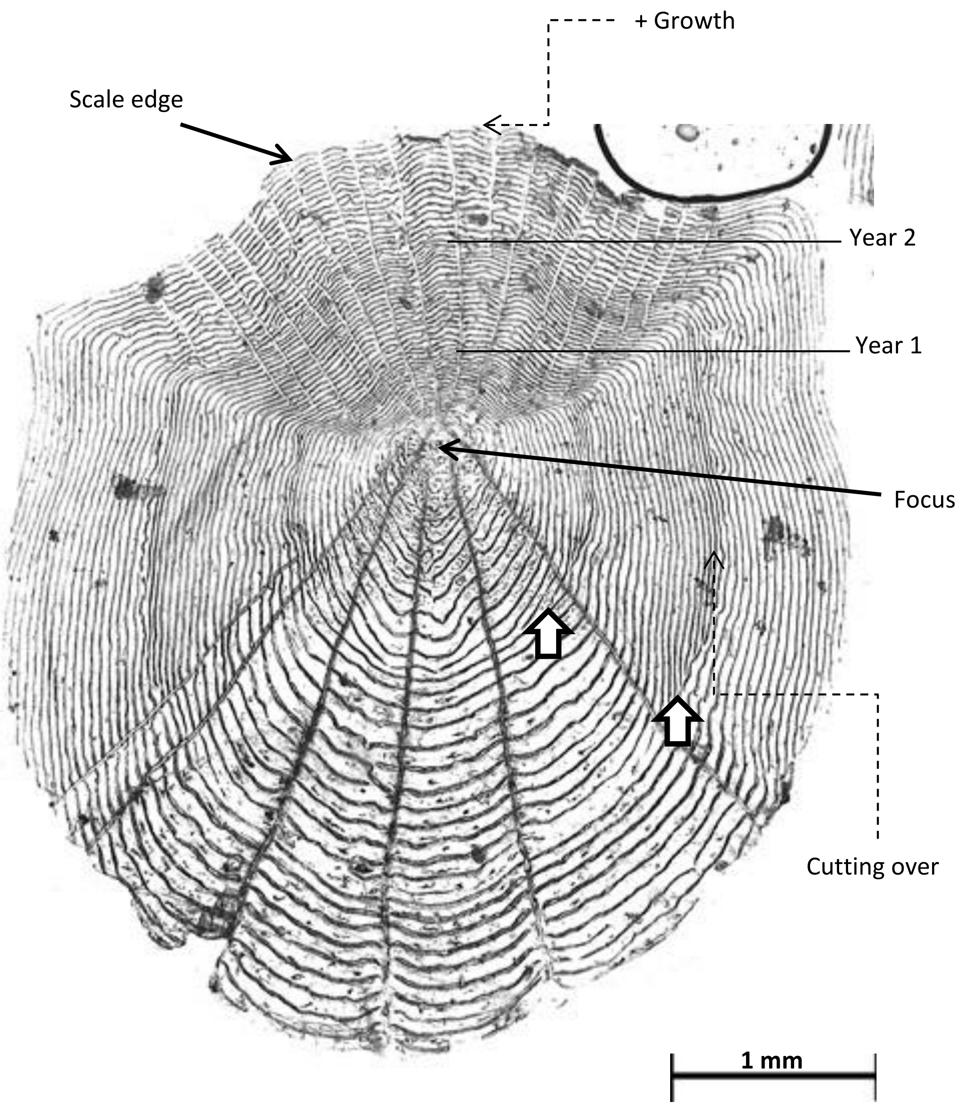
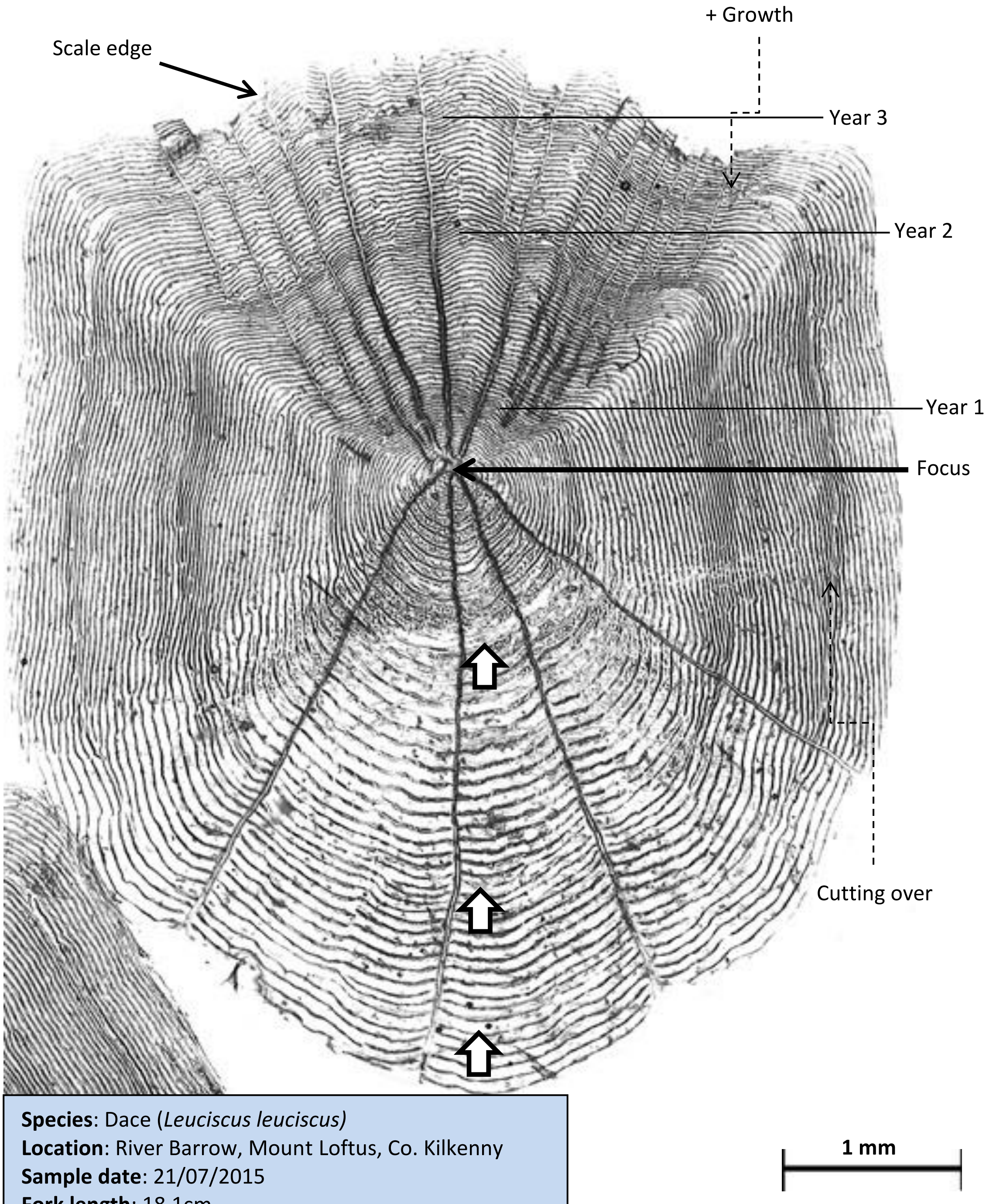


Plate No: 65



Species: Dace (*Leuciscus leuciscus)*
Location: River Barrow, Mount Loftus, Co. Kilkenny
Sample date: 21/07/2015
Fork length: 18.1cm
Age: 3+
Magnification: x30

Comments: Significant cutting over appears in year 3. Posterior seams (see white arrows) indicate presence of an annulus (see Section 5.0, Table 4.15).

5.0 Glossary of terms

Annual zone: A concentric region of the scale referring to a complete year of life

Annulus: The theoretical boundary between two successive annual zones. Annual zones (annuli) on a scale are characterised by a succession of bands of wide-spaced and narrow-spaced circuli. The annulus is an ideal or theoretical line running midway between the last of the narrow-spaced circuli (may be discontinuous) of a winter band and the first of the wide-spaced circuli of the following summer band. As a general rule, a candidate annulus is identified by a dense grouping of circuli

Anterior edge: The embedded end of a scale

Anterior crest: A prominent ridge/crown-like feature formed on the anterior edges of scales in roach, rudd and their hybrids

Back-calculation: The calculation of estimated fish body length associated with each annulus

b growth: A growth pattern often precedes the smolt stage of migratory salmonids, particularly sea trout. Referred to as “pre marine migration run-out” or “compensatory” growth; a period of faster growth at the end of the last freshwater annulus. Often absent or difficult to detect and may be associated with smaller smolts in an effort to reach larger size prior to migration. While noted throughout the document, b growth is not added to ageing notations

Core (otolith): The point on the otolith that is in the centre of the concentric lines; synonymous with nucleus

Chaining: describing the erosion/bunching of circuli to suggest an annulus, particularly in older cyprinids

Circuli: Circuli appear on the surface of the scale as dark concentric lines; synonymous with rings

Cutting over: Disruption of circuli development on scales from erosion and/or reabsorption. Can often be associated with an annulus, particularly in spawning marks of salmonids and dace.

Dorsal edge: The edge of the ageing structure facing the dorsal side of the fish

Erosion: Reabsorption of the edge (and sometimes the surface) of a scale. Can often occur during the spawning process. Most frequently observed in salmonids

False check: Also known as false annulus. Sometimes used synonymously with "check". Refers to a zone of slow growth that is not counted as an annulus

Focus: The point on the scale or operculum that is in the centre of the concentric lines; synonymous with nucleus

Isometric growth: Growth of hard structures that is directly proportional to the length of the fish

Posterior edge: The exposed end of a scale

Posterior margin: The margin that divides embedded and exposed part of a scale

Posterior seam: Ridge/band of fused circuli that occurs on the exposed part of the scale. Used primarily for indicating an annulus in cyprinids but can be used to highlight this feature in all species	
Plus (+ growth): Region of wide-spaced circuli at outer part of exposed scale which may follow the last annulus signifying that a full year of growth has not been completed	
Re-entry mark: Growth check associated with anadromous salmonids, where they may have migrated back into freshwater from the sea or estuary (juvenile migrants can also have checks on outward migration)	
Regenerated (replacement) scales: Scales that have formed at a later stage in fish development. They form after the loss of a previous scale. Does not include all circuli or relevant information so are not used in the ageing process	
Scale edge: The end point of the scale or opercular bone	
Sea winter: A dark band composed of a number of closely spaced circuli, associated with slow growth during winter. The term is used in describing the annulus pattern of salmon and sea trout scales	
Spawning mark: Erosion associated with the spawning migration. Spawning marks in salmonids are characterised by intense "cutting over" and erosion on the lateral part or sides (?) of the scale, where several circuli can disappear into one another during the spawning process. This process is less destructive in cyprinids, with less absorption occurring and more of a chaining type of annulus formation	
Summer band: A light band composed of a number of more widely spaced circuli, thought to be associated with rapid growth during the warmer period of the year	
Summer check Narrow-spaced circuli, generally fewer in number than a winter band, occurring within a summer band. Normally used in the ageing of Atlantic salmon during its adult marine growth phase to differentiate a summer check from a true annulus. Also known to occur in pollan.	
Ventral edge: The edge of the ageing structure facing the ventral side of the fish	

From McCarthy and Kennedy 1965); Kennedy (1969); Kennedy and Fitzmaurice (1974); Fahy (1980); ICES (1984); Steinmetz and Muller (1991); Pierce *et al*., (1996); CSTP, (2010); CES (2011); CSTP, (2016)

6.0 References

Able, K.W. and Lamonaca, J.C. 2006 Scale formation in selected western North Atlantic flatfishes. *Journal of Fish Biology* **68**, 1679-1692

Allan, I.R.H. and Ritter, J.A. 1977 Salmonid Terminology. *Journal du Conseil / Conseil Permanent International pour l'Exploration de la Mer* **37** (3), 293-299.

Ashford, J.R., Wischniowski, S., Jones, C and Bobko, S. 2001 A comparison between otoliths and scales for use in estimating the age of *Dissostichus eleginoides* from South Georgia. *CCAMLR Scicrzce* **8**, 75-92.

Aymes, J.C.M., Vignon, M., Beall, E., Guéraud, F and Gaudin, P. 2015 Age validation of the Kerguelen Islands brown trout, *Salmo trutta* L., and selection of the otolith optimal zone for investigating chronological data series. *Fisheries Research* **176**, 22-29.

Bagenal, T.B. and Tesch, F.W. 1978 *Age and growth*. In T.B. Bagenal (ed) *Methods for assessment of fish production in freshwater*, 3rd edition, 101–136. Oxford. Blackwell Scientific Publications.

Barbour, E.S. and Einarsson, S. 1987 Ageing and growth of charr, *Salvelinus alpinus* (L.), from three habitat types in Scotland. *Aquaculture Research* **18**, 63-72.

Bardonnet A., Gaudin, P. and Thorpe J.E. 1993 Diel rhythm of emergence and of first displacement downstream in trout (*Salmo trutta*), Atlantic salmon (*Salmo salar*) and grayling (*Thymallus thymallus*). *Journal of Fish Biology* **43**, 755-762.

Baroudy, E. 1995 Arctic charr (*Salvelinus alpinus*) in Windermere (Cumbria). *Environmental Services,* 185-192. Division of Life Sciences, Kings College London.

Billard, R. 1996 Reproduction of pike: gametogenesis, gamete biology and early development. In: Craig J.F. (ed.), *Pike*, 13-43. Dordrecht. Fish and Fisheries Series. Springer.

Bullock, A.M and Roberts, R.J. 1974 The dermatology of marine teleost fish. The normal integument. *Oceanography Marine Biology Annual Review* **13**, 383-411.

Bracken, J.J., 1973 The Age and Growth of Pike from Irish trout rivers. *Irish Fish Investigations* **12**, Series A (Freshwater).

Bräger, Z. and Moritz, T. 2016 A scale atlas for common Mediterranean teleost fishes. *Vertebrate*

Zoology **66 (3)**, 275-386.

Butler, J. L. 1992 Collection and preservation of material for otolith analysis. In D. K. Stevenson and S. E. Campana (eds.), Otolith microstructure examination and analysis. *Canadian Special Publication of Fisheries and Aquatic Sciences* **11**, 13-17.

Campana, S.E. and Neilson, J.D 1985 Microstructure of Fish Otoliths. *Canadian Journal of Fisheries and Aquatic Sciences* **42**, 1014-1032.

Campana, S.E. 1999 Chemistry and composition of fish otoliths: pathways, mechanisms and applications. *Marine Ecology Progress Series* **188**, 263-297.

Campana, S.E. 2001 Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology* **59**, 197–242.

Caffrey, J.M., Hayden B., and Walsh T. 2007 Dace (*Leciscus leuciscus L*.): an Invasive Fish Species in Ireland. *Irish Freshwater Fisheries, Ecology and Management* **5**. Central Fisheries Board, Dublin, Ireland.

Casselman, J.M., 1973. Analysis of hard tissue of pike *Esox lucius* L., with special reference to age and growth, p.p. 13-20, in: Bagenal. T.B. (Ed), *Ageing of Fish* . Unwin Bros ltd, Old Woking

Chilton, D.E. and Beamish, R.J. 1982 Age Determination Methods for Fishes Studied by the Groundfish Program at the Pacific Biological Station. *Canadian Special Publication of Fisheries and Aquatic Sciences* **60**.

Clark, C.F. and Steinbach, F. 1959 Observations on the Age and Growth of the Northern Pike, *Esox lucius* L., in East Harbor, Ohio. *Ohio Journal of Science* **59 (**3), 129-134.

Conover, D.O. 1992 Seasonality and the scheduling of life history at different latitudes. *Journal of Fish Biology* **41** (Supplement B), 161-178.

Cowx, I.G. 1983 The biology of bream, *Abramis brama* (L), and its natural hybrid with roach, *Rutilus rutilus* (L), in the River Exe. *Journal of Fish Biology* **22**, 631-646.

Cragg-Hine, D. and Jones, J.W. 1969 The growth of Dace (*Leuciscus leuciscus*), Roach (*Rutilus rutilus*) and Chub (*Squalius cephalus*) in Willow Brook, Northamptonshire. *Journal of Fish Biology* **1**, 59-82.

Craig J.F. (ed.) 1996 *Pike: Biology and exploitation*. Fish and Fisheries Series **19**. Chapman and Hall, London

CSTP 2010 Manual on Sea Trout Ageing, *Digital Scale Reading and Growth Methodology* (Poole, R. (Ed.). Produced by the participants of the Celtic Sea Trout Project Workshop on Sea Trout Age. Determination and Digital Scale Reading Methodology. 24th-28th May 2010.

CSTP 2016 Milner, N., McGinnity, P. and Roche, W. Eds. Celtic Sea Trout Project – *Technical Report to Ireland Wales Territorial Co-operation Programme 2007-2013*. (INTERREG 4A).

Dahl, K. 1909 The assessment of age and growth in fish. A short account of the development of present methods and main literature on the subject. *Internationale Revue der gesamten Hydrobiologie und Hydrographie* **2**, 758 –769.

Elliott, J.M. 1994 *Quantitative Ecology and the Brown trout*. Oxford series in Ecology and Evolution. Oxford University Press Inc., New York.

Elliott, J. M. 2009 Validation and implications of a growth model for brown trout, *Salmo trutta*, using long-term data from a small stream in north-west England. *Freshwater Biology* **54**, 2263–2275.

Fahy, E. 1980 Sea trout from the Currane Fishery in 1973 and 1974. *Irish Fisheries Investigations* **19***,* Series A (Freshwater).

FAO, 1974 *Manual of Fisheries Science **2**. Methods of Resource Investigation and their Application*. In M.J. Holden and D.F.S. Raitt (eds.), *Food and Agriculture Organization of the United Nations*, Rome, June 1974.

Ferguson, A., Himberg, K.M. and Svärdson, G. 1978 Systematics of the Irish pollan (*Coregonus pollan* Thompson). An electrophoretic comparison with other Holarctic Coregoninae. *Journal of Fish Biology* **12**, 221-233.

Ferguson, A., and Taggart, J.B., 1991 Genetic differentiation among the sympatric brown trout (*Salmo trutta*) populations of Lough Melvin, Ireland. *Biological Journal of the Linnean Society* **43(3),** 221-237.

Fishbase (biology of dace).www.fishbase.org/summary/4662. Accessed 12/05/2017.

Fisheriesireland (www.fisheriesireland.ie)/Research-and-Development/fish-species (2017). Accessed

20/04/17.

Francis, R. 1990 Back-calculation of fish length: a critical review. *Journal of Fish Biology* **36**, 883–902.

Frost, W.E and Kipling, C. 1959 The Determination of the Age and Growth of Pike (*Esox lucius* L.) from Scales and Opercular Bones. *ICES Journal of Marine Science* **24 (2)**, 314–341.

Frost, W.E. 1978 The scales of the charr, (*Salvelinus willughbii Gunther*), in Windermere, and their use for the determination of age and growth. *Journal du Conservation International et Exploration de la Mer* **38**, 208 - 215.

Harrison, A.J., Kelly, F.L., Rosell, R.S., Champ, T.W.S., Connor, L. and Girvan, J.R. 2010 First record and initial hydroacoustic stock assessment of pollan *Coregonus autumnalis* Pallas in Lough Allen, Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* **110B**, 69-74.

Harrod, C., Griffiths, D., McCarthy, T.K and Rosell, R. 2001 The Irish pollan, *Coregonus autumnalis*: options for its conservation. *Journal of Fish Biology* **59**, 339-355.

Hartley, P.H.T. 1947 The coarse fishes of Britain; final report on the coarse fish investigation. *Freshwater Biology Association* **12**. Scientific Publication.

Hayden, B., Pulcini, D., Kelly-Quinn, M., O'Grady, M., Caffrey, J., McGrath, A. and Mariani, S. 2010 Hybridisation between two cyprinid fishes in a novel habitat: genetics, morphology and life-history traits. *BMC Evolutionary Biology* **10 (1)**, 169.

Griffiths, D.G. and Kirkwood, R.C. 1995 Seasonal variation in growth, mortality and fat stores of roach and perch in Lough Neagh, Northern Ireland. *Journal of Fish Biology* **47**, 537-554.

Ibàñez, A.L., Britton, J.R. and Cowx, I.G. 2008 Relationship between scale growth checks, circuli formation rate and somatic growth in *Rutilus rutilus* (L.) a fish farm-reared cyprinid. *Journal of Fish Biology* **72**, 1023–1034.

International Council for the Exploration of the Sea, 1984 *Report of the Atlantic Scale Reading Workshop*, 23-28 April 1984, Aberdeen, Scotland. 54pp.

International Council for the Exploration of the Sea, 2009 *Annex 4: manual for the ageing of Atlantic eel*. In ICES Workshop on Age Reading of European and American Eel (WKAREA), 20–24 April 2009, Bordeaux, France. ICES CM 2009:ACOM **48**.

International Council for the Exploration of the Sea, 2011 *Report of the Workshop on Age Determination of Salmon (WKADS)*, Galway, Ireland. ICES CM 2011/ACOM: **44**, 67pp.

Igoe, F. and Hammar, J. 2004 The Arctic char, *Salvelinus alpinus* (L.), species complex in Ireland: a secretive and threatened Ice age relict. *Special Edition of Biology and the Environment*. *Royal Irish Academy,* **104**, 73-92.

Jackson, J.R. 2007 Earliest References to Age Determination of Fishes and Their Early Application to the Study of Fisheries. *Fisheries* **32 (7),** 321-328.

Jensen, A. J. & Johnsen, B. O. 1981 Difficulties in aging Atlantic salmon, *Salmo salar* and brown trout, *Salmo trutta* from cold rivers due to lack of scales as yearlings. *Canadian Journal of Fisheries and Aquatic Sciences* **39**, 321 - 325.

Kaeding, L.R. 1976 *Condition, Annulus Formation, Growth, and Food Habits of Brown and Rainbow Trout from Habitats with Contrasting Temperature Regimes on the Firehole River, Yellowstone National Park*. Masters Thesis in Zoology. Montana State University.

Kennedy, M. and Fitzmaurice, P. 1968 The biology of the bream *Abramis brama* (L.) in Irish waters. *Proceedings of the Royal Irish Academy* **67 (B) (5)**, 95-157.

Kennedy, M. 1969 Spawning and Early Development of the Dace *Leuciscus leuciscus* (L.). *Journal of Fish Biology* **1**, 249-259.

Kennedy, M. and Fitzmaurice, P. 1971 Growth and food of brown trout *Salmo trutta* (L.) in Irish waters. *Proceedings of the Royal Irish Academy* **71 (B) (18)**, 269-352.

Kennedy, M. and Fitzmaurice, P. 1974 Biology of the rudd *Scardinius erythrophthalmus* (L) in lrish waters. *Proceedings of the Royal Irish Academy* **74 (B)**, 245-303.

Kerr, L.A. and Campana, S.E. 2014 Chemical composition of fish hard parts as a natural marker of fish stocks. In S. X. Cadrin, L. A. Kerr and S. Mariani (Eds), *Stock identification methods: Applications in fishery science 2nd edition*. Academic Press.

Klein, R., Paulus, M., Tarricone, K., Diana and Teubner, D. 2012 Guideline for Sampling and Sample Treatment of Bream (*Abramis brama*). *Guidelines for Sampling, Transport, Storage and Chemical Characterization of Environmental and Human Samples*. Trier University, D-54286 Trier.

Klemetsen, A., Amundsen, P., Dempson, J. B., Jonsson, B., Jonsson, N., O'Connell, M. F. and Mortensen, E. 2003 Atlantic salmon *Salmo salar* L., brown trout *Salmo trutta* L. and Arctic charr *Salvelinus alpinus* (L.): a review of aspects of their life histories. *Ecology of Freshwater Fish* **12**, 1-59.

Klumb, R.A., Bozek M.A., and Frie, R.V. 2001 Validation of three back-calculation models by using multiple oxytetracycline marks formed in the otoliths and scales of bluegill × green sunfish hybrids. *Canadian Journal of Fisheries and Aquatic Sciences* **58**, 352-364.

Kornilovs, G. 2015 REPORT OF THE BALTIC PERCH AGE DETERMINATION WORKSHOP. *Baltic Sea Regional Project Lead Laboratory on Age Determination and Fish Stomach Analysis*. RIGA, 15-17 FEBRUARY 2005.

Kucharczyk, D., Luczynski, M., Kujawa, R., Kaminski, R., Ulikowski, D. & Pawel Brzuzan, P. 1998 Influences of temperature and food on early development of bream (*Abramis brama L*). *Archiv für Hydrobiologie* **141**, 243 - 256.

Lea, E. 1910 On the methods used in the Herring-investigations. *Conseil Permanent International pour l'Exploration de la Mer* **108 (1)**, 14–22.

Le Cren, E. D. 1947 The Determination of the Age and Growth of the Perch (*Perca fluviatilis*) from the Opercular Bone. *Journal of Animal Ecology* **16 (2)**, 188-204.

Maitland, P.S., Winfield, I.J., McCarthy, I.D. and Igoe, F. 2007 The status of Arctic charr *Salvelinus alpinus* in Britain and Ireland. *Ecology of Freshwater Fish* **16**, 6-19.

Maitland, P. S. and Herdson, D. 2009 *Key to the Marine and Freshwater Fishes of Britain and Ireland*. Environment Agency, Bristol.

Mann, R.H.K. 1973 Observations on the age, growth, reproduction and food of the roach *Rutilus rutilus* (L.) in two rivers in southern England. *Journal of Fish Biology* **5**, 707-36.

Mann. R.H.K and Beaumont, W.R.C. 1990 Fast and slow growing pike and problems of age determination from scales. *Aquaculture and Fisheries Management*, **21**, 471-478.

Martinson, E.C., Masuda, M.M. and Helle, J.H. 2000 Back-calculated fish lengths, percentages of scale, growth, and scale measurements for two scale measurement methods used in studies of Salmon growth. *North Pacific Anadromous Fish Commission* **2**, 331-336.

McCarthy, D. and Kennedy, M. 1965 The Biology of Irish Coarse Fishes: A Synopsis of Published Irish, British and Continental Data and of Current Irish Research on the Species found in Ireland. *Inland Fisheries Trust*. Unpublished internal document.

Morales-Nin, B. 1992 Determination of growth in bony fishes from otolith microstructure. *FAO Fisheries Technical Paper* **322**. *Food and Agriculture Organization of the United Nations*, 51pp. Rome.

Ogle, D. 2013 shR Vignette - Back-Calculation of Fish Length Northland College.

O' Grady, M.F., Kelly, M. and O' Reilly, S. 2008 Brown Trout in Ireland. *Irish Freshwater Fisheries Ecology & Management Series* **6**, Central Fisheries Board, Dublin, Ireland.

Parrott, A.W. 1934 The variability and growth of the scales of brown trout (*Salmo trutta*) in New Zealand. *Transactions and Proceedings of the Royal Society of New Zealand* **63**, 497-516.

Panfili Jacques, De Pontual Helene, Troadec Herve, Wright Peter J. (2002). *Manual of Fish Sclerochronology*. Ifremer. https://archimer.ifremer.fr/doc/00017/12801/

Patterson, R.T., Wright, C., Chang, A.S., Taylor, L.A., Lyons, P.D., Dallimore, A., and Kumar, A. 2002 British Columbia Fish-Scale Atlas. *Palaeontologia Electronica* **4 (1)**, 88pp.

Pierce, C.L., Rasmussen, J.B. and Leggett, W. 1996 Back-calculation of fish length from scales: Empirical comparison of proportional methods. *Transactions of the American Fisheries Society* **125**, 889–198.

Raat, A.J.P. 1988 Synopsis of biological data on the northern pike, *Esox lucius* Linnaeus, 1758. *Food and Agriculture Organization of the United Nations. Fisheries Synopsis* **30 (2)**, 178p. Rome.

Ricker, W.E. 1975 Computation and Interpretation of Biological Statistics of Fish Populations. *Department of the Environment Fisheries and Marine Service*. Ottawa, Canada.

Roberts, M.B.V., Reiss, M.J. and Grace, M. 2000 *Advanced Biology*. Nelson, Walton-on-Thames.

Rosell, R., Harrod, C., Griffiths, D. and McCarthy, T. K. 2004 Conservation of the Irish Populations of the Pollan *Coregonus autumnalis*. *Biology and Environment: Proceedings of the Royal Irish Academy. Threatened Irish Freshwater Fishes* **104 (B) (3)**, 67-72.

Rosell, R.S. 1997 The status of pollan *Coregonus autumnalis* pollan Thompson in Lough Erne, Northern Ireland. *Biology and Environment*: *Proceedings of the Royal Irish Academy* **97 B**, 163-71.

Ryan, D., Shephard, S. and Kelly, F. 2016 Temporal stability and rates of post-depositional change in geochemical signatures of brown trout *Salmo trutta* scales. *Journal of Fish Biology* **89** (3).

Secor, D.H. 2004 Fish migration and the unit stock: three formative debates. In S.X. Cadrin, K.D Friedland and J.R. Waldman (eds.), *Stock Identification Methods*, 17–44. Burlington. Elsevier.

Secor, D.H., Dean, J.M. and. Laban E.H. 1992 Otolith Removal and Preparation for Microstructural Examination, p.19-57. In D.K Stevenson and S.E Campana (ed.) Otolith microstructure examination and analysis. *Canadian Special Publication of Fisheries and Aquatic Sciences,* **117**.

Schneider, J.C. 2001 Aging Scales of Walleye, Yellow Perch, and Northern Pike. *Michigan Department of Natural Resources*. Fisheries Technical Report 2001-1, 108pp.

Shafi, M. and Maitland, P.S. 1971 The age and growth of perch (*Perca fluviatilis* L.) in two Scottish lochs. *Journal of Fish Biology* **3**, 39-57.

Shearer, W.M. (Ed.) 1992 ICES COOPERATIVE RESEARCH REPORT **188**. *Atlantic Salmon Scale Reading Guidelines.* ICES. Copenhagen.

Sigler, W.F and Sigler J.W 1990 *Recreational fisheries: management, theory, and application*. Reno, Nevada 89557, USA. University of Nevada Press.

Spanovskaya, V.D. & Grygorash, V.A. 1977 Development and food of age-0 Eurasian perch (*Perca fluviatilis*) in reservoirs near Moscow, USSR. *Journal of the Fisheries Research Board of Canada* **34**, 1551 - 1558.

Steinmetz, B. and Müller, R. 1991 *An Atlas of Fish Scales and Other Bony Structures Used for Age Determination*. 51pp. Samara Publishing.

Taylor, R.J. 2012 *Applications of fish scale analysis to understand growth dynamics of fish populations*. PhD Thesis, University of Hull.

Thorne, A., MacDonald, A. and Thorley, J.L. 2016 The abundance of large, piscivorous ferox trout (*Salmo trutta*) in Loch Rannoch, Scotland*. PeerJ* **4**:e2646; DOI 10.7717/peerj.2646.

Toner, D. and Rougeot, C. 2008 Farming of European perch. *Aquaculture explained: Special Publication* **24**.

Treer, T., Opačak, A., Aničić, I., Safner, R., Piria, M., and Odak, T. 2003 Growth of bream, *Abramis brama*, in the Croatian section of the Danube. *Czech Journal of Animal Sciences* **48**, 251-256.

Tzadik, O.E., Curtis, J.S., Granneman, J.E., Kurth, B.K., Pusack, T.J., Wallace, A.A., Hollander, D.J., Peebles, E.B. and Stallings, C.D. 2017 Chemical archives in fishes beyond otoliths: A review on the use of other body parts as chronological recorders of microchemical constituents for expanding interpretations of environmental, ecological, and life-history changes. *Limnology and Oceanography* **15**, 238–263.

Wheeler, A. 1969 Fishes of the British Isles and North West Europe. 613pp. Macmillan. London.

Williams, J.E. 1955 Determination of age from the scales of northern pike *Esox lucius* L. Michigan *Department of Conservation, Fisheries Research Report* **1449**.

Wilson, J.P.F. 1984 A review of the biology of the pollan *Coregonus autumnalis* pollan Thompson – an endemic Irish salmonid species. *Proceedings of the Royal Irish Academy* **84 B**, 123-7

Wilson, J. P. and Pitcher, T. J. 1983 Age determination and growth of the pollan *Coregonus autumnalis pollan* Thompson, of Lough Neagh, Northern Ireland. *Journal of Fish Biology* **24**, 151-163.

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