

Research Article

Chub (*Leuciscus cephalus*): a new potentially invasive fish species in Ireland

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Abstract

The chub is a freshwater fish of the family Cyprinidae, which is widely distributed throughout Europe. Prior to 2001 there were no reports of chub being present in Ireland. In 2001 and again in 2004 it was reported that an angler had caught chub in a section of the River Inny. On neither occasion were live specimens retained for authentication. In 2005 a number of live, angler-caught chub from this river were formally identified. In order to determine the status of this non-native and potentially invasive fish species in this renowned Irish coarse, game and pike fishery, an electric fishing survey was conducted in 2006. Seventeen chub were captured during this operation. All were taken from one relatively short (c. 0.8 km), shallow (≤ 0.5 m) and moderately fast flowing section of river. The fish ranged in fork length from 15 to 41 cm and in age from III+ to X+ years old. Among the fish captured, there were two immature fish, six females and nine males. The stomach contents revealed a diet of insect, fish, plant material and detritus. A relatively fast growth rate was recorded. While relatively few chub were captured during the survey, those examined were healthy and most were in spawning condition. It is considered that the chub were introduced to the river by anglers in an effort to increase the diversity of coarse angling species available in Ireland. The potential impact of the chub on natural biodiversity and on the community composition of native and naturalised fish species in the river is discussed.

Key words: alien, fish, Cyprinid, River Inny

Introduction

Ireland is an island nation at the western edge of mainland Europe. The country was effectively separated from mainland Europe during the early stages of the retreat of the last ice age (Fitzsimons and Igoe 2004; Igoe 2004). This separation provided a physical barrier that prevented stenohaline species colonising from the East. As a result, Ireland has a relatively reduced fauna and flora (Igoe 2004). Ireland's freshwater fish community is far less diverse than that of Britain or mainland Europe. In respect of fishes, Ireland has 28 freshwater species (Fitzsimons and Igoe 2004), compared with 236 in Europe (Moriarty and Fitzmaurice 2000; FAME 2004). Consequently, all of Ireland's indigenous freshwater species are euryhaline, having some degree of tolerance to salt water (Quigley and Flannery 1996; Fitzsimons and Igoe 2004). They include salmon

(*Salmo salar* Linnaeus), trout (*Salmo trutta* Linnaeus), pollan (*Coregonus autumnalis* (Pallas)), char (*Salvelinus alpinus* (Linnaeus)), river lamprey (*Lampetra fluviatilis* (Linnaeus)), sea lamprey (*Petromyzon marinus* Linnaeus), brook lamprey (*Lampetra planeri* (Bloch)) and eel (*Anguilla anguilla* (Linnaeus)). Archaeological and documentary accounts indicate that humans were responsible for the introduction of cyprinids, pike (*Esox lucius* Linnaeus) and perch (*Perca fluviatilis* Linnaeus) (Wijngaarden-Bakker 1985; McCormick 1991, 1999; Moriarty and Fitzmaurice 2000).

Ireland is renowned for the quality of its angling waters and wild fish stocks. The main angling categories are salmonid, coarse, pike and sea. In one of the few comprehensive reports on the economic worth of angling in Ireland the bream (*Abramis brama* (Linnaeus)) was recognised as the most important of fish species in terms of angling revenue generation (Whelan and

Marsh 1988). At its peak in 1996, tourist coarse angling was worth €76 m to the Irish economy (Failte Ireland 2001). This has since fallen to €56 m in 2005 (Failte Ireland 2006). The reasons for this decline are numerous and varied, but include the fact that many foreign anglers are choosing new and more competitively priced venues, such as Scandinavia.

Chub (*Leuciscus cephalus* (Linnaeus, 1758)) is a highly prized angling species in Britain and Europe. The absence of chub from the rivers of Ireland, many of which provided an ideal habitat for the species and excellent conditions for the angler, provoked considerable controversy among the visiting angling community. However, it is the policy of the Fisheries Boards in Ireland to preserve our indigenous and naturalised fishes and to prohibit the introduction of non-native and potentially invasive species (National Policy for the Management, Development and Conservation of Coarse Fish Species in Ireland, Central Fisheries Board, in preparation).

In 2001 and 2004 there were unconfirmed reports from anglers that chub had been caught in the River Inny, a major tributary of the River Shannon. No specimens, however, were retained for identification and authentication. In 2005 three live chub were caught in the River Inny and officially identified by fisheries scientists from the Central Fisheries Board. These fish had probably been illegally introduced to the river by anglers with a view to establishing a population of this species in Ireland.

Chub belong to the family Cyprinidae and are indigenous to many parts of eastern and western Europe, including England (Cowx 2001; Hellawell 1971). In Europe, chub are found from southern France northward to Scandinavia and eastwards into the former Soviet Union (Cowx 2001; Turkmen 1999).

Chub prefer lotic habitat conditions, shallow water and gravel banks with moderate to high water flow for spawning. The preferred substrate of chub is coarse gravel (Lelek and Lusk 1965; Cowx and Welcomme 1998). Young fish form schools in shallow water, while larger specimens tend to be solitary, often residing under overhanging trees or roots (Wheeler 1998, Cowx 2001). Chub have a diet composed of insect, fish, plant material and detritus. Fry and young juvenile fish feed extensively on small aquatic invertebrates, while fish up to five years of age consume mainly vegetation and aerial insects (Hellawell 1971; Mann 1976). Chub can adopt a piscivorous diet when they reach a length of

circa 15 cm and the proportion of fish in the diet increases with length (Mann 1976; Vitali and Braghieri 1984).

The present study aimed to determine the distribution and status of chub in the River Inny. This reflects the potential risk to the natural biodiversity and community composition of native and naturalised fish species in this river and in the Shannon catchment.

Materials and methods

Site description

The River Inny, an order 5 river (Strahler 1952), is one of the major tributaries to the River Shannon (Figure 1). The river is 88.5 km long and occupies a catchment area of 782.46 km² (O'Reilly 2002). The river rises in Co. Westmeath and flows through Loughs Sheelin, Kinale, Derravaragh and Iron before discharging into Lough Ree (Figure 1). The river is renowned among anglers for the abundant stocks of wild coarse fish present. The River Inny, from Lough Derravaragh to Lough Ree (circa 40 km), was surveyed during the present study. This section was selected for investigation as no reports of chub from coarse anglers had been reported upstream of Lough Derravaragh. The river between Lough Derravaragh and Lough Ree is wide, varying between 25 and 30 m. The adjacent land use for much of the length is lowland pasture. From Lough Derravaragh to Abbeyshrule and from circa 50 m downstream of Shrule Bridge to Lough Ree the river is relatively deep (mean depth = 2.3 m) and moderately slow flowing (Figure 1). The predominant substrate type comprises of mud and silt. From Abbeyshrule to circa 50 m downstream of Shrule Bridge the river is shallow (circa 0.5 m), fast flowing and dominated by coarse gravels and boulders substratum.

Fish Survey

The River Inny, from Lough Derravaragh to Lough Ree (Figure 1) was electrically fished in June 2006. Because of flood events and consequent unsafe survey conditions during this period, it was not possible to electric fish the shallow and fast section in the vicinity of Abbeyshrule (circa 1.8 km long).

All of the fish species, except chub, that were captured during the survey were processed and returned alive to the river. Any chub captured

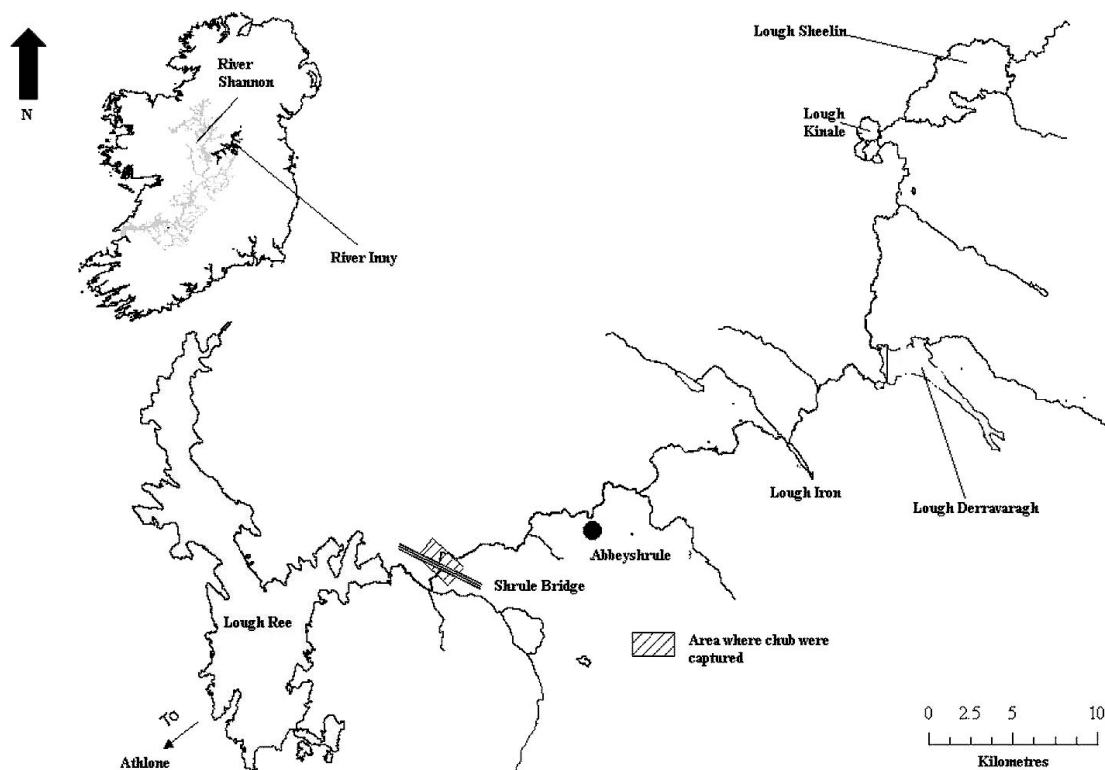


Figure 1. Map showing location of the River Inny and the river sections sampled in 2006 (from Lough Derravaragh to Lough Ree).

was retained for subsequent laboratory analysis. Fork lengths (LF) were measured to the nearest centimetre and the fish were weighed to the nearest 0.1 g. Scales were removed for age and growth analysis. Growth rates were determined through “back calculation” (von Bertalanffy 1960). The t-Student test ($P < 0.05$) (Siegel and Castellan 1988) was used to evaluate significant differences between male and female growth rates. Sex and maturity stage, followed Kesteven (1960) and Nikolskij (1963), was determined for each fish by visual examination of the gonad tissue. Stomachs were removed and the food contents analysed. Most of the food items in stomachs were digested and identification to species level was impossible. Diet composition of the fish was described as the percentage of the total content of the stomach.

Physico-chemical analysis

Thirty-two surface water samples were collected from the sections of the river surveyed and analysed for nutrient concentration (Total

Phosphorus (TP mg/l P), Molybdate Reactive Phosphorus (MRP mg/l P), and Total Oxidised Nitrogen (TON mg/l N)). Total Phosphorus values above 0.063 mg/l P, MPR values above 0.02 mg/l P and TON values above 11.3 mg/l N would indicate artificial enrichment (Caffrey 2005).

Water depth was measured at regular intervals (circa 1 km) along the channel using a hand-held depth sounder. Water clarity was recorded using a Secchi disk and sediment samples were collected using a Van Veen grab (Woods Hole Oceanographic Institution 2007).

Vegetation

The abundance of marginal, emergent and submerged vegetation was recorded within channel using the DAFOR scale (Caffrey 1990). An eight-grapple was used to retrieve submerged vegetation at regular intervals from the river (Caffrey 1990). Water velocity status was estimated visually (slow, moderate and fast) (Caffrey 1990).

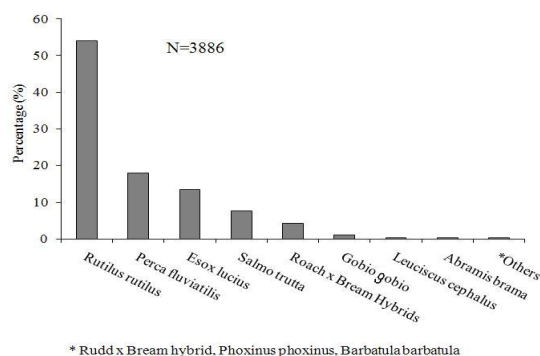


Figure 2. Relative composition of the fish community recorded in the River Inny in 2006.

Table 1. Number of male and female in each maturity stage. (Terminology as per Kesteven, 1960 and Nikolsky, 1963).

Sex	Developing Stage	No.
Male	Maturing II	1
	Developing III	3
	Developing IV	2
	Gravid V	2
	Spawn/Spent VII	1
Female	Gravid V	3
	Spawning VI	1
	Spawning/spent VII	1
	Spent VIII	1

Results

Water quality conditions in the River Inny at the time of the survey were good and no evidence of artificial enrichment was recorded from the samples analysed. Levels of TP ranged from 0.012 to 0.032 mg/l P. MRP values were all <0.006 mg/l P and TON values were also very low, ranging from 0.993 to 1.205 mg/l N. The mean water temperature was 18°C. Throughout the section of the river surveyed, the water was clear and the visibility was good (maximum Secchi readings = 3.4 m).

An abundant and diverse macrophyte flora occupied the 40 km-long section of river surveyed. Of the emergent species present, Common reed (*Phragmites australis* (Cav.) Trin. ex Steudel) and Reed canary-grass (*Phalaris arundinacea* L.) were dominant, collectively

occupying c. 70 % of both banksides. These tall emergent species commonly formed dense, continuous, and monodominant stands along the margins. Other abundant emergent species (circa 30% cover) present included Common club-rush (*Scirpus lacustris* L.) and Branched bur-reed (*Sparganium erectum* L.). Water horsetail (*Equisetum fluviatile* L.), Fine-leaved water-dropwort (*Oenanthe aquatica* (L.) Poiret) and Arrowhead (*Sagittaria sagittifolia* L.) were occasionally recorded (10 % cover) along the margins. Yellow water-lily (*Nuphar lutea* (L.) Sm.) was the most common floating-leaved species present (c. 10 % cover). Ivy-leaved duckweed (*Lemna trisulca* L.) and Common duckweed (*Lemna minor* L.) were prevalent in enclosed backwaters. Of the submerged vegetation Perfoliate pondweed (*Potamogeton perfoliatus* L.) was the most abundant (30-40 % cover). Dense stands of this trailing broad-leaved vegetation occupied long sections of the river. This provided a rich and varied habitat for macroinvertebrates and fish species. Canadian waterweed (*Elodea canadensis* Michx.) formed occasional stands (3-5 % cover).

Eleven fish species were recorded during the survey. These were roach, perch, pike, brown trout, roach x bream hybrids, rudd x bream hybrids, gudgeon (*Gobio gobio* (Linnaeus), chub, bream, minnow (*Phoxinus phoxinus* (Linnaeus)) and stone loach (*Barbatula barbatula* (Linnaeus)) (Figure 2). Roach was the most abundant species, representing 54 % of all fish caught. Seventeen chub (0.44 % of all fish captured; Figure 2) were caught during the survey. All chub were caught in a short (circa 0.8 km), shallow (≤ 0.5 m) and fast flowing section of the river with a gravel and boulder substratum. This erosive river section was characterized by overhanging trees, mainly Willow (*Salix* spp.) L., Hawthorn (*Crataegus monogyna* Jacq.) and Elder (*Sambucus* spp. L.).

Male chub were more abundant than female, with a sex ratio of 1.5:1.0. The majority of the male chub were at an advanced stage of maturation (developing stage III and IV). Three of the six female fish were ripe (gravid stage V) (Table 1). Two of the chub caught were immature.

The chub ranged in fork-length between 15 cm and 41 cm and in weight from 33 g to 1061 g (Figure 3). The females were relatively smaller than the males, ranging from 32 cm to 36 cm LF. The males ranged between 29 cm and 41 cm LF. The fish ranged in age from III+ to X+. Fish

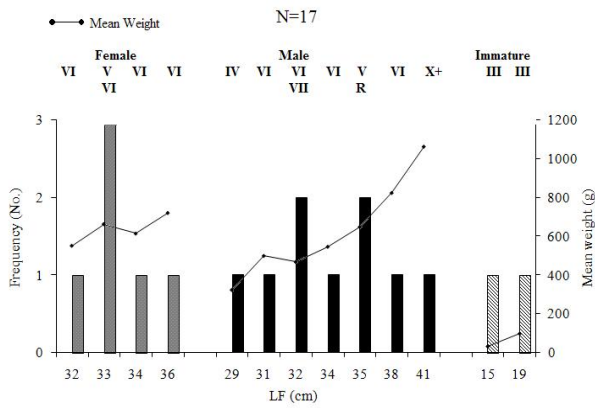


Figure 3. Length-weight, length-frequency distribution and age (in roman letter) at length of chub in the River Inny in 2006. R= replacement scale.

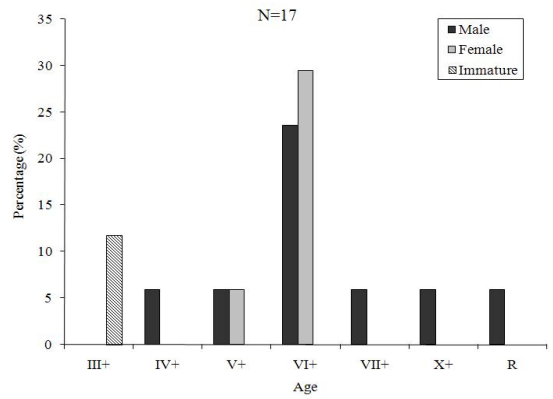


Figure 4. Percentage of male, female and immature chub in each age class from the River Inny in 2006. R= replacement scale.

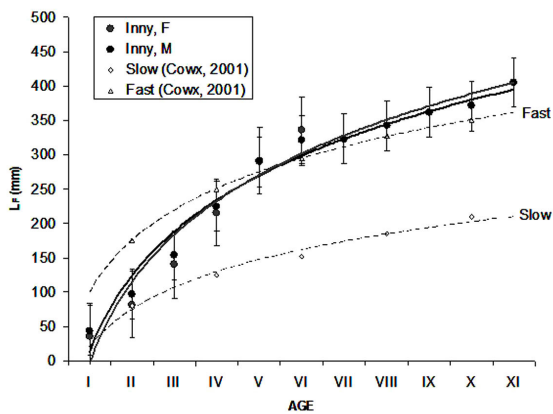


Figure 5. Growth rates (mean LF ± S.E.) for chub in the River Inny in 2006 and for chub in British waters, after Cowx (2001).

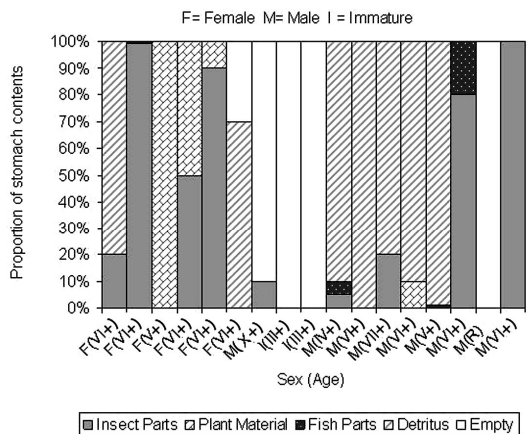


Figure 6. Diet composition of chub from River Inny in 2006 by sex and age. R= replacement scale.

aged VI+ years old dominated the population. Of these 29.4 % were female and 23.5 % were male (Figure 4). The oldest female was VI+ years old. The oldest chub caught was a X+ year-old male, measuring 41 cm (LF) (Figure 3). An examination of a scale sample from this fish showed multiple annuli close to the scale edge and it was difficult to ascertain the true age of the fish, due

to the proximity of the annuli to one another. The two immature fish were III+ years old.

In the River Inny chub displayed a linear growth pattern and fast growth rates when compared with the data for chub in British rivers provided by Cowx (2001) (Figure 5). There was no significant difference between male and female chub growth rates in the River Inny

($P < 0.05$). It was not possible to detect any obvious change in the arrangement of circuli that would give an indication of the time the fish were introduced into the River Inny.

The chub in the River Inny has a diet composed of insect, fish, plant material and detritus (Figure 6). The fish examined consumed mainly detritus and insects. The insects identified were Coleoptera, Diptera and Trichoptera larvae. Fish remains were present in the stomachs of four of the fish. It was not possible to identify the fish to species level. The diets of male and female chub were similar (Figure 6). The immature fish had no food in their stomachs.

Discussion

Chub is a non-native fish species in Ireland. It should be recognised, however, that not all non-native species are necessarily invasive and that some provide considerable benefit to society (Stokes et al. 2006). A non-native species becomes invasive where it is capable of establishing stable populations, colonising irreversibly and spreading rapidly in natural or semi-natural ecosystems (Scalera and Zaghi 2004). When non-native species become invasive they can transform ecosystems and threaten native and conservation species (Stokes et al. 2006). It has been acknowledged that invasions by non-native species represent one of the greatest threats to natural biodiversity, second only to habitat destruction (Scalera and Zaghi 2004).

Over the past century, only a few non-native fish species have become invasive in Ireland. Roach were first introduced to the Munster Blackwater in the south of Ireland in 1889 (Went 1950; Fitzmaurice 1984). The initial spread of this species was slow, but by the mid-1970s roach were becoming invasive and increasingly widespread in Ireland. Currently, roach are present in most river catchments in the country and may now be considered to be naturalised. The introduction of roach in Ireland has had significant consequences. It is a fast-growing and a prolific opportunistic species that has impacted on the fish community structure in most Irish watercourses (Caffrey and McLoone 2005). In cyprinid fisheries, the closely related rudd (*Scardinius erythrophthalmus* (Linnaeus)) has been the most adversely affected species, although a decline, in bream populations in some watercourses may also be a consequence of

direct or indirect competition with roach (Caffrey and McLoone 2005; Caffrey and Conneely 2007). Roach hybridise readily with rudd and bream. In recent years scientific surveys have revealed that roach x bream hybrids are becoming more numerous than roach in some locations (Caffrey and McLoone 2005).

Dace (*Leuciscus leuciscus* L.) is another non-native species that was introduced to the Munster Blackwater from Britain in 1889. Until the early 1980s dace were, more or less, restricted to this catchment (Caffrey et al. 2007). The species has since been recorded in Doon Lake and in a number of major river catchments in the south of Ireland. Dace was first recorded from the lower reaches of the River Shannon in 1994. In these catchments dace have established large sustainable populations and compete directly with resident fish for food, habitat and spawning substrates (Caffrey et al. 2007). Dace are not considered to be naturalised in Ireland as there are many catchments in which they have not yet been recorded.

Chub is a rheophilous species that is known to inhabit moderately fast flowing river sections, although it also resides in slower flowing or even, still water habitats (Huet 1959; Mann 1976; Copp 1992; Wheeler and Newman 1992; Fischer and Eckman 1997; Cowx 2001; Arlinghaus and Wolter 2003). In the River Inny, chub were recorded from only one short section (0.8 km), within the 40 km-long survey stretch. This section was wide, shallow, moderately fast flowing, sparsely vegetated and the substrate comprised coarse gravel. Upstream and downstream of this riffle area, long sections of deep and slower flowing water characterised the river. In these latter areas, an abundance of submerged and reed-fringe vegetation occupied the channel. Chub favour river habitats that support healthy macrophyte communities. Indeed, Smith (1989) observed a direct correlation between the density of chub and the abundance of instream and riparian flora in some English rivers. It is, therefore, probable that the chub recorded from this riffle area also occupy deeper, more vegetated habitats at different times of the year.

The diversity of habitat types present in the River Inny provides a multitude of suitable spawning, nursery and adult habitats for chub populations. The link to the River Shannon catchment, and ultimately to the River Erne system, through Lough Ree, affords a direct pathway by which the chub can spread widely within the country. As chub have not yet been

recorded from any other river in Ireland, it is probable that, the species has been only recently introduced to this country. It is clear that suitable habitat for chub is present in rivers throughout Ireland and it is only a matter of time, in the absence of intervention, before this species is recorded from suitable waters the length and breadth of the country.

Chub adopt a multiple or batch spawning strategy and may spawn up to three occasions between May and August (Nunn et al. 2002). In Britain, a minimum temperature of 15°C is required to induce spawning activity (Cowx 2001). The mean water temperature recorded in June 2006 in the River Inny was 18°C. It is clear that ambient temperature in the river, therefore, is no impediment to spawning. During the fish ageing operation the arrangement of circuli and annuli was closely examined in an effort to detect any irregularities that might indicate when the fish had been transferred from their native waters, probably in Britain, into the River Inny. No such determination could reliably be made. It is not clear, therefore, exactly when or where in the river the fish were stocked, if the stocking was accidental or intentional, whether stocking occurred on one or more occasions, or if the young chub recorded during the survey were actually spawned in Ireland.

Chub from the River Inny exhibited fast growth rates when compared with fish from English rivers (Cowx 2001). The growth rate among the River Inny fish was slightly slower than that displayed by the fast-growing English chub up to the age of V+. Thereafter, the growth rate among the Irish fish continued to increase and showed no sign of slowing, up to the age of X+, which was the oldest fish captured. At X+ years, the mean fork length for fast-growing English chub was 348 mm, while River Inny fish of the same age were 371 mm. This demonstrates that the habitat provided in the River Inny is suitable for chub growth. The Irish chub also exhibited fast rates of growth when compared with fish from established populations in rivers in Europe (Libosvsky 1956; Philippart 1972).

In rivers within their home range chub are omnivorous and eat almost anything of nutritional value (Cowx 2001). Fry and juvenile chub feed extensively on chironomids and insect larvae. As they grow up to V+ they supplement this diet with macrophytes and aerial insects (Hellawell 1971; Cowx 2001). At about this age, depending on the nature of the river, chub adopt a more benthic habit and become piscivorous. It

has been demonstrated that the proportion of fish in the diet increases with the length of the chub (Cragg-Hine 1969; Mann 1976). Among the chub recorded from the River Inny, fish remains were present in four of the 17 chub captured. It is possible, therefore, that, as population levels expand, the threat of piscivory to the resident fish population in this river could increase.

Chub is a non-native fish that was recently introduced to the River Inny probably by British coarse or pike anglers. Fish scale analysis has failed to shed light on the date the fish were introduced. An examination of the specimens captured, however, revealed that they were healthy and that the majority were in spawning condition. The study further revealed that long sections of the River Inny provide a habitat that is suitable for the establishment, growth and proliferation of the species. The fact that the chub can spread naturally to other major river systems via Lough Ree and the River Shannon, or that they may be purposely translocated by anglers who wish to have chub in their own river systems, means that the species may become more widespread in Ireland.

At the low density recorded in the River Inny in 2006, chub do not appear to pose a problem for natural biodiversity or for the resident fish communities. It is probable, however, that, as the chub become more abundant and widespread, they will impact on our native or naturalised fishes. The impact could be direct, through predation, or indirect, by competing for available habitat or for common food items. A further risk associated with the introduction of non-native, invasive species relates to the viral, bacterial or parasitic fauna that these fish harbour (Hoffman and Schubert 1984; Boxshall and Frear 1990; Kennedy 1994; Beyer et al. 2005).

It is current policy within the Fisheries Boards in Ireland to develop, manage and protect our native and naturalised fish species and to actively monitor and control the introduction and spread of non-native species. In order to prevent the River Inny chub population from becoming invasive in Ireland, a programme of electric fishing to collect and remove all chub in the river will be implemented.

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