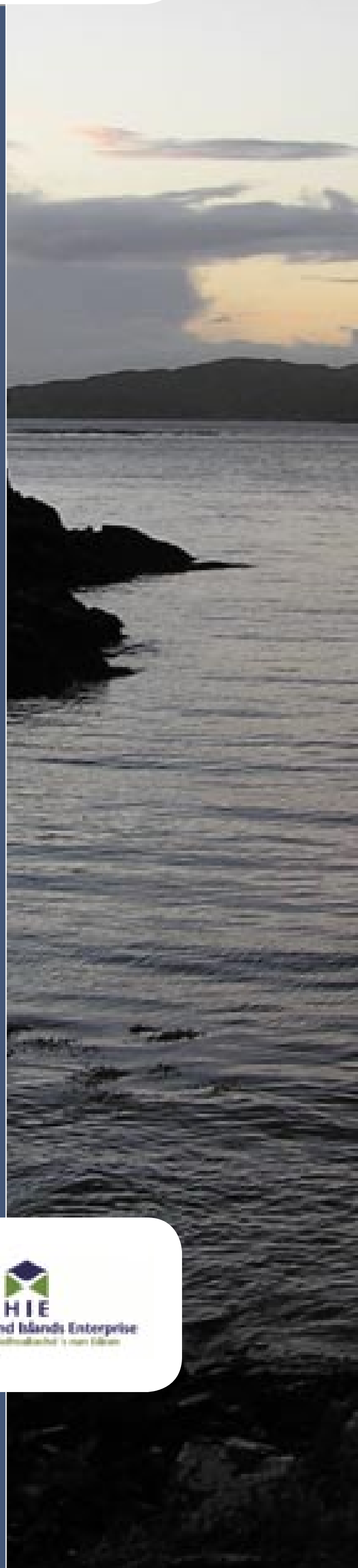
West Sutherland Elver Survey



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West Sutherland Fisheries Trust

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Communities Project for Highland Biodiversity Ref: CPHB12

ABOUT THIS DOCUMENT

The 'West Sutherland Elver Survey' project Ref: CPHB12 is one of 24 being undertaken in Highlands with assistance from the Highland Biodiversity Partnership. The Highland Biodiversity Partnership (www.highlandbiodiversity.com) is funded by the Heritage Lottery Fund, Highland Council, Scottish Natural Heritage, Highlands & Islands Enterprise and RSPB Scotland. The Highland Biodiversity Partnership provides funding for local projects that conserve or enhance the natural heritage, encourage communities to look after it and take forward the aspirations of Highland's seven Local Biodiversity Groups. As part of the Highland Local Biodiversity Action Plan (LBAP) Review (2006) the Groups were asked to prioritise project ideas arising from their LBAPs. The resulting priorities were then worked into proposals by the Groups, which were pulled together as a funding bid to the Heritage Lottery Fund's 'Your Heritage' programme. The funding bid was successful and the Communities Project for Highland Biodiversity started in June 2007 and the West Sutherland Elver Survey started in the summer of 2007.

ACKNOWLEDGEMENTS

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WEST SUTHERLAND FISHERIES TRUST

The West Sutherland Fisheries Trust (WSFT) (www.wsft.co.uk) is a charity (SC24426) established in 1995.The Trusts objectives are the conservation of all native fish species within the area. This involves working with owners and users to provide sustainable management of the habitat and fish stocks. The Trust area extends from the Hope in the north to the Garvie in the south, and covers all catchments flowing west.

CONTENTS

EXECUTIVE SUMMARY

Elvers have been fished in Sutherland since the 1970's to the present by a handful of fishers. Anecdotal evidence for elver declines reported in this survey supports the decline in elvers seen since the 1980's throughout Europe. In the rest of Europe data indicates a continuing decline in recruitment to 1% at present and stock to around 10% at present, and that this decline will continue if no action is taken to restore eel stocks. In Scotland a lack of eel specific data or eel data covering the period between the 1970's till present does not permit any rigorous analysis of the status of elver recruitment or eel stocks in general. Under these conditions application of the Precautionary Principle implies that all detrimental actions to eel stocks should be prohibited until suitable data can be gathered. Support should be given to Fisheries Research Services who are tasked with the development of a Scottish Eel Management Plan as directed by the European Community and a statistically appropriate monitoring program should be encouraged.

West Highland eel have been identified as having potentially important genetic value to the panmictic European eel stock and potentially high biodiversity value to the highlands, though there is very little information on either of these aspects. Research on the genetic and biodiversity value of eels to the Highlands would raise the profile of eels and clearly demonstrate their value to the local public, Scotland and Europe.

The cause for the initial decline in eel stocks initiating the decline in elvers has been suggested to be habitat loss, though additional negative impacts of pollution, climate change, overfishing and introduction of a parasite severely affect stocks. Increased fishing pressure on elvers caused by an increased demand for elvers in Asia in the 1990's has been identified as causing increased pressure on eel stocks already in decline. Overwhelming evidence for the decline of eels elsewhere in Europe, problems detecting eel declines soon enough, lag phase between detection and recovery, inappropriate data collection and poor understanding of population dynamics, indicates that all causes for decline should be minimised. Eel Management Plans dictate that all forms of eel fishing should be stopped until 40% escapement of spawners (silver eels) can be clearly demonstrated. This should be achieved thorough new eel surveys and better coordination between Fisheries Trusts and Fisheries Research Services.

INTRODUCTION

ELVER DEFINITION

An elver is a 1 year old European eel (*Anguilla anguilla*) approximately 70mm long, light brown to dark brown in colour, with no patterning. Elvers are found among mid shore seaweed anywhere along the coast throughout the year but particularly in estuaries before migrating into river systems during early summer in Sutherland. Elvers are most notable on the edges of rivers close to the surface and on damp stones, culverts and walls of weirs during migration. The term recruitment refers to elvers migrating in to freshwater and joining the freshwater eel stock.

LOCAL CONCERNS OVER ELVERS

In 2006 the Sutherland Local Biodiversity Action Plan identified local concerns over decline in elver migrations. This concern arose from three factors:

1. Identified decline of elvers across Europe
2. Lack of local information on the health or elver/eel stocks
3. Presence of elver fishing in Sutherland

Since 1999 European researchers have insisted that "European eel (*A. anguilla*) stocks are outside safe biological limits", with a drop of 99% in stocks since the 1980's, while Japanese eel (*A. japonica*) dropped by 99% since the early 1970's and the North-American eel (*A. rostrata*) suffering steep drop-offs as well (ICES 2002 & 2006). By the mid-1990s, the low recruitment had lasted for a period equivalent to the average life-span of a mature eel in the northern part of its range, and there was widespread concern in Europe that the stocks could be on the verge of collapse (Potter & Dare 2003). After research in individual EC countries and joint research programs, eels have been unanimously identified as in serious decline. This caused the EC parliament to make legislation and insist on Eel Management Plans (EMPs) to be established by 2009.

The decline of the European eel is often attributed to over fishing, with a drop of Elver catches in England and Wales to 1% over the last 20 years and European Silver eel fishing allowing less than 3% of the stock to return to the sea each year. There is good evidence from a number of major elver fisheries throughout Europe of a long-term decline in elver recruitment and in 1998 elver catches in Europe were reported to be down by 60 per cent on the previous year and to be the lowest ever recorded (MAFF 2000). The Environment Agency (EA) acted on this concern by putting together a National Eel Management Strategy for England in 2001 and now regulates the fishing for eels in England.

Eels are the fastest declining UK vertebrate and are listed as a Priority Species in the recently revised UK Biodiversity Action Plan (UKBAP) and Scottish Biodiversity Action Plan (SBAP), identifying eels to be in 'significant decline' with '>25 % reduction of numbers'. Eels were also added to the Scottish Executive's 'Scottish Biodiversity Strategy' list in 2004. Even the Royal Society of Edinburgh (Rands, 2000) noted that, "In particular, knowledge of eel stocks is very limited, and management of eel fisheries in areas such as Wester Ross is completely unregulated and the current situation can only be detrimental to what are widely regarded as depleted eel populations". Decline in both elver migrations and eel stocks outside Scotland, linked with the concern that elver fishing is continuing unregulated in Sutherland has brought about the need to identify the status of elvers in Sutherland. This question is fuelled by a certain amount of demonization of elver fishers in England by the national press and the occasional friction between river owners or concerned naturalists with elver fishers in Sutherland.

The following extract is from a BBC report “Elver poachers face night patrol” from 15th April 2002.

“At this time of the year [April], up to 400 fishermen can be found on the [Severn] river bank on a single night. Poachers face up to 2 years in prison if they are caught trying to catch the young eels with illegal trawl nets or without a licence. Some fishermen try to use the advantage of ropes, floats and even boats to cash in during the elver season – all of which are illegal”.

In 2006 the Environment Agency made the following comment:

“This year we have stepped up our campaign against illegal fishermen and have worked closely with the police who sometimes bring their canine colleagues to help ensure against breach of the peace. We have a large stock of seized nets in our depot that will be destroyed once offenders have been dealt with by the courts”.

Surely with such conviction for enforcement elvers must be in serious decline? However, some research on the river Severn suggests that current levels of Elver fishing may not affect the river eel population as the rivers can only support a finite population of Yellow eels which is far exceeded by the excessive annual supply of elvers. Often alternative causes of stock decline are suggested, such as: climate change, pollution, habitat destruction and disease. However, the EA (2006) responded to such comments with, "Elvers numbers across Europe are thought to have fallen by up to 98% in recent years. Whilst it [the decline] may not be that bad on the Severn they clearly need all the help they can get". Are elver fishers being demonised based on unjustified fears, contribution little to stock decline and actually a valuable source of information on stocks? Or are fishers seriously detrimental to eel stocks, with ramifications for local biodiversity. What is really going on?

AIMS AND OBJECTIVES OF THE WEST SUTHERLAND ELVER SURVEY

Aims

1) To increase knowledge of the current distribution and abundance of eels and specifically elvers in Sutherland as a baseline from which better management can be proposed.
2) Increase public awareness on eel natural history and fisheries.
3) To engage volunteers from sporting and commercial fishing to learn more about the eel fishery.

This will be achieved by the following objectives:

1) Capture all existing published information on these stocks.
2) Public response to call for information on eels.
3) Complete questionnaire survey and interviews with contributions from volunteers and produce final report.

This project will contribute data from Sutherland to inform Fisheries Research Services (FRS) who are tasked with the creation of a National Eel Management Plan for Scotland. The area covered in this survey and by the WSFT extends from the Hope in the north to the Garvie in the south, and covers all catchments flowing west.

LIFE HISTORY OF THE EUROPEAN EEL

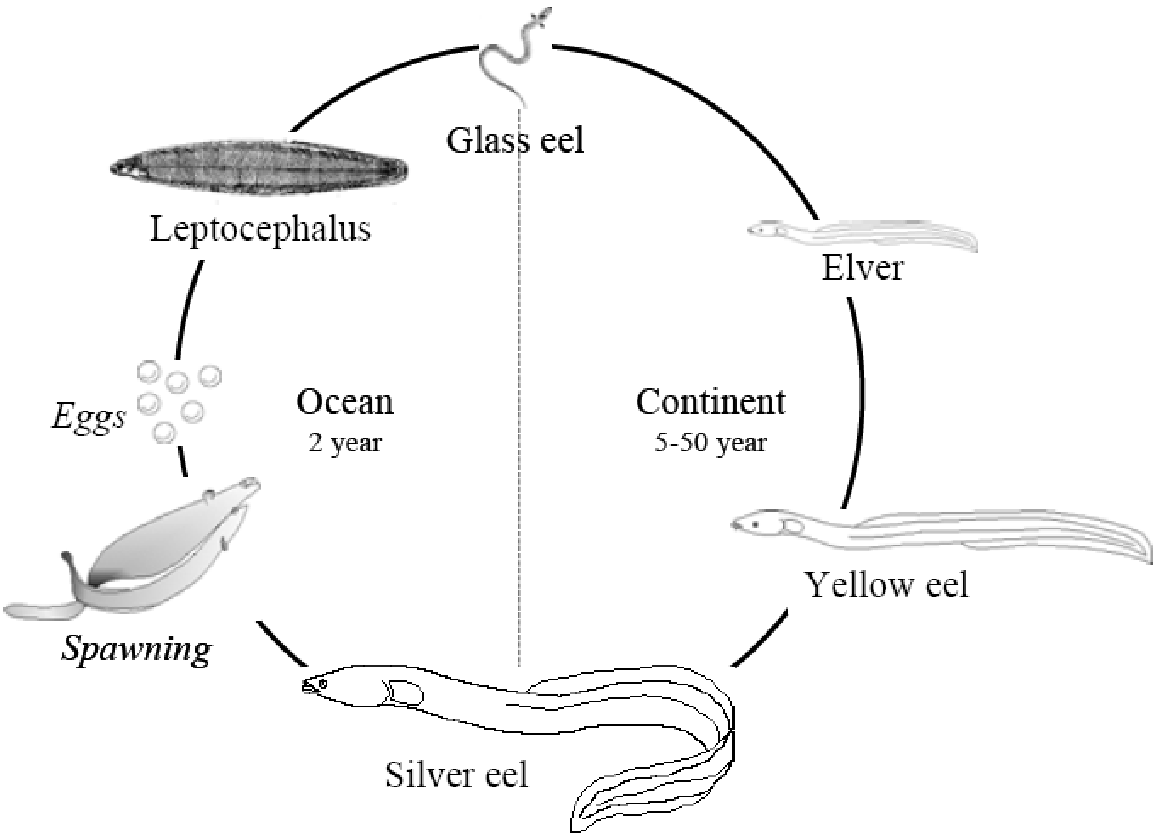

Figure 1: The life cycle of the European eel *Anguilla anguilla*.

Eels are teleost fish (fish with bony skeletons) belonging to the superorder Elopomorpha and the family Anguillidae and have a complex life history. The genus *Anguilla* includes 15 species and three subspecies which can be found in all temperate and tropical waters except the southern part of the Atlantic and east coast of the Pacific. Eels are a catadromous fish (mostly living in fresh water and breeding in the sea, as opposed to anadromous fish such as salmon) with a carnivorous diet which changes during each stage of their life cycle. The European eel (*A. anguilla*) occurs in fresh and brackish waters in almost all of Europe (including the Baltic and Mediterranean) and in Northern Africa.

LARVAL STAGE

The entire life cycle of the European eel (fig. 1) is not fully understood but eel eggs are found in spring and early summer in the Sargasso Sea between Bermuda and Cuba, 5,000km from Scotland. The exact details of spawning are unknown as a mature eel has never been found in the Sargasso but the site of spawning and timing can be traced back from the presence of progressively larger *A. anguilla* larvae found at increasing distances from one point source in the Sargasso Sea (fig. 2). The European eel spawns primarily from March to June within a narrow ellipse extending east–west from approximately 48^{o} to 74^{o} W between 23^{0} and 30^{o} N. The presence of a singular spawning ground and timing, along with genetic evidence, supports the hypothesis that European eels are Panmictic (from one stock, random mating at a singular spawning ground at one time) even though European eels are found from Morocco to Iceland. Variation in the exact location and timing and some genetic evidence suggests that there may be 3 minor sub populations, Northern Europe, Central and Mediterranean and North Africa.

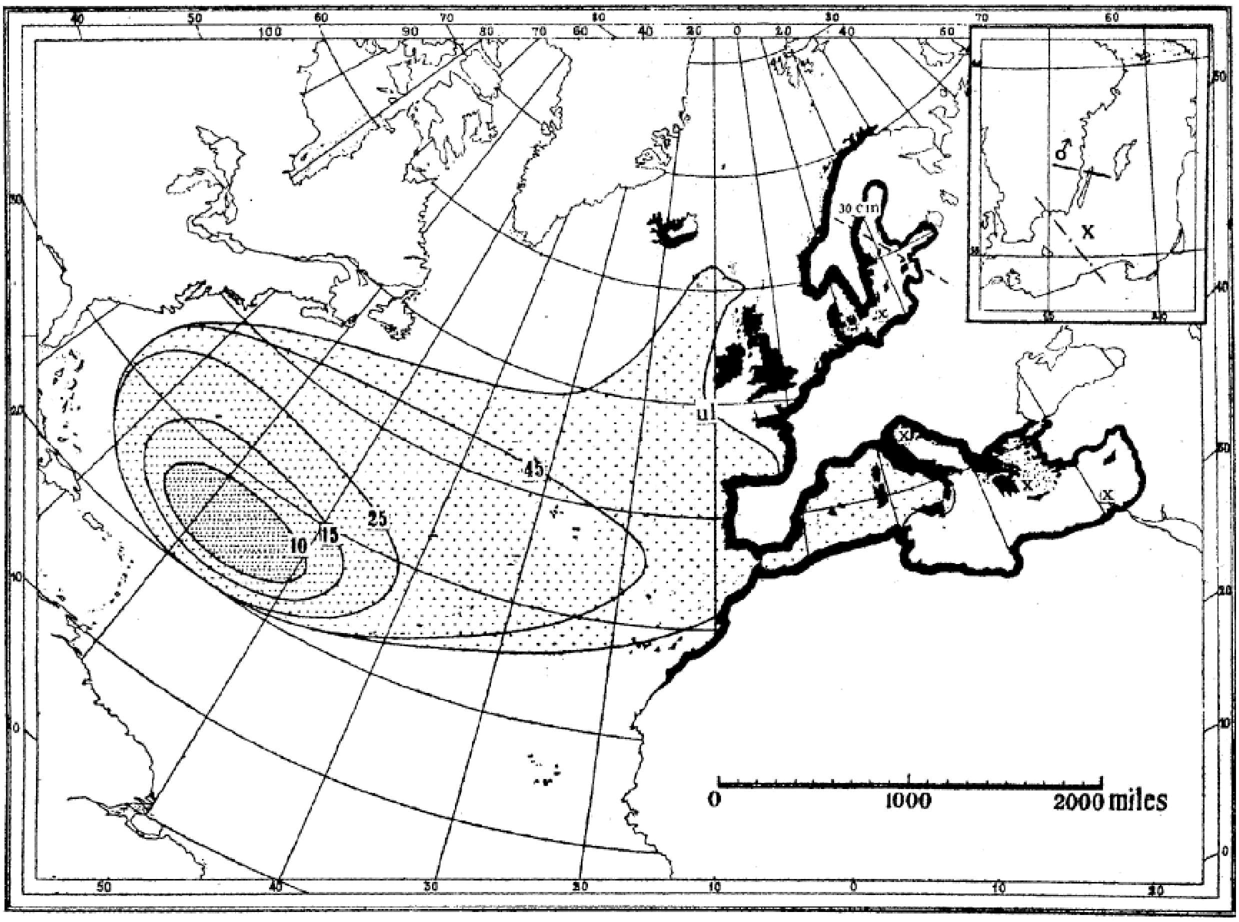

Figure 2: Distribution patterns of European eel larvae with the size of the larvae in mm (from Schmidt 1923).

Within a few days of spawning eel eggs metamorphose into transparent blade shaped larvae (Leptocephali), which drift to Europe on the Gulf Stream and the North-Atlantic Drift. Leptocephali are retained in the currents that transport them to Europe initially by passively drifting in the main current along the Eastern American seaboard at a depth of 50-300m. Then as they grow larger than 5mm they gradually change to an active vertical migration behaviour catching the currents travelling across the Atlantic, moving to shallow warm depths (35–125m) at night then diving to deeper, colder depths (300–600m) during daylight.

In November to April, after 8-9 months in the Atlantic, leptocephali reach European continental waters between southwest Europe and northwest Africa and metamorphose into 50mm long (<1g) unpigmented "Glass Eels". Most of the estimated annual 2000 million glass eels enter coastal waters, estuaries and rivers via the Bay of Biscay, with very few glass eels reaching the coast in northern Europe. Glass eels are then driven into costal waters darkening in colour to yellow-brown at which point they are considered to be elvers (5-70mm or 2500-3000/kg). Glass eels collect in estuaries and close to shores as determined by proximity to the continental shelf, winds, currents and tides. At this point there is clear developmental shift in salinity preference, with glass eels preferring 100% sea water, semi-pigmented elvers showing no clear preference and fully pigmented elvers preferring fresh water. During this transitional period elvers collect under stones and are closely associated with mats of Bladder Wrack sea weed (*Ascophyllum nodosum*), which provides a sheltered and humid habitat for many other mobile mid-shore animals such as blennies (*Zoarces viviparous*).

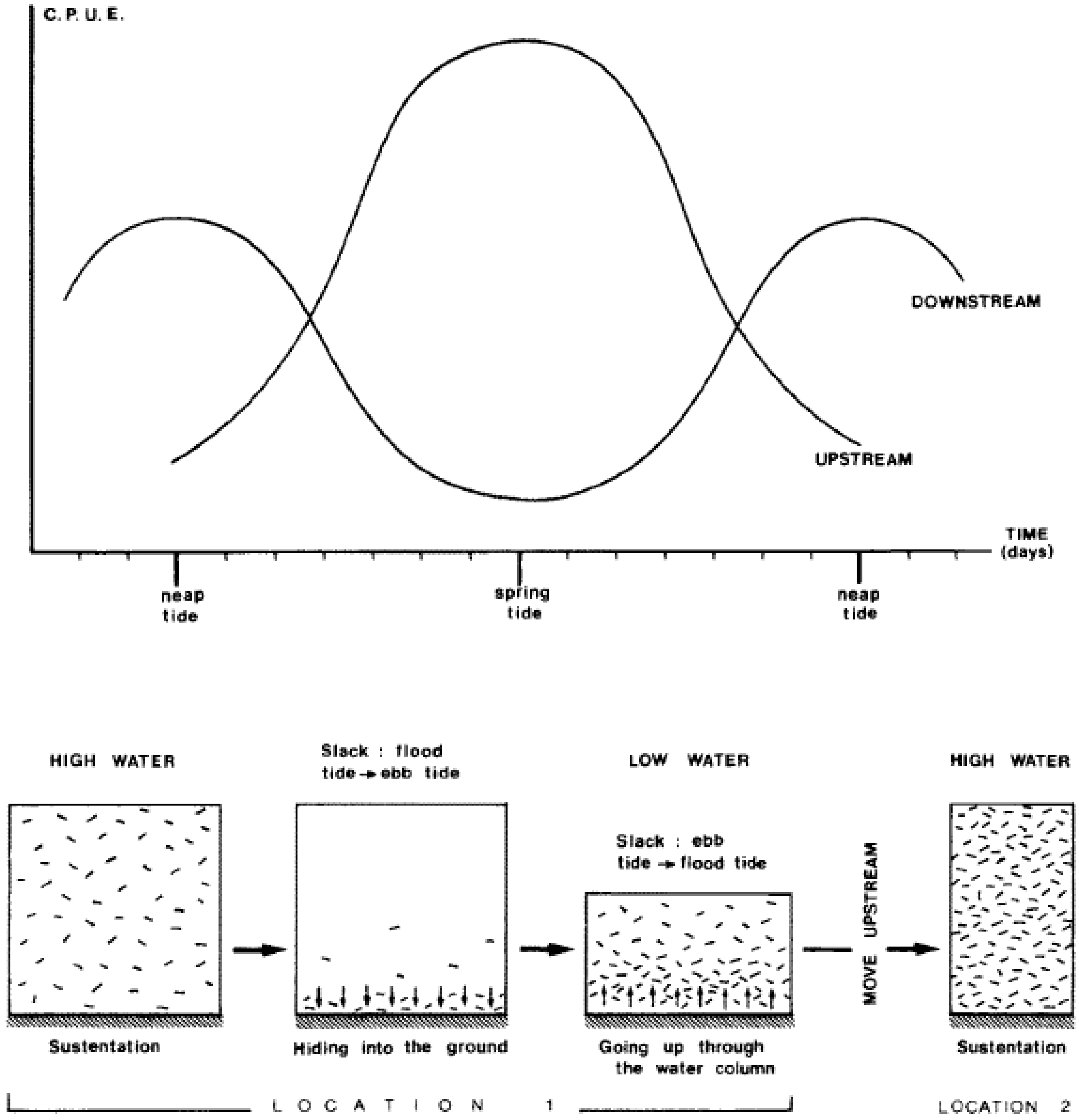

Figure 3: Behaviour of elvers entering estuaries causing flow-carried upstream movement (from Gascuel 1986). Top: theoretical variation in concentrations of elvers in the upstream and down stream currents of an estuary during neap and spring tides. Bottom: elvers actively swim in the entire water column during ebb and high tides then hide in the estuary bed during ebb.

ELVER RECRUITMENT

Though the majority of eels migrate into freshwater, otolith microchemistry studies have revealed that a small percentage of eels never migrate into freshwater, but spend their entire life history in the ocean or move back and forth between the sea and fresh water (Arai et al 2006). However, generally once near river mouths and when elvers have pigmented sufficiently, elvers start an active vertical migration process, edging further up the estuary using flood tides (fig. 3). Elver migration is triggered when the water temperature in estuaries is 10-12^{o}C and inhibited if the range of the thermic variation between the sea and fresh water exceeds 3-4°C. If there is large spring tide more elvers are transported up river in an apparent wave of upstream migration by actively 'riding' Spring tide surges. All these factors generally result in a peak of Elvers entering rivers in Sutherland between May and June. On entering rivers, during the next 5 years eels perform an initial rapid dispersion upstream driven by density at the point source, with more 1-5 year old eels found actively moving over weirs than older eels. During this first phase of this dispersion, young yellow eels (often called bootlace, bolts or fingerlings) start a series of metabolic changes and turn olive-brown or gray-brown on top with a silver or yellow-silver belly by 130mm, at which point they are considered to be "Yellow Eels" and fully adapted to life in fresh water. These metabolic changes include the production of slime, an ability to breathe through the skin and the production of a toxin to deter fish predators.

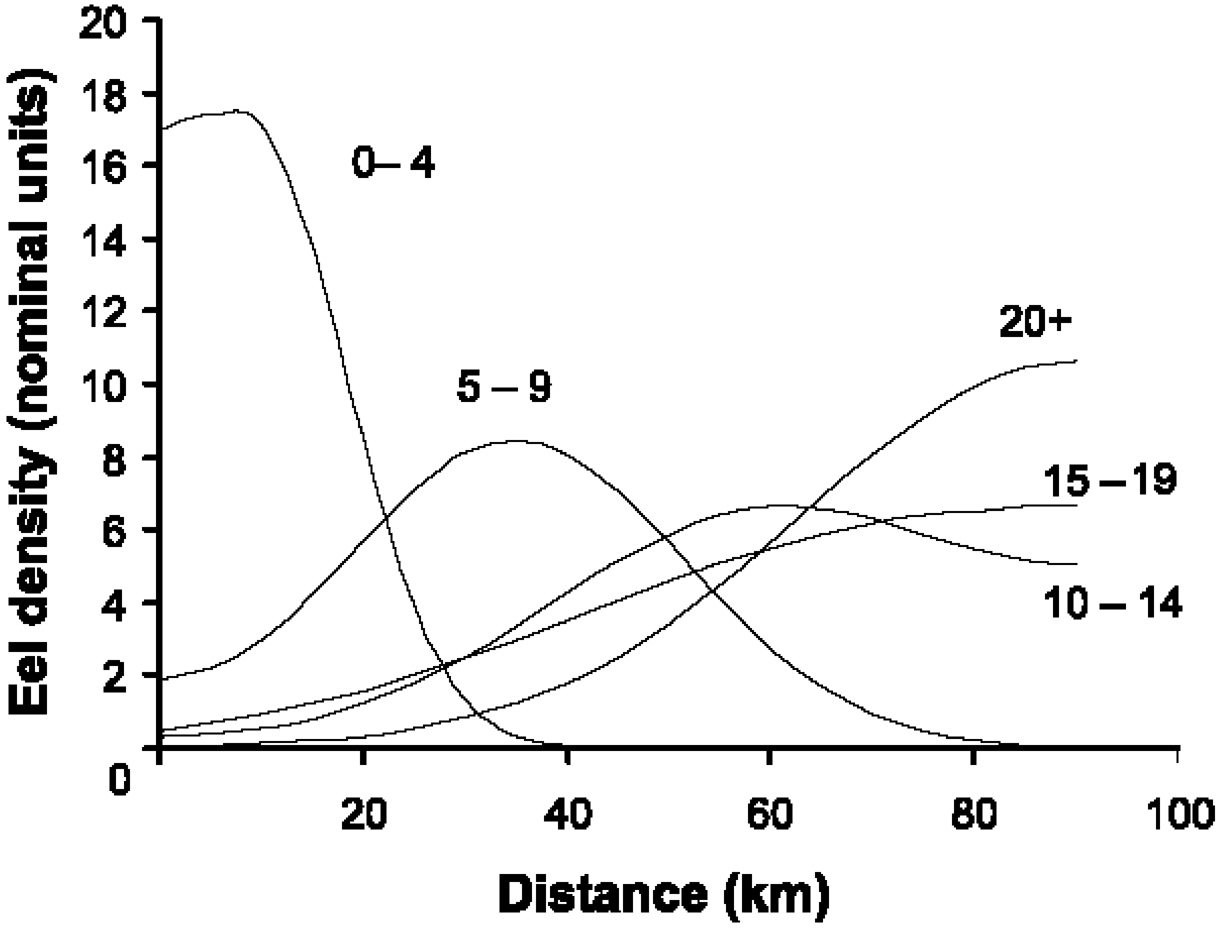

Figure 4: Simulated distribution of eel sizes up river over time (from Ibbotson et al. 2002)

SEDENTARY YELLOW EELS

After this initial phase, yellow eels follow a much slower dispersion rate, which is equivalent to random diffusion of particles (Ibbotson et al 2002). Thus the traditionally perceived movement of the eel population upstream by a wave-form migration process does not occur, Instead colonisation of freshwaters by eels can be seen as a two-phase dispersion process. During the second phase of dispersal, yellow eels >200mm display a more sedentary lifestyle, particularly in small catchments (Laffaille 2005a), and slowly disperse to areas of lower eel density (fig. 4) (Ibbotson et al 2002). At this point yellow eels spend most of their time during the day lying flat on mud or with the upper part of their body upright, or lying in holes and at night feeding on various animal foods. Yellow eels also display sexual dimorphism in size/body weight with age, as male eels mature at a smaller size to females and larger older eels further up stream tend to be female as they have had longer in the system to disperse up stream.

Eels over 300mm appear to have behavioural changes and preference to microhabitats: small eels prefer shallow habitats with strong abundance of aquatic vegetation; and larger eels prefer intermediate to deeper habit with less association to aquatic vegetation. Thus the population density, and sometimes the size distribution of eels can vary according to the depth of the lochs. In Ireland the highest concentrations were found in shallow water between 1 and 3 m deep. Distance from tidal limits, altitude (with few eels 100m above sea level), natural and anthropogenic migration barriers, habitat productivity and, especially, availability of day-time refuges were found to be the main determinants of density, biomass and population structures (Potter & Dare 2003), with the largest eels coming from more alkaline lochs in the Highlands (Williams 1976). In colder climates such as Scotland yellow eels often hibernate over winter, and as a result of either hibernation or of seasonal migration, fewer and smaller eels are active early in the summer than later.

In Scotland there is considerable spatial variation in the distribution of eels, with eels being much less likely to be absent from the North West of Scotland (Godfrey, 2007), which probably reflects the proximity of the NW Scotland to the continental shelf (Knights et al 2001). In Scotland in general the mean density of eels was estimated to be 4.33 eels per $100m^2$ which was an order of magnitude lower than England (Godfrey 2007), though this might be expected due to lower temperatures and poorer feeding in Scotland. However, eel densities above 4.33 eels per $100m^2$ were recorded in West Sutherland and the Western Isles (Godfrey 2007).

SILVER EEL MATURATION

Once yellow eels have stored sufficient body fat (⅓ of total body weight), yellow eels partially mature into Silver eels by a gradual physiological process between spring and September. The silvering process is a change to dark grey-green on top, with silver flanks and belly. Eels develop spherical large diameter eyes, with a change in visual sensitivity of the retina pigments from green-sensitive to blue-sensitive for vision in deep ocean waters and grow larger pectoral fins. Silver eels reduce their feeding as they begin to reabsorb their own gut and gonads start primary development. Silvering is initiated by a peak of growth hormone at the end of spring, with the different events related to silvering occur during the summer season (July and August), and by September all silver eels have the typical external aspect of migrants. A drop in temperature appears to trigger the cessation of feeding, leading to migratory movements to the sea under the appropriate environmental conditions.

Generally the male European Eel reaches maturity at between 3-9 years and the female between 5-18 years. In the UK estimates range from 7-20 years (300-500mm) for males and 9-50 years (500-1000mm) for females. In a study in 1975 (Williams 1976) Highlands eels were identified as on average 10-40 years old (51 years oldest recorded), maturing between 17-27 years old, reaching 0.55kg in 17 years. In 2006 the average silver eel size recorded in Wester Ross was 371.3mm and currently a growth rate of 13-14mm/year for Scotland with males maturing from 25+y (33+cm) and females at 31+y (42+cm) is suggested by FRS

(Godfrey 2007). Mean eel length in NW Scotland between 1996 and 2006 was 221mm, which is slightly smaller than the East coast of Scotland as would be expected from effects of density dependent growth and higher recruitment on the west (Godfrey 2007).

MIGRATION

In the highlands, silver eels were recorded migrating to the sea from late September until late October (Williamson 1976). Migration normally occurs on moonless nights often associated with spates and stormy weather, and eels may sometimes cross short distances over land. Silver eels at this stage are only partly mature adults.

There have been very few observation of eel movements from leaving the coast until finding eggs in Sargasso Sea. Laboratory experiments have shown that Silver eels have heightened magnetic orientation in autumn in the direction of the Sargasso Sea (van Ginneken et al. 2005b) and energy-balance studies performed in swim-tunnels have demonstrated the capacity of eels to utilise their fat reserves to swim constantly day and night for at least 6-7 months (though eels have been shown to swim 5533km in 117 days and only burning up 19.7% of body weight). Silver eels are thought to swim at depths below 200m (some have been caught at 300-700m), where they would catch the cold Canaries current (<10ºC) and North-equatorial currents. At this temperature gonad development would be sufficiently slow to keep the eels streamline enough to make the Sargasso Sea within 6-7months. This hypothetical migration would place them in the Sargasso Sea in March-June in time for spawning.

SPAWNING

Silver eels on reaching the Sargasso Sea would pass through a sub-tropical convergence zone, where warm southern water collides with colder Northern waters, forming a natural boundary of water types for many marine organisms. On crossing into the warmer water an odour imprint similar to salmon may cause eels to stop migrating (van Ginneken 2005a) and gonads would rapidly develop in the warmer water, releasing pheromones, which cause eels to aggregate and spawn. Spawning is believed to occur at around 100-300m, with each female producing 2 to 10 million eggs, after which the eels die. Spawning is collective, simultaneous, and possibly triggered by pheromones.

THE ECOLOGICAL IMPORTANCE OF ELVERS AND EELS TO THE HIGHLANDS

Eels used to represent more than 50% of the standing fish biomass in most European aquatic environments, participating significantly in the food webs and contributing to the functioning of a wide extent of continental and inland hydrosystems (Feunteun 2002). Due to the eels multiple interactions with the surrounding ecosystem eels are considered to be an important nutrient flux to and from the sea and a keystone species, maintaining a balanced riverine ecology, both as a predator/scavenger and prey species.

As predators, eels become increasingly piscivorous with increasing length. Most research on the diet of eels has been in nutrient rich basic habitats and concluded that eels <300mm fed mostly on Salmonid ova and parr, *Trichoptera* sp. Larvae, *Simulium* sp. Larvae, Asellus sp., Nymphs *Ephemeroptera, Gammarus pulex, Diptera larvae* and eels >300mm fed on *Gammarus, Asellus,* crayfish and fish (Sculpin and Stickleback). Comparisons of eel diets with those of juvenile salmon *Salmo salar* and trout *S. trutta* showed that eels preyed more on benthic invertebrates, whereas the salmonids took more mid-water and surface prey. Mann & Blackburn (1991) concluded that in chalk rich salmonid nursery streams, eels do not have a measurable effect on the salmonid population through predation or by utilizing the same food source. However, there is no research on the feeding habits of in acidic, nutrient poor waters such as the highlands, where eels may tend to eat more fish due to lower number of large invertebrates.

Eels as a prey species are an important component of the diet of species listed in the UKBAP and SBAP, such as Otters, Bittern, Osprey and Herons, which preferentially select eels over salmonids due to the higher fat content of eels. In addition, elvers provide a significant source of food for many other species in the spring, at a time when demands of the breeding season are at their height. It is important, therefore, to ensure that eel populations are sufficient to sustain predation by these species.

One overlooked aspect of Highland eels is their potential genetic value to the European eel stock as a whole. With scarcer food and a cooler climate, Highland eels grow at a slow rate (9-17mm per year) and mature at an older age (up to 50 years). With the slowest growers theoretically still in Scottish waterways from the time before the 1979 elver recruitment collapse, Scotland may represent a genetic repository of eels (Godfrey 2007). This ‘gene bank’ may help to maintain a healthy high genetic diversity in the Panmictic eel stock by retaining the genetics of a year class that may have been ‘fished out’ years before in Europe or buffer against sequential years of natural low production of eels due to climatic variation.

ECONOMIC VALUE OF EELS

In Europe in 1997 approximately 30 000 t of eel were harvested, compared to 1300 t of Japanese Eels in Asia and 1000 t of American Eels in the USA (Moriarty and Dekker, 1997). Approximately 25,000 people in Europe generate income from eel fisheries and aquaculture, and in England and Wales it forms part of the traditional fishing economy as the most valuable commercial inland fishery in England. However, the entire fishery across Europe is seasonal and most participants supplement their income from other sources, though there has been a decline in recent years from a turnover of £5 million in 1997/98 to around £1 million in 2003 (Potter & Dare 2003).

GLASS/ELVER FISHERY

Elvers are caught in many estuaries in UK and Europe and are sold for human consumption, on-growing in farms and restocking. In a few cases eels are ranched, with the intention of recapturing all the surviving adult eels. The fisheries take place in estuaries and at the mouths of rivers and dams where the natural concentration of glass eels or elvers can more easily be exploited. Hand-held or ship-based nets are used, which are moved manually or are fixed, and include trawls, stow nets, and fyke nets. In Spain and Portugal, fishermen use hand-held nets and traps. In France, glass eels are caught by small trawlers using wing nets and trawls. In England, the hand net is the only legal instrument for fishing eels.

Thirty years ago, elvers in England and Wales used to be exploited for domestic consumption, but they are now mostly exported live to the low countries of Europe and Asia where they are ongrown in fish farms and marketed for consumption, as eels cannot be bred in captivity. The main European glass eel/elver fisheries are concentrated along the Atlantic coasts of Portugal, Spain, France, Morocco and the Bristol Channel in the UK. The main fisheries for elvers in the UK are in the Severn, Wye and Parrott with smaller fisheries in Morecambe Bay. The River Severn supports the largest elver fishery in the UK, with a current annual catch estimated in the region of 10 t. In 1999, more than 300 t of glass eels were caught by professional fishermen in Europe, of which 245 t (EUR 33.6 million) were caught by professional fishermen in France. Moreover, about 75 t of glass eels/elvers are caught in France by non-professional fishermen.

Elver fishing in Scotland started in the 1970’s when demand on the continent and then in Asia in the 1980’s encouraged a few enterprising individuals working rivers in England to look north of the border for new sources of elvers. In Scotland, during the mid to late 1990s there was a short period of exploitation of elver, estimated at 1-2 tonnes per annum, in response to the rise in demand and thus prices. Much of the fishing for elver occurred on the West Coast and Western Isles during the 1990’s. Elver fishing has since declined markedly and extensive government enquiries indicated that no commercial elver fisheries operated in Scotland during 2004 or 2005.

ELVER TRADE AND AQUACULTURE

Towards the end Of the 1990s, there was a serious fall in the number of Japanese eels available to satisfy the demand in the Japanese food market. To bolster the dwindling local supply, European eels were imported to Asia in large numbers to supply farming operations, leading in turn, to overfishing and poaching in Europe, and a surge in eel prices. The size of the farming industry in Asia is now so large that only limited amounts of Japanese elvers are used.

Prior to 1994, less than 20 t of European elvers were exported to Asia each year, increasing to about 50 t during the 1994/95 season and as much as 230 t during the 1996/97 season. Exports decreased sharply from the 1996-1997 season to the next, to 90 t, later stabilizing at about 100-130 t, levels at which exports are currently estimated. With the relatively abundant supplies of European elvers and cheap prices compared to those for Japanese species, 70% of farms in mainland China began to breed European Eels at the end of the 1990s. Since the 1990s, however, an increase in Asia's demand for European elvers to supply eel farms has driven up elvers prices, which, in turn, has stimulated smuggling. Increasingly, European users of elvers are out-competed and restocking programmes in certain European countries may end. Elver prices have been: £50–60/kg mid-1990s; £150/kg late-1990s when demand from Chinese eel farms was at its height; £180/kg in 1997; £50–60/kg early 2000s; £83/kg in 2004 though it reached £150/kg in April 2002; £300/kg in March 2004; £435/kg in 2005, peaking at £525/kg because of rising demand and falling supply; and £300/kg in 2006.

Recently demand from China has decline because of increased farm efficiency and higher survival rates and the impositions of local controls in attempts to prevent overproduction (Pawson et al 2005).

YELLOW/SILVER FISHERY

While wild-caught elvers are mostly exported to China, almost all the European Eel catch and farmed specimens are consumed in Europe. A major decline in European Eel stocks has occurred since the middle of the 1900s (Dekker, 2002) and during this time, European Eels have been consumed in large quantities in Europe, mainly by Spain. In northern Europe traditional fisheries, particularly in the Baltic and Northern Ireland, focused on mainly silver eels on their way to the sea to spawn (Dekker, 2002). Elsewhere, eel fisheries are maintained by restocking within the country, often supplemented by imports, mainly from France, Spain and Portugal (Dekker, 2000a). The yellow/silver eel fisheries are generally small-scale operations and must be largely considered artisanal (Moriarty and Dekker, 1997). In 1997 302 t (USD3.2 million) of yellow/silver European Eels were consumed.

The fishery for yellow eels involves the use of cheap and fairly simple gear - baited traps, fyke nets, baited long lines, spears or shore seines. Generally eel traps do not interfere with other species such as salmon.

The best time to catch silver eels in Europe is when they are migrating to the sea; by that stage, they have reached their maximum size, their fat content is high and they are in peak condition. The capture of migrating silver eels often requires fairly large, robust and expensive pieces of equipment and in many fast flowing rivers it is sometimes not possible at all.

In the UK the main fisheries for yellow/silver eel are based in southern and eastern lowland England (Dekker 2005). Lough Neagh (N. Ireland) produces over 500 t of grown eel annually and employs 300 people fishing yellow and silver eel (Rossell et al, 2005). In Scotland a small yellow/silver eel fishery has existed at least since 1573, though no official records have ever been kept for eels in Scotland. During the 1960s-1970s eel catches in Scotland were estimated at around 10-40 t per annum. A survey carried out in 1989 showed only 17 eel fisheries in operation, eel catches ranging from 0.25 to 10.76 t (total: 23 t), none providing a sole income. In 2003 the total fishery took 2-3t, with yellow eels dominating the catches (apx 95% by weight). The last of these fisheries (Lunan Burn, Tayside) closed in 2006 with its catch declining to 5% of the original level. Over-fishing has been suggested to be the cause of the collapse of the yellow/silver eel fishery in Scotland.

EVIDENCE FOR DECLINE IN EELS

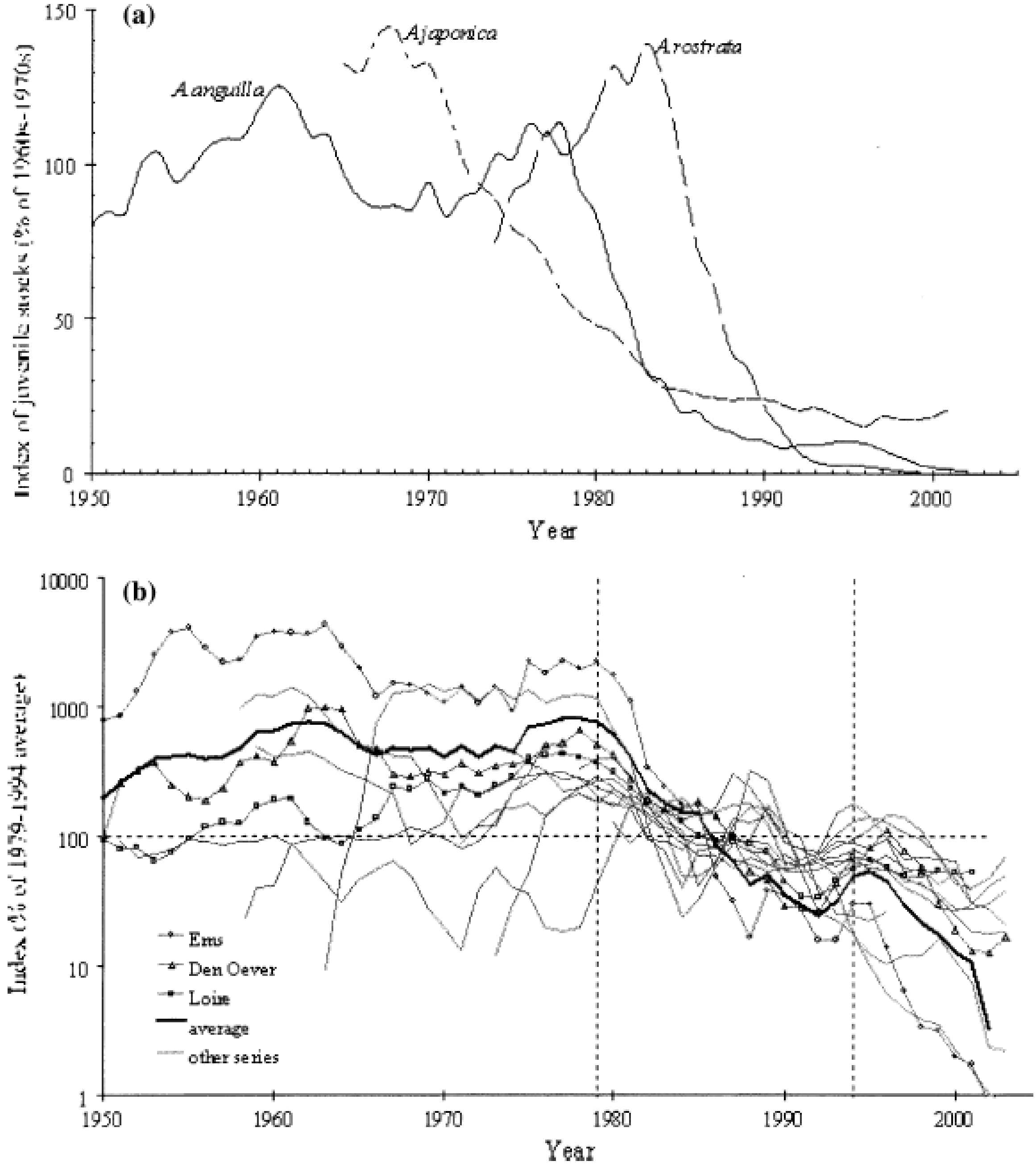

Figure 5: (a) Time trends in juvenile abundance of the major eel stocks of the world. For *Anguilla anguilla,* the average trend of the four longest data series is shown; for *A. Rostrata*, data represent recruitment to Lake Ontario; for *A. Japonicas* data represents landings of elver in Japan. (b) Trends in elver recruitment into European rivers. From Dekker 2004.

ELVER DECLINE

There is unrefuted evidence from a variety of sources that elver recruitment declined throughout Europe after the early 1980s (fig. 5b). In England and Wales it peaked between 1972 and 1982 but subsequently declined catastrophically and now stands at just one per cent of peak historic levels (fig. 6). A similar situation was reported by Briand et al. (2003) for the Vilaine estuary in France, with high recruitment between 1973 and 1983, peaking in

1979 followed by a fall. Dekker (2003) estimated the decline in recruitment after the early 1980s to be up to 90% on a pan- European basis.

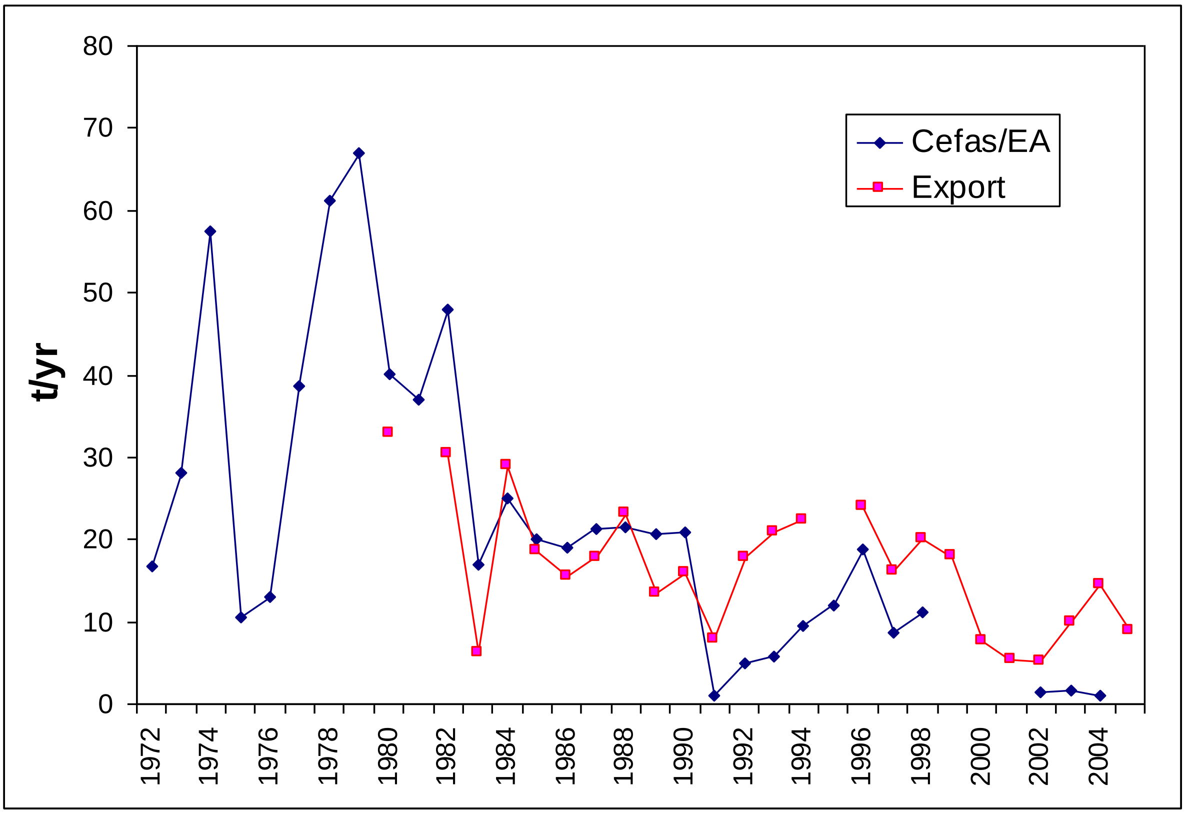

Figure 6: Annual UK (England and Wales) catch of glass eel (tonnes) from Cefas Environment Agency and nett export estimates between 1972 and 2005. It is assumed that > 95% is taken from the Severn Estuary. Effort has stayed same since 1980s.

STOCK DECLINE

The decline of the species has been reported by scientists since the 1940s in Northern Europe, and since the 1980s in the rest of the continental range (fig. 5a). The scientists from Indicang (pan European eel research group) have demonstrated that the European eel stocks are in decline and in some regions, mainly in the North of its distribution area (rivers of the North Sea, the Norwegian Sea and the Baltic Sea) the situation is critical (fig. 7).

Most scientists show that eel stocks have declined by a factor of ten during the past decade (Moriarty and Dekker, 1997). Although some of restocking programs have succeeded in sustaining local fisheries (e.g. Northern Ireland; Baltic Sea; and Italian lagoons), this general decline is still continuing in all waters where significant stocking was not made and where natural recruitment continues to decrease or, at the best, remains stable (Moriarty and Dekker, 1997). Recent yellow/silver eel catches (CEFAS) in England and Wales were estimated to be less than 5.0% of natural yields (Potter & Dare 2003).

PROBLEMS IDENTIFYING STOCK DECLINE

However there has been debate over whether a stock decline is occurring in some areas, as some monitoring continue to show no change in stock despite elver fisheries (England: Tweed, Severn and Dee). For example the River Severn Management Plan concluded that there has been: 1) no change in eel distribution throughout the river, 2) no overall change in density or biomass and 3) no change in the size structure of the population in the Severn. Based on these assumptions the general conclusion of these results was that scattered and low intensity commercial fisheries in England and Wales have had little impact on stocks and spawner (silver eel) escapement. However, the Environment Agency insists that the absence of widespread detectable changes in yellow eel abundance or population structure should not lead to an assumption that recruitment is necessarily adequate. This view is taken because: 1) the majority of these monitoring programmes were not designed to monitor eel population change; and 2) the effects of reduced recruitment may only just be identifiable in stocks due to a lag period.

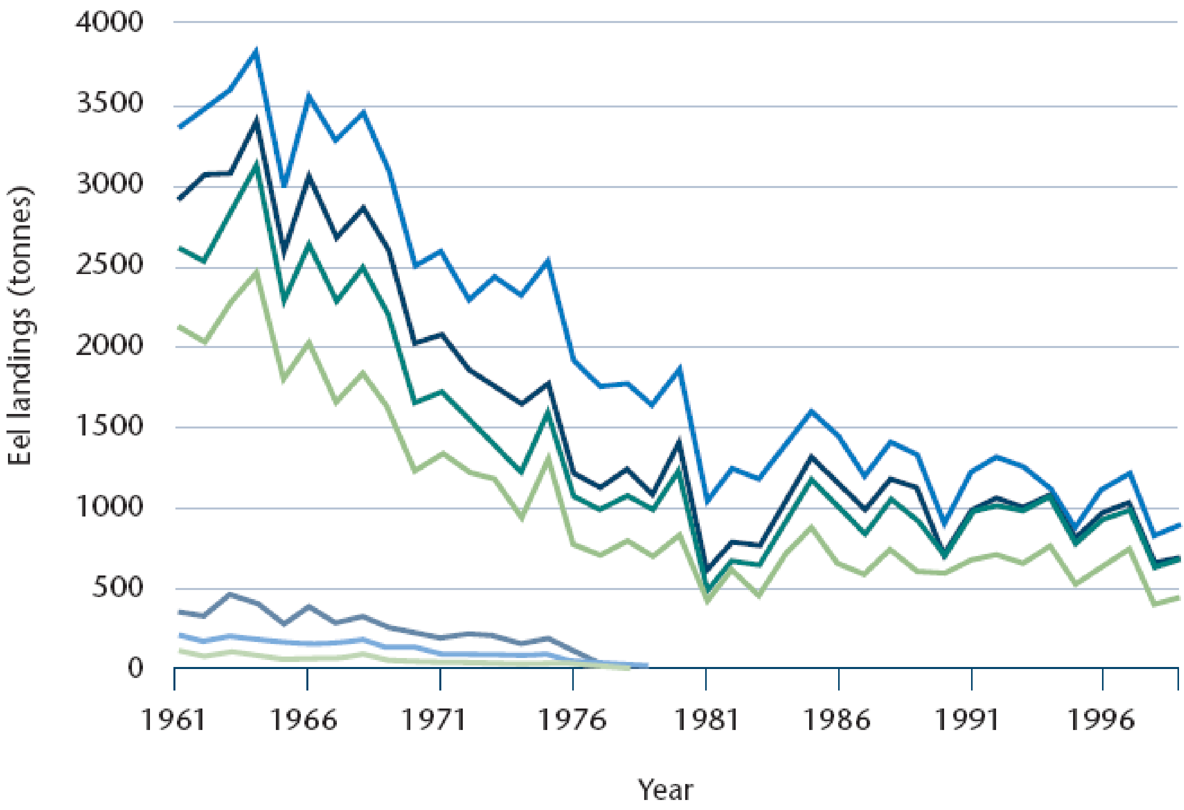

Figure 7: Eel landings from countries bordering the Baltic Sea. From the Environment Agency UK.

More thorough research on the Severn indicates that there has been a significant and marked reduction (circa 50%) in the proportion of small eels <150 mm in the lower Severn population between 1983 and 1998/99. This reflects the apparent decline in elver runs since the early 1980s. There may have been a corresponding increase in the proportion of large female eels (>450 mm) in the population. Furthermore, a reference condition model suggests that the yellow eel population in the Severn is 60% lower than would be expected. Examination of less robust data sets for a number of other rivers in England also indicated no statistically significant decline in stocks of yellow eels or changes in population structure over the past 20 to 30 years. However, more rigorous monitoring by the Environment Agency on the rivers Frome and Piddle (Dorset) found significant declines in eel numbers, but not biomass. Biomass appeared to have been maintained largely by a change in population structure, from domination by small male eels to domination by large females. A similar situation is seen in the Lough Neagh fishery (Northern Ireland), where lower densities are now favouring production of females and now predictions in 2006 based on current stock (fig. 8) shows both yellow and silver eel fisheries are in serious continued decline (Allen et al 2006).

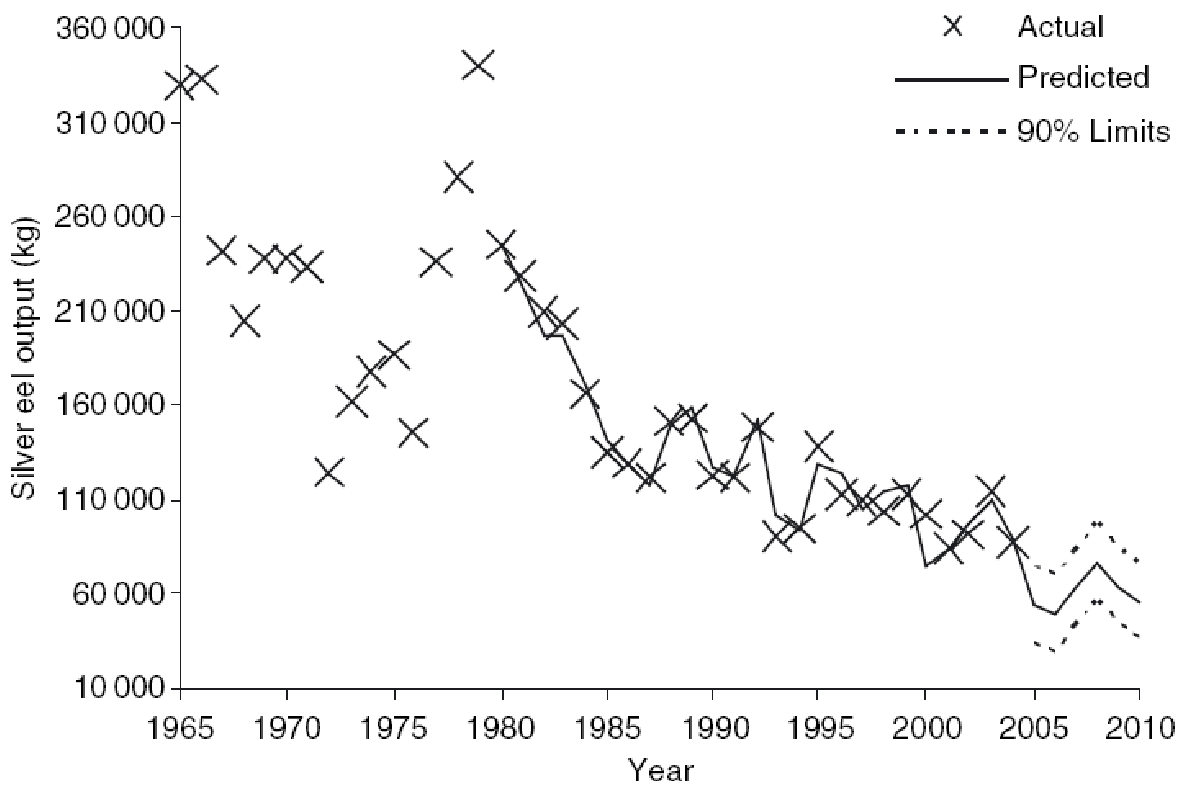

Figure 8: Actual and predicted Silver eel output for Lough Neagh, N. Ireland (from Allen at al. 2006).

MONITORING ISSUES

Monitoring issues arise from: use of catch statistics without information on fishing effort to estimate stock; collection of numbers of eels without lengths - missing any size structure change; collection of total biomass without size structure (this is particularly relevant now there is a better understanding of 2 phase dispersal of eels in river systems, as reduced recruitment will cause eel abundance (not biomass) to decrease more in an upstream direction whilst it may remain stable or decrease to a lesser extent down stream); and/or sampling at bias positions that maintain numbers and size distributions long after changes in the majority of the catchment, as the effects of reduced elver recruitment will not be easy to identify down river as density remains constant with little pressure for any eel to move up stream.

DETECTION LAG PERIOD

There appears to be a strong link between spawner (silver eel) escapement and recruitment, with reduced recruitment adding to the existing problem of reduced stock levels. But, because of eels long life cycle and relatively low mortality rates (20–70% during inland stages according to sites and age groups), a delay of 10–20 years is observed between a recruitment failure and the decline of a fishery (Moriarty and Dekker, 1997). In the case of low mortality rates, there is even a biomass increase during 10 years following the recruitment decrease (fig. 9). For these reasons scientists expect the recent (and ongoing) decline in recruitment to result in far fewer adult eels in the future and extreme caution should be taken in stock predictions.

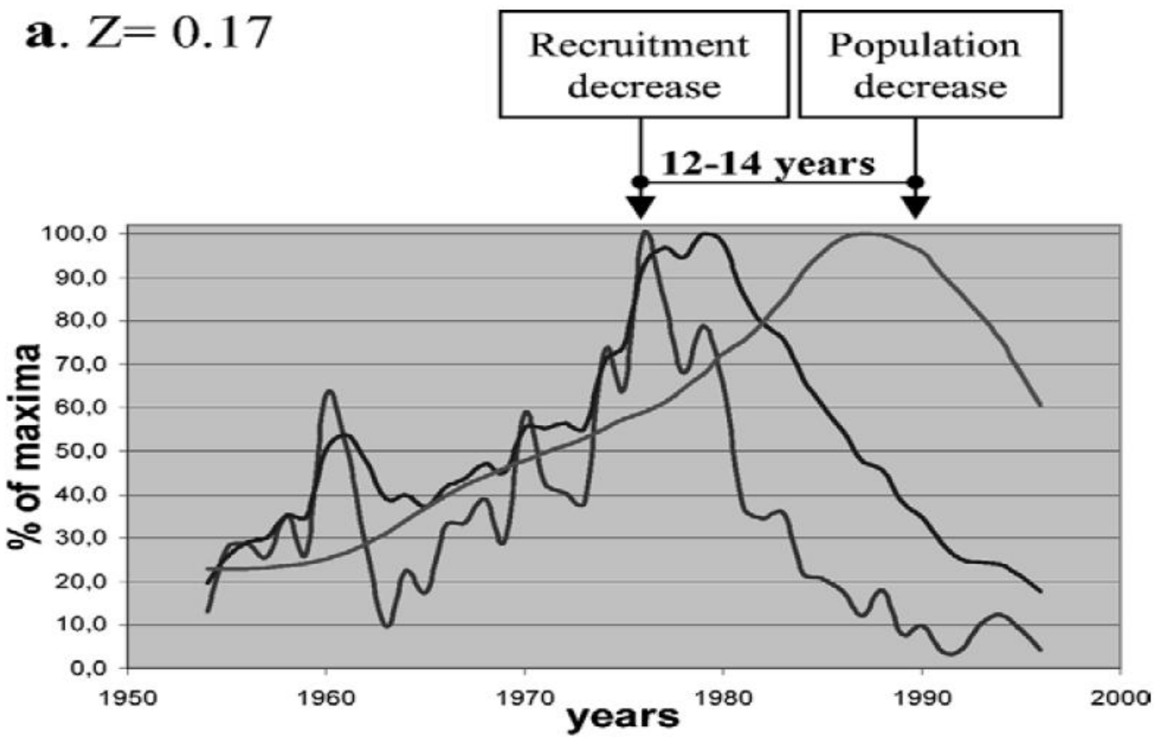

Figure 9: Delayed stock decline caused by recruitment decline (from Feunteun 2002).

EEL DECLINE IN SCOTLAND

As neither the yellow/silver eel fishery or the elver fishery were of little economic importance and involved few individuals across Scotland, the fisheries have been and continue to be unregulated thus there has been no formal recording of catches or government incentive to collect fisheries independent data.

There are only 3 sets of fisheries independent data available on eels in Scotland: 1) Highlands and Islands Development Board survey of the potential of commercial eel fishing in the Highlands (Williamson 1976), which concluded that there were insufficient eels to support fulltime eel fishermen and is only useful for analysis if the survey is repeated; 2) Fisheries Trust salmonid electro-fishing surveys which started in 1996; and 3) a government eel specific survey site at Allt Coire nam Con, Loch Shiel, Argyll, showing a decline before the Fisheries Trusts electro-fishing surveys (fig. 10).

In 2007 FRS analysed eel abundance classes from Fisheries Trust databases of salmonid surveys which were not the property of SNH. Though numerical data was available on request, FRS concluded that abundance class data (i.e. 1-10, 11-100, 101-1000) was unsuitable for rigorous statistical analysis. Moreover, FRS concluded that the use of electro-fishing for the collection of eel density was subject to strong variables, such as substrate, habitat, distance from sea, altitude and repeatability, which were not accounted for in all data sets. Information on eel sizes which is important for examining size structure, causes of stock fluctuations and population health, was not collected by all Trusts.

FRS stressed that though the Fisheries Trusts' data is far from ideal and violates many statistical assumptions, Fisheries Trusts' electro-fishing data is the best scientific data available. Based on this FRS concluded that over the 1996-2006 period: 1) there was no evidence for a change in the percentage of sites where eels were absent, as would be expected in a period of severe ongoing decline in recruitment; 2) there was no evidence for significant temporal change in yellow eel recruitment caused by reduced elver recruitment; and 3) West Sutherland Fisheries Trust 864 electro-fishing survey data show a slight increase in trend lines.

However, the Fisheries Trusts' data set is from a period after the general European decline from 1970-95 and thus does not indicate natural levels or the effects of the decline. Furthermore, identifying abnormal size structure and biomass changes caused by a recruitment decline is difficult if left too long after the initial decline. This is due to the initial rapid growth of eels if recruitment is restricted (due to density dependent growth), with growth slowing significantly after 14 years. Thus FRS's examination of the 1996-2007 Trusts' data was unlikely to identify the effects of the recruitment collapse in 1980's on eel stocks.

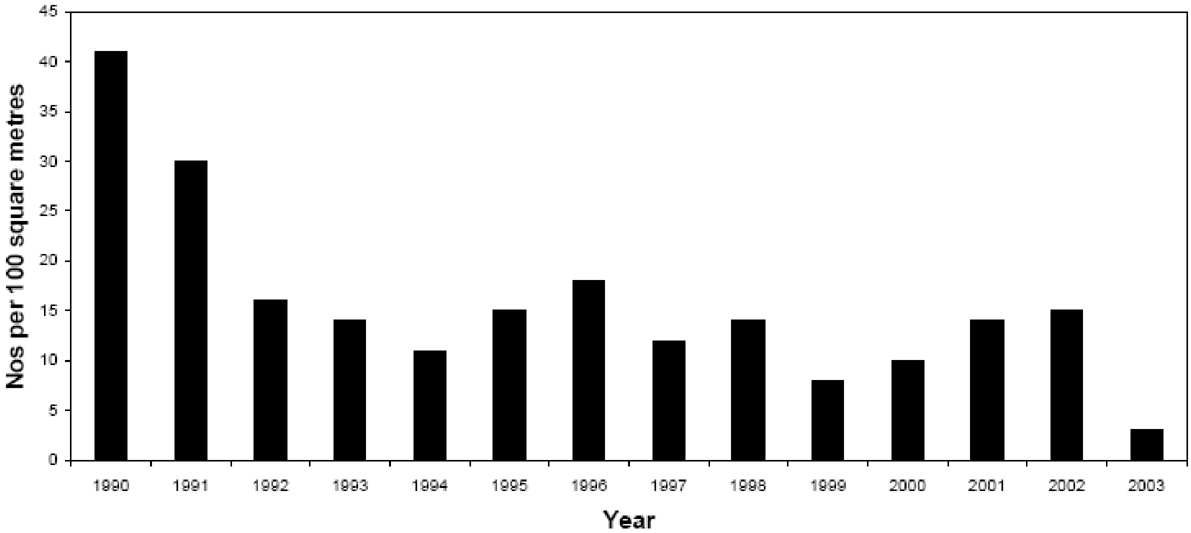

Figure 10: Density of yellow eel from burn in North Argyll collected by FRS. Shows decline then apparent level out at a lower number (from Godfrey 2007).

CONCLUSION ON TEMPORAL CHANGES IN RECRUITMENT AND STOCK

- Across Europe there is a serious continual decline in recruitment which appears to have bottomed out at around 1% of historic natural levels.
- Decline in recruitment has caused a severe decline in stock in Northern Europe and Baltic areas (due to naturally less recruitment in conjunction with the current recruitment decline).
- Stock decline is now becoming apparent in areas close to the continental shelf (France, Britain, Portugal and Spain) previously exposed to naturally high levels of recruitment.

- Reduced recruitment causes an initial increase in large females in the stock without an easily identifiable decrease in biomass and then a lag period before a decline in stock biomass becomes apparent.
- Stock models predict declines in stocks currently believed by some to be unaffected by the recruitment decline.
- Emigrating spawners are being replaced at ever lower numbers.
- In Scotland there is no data to determine temporal changes in recruitment, though a decline is likely to have occurred during the same period as England and Ireland.
- In Scotland there is insufficient data to determine temporal changes in stock, as there is a lack of records over a sufficient time periods and no coordination of the type of sampling or data analysis.
- Fisheries Trust electro-fishing salmonid surveys were not designed to identify changes in eel stocks and if non-government sources are to be used for monitoring clear guidelines should be set by the government on eel data collection.
- Social demand to restore a depleted local stock emerges at least 7–14 years after the recruitment failure and social demand does not occur simultaneously in Europe due to geographically differing levels of recruitment and growth rates.

PROBABLE CAUSES OF ELVER RECRUITMENT AND EEL STOCK DECLINE

LINK BETWEEN STOCK AND RECRUITMENT DECLINE

Dekker (2003) argued that a reduction in spawning stock, caused by a declining eel stock in Europe as a whole may have been sufficient to cause the recruitment collapse recently observed in the 1980. Dekker provided evidence that the decline in recruitment was preceded by a decline in eel landings approximately two to three decades earlier, as the time lag roughly corresponded to a generation period for the faster growing eels from mid and south European latitudes. Thus initial decline in stock could not be attributed to reduced recruitment but reduced stock could be a potential cause of reduced recruitment. So what has caused the reduction in stock causing reduced recruitment? The following causes for recruitment and stock decline are generally given (Dekker, 2003; Kirk, 2003; and Russell & Potter 2003) for the reduction of eels in Europe.

Recruitment decline

1. Over-exploitation
2. Changes in oceanographical conditions, possibly linked to climate change
3. Reductions in accessible freshwater habitat
4. Degradation of freshwater habitats
5. Pollution
6. Parasitism

Stock decline

1. The loss of good yellow eel habitat, such as loss of wetlands, pollution or over abstraction of rivers
2. Barriers to migration, both in terms structural physical barriers, e.g. weirs but also of water quality and quantity barriers
3. Over-fishing
4. A reduction in the number of elvers stocked in waters beyond the normal migration range

CLIMATE CHANGE

Some recent papers suggest that marine events are the main factor responsible for the decline of eels. Some scientists suggest that a northwards shift in the north wall of the Gulf Stream could have caused some leptocephali of European Eels to follow longer, more northerly routes. This could have exposed them to less favourable temperatures and affected food availability. In Japan there has been a decline in catches of Japanese glass eels in years when El Niño occurs, when, according to computer simulation, many Japanese glass eels swim in unfavourable ocean currents. Climatic events are responsible for current shifts reducing recruitment in major systems such as the Baltic Sea. Knights (2003) speculated that long-term oceanic and climate changes may be impacting on recruitment of anguillid species throughout the Northern Hemisphere. A possible reduction of oceanic productivity is also suggested to explain long-term reduction size of glass eels recruiting to inland waters.

PARASITES

A parasitic nematode *Anguillicola crassus*, was spread to eel stocks in European and then the UK from Japanese eel imports to European in 1980's (Kirk 2003). The parasite which grows in the swim-bladder has been suggested to cause serious associated physiological effects which may impair the capacity of European eels to undertake the migration to the Sargasso Sea. Currently there is no direct evidence that it prevents the silvering process or causes significant effect on the transatlantic migration (Moriarty & Dekker 1997), however, the impact could be considerable. The parasite appears to be widespread in Europe and high rates of infestation within populations and high levels of incidence within individuals have been widely reported. Japanese research indicates that the presence of the parasite may lead to dysfunction of the swim-bladder as a hydrostatic organ, cause reduced tolerance to stress, affect the eel's physiology and reduce its swimming speed. Monitoring of the parasite has started in Scotland and recorded the parasite in 2 catchments (per. Com. Willie Yeoman). Such research will be of substantial value in determining what fraction of stock decline can be attributed to the effects of the parasite.

HABITAT LOSS (DRAINAGE, BLOCKAGE AND POLLUTION)

Most researchers attribute the main cause of stock decline (and thus recruitment decline) to reduced habitat availability, as available wetland habitats for eels in Europe are thought to have been reduced by at least 50% during the last century. Currently the habitat area in Europe available to eels is estimated at over 87 000 km^2 (Moriarty and Dekker, 1997). Habitat loss is caused by dams, drainage of wetlands and reduced water quality.

Reduced water quality due to organic pollution causing low dissolved oxygen causes serious barriers to eels in many European rivers. This is of major concern as cities causing high organic pollution tend to be situated at river mouths thus blocking access of entire watersheds to eels (and other aquatic organisms). Deteriorating water quality in water systems all over Europe may also have contributed to loss of eel productivity, which was also suggested to be the major reason for the decline of eels in Japan. In the UK reduced water quality has had a major impact on eels in the Thames and Mersey, where actions have been taken to improve anoxic conditions caused by organic pollution to successfully encourage eels back into those watersheds. In these situations the eel is a reliable bio-indicator of habitat availability and connectivity, as a population declines in a given catchment very often indicates a disturbance of the hydrosystem's ecological functioning (Feunteun 2002). Moreover, when restoration programs seek to restore eel stocks in given catchments, the various actions are favourable for many other species.

DAMS

Tatsukawa (2001) concluded that the construction of river dams was one of the major reasons for the decline of eels in Japan. Loss of freshwater habitat to the construction of dams has occurred in a number of countries in Europe, which has modified habitat quality and, unless supplied with eel passes, reduced access to upstream habitats. An indication of the accessibility to eels is the presence of salmon as if physical obstructions are impassable to salmon they are generally impassable to eels. Though eels may go round or travel over ground (particularly small eels <120 mm), they can not climb vertical slopes 50-60% longer than their body length, elvers cannot ascend flows more than 0.5m/s and yellow eels cannot ascend flows more than 2.0m/s.

Hydroelectric dams present a controversial problem for eel migration, as eels require eel passes to negotiate up stream and measures need to be taken to reduce silver eel mortality through turbines during down stream migration. Eel mortality through turbines was estimated at 16-26% on the River Meuse (Winter et al. 2006) but is strongly influenced by turbine design and eel length. Eels have been of minimal concern in conjunction with hydroelectric systems in Scotland and no measures have been taken to facilitate silver eel migrations, although SEPA, under the Water Framework Directive, are responsible for ensuring the connectivity of river habitats. For hydroelectric dams, up stream eel passes would be easy to install but down stream would require retro-fitting intake protection facilities at considerable costs. Selective spillways open during migration periods could be installed with non-mechanical infrasound barriers around turbines (Sand et al, 2000) if more information was known about the migration timing of silver eels in Scotland.

SUB-LEATHAL POISONING

Though pollution is certainly extremely low in Sutherland, eel recruitment in Sutherland may suffer from pollution affecting eels in the rest of Europe. The contribution of various pollutants on eel mortality has been widely studied, and the quantity of bioaccumulated contaminants during the inland growth stage probably has a key influence on breeding success, larval survival and migration success of glass eels and elvers. Due to the long lifecycle, benthic habit, diverse feeding at various levels in the food web and long term fat storage, eels are efficient bioaccumulators of substantial body burdens of a variety of heavy metals and persistent organic pollutants. Due to this, the use of the European eel as a species for pollution biomonitoring was initially proposed more than 20 years ago.

There is no proof of significant mortality due to persistent pollutants (except in major but isolated accidents) and several studies have shown that a number of pollutants such as organochlorine compounds have decreased significantly during the past 20 years. The observed concentrations are most often below acute toxicity levels for eels, and it is suggested that contamination, in particular by PCBs is not responsible for the decline of European eel. However, recent studies have found quantities of Brominated flame retardants and PCBs (even though they were banned 20 yeas ago) in samples of eels across Europe below acute toxicity level for eels, though unsuitable for human consumption (Santillo, D., et al., 2005). Sub-lethal concentrations have many consequences on the physiology of eels which appear to be much more sensitive to pollutants than many other species. Though the effect of sub-lethal doses of contaminants on reproductive success of eels is poorly known, a wide range of contaminants such as PCBs, pesticides, heavy metals and plastifiers disturb reproductive hormonal cycles in fishes and therefore, reduce the breeding success. Moreover, brominated flame retardants (which mimic thyroxin and affect neurobehavioral development) and PCBs (which mimics estrogens, and impairs egg quality and embryonic development) are highly fat soluble accumulating in eels as they build up fat reserves to 1/3 of body weight over many years. Thus when fat reserves are mobilised for energy during migration to the Sargasso Sea pollutants are released into the eels blood stream. Once released into the eel they may cause acute toxicity or sub-lethal levels may cause the eel to change sex or mature too early, reducing the hydro-dynamics of eels such that they may not reach the Sargasso.

OVER EXPLOITATION

Though loss of wetlands in Europe is thought to have reduced the available eel habitat by at least 50%, there is some evidence that habitat loss and pollution alone are not sufficient to explain the extent and timings of the decline in recruitment (Knights et al., 2001). When the number of eels arriving on the coast is super-abundant and freshwater mortality is density dependent then the effects of recruitment variation (by factors such as elver fishing) on the numbers of older eels found in freshwaters may be negligible. However, at some point reduced recruitment through fishing will reduce stock and this point has probably already been reached in the European eel.

The declining recruitment of glass eel/elvers to Europe as a whole have given rise to major concerns over the sustainability of European eel fisheries without effective management in place (Castonguay et al. 1994, Moriarty & Dekker 1997; Dekker 2002; ICES 2003, 2004; Russell & Potter 2003; Starkie 2003). A total of 25– 30 000 t of eels are exploited every year in Europe. Glass eel/elver fisheries account for 800–900 t per year, which only represents 2.7% of the total yield by weight. However, 2.7% includes more than 2.4 billions young eels, sufficient to restock all the European waters with 0.1 kg ha^{-1} (Moriarty and Dekker, 1997) and the immediate link between the increased demand for European Eel (glass eels) in Asia and the decline of the species population is highly debated by fisheries scientists. Conversely, some fisheries, located mainly in Northern Europe, focus on silver eels, with a total yield of silver eels in Europe at about 2000t per year (Moriarty and Dekker, 1997). This accounts for 6.7% of the yield but a significant part of silver eel stock seems to be exploited in certain regions such as in Northern Ireland or in Norway (Moriarty and Dekker, 1997). In a number of cases, the escapement of silver eels seems to be extremely reduced by the fisheries.

NATIONAL EEL MANAGEMENT PLANS

Broadly speaking, there were five principal conservation measures in place in 2002 for glass eel and elver fisheries:

1. A ban on commercial fishing in Denmark, Germany, Netherlands, Northern Ireland, Republic of Ireland and Sweden.
2. A requirement for elver passes in Denmark, France, Republic of Ireland, England, Netherlands and Sweden.
3. Gear type regulations in France, England, Portugal and Spain.
4. Closed seasons in France, Portugal and Spain.
5. Licences for fishing/dealing in France, England, Italy, Portugal and Spain.

Seven conservation measures had also been drawn up by 2002 for yellow and silver eel fisheries in Europe:

1. Gear controls in all countries.
2. Controls on net mesh sizes in Denmark, Italy, Netherlands, Republic of Ireland and England
3. Closed fishing seasons in Denmark, France, Netherlands, Northern Ireland, Portugal, Republic of Ireland, Spain and Sweden.
4. Licences for fishing/dealing in France, Germany, Italy, Netherlands, Northern Ireland, Republic of Ireland and England.
5. Limits on the size of eels caught in Spain, Denmark, Italy, Netherlands, Northern Ireland, Republic of Ireland and Sweden.
6. Free gaps in weirs in Denmark; Northern Ireland, Republic of Ireland and Sweden.
7. Quotas in Northern Ireland.

In 2003 based on the findings of stock decline across Europe and the consensus that previous measures to protect stock were insufficient unless imposed simultaneously across Europe, the Commission of the European Communities produced a communication to the Council and the European Parliament on 'Development of a community action plan for the management of European eel' (Com. 2003. 573 final). In October 2005, the EC Commission presented a proposal aimed at establishing measures for the recovery of the European eel stock (Com. 2005. 472 final). The objective of the proposal was to achieve a recovery of the European eel stock to historic levels of adult abundance and elver recruitment. The principal element of the regulation was the establishment of national Eel Management Plans (EMP), including measures by means of which each Member State would achieve the objective of a 40% escapement of silver eel from each river basin (measured with respect to undisturbed conditions, reflecting conditions in the absence of a fishery or other man-made losses.) This developed into Commission staff working paper 'Report of the second meeting of the subgroup on review of stocks, of the Scientific, Technical and Economic Committee for Fisheries eel management 2006' (sgrst-06-02) and in 2005 the EC Commission included the eel in the Data Collection Regulation and set standards for National Data Collection for the European eel (European Council Regulation 1543/2000 and European Commission Regulations 1639/2001, 1581/2004). Then in September 2007 the Council Regulation (EC no 1100/2007) established measures for the recovery of the stock of European eel to ensure

40% silver eel escapement, through the implementation of river basin EMPs by 2009 and closure of fisheries if unsuccessful by 2015. Eel management plans must: indicate limits on commercial activity, habitat conservation, restocking measures, structures to facilitate migration and aquaculture measures; either reduce fishing effort by at least 50% of 2004-2006 levels or reduce other anthropogenic mortality factors equivalent to catches; retain 60% of eel catches less than 12cm long for restocking by 2013; and must establish full traceability on eel catches and trading by July 2009.

Eel management plans are designated to cover River Basin Districts (RBD) as defined under the Water Framework Directive (FRD). Scotland has 2 RBD's, The Scotland River Basin District north of the Border Hills and the Solway Tweed RBD south of the hills into England. Within the Scotland RBD there are over 100 catchments with a range of catchment and habitat types (Godfrey 2007). Regulation of elver fishing in Scotland is now mandatory due to new EC regulations and if targets are not met fishing may be subject to closure. Implementation of a Scottish EMP will be through Fisheries Research Services, who are currently drafting an EMP for Scotland for implementation by 2009. Eels are also covered under Water Framework Directive (WFD), where specific extensions could be implemented for eels as an indicator of river connectivity and ecological and chemical status. The WFD is implemented through SEPA and SNH.

There are no international rules to monitor, control or limit international trade in eels, though the listing of the American Eel in CITES Appendix III has been suggested by various scientists.

QUESTIONNAIRES

PRESS RELEASES AND QUESTIONNAIRES

Questionnaires were designed with both forced and open ended questions to gather qualitative and quantitative data. In January 2008 questionnaires and an eel fact sheet were sent out to all estate owners, elver fishers and key members of the public with long association with river management or fishing in the WSFT remit area. Where replies were not given recipients were contacted where possible and verbal information was collected by phone or meeting.

Appeals were made to the general public for information on elvers and eels in 2 press releases, one in the Northern Times on the 8th February 2008 and one in the Ullapool News on the 13th February 2008. Press releases contained information to raise public awareness of eels

GENERAL RESPONSE

Of the 29 questionnaires sent out to, 11 were completed, several people working on estates gave verbal information instead and several gave non structured interviews on specific topics by phone or by personal visits. Even though questionnaires were structured statistical analysis was not possible due to the high variation in responses, with most responses tending to be only on one issue. Thus responses to questionnaires, verbal information and interviews are given below as general comments on subjects. In total information was collected from 3 elver fishers, 3 estate workers, 11 estate owners, 1 fisheries biologist and 1 angler. Generally respondents knew very little on eels and close to nothing on elvers, with most detailed responses coming from key individuals who tended to be elver fishers, keepers, and amateur naturalists. Though many were unable to comment on eels, some did comment that the information sheet sent out was very interesting and would give more attention to eels in consecutive years. Only one response (from a yellow/silver eel fisherman from Orkney) was received after the press releases.

ELVER FISHING IN SUTHERLAND

There has been no elver fishing before the 1970's when a man with an elver business on the River Severn acquired permission to fish the River Laxford. Between the 1970's to the mid 1980's elvers were heavily fished on the Laxford and held in tanks at Achfary. After a period of no fishing a different elver fisher started fishing Laxford in the 1990's, growing on elvers to silver eels in Alness (this was also tried with elvers from Polla in the 1970s). In 1997 elver fishing was stopped on the Laxford due to ecological concerns and possible irresponsible fishing after the discovery of traps full of dead elvers.

Since the 1990's other elver fishers are known to have fished on the Inver, Manse, Oldany, Culag, Kirkaig, Geisgill, Polla, Hope, Scourie, Glen Leireag, Loch Raa and Rhiconich systems. During this period there have been 2 main elver fishers, one fisher having worked for around 12 years around Assynt (1996- present) and the other for about 4 years around Achiltibuie from 2000-2004, with a couple of people helping them over the years in adjacent areas north and south of Assynt. None of the fisher relied on elver fishing for sole incomes. Other elver fishers were mentioned to have existed in previous years in the Western Isles and Wester Ross. Current level of elver fishing in 2007 in West Sutherland is low (3-4 fishers) and fishers explained that fishing effort has declined due to price and reduced migration of elvers and that continued fishing in 2008 onwards is likely to be economically unviable. Most elver fishers maintained that they were only catching a surplus yield of elvers as they were hyper abundant compared to the numbers the rivers could support.

PERCEIVED TEMPORAL CHANGES IN ELVER RUNS

Several persons recalled very good elver runs during 1960's, particularly on the Culag by the old mill, on the Inver at the bridge at Lochinver Village, on the Badna Bay burn on the Laxford and on the Polla where a massive elver run was observed in July or August.

Clearly elver fishing was profitable on the Laxford during 1970's and into the 1980's. During the 1990's elver fishing had declined from good fishing to economically unviable. Three recipients, an estate owner (20 years), a night watchman (10 years) and 2 elver fisher (4 and 12 years) reported successive yearly decreases in elver runs with detail over these years. However, one recipient observed no overall change in elvers arriving in Sutherland as a whole attributing variation in runs on different rivers to variation in environmental factors affecting the position of arrival of elvers along the coast.

Elvers were observed running by non elver fishers on: Inver, Culag, Laxford, Kirkaig, Lone Burn, Polla, Dionard, Glen Leireag, Garvie, Loch Raa and Alt an Fhealing (Badna Bay).

PERCEIVED TIMING OF ELVER RUNS AND CONDITIONS FOR GOOD RUNS

Only 3 people commented on the timing of elver runs, 2 elver fishers and a night watchman on the Laxford. The consensus was that elver runs occurred during rising spring tides after periods of warm weather, with elvers running 2-3 times per year. There was a strong belief that warm river water encouraged good elver runs and one elver fisher believed elvers selected warmer water burns over colder burns. Low river flow, which would make elver runs easier, may clearly coincide with good weather and increased temperature, thus the exact influence of flow or temperature is not clear. Continuous spate conditions were suggested to hold elvers in lower rivers and estuary sections preventing running, then when spates ended a pulse of built up elvers makes elver runs of great magnitude. Normal conditions were thought to allow continual lower density runs, which would be less easy to spot and fish. Low flow rates of warm water appear to be optimal conditions for elver runs.

One fisher said that the times of arrival to shore (not up rivers) have become less predictable and are not dependent on tides or lunar cycles or storms. He concluded that elvers can arrive between March and July, collecting under stones at low tide. Eels were believed by the fishers to be found in all rivers and burns and elvers do not seem to select one river system over another. The irregularity of elver runs on specific rivers was attributed to delivering elvers from main coastal currents passively at estuaries according to tides, winds and currents at time of arrival. Fingerlings (elvers that arrived the previous year) are commonly found in elver traps by fishers during runs.

LAXFORD ELVER RUN RECORDS

From 1993 to 1998 elver runs were recorded by a night watchman on the Laxford (table1). The earliest run was 24th May and the latest 22nd August, with many runs of large numbers of elvers in 1997 (see appendix for details). Elvers run generally over 1 month between June and July, with elvers commonly accompanied by fingerlings during elver runs. Timing of runs was considered to be unpredictable though it seemed to be related to river temperature ($17^{o}C$ was recorded) and absence of spates. A close examination of runs shows a pattern of similar peak months of runs (July), similar lengths of runs (mean 4.2 days: median 4 days: range 1-12 days), similar time between runs and mean length of run (mean 9.7 days: median of 9 days: range 4-20 days) and with mostly 2 runs per month. This would support a strong relation to spring tidal cycles even if the exact timing for both start and end of runs varies a little as would be expected with the influence of the many other environmental factors affecting the timing and numbers.

Table 1: Elver run times on the River Laxford

Year	Months	Run span in Months	Total Days Running
1993	28th May - 27th June	1	10
1994	21st June – 23rd July	1	6
1995	13th June – 1st July	½	12
1996	14th June – 19th July	1	6
1997	30th May – 22nd Aug.	3	25
1998	7th June – 10th Aug.	1	6

YELLOW/SILVER EELS

The WSFT found eels in all 31 rivers sampled using electro-fishing in their remit area. With the exception of WSFT electro-fishing surveys, yellow and silver eels were only reported in the Dionard, Durness lochs, Manse, Loch Raa and Badna Bay burn, though generally eels are considered to be in every watercourse in Sutherland. A non WSFT survey on the Dionard in 1995 found 1-2 eels per 25 yard mostly of a size of 150-230mm. Yellow and Silver eels have been caught in August prior to 1953 on the Dionard. On the Dionard yellow/silver eel numbers are considered to be small but have stayed the same over the last 25 years. Large eels have been spotted in the Durness lochs (limestone lochs). Wrist thick eels have been caught on the Duart in the manse trap (silver eels were caught during October/November) and a large number of eels were seen on the Duart below the salmon hatchery.

Loch Raa has been fished for yellow/silver eels relatively successfully for a few years between 2000 and 2004 using a fyke net to supply eels for smoking in Achiltibuie. Catches in Loch Raa were best during October/November which was considered to be the silver eel run, but catches were insufficient for continued economic exploitation. Silver eels seen moving down stream at Badna Bay burn in November and yellow/silver eels were also seen in Loch Vatachan.

Outside Sutherland silver eel fishing existed until recently in South Uist and at Boardhouse mill in NW mainland Orkney from 1982 to 1992 (per.com. Fergus Morison). At Boardhouse mill silver eels were fished at a level of between half and one tonne per annum with no apparent decline. Mr Morison did not believe that there had ever been a silver eel fishery on Orkney before or since, though he pointed out that several tons were fished from Orkney over a couple of years during the HIDB 1975 eel project (Williamson 1976) and since 1992 Dutch brown eel fykers were invited by the trout fishing club to clear out the eels in lochs all over Orkney which were considered as vermin.

Mr Morrison found that there were distinct differences in eels from different places, most notably from Swannay loch (weighing 2kg on average and up to 4kg) where the eels were much fewer but much bigger than Boardhouse. Mr Morison points out that there was evidence of severe pollution in most small watercourses, especially at Swannay where 200 cows and a cheese factory caused sever pollution for several years. Mr Morrison suggests from his observations that: 1) a clear relationship exists between carrying capacity of a loch (total biomass possible) and number/sizes of eels if elvers are not getting in; 2) the numbers and weights of eels gives an indication of the health of the stock assuming constant carrying capacity in the loch, fewer fish therefore being heavier; and 3) the existence of plenty of smaller females would seem to indicate a sustainable elver or yellow/silver fishery.

PERCEPTION OF IMPACT OF EELS ON RIVERS

Previously most involved with salmonid management on rivers held eels in little regard due to the belief that eels predate on salmonid ova and parr. Currently, most owners of rivers do not operate angling solely for profit and have a wider understanding of the ecological benefits of eels as part of the natural ecosystem. Owners accept that eels contribute to salmonid mortality through predation of ova and parr (with some direct observation), and hold the strong belief that eels compete for food with salmonids in rivers where food is limited (as in the Highlands) but appreciate the value of eels as a food source for otters, salmonids and bird populations (including Black throated Divers, Common Gulls and Hooded Crows).

DISCUSSION

STATUS OF EELS IN SUTHERLAND

There is strong anecdotal evidence for declining elver migrations in Sutherland over the last 10 years and perhaps since the 1960's, which supports the overwhelming evidence for recruitment decline across Europe. Elver decline seen since the 1980's in Europe is believed to be caused by stock decline across Europe prior to the 1980's. Stock decline may have been further increased due to the export of elvers to Asia starting in the 1990's, which certainly caused renewed interest in elver fishing in Sutherland in the 1990's and the higher elver prices in the early 2000's kept elver fishing profitable. On the continent declines in elvers seen 10-20 years ago are now causing detectable reduction of stocks in most of Europe. Based on reliable models using data from Northern Ireland, reduced stocks are only expected to decline further. Though the loss of habitat and environmental change may be the strongest causes for initial decline, the recovery of European eel stocks requires reduced exploitation to maximise recruitment across Europe and alleviate other less controllable factors causing of stock decline. Removal of elvers from recruitment by fishing in a situation of continued decline is clearly detrimental to eels stocks and will only increase the negative feedback between reduced recruitment and reduced stock. Across Europe restrictions on exploitation are being imposed in all fisheries, though in Scotland due to the limited number of fishers, no restrictions have been imposed so far.

Experience from Europe, England and Ireland all indicate that if a decline in recruitment can be seen in Scotland then a decline in stocks in Scotland is highly probable. However, there is no statistically robust data on Scotland to indicate any temporal change in recruitment, stock or whether the EC 40% escapement of spawners is being met. In such a case where scientific understanding is poor, as for the European eel and specifically in Scotland, there is a greater need for precaution to take account of uncertainty and it would be prudent to apply the Precautionary Principle.

The Precautionary Principle:
"*Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty* [where monitoring is insufficient] *should not be used as a reason for postponing cost effective measures to prevent environmental damage*" (Principle 15 of the Rio Declaration on Environment and Development).

The Precautionary Principle (around which EMPs have been designed and the 40% spawner escapement set) states that action is required as 'environmental damage' may be occurring. The longevity of such damage is emphasised by research by Feunteun (2002) who predicted that for a stock reduced to 10% by falling recruitment it will take 12-20 years for full stock recovery at a low mortality rate (such as eels in Scotland) and with complete recruitment return (fig. 11). The management objectives for European eel are based around establishing long-term sustainable use of the eel stocks. The application of a precautionary approach requires that any fishing activities must have prior management authorisation and be subject to periodic review. The Guidelines also indicate that if stocks are approaching or failing to meet their reference levels, corrective measures should be initiated without delay, and they should be designed to achieve their purpose promptly, on a timescale not exceeding two or three decades. Thus, in the light of the potential long term severity of a decline and lack of data for eels in Scotland, research and monitoring should be performed to determine the current and natural spawner escapement values and action taken to safeguard against factors causing reduction of spawner escapement below 40% of the natural level.

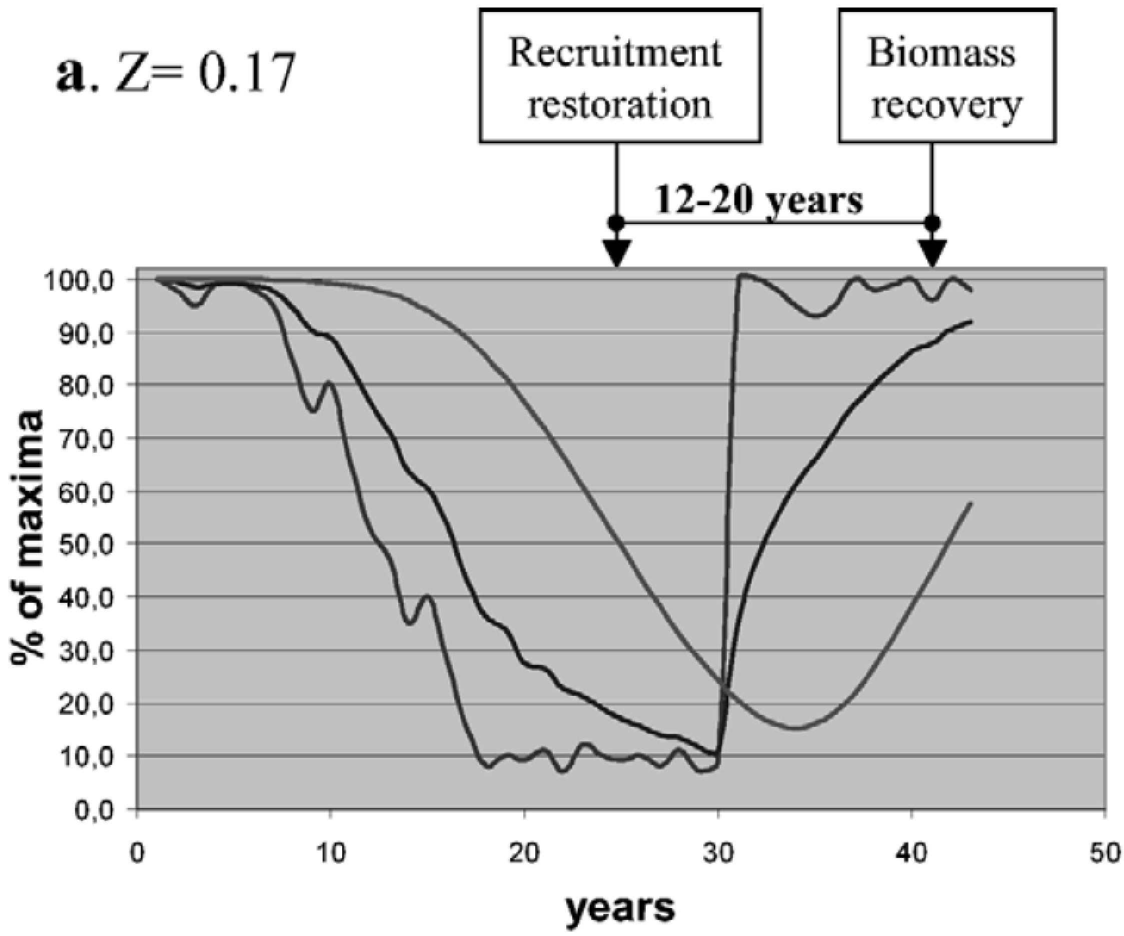

Figure 11: Eel biomass recovery after full restoration of recruitment (from Feunteun 2002).

The root causes for the lack of data on eels in Scotland are the previous low value of eels economically or ecologically. However, eels in NW Scotland may have European economic significance for the panmictic European eel stock as a gene bank of old eels. Moreover, eels may be a key species in Highland biodiversity. Thus factors causing spawning escapement to drop below 40% in Scotland, such as elver fishing, hydro-electric dams, use of brominated flame retardants and parasites, would need to be managed under a Scottish EMP if there was strong evidence for the 'value' of eels. Clearly, research into the genetic importance of eels in NW Scotland and the importance of eels to Highland biodiversity is urgently required to raise the understanding and profile of eels, and to reinforce the importance of the collection of eel specific data.

WHAT ACTION NEEDS TO BE TAKEN LOCALLY?

Though the responsibility for action regarding eels lies with FRS, SNH and SEPA, there is a role for Biodiversity groups to support research and monitoring, lobby for more information and raising awareness of eels. Such actions will help the development of the EMP by FRS for implementation in Scotland in 2009. The following recommendations to should be supported:

1. Government bodies responsible for action should be encouraged to establish a sampling strategy in key ecologically sensitive areas in NW Scotland based on EC sampling recommendations (European Council Regulation 1543/2000 and European Commission Regulations 1639/2001, 1581/2004).

2. If non-government eel data is to be used a formalised system of data sharing needs to be established and guidance should be given by FRS to Fisheries Trusts on eel sampling.

3. The network of Fisheries Trusts in Scotland should be encouraged and supported to coordinate the collection of eel specific data and join European eel projects such as INDICANG (www.ifremer.fr/indicang) or FP6-project SLIME.

4. Government bodies should be lobbied to initiate research into the biodiversity value of eels in the Highlands.

5. Government bodies should be lobbied to initiate research into the genetic value of eels in NW Scotland.

6. Government bodies should be lobbied to initiate research into the effects and solution to Hydro-electric dams and parasites.

7. New hydro-electric schemes on main water course should be encouraged to include the impact on eel upstream and down stream movement in environmental impact assessments in the light of infringement of EC legislation imposed through EMPs.

8. SEPA should be encouraged to use eels as indicators under the Water Framework Directive, as bio-indicators, indications of water way connectivity or health of waterways.

9. Government and oil industries lobbied to ban the use of brominated fire retardants and promote the use of non-brominated (often halogen-free) alternatives.

10. EMP should not encourage any form of eel fishing until 40% spawner escapement can be clearly proven.

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APPENDIX: ELVER RUN RECORDS ON RIVER LAXFORD 1993-1998

28 May 1993	Elver fishing
29 May 1993	Elver fishing
30 May 1993	Elver fishing
01 June 1993	Gordon Williamson studies elvers over night
10 June 1993	Elver fishing
11 June 1993	Elver fishing
12 June 1993	Elver fishing
13 June 1993	Elver fishing
26 June 1993	Elver fishing but no elvers running
27 June 1993	Elver fishing but no elvers running
21 June 1994	Few elvers on rocks but no run
25 June 1994	Few elvers up wet rocks
02 July 1994	Elvers around, up rocks etc.
04 July 1994	Elvers
18 July 1994	Few elvers around
23 July 1994	Few elvers on rocks
13 June 1995	A elver seen
14 June 1995	A elver seen
19 June 1995	Slight increase in activity but still small numbers
23 June 1995	Elvers running strongly after days warmth
24 June 1995	Very good run after very warm day (elver fishers here)
25 June 1995	Running well(elver fishers here)
26 June 1995	Hatchery water 17 deg C, elvers running well
27 June 1995	Running well
28 June 1995	Running well
29 June 1995	Running well
30 June 1995	Running well
01 July 1995	Running well
14 June 1996	A few elvers on rocks
15 June 1996	Good run (fishers here)
16 June 1996	Elver run over
20 June 1996	A few elvers around
24 June 1996	A few elvers running
27 June 1996	A few elvers around
19 July 1996	Small elver run and elvers on rocks

30 May 1997	Elver fishers took 6kg today
01 June 1997	Good elver activity
03 June 1997	At 00:15 Phenomenal number at rock face, 19:00 Hooded crows and common gulls eating elvers
04 June 1997	Elvers still in massive numbers (fishers here)
05 June 1997	Fishers here
06 June 1997	Fishers banned from Laxford from now on
07 June 1997	Run slowed right down
08 June 1997	Elver numbers right down now
09 June 1997	Elver numbers right down now
10 June 1997	Elver numbers right down now
11 June 1997	Elver numbers right down now
13 June 1997	Elver run stopped
25 June 1997	Small numbers running again
28 June 1997	Small numbers running
10 July 1997	2-3 elvers on rocks
11 July 1997	A small run in good running conditions; fingerlings also coming up
12 July 1997	Small run
20 July 1997	2 elvers on rock
21 July 1997	A few elvers running and fingerlings moving up river
22 July 1997	More than few running
26 July 1997	Fingerlings running
29 July 1997	Fingerlings and elvers still running
09 August 1997	Elver and fingerlings running
14 August 1997	Elver and fingerlings running
16 August 1997	Elver and fingerlings running
22 August 1997	A few elvers on rocks
07 June 1998	A few on rock face
18 June 1998	Elvers on rock face in fair numbers
19 June 1998	Elvers in good numbers
20 June 1998	Elvers in good numbers
27 June 1998	Elvers in good numbers
10 August 1998	Elver and fingerlings running

ELVER RECIPE

Elver recipe from The Times 13th December 2007 – ‘Elver poachers put ‘White gold’ on critical list’.

SERVES TWO

Ingredients

400g elvers
100g garlic
25g crushed Espelette pepper
Olive oil, salt, pepper
Parsley to taste

Method

Fry the garlic and Espelette pepper in very hot olive oil, add the elvers, cook for two minutes, add salt and pepper and serve with parsley.