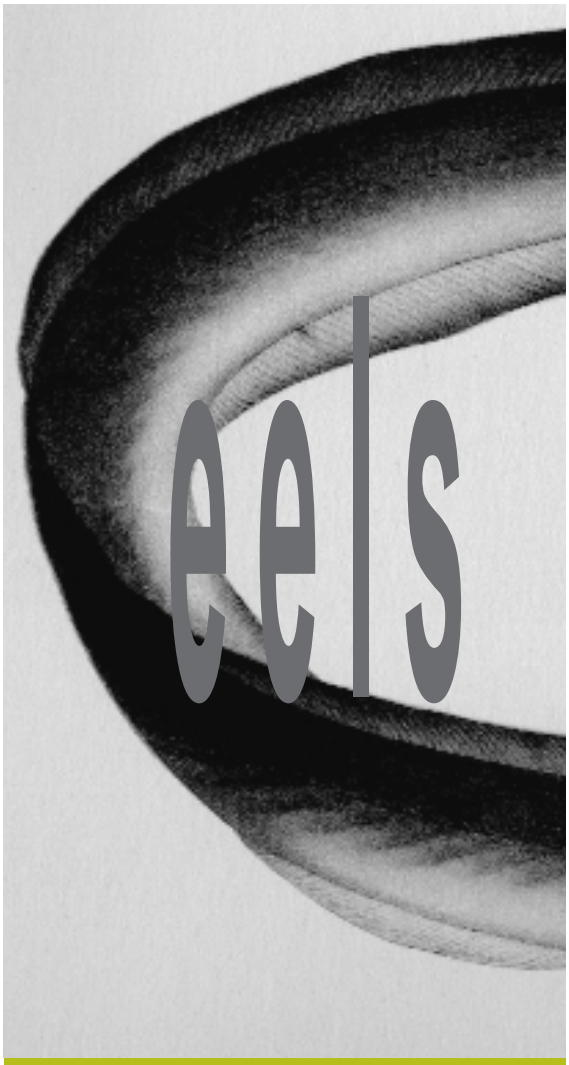


ILLUSTRATION: TEMMINCK & SCHLEGEL (1846)

EELS
THEIR HARVEST AND TRADE IN EUROPE AND ASIA

STÉPHANE RINGUET
FUMIHITO MUTO
and CAROLINE RAYMAKERS

EEL POPULATIONS OF SOME SPECIES IN THE GENUS *ANGUILLA* HAVE DECLINED DRAMATICALLY OVER THE LAST TWENTY YEARS. THIS LOSS HAS BEEN ATTRIBUTED TO CHANGES IN OCEAN CURRENTS AFFECTING MIGRATION, THE LOSS OF RIVER HABITAT, POLLUTION, THE IMPACT OF INVASIVE SPECIES AND LOCAL FISHING. INTERNATIONAL TRADE MAY ALSO HAVE PLAYED A ROLE IN THE SPECIES' DECLINE. 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. BY 2001, CATCH FIGURES FOR EELS WERE THE LOWEST ON RECORD. THIS REDUCTION IN EEL NUMBERS IS ESPECIALLY WORRYING SINCE THESE FISH ARE AN ESSENTIAL FOOD FOR MANY PREDATORS; MOREOVER, THE TRADE IN EELS PROVIDES A SOURCE OF INCOME FOR A CONSIDERABLE NUMBER OF PEOPLE IN ASIA AND EUROPE. EELS ARE PARTICULARLY VULNERABLE OWING TO THEIR LONG AND COMPLEX BIOLOGICAL CYCLE, ABOUT WHICH MUCH IS STILL UNKNOWN.

INTRODUCTION

The European Eel *Anguilla anguilla*, Japanese Eel *Anguilla japonica*, and American Eel *Anguilla rostrata* are the principal *Anguilla* species considered to be of the greatest commercial importance for food. Among the many popular eel dishes consumed around the world, *kabayaki* - marinated grilled eel - is a national dish in Japan during July and August, while smoked eel is favoured in Europe and North America, and eel larvae are eaten as appetizers in Spain.

About 95% of eels in the food trade have been raised in captivity, but most of this production is based on catching and rearing wild-caught juvenile "glass eels". Since the mid-1990s production has increased rapidly (Figure 1), while populations of all three species have suffered serious declines (Moriarty and Dekker, 1997; Tzeng, 1999; Tatsukawa, 2001). Although European Eel populations have always been low, recruitment has declined considerably since the late 1970s (Moriarty and Dekker, 1997). The causes of the decline in all three species are not well understood, and have been attributed to different factors affecting recruitment, growth and/or the eel's reproductive stages (FAO, 1993; Tatsukawa and Matsumiya, 1999; Kim, 2000). The need for radical management action is clearly urgent (Matsumiya, 1999; Kim, 2000; Dekker, 2000b) and has been communicated several times (FAO, 1993; Moriarty and Dekker, 1997). In an effort to improve understanding of these biologically mysterious animals and to aid eel conservation, the Government of Japan is funding research of a joint programme between scientists and industry into finding effective measures to increase eel populations (Japan Fisheries Resource Conservation Association, 2001).

The international trade in eels was identified in the current four-year programme of TRAFFIC Europe as an important area of study in response to reports of the relatively recent and rapid decline in populations of the three main species in trade. The study aimed to explore the reasons for this fall in numbers and to evaluate the degree of threat posed by the trade. Because the global dimensions of the trade in eels are little understood, TRAFFIC examined the status of the trade in Europe and Asia - the primary markets - the control measures in place and the current management goals of producing countries.

METHODS

Information presented in this paper is based on work carried out by TRAFFIC staff in Europe and East Asia over a period of one year during 2001-2002, and forms part of a broader ongoing TRAFFIC study on the eel trade. Research consisted of examination and analysis of data collated by European Customs authorities (EUROSTAT), FAO (FISHSTAT), Japan Marine Products Importers Association (JMPIA), Sea Products French Office (OFIMER), Japan's Ministries of Finance (MOF) and of Agriculture, Forestry and Fisheries

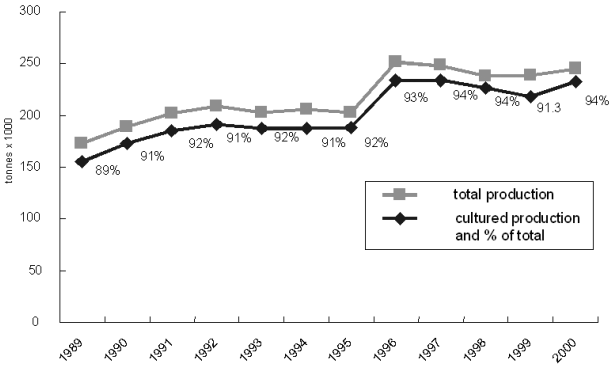


Figure 1. World production of eels (t). *Sources: Anon., 2001a,b*

(MAFF). Interviews were conducted with key scientists and stakeholders, fishermen, fish trading companies, governmental fisheries departments, and associations involved in the culture of eels. Information relating to management and monitoring surveys was extracted from the literature.

Some members of the International Council for the Exploration of the Sea/European Inland Fisheries Advisory Commission (ICES/EIFAC) Working Group on Eels (WGEEL), responsible for collation of data relating to the European Eel and other species, were consulted. This body is a coalition of two former working groups on eels - namely the ICES/ACFM (Advisory Committee on Fisheries Management) Working Group on Eels and the FAO/EIFAC Working Party on Eels (WPEEL). The EU Concerted Action (a collation of existing data designed to formulate a management plan for eels in the European Union, drawn up during 1994 to 1997) presented a general overview of the management of the European Eel through the contribution of scientists from ten European countries (see Moriarty and Dekker, 1997). Several reports on the European Eel (ICES, 1994; 1996; 2000; 2002), which include recommendations concerning management issues, were also examined.

The present article focuses on European and Japanese Eels. Glass eels of both species are referred to herein as European glass eels and Japanese glass eels, respectively.

Customs data: Customs codes for all goods in trade in Europe follow the Harmonized Commodity Description and Coding System (HS), in effect since 1988. The system is made up of figures representing the Customs value, the origin and the tariff description. It comprises an eight-figure sequence, the first six numbers being the same in each country party to the system, with the remaining two numbers used by each country for their own purposes. All *Anguilla* species are recorded under the same tariffs, with separate codes for different products: for example, live eels, chilled eels, frozen eels or smoked eels are, respectively, recorded under the following numbers: 0301.92.00, 0302.66.00, 0303.76.00 and 0305.49.50. European statistics thus only provide information about the international trade of the *Anguilla* genus, rather than the individual species.

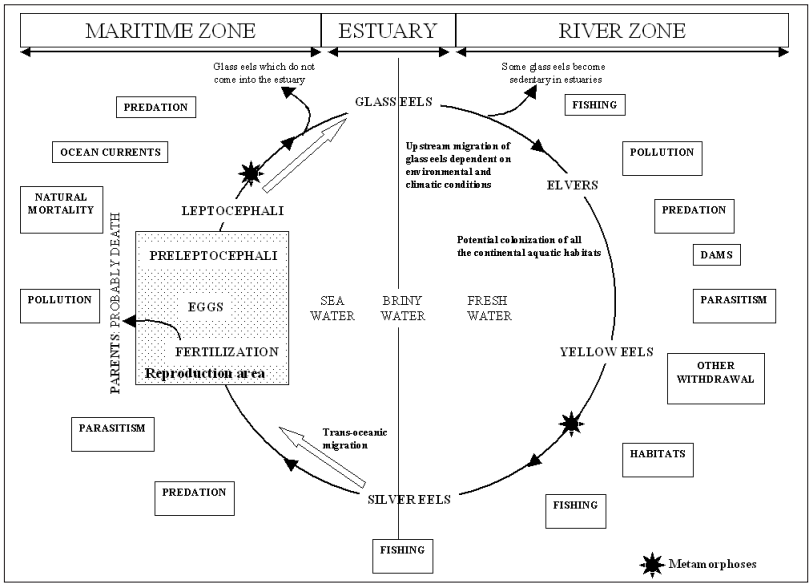


Figure 2. The biological cycle of the eel and the principal threats it faces. Little is known about the eel's migration routes and mystery still surrounds the different stages of its life cycle.

The HS system has also been adopted in Japan, mainland China and Taiwan where it is applied more rigorously than in the EU. These countries have a basic code of four digits and include up to a further seven digits to identify eel items in more detail. Japan's system is composed of nine digits and covers live eels, eel fry for culture, fresh or chilled eels, frozen eels, prepared or preserved eels, whole or in pieces. All refer to *Anguilla* spp. (Anon., 2002e). Mainland China uses a system comprising 11 digits which has been in effect since February 2002. Sometimes products are mixed with conger eels, and there is no specific code for glass eels (Anon., 2002b). Taiwan has also introduced an 11-digit code system. The code for young eels used for culture is divided into three stages but there are no specific codes for Japanese, European and American Eels (Anon., 2002c).

Species Description

Eels are teleost fish (fish with bony skeletons) belonging to the superorder Elopomorpha and the family Anguillidae (Nelson, 1994). According to the most recent taxonomic revision, the genus *Anguilla* includes 15 species and three subspecies (Watanabe, 2000) which can be found in all temperate and tropical waters except the southern part of the Atlantic and east coast of the Pacific (Williamson and Tabeta, 1991; Avice, 2001). Eels are amphihaline species (aquatic species which pass periodically at well defined stages of their life cycle, from salt to freshwater and vice versa) (Figure 2), with a carnivorous diet which changes during each stage of their life cycle. In most continental waters, eels account for a significant proportion of animal biomass in

Figure 3. Rough sketch of the spawning area (***black dot***), distribution (***grey area***), and larval migration (***arrows***) of the American Eel ***Anguilla rostrata*** (1); European Eel ***A. anguilla*** (2); and, Japanese Eel ***A. japonica*** (3).

the sea and form an important component of fish communities and essential food items for many predators such as otters and herons. They are an important link in the food chain and, as migratory fishes, are essential to organic matter fluxes between marine and continental waters.

The European Eel is generally considered a panmictic species ((i.e. eels of one species constitute one population). However, recently available genetic evidence against panmixia in the European Eel has been underlined (Wirth and Bernatchez, 2001). These results from genetic studies suggest that three putative, genetically distinct sub-groups may exist, respectively, in northern, western and southern regions of Europe.

Biology

Little is known about the life cycle or migration routes of the eel. It is known that the European Eel (and the American Eel) spawns in the Sargasso Sea in the western Atlantic Ocean, and the Japanese Eel, off the Mariana Islands in the western Pacific Ocean, and that the newly hatched larvae (*leptocephali*) are carried inland on currents (Figure 3) (Tsukamoto, 1992). By the time young eels reach the continental shelf and river estuaries, they have developed into transparent, cylindrical fish, known as glass eels, which are approximately five centimetres long and weigh less than one gramme. They continue their migration, usually to freshwater habitats, and their skins turn a darker colour; at this stage of their life cycle they are referred to as elvers in Europe and the USA, or *kuroko* (blacky) in Japan. Once the eels have reached about 10 cm long they enter their immature adult or 'yellow eel' phase, which can last between five and nine years, depending on the species, sex and geographic location of the growing habitat. The male European Eel reaches maturity at between three and nine years and the female between five and 18 years, and can spend 20 years in inland waters (Keith and Allardi, 2001), while the Japanese Eel spends 12 to 15 years in fresh water/estuaries before returning to the sea to spawn (Tsukamoto *et al*., 1998). The adult eel takes on a silvery appearance with the onset of sexual maturity (and is referred to as a silver eel) (Tesch, 1977). It ranges in size from 30 cm to one metre in length and weighs 300 g to three kilogrammes, the females always bigger and longer than the males. The European Eel can take 1.5 years (Antunes and Tesch, 1997) and as long as three years (Dufour, 1996) to return to the sea; the duration of the Japanese Eel's migration to the sea is unknown. All anguillid eels die after spawning (Haro, *et al.,* 2000) (Figure 3).

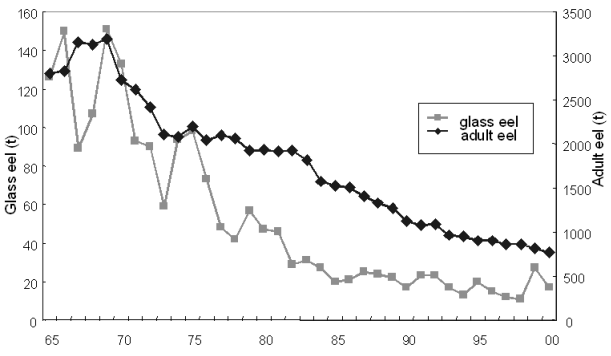


Figure 4. Total catch of eels in Japan (t). *Source: Anon., 1969-2000*

What occurs between the silver eel and glass eel stages is also largely unknown. The spawning grounds have only been detected from the appearance of planktonic eel larvae (Schmidt, 1922; Tsukamoto, 1992). Tanaka *et al*. (1999) and Mochioka (2001) suggest that eel larvae in the wild feed on plankton or organic detritus.

The range of the European Eel extends across all accessible continental or coastal hydrosystems which are linked with the Baltic and North Seas, as well as the English Channel, Atlantic and Mediterranean coasts between Iceland and Mauritania (23° to 70° N). The Japanese Eel ranges from Vietnam, the Philippines, Taiwan, mainland China, the Korean Peninsula, and the Japanese Archipelago, excluding some northern areas.

Status of Wild Populations and Fisheries

Description of eel fisheries

Eels, from the glass eel to the silver eel stage, are exploited by commercial fishers and anglers. In East Asia, only Japan traditionally consumes eels as food (although eel has started to be served in restaurants in South Korea). The annual catch of Japanese glass eels in Japan fluctuates, but the trend is one of overall decline (Figure 4) (Anon., 1969-2000). All glass eels caught in Japan are used in eel culture, and the silver eel and yellow eel fisheries there are quite minor.

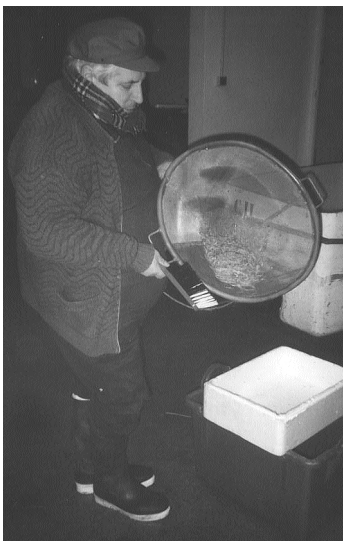
The European Eel is the only eel species targeted in Europe, with an estimated annual catch (of eels at all stages of their life cycle) of approximately 30 000 t (Moriarty and Dekker, 1997), compared to figures in Asia for Japanese Eels of 1300 t (and in the USA for American Eels of 1000 t) (Anon., 2001c). The impact of this exploitation on eel populations is unknown, although the yield of yellow and silver European Eels has declined. The total number of eel fishermen in Europe is estimated at approximately 25 000 (Moriarty and Dekker, 1997). The fisheries occur in inland countries, the Northeast Atlantic and Mediterranean regions (Anon., 2001c). Eels are targeted at the stage they have reached in their life cycle when they pass through coastal waters, estuaries and rivers: glass eels are caught in southwest Europe and northwest Africa, yellow eels throughout the distribution area. Compared with the southern part of Europe, few glass eels reach the coast in northern Europe and traditional fisheries there (particularly in the Baltic and Northern Ireland) focus on adult (mainly silver) eels on their way to the sea to spawn (Dekker, 2002a). Recruitment is estimated at about 2000 million eels annually (Dekker, 2000b), most of which enter coastal waters, estuaries and rivers via the Bay of Biscay.

S. RINGUET/TRAFFIC

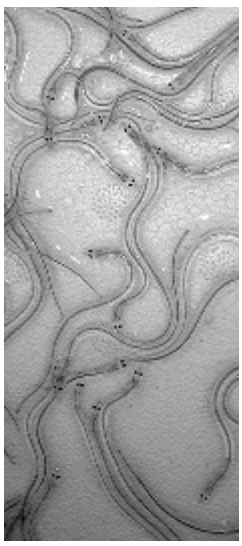
Eel fishing boat near the Arzal dam, Brittany, France. Owing to ocean currents, most eels arriving in Europe enter coastal waters, estuaries and rivers via the Bay of Biscay.

The main European glass eel fisheries are concentrated along the Atlantic coasts of Portugal, Spain, France, Morocco and the Bristol Channel in the UK. Elsewhere, eel fisheries are maintained by restocking within the country, often supplemented by imports, mainly from France, Spain and Portugal (Dekker, 2000a). In this context, restocking refers to the practice of maintaining a stock by regular release of juveniles that are introduced from other areas. The fisheries are generally small-scale operations and must be largely considered artisanal (Moriarty and Dekker, 1997). All stages of the fishery are seasonal and most participants supplement their income from other sources. The main season for catching glass eels in France and Japan is between November and April. Closed seasons are in operation in some countries and are usually based on the traditional fishing seasons in place in those countries (e.g. Ireland), or are related to regulations established to allow unhindered migration of salmonids (e.g. Denmark and Northern Ireland).

A professional fisherman with glass eel catch on a tributary of the River Loire, France (left); the size of the catch can fluctuate hugely, and is influenced by many factors, including environmental conditions, the phases of the moon, temperature, and tides. It took three hours to catch the amount illustrated here. Glass eels (right).



S. RINGUET/TRAFFIC



T. NIELSEN

In France, glass eels represented about 75% of the estuarine fisheries turnover (USD30 million) for the season 1997/1998 (Perraudeau, 2000), and were the most common fish caught in the Bay of Biscay in 1997. In that year, the total production of amphihaline species fisheries was 1750 t (valued at USD81.77 million) and was composed of 410.5 t of European glass eels (valued at USD72.65 million), and 302 t (USD3.2 million) of European Eels at other biological stages (Castelnaud, 2000). In 1999, more than 300 t of glass eels were caught by professional fishermen in Europe, of which 245 t were caught by professional fishermen in France. This represents a turnover in France of EUR33.6 million. Moreover, about 75 t of glass eels are caught in France by non-professional fishermen (Castelnaud, 2002).

The decline in eel landings in Asia and Europe

According to Anon. (2001c), landings of European Eels, Japanese Eels and American Eels dropped to 43.5%, 64% and 8.3%, respectively, over a period of 17 years (1984 to 2000) (Table 1). A few data series which take into account some fishing pressure indices, like the Catch Per Unit Effort (CPUE)[1], show the same trends. On the Loire (France), for example, a fisher caught 45 kg of eels per fishing trip (a total of four hours per trip) during the 1975-1978 period and only three to four kilogrammes of eels per fishing trip in 1997 (P. Elie, pers. comm., 2001).

Fishing methods

A variety of fishing gears has evolved for capturing eels. In France, for example, 19 types of gears and nets are permitted to be used by professional fishermen and characteristics between these are often adapted to meet their specific needs; amateurs are allowed to use 11 types of gears and nets (with special restrictions on shape and size).

Glass eels

Glass eels are exploited commercially in England, France, Spain, Portugal, Italy and Morocco. The fisheries take place in estuaries and at the mouths of rivers and dams where the natural concentration of glass eels 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 (a trap consisting of a net suspended over a series of hoops laid horizontally in the water).

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 the UK, the hand net is the only legal instrument for fishing eels. Glass eels are caught in the River Severn and are reported to be of the highest quality in Europe. The method of

	1965	1974	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Anguilla japonica[1]	-	2164	2125	2132	2013	1940	1607	1475	1280	1192	1203	1066	1042	1023	1014	916	904	830	765
A. anguilla[2]	18174	15878	13716	12384	13412	12834	14532	12438	12774	12157	13220	11721	12180	9873	9996	11402	8835	7786	7742
A. rostrata[1]	-	1412	1211	1414	1377	1288	1735	1790	1713	1872	1682	1649	1748	1284	1316	1270	1244	1125	1107
Total	**18174**	**19454**	**17052**	**15930**	**16802**	**16062**	**17874**	**15703**	**15767**	**15221**	**16105**	**14436**	**14970**	**12180**	**12326**	**13588**	**10983**	**9741**	**9614**

Table 1. Landing statistics for eels since 1965 (in tonnes). [1]*Anon., 2001c;* [2]*reported by FAO database, with minor corrections (ICES, 2002).*

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
A. japonica																
Japan total[1]	151	133	93	90	59	93.58	98	73	48	42	57	47	46	29	31	27
Chongming Island, Mouth of Yangtze, Mainland China[2]	-	-	-	-	-	0.508	0.246	0.132	0.095	0.276	0.369	0.982	0.636	1.282	0.773	0.644
Korea total[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. anguilla																
Europe[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
England and Wales[5]	-	-	-	18	28	58	10	12	38	62	68	40	37	48	16	25
France (Loire)[6,7]	225	453	330	311	292	563	495	770	654	523	608	502	284	266	276	168
Spain and Portugal (Minho River)[6]	-	-	-	-	-	1.6	10.5	20.0	36.6	24.3	28.4	21.3	54.2	16.4	30.4	31.4
Denmark (Ems)[6]	1.68	0.68	1.68	3.89	0.29	4.13	1.03	4.20	2.17	2.02	2.77	3.19	0.96	0.67	0.09	0.35
Italy (Tiber)[6]	-	-	-	-	-	-	11.0	6.70	5.90	3.60	8.40	8.20	4.00	4.00	4.00	1.80
Belgium (Ijzer)[6]	-	-	-	-	-	0.94	0.26	0.62	0.45	0.39	0.67	0.36	0.07	0.14	0.01	0.00

Table 2. Annual catches of Japanese and European glass eels (t). - = no data available

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
A. japonica																
Japan total[1]	20	21	25	24	22	17	23	23	17	13	20	15	12	11	27	-
Chongming Island, Mouth of Yangtze, Mainland China[2]	0.303	0.411	0.627	0.177	0.289	1.17	0.005	0.003	1.1	-	-	-	-	-	-	-
Korea total[3]	-	-	-	-	-	-	-	7.141	5.135	5.94	7.09	8.693	8.573	3.398	7	-
A. anguilla																
Europe[4]	-	-	-	-	-	-	-	-	-	500	350	370	145	280	199	-
England and Wales[5]	20	19	21	21	20	20	1	5	6	10	12	19	9	12	-	-
France (Loire)[6,7]	159	137	93	138	61	76	30	32	80	95	68	32	90	80	95	-
Spain and Portugal (Minho River)[6]	20.7	12.5	8.2	8.0	9.0	6.0	9.0	10.0	7.6	4.7	15.2	8.7	7.4	7.4	-	-
Denmark (Ems)[6]	0.26	0.09	0.008	0.07	0.01	0.1	0.05	0.00	0.02	0.04	0.02	0.00	0.00	0.00	0.00	0.00
Italy (Tiber)[6]	2.50	0.20	7.40	10.50	5.50	4.40	0.80	0.60	0.50	0.50	0.30	0.10	0.10	0.13	0.06	0.07
Belgium (Ijzer)[6]	0.01	0.03	0.03	0.05	0.03	0.22	0.01	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.02

Table 2 continued. Annual catches of Japanese and European glass eels (t). - = no data available; [2]Shi (1993); [3]Lee *et al.* (1999); [4]Nielsen (1998, 2000); [5]in ICES, 2002; [6]Dekker, 2002b; [7]ICES, 2002 for the years 1998 and 1999

A glass eel fishery based at the mouth of a lock on a tributary of the River Loire, France. Fisheries take place in estuaries and at the mouths of rivers and dams where the concentration of glass eels can more easily be exploited.

S. RINGUET/TRAFFIC

fishing has a significant impact on the quality of the fish. Trawling compresses glass eels with small fish and detritus which may damage the eel's skin and compromise its osmoregulation and defence mechanisms (Anon., 2002g). Some fishermen use boat engines in excess of the maximum horsepower permitted and if the speed of the fishing boat is too high while fishing, the eels swallow water. Both methods of fishing may cause the eels to swell and turn cloudy after a few days, and death follows quickly. It should be emphasized that the fishermen are paid by the weight of the product caught, rather than the quality.

Elvers, yellow and silver eels

In Europe, elvers moving upstream are sometimes captured, either for direct use as food, or for safe and quick transportation to waters otherwise only reached after a long and hazardous journey.

Yellow eels of a reasonable size, though less valuable than silver ones, are nevertheless readily marketable. 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. Of these, the first three methods are the most commercially viable; choice may, however, be governed by what is permitted locally. Generally speaking, small eel traps and trap nets do not interfere with other species such as salmon, and, from a conservation perspective, it is often considered desirable to keep down the number of eels which would otherwise prey on other species of fish.

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, for example in many fast-flowing rivers, is sometimes not possible at all.

The decline of glass eel catches

Asia: Japan used to catch large numbers of Japanese glass eels, but this figure has been declining since the 1970s (Table 2; Figure 4). Data showing the CPUE are available in a few cases. Isono (1999) drew attention to the declining recruitment when he used these data in Tanegashima Island in 1991 and recorded a CPUE (catch/person/hour) of 46, a value that gradually decreased year after year; in 1997 it had fallen to 14. Tzeng (1997) used CPUE (No./day) for the seasons 1991/92-1994/95 which showed a negative correlation with water temperatures. CPUE of adult eels are not available. Kato (1999) considered that MAFF catch data (e.g. Anon., 1969-2000) for Japanese eels are an accurate reflection of abundance.

Europe: In estuaries in France, the total European glass eel catch has decreased from about 1345 t in 1970 to 520 t in 1989 (Castelnaud *et al*., 1994). According to Nielsen (1998, 2000) the catch has been more or less in decline since 1994 (Table 2).

Analysis of the available recruitment data series (12 countries and 19 river catchments) from both catch records and scientific surveys across much of the geographic range of the European Eel show that, following the high catch levels of the 1970s, supply began to fall (ICES, 2000). During the 1980s, the downward trend continued, stabilizing in the 1990s (Table 2). Recent years, however, show a continued decline; 2001 catch figures are the lowest on record for all series where data have been reported (ICES, 2002).

[1]*Catch Per Unit Effort: the amount of catch that is taken per unit of fishing gear, e.g. the number of fish per longline hook/months is one way to express CPUE. CPUE can be used as a measure of the economic efficiency of a type of gear, but normally it is used as an index of abundance, i.e. a proportional change in CPUE is taken to represent the same proportional change in abundance. Nominal CPUE is simply the measure of CPUE from the fishery. However, it is known that there are many factors (including economics, geographical distributions) which may affect CPUE but do not represent changes in abundance. Therefore, CPUEs are often "standardized" using a variety of statistical techniques to remove the effect of those factors which are known not to be related to abundance. Thus, using the standardized CPUE will be more appropriate for an index of abundance.* Source: http://www.fao.org

THREATS

Habitat damage

The fall in eel populations is often attributed to the decline in quality and accessibility of their continental habitat: the loss of wetlands in Europe is thought to have reduced the available eel habitat by at least 50%. Currently the habitat area in Europe is estimated at over 87 000 km^2 (Moriarty and Dekker, 1997).

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 (Anon., 2001e), which has modified habitat quality and, unless supplied with eel passes, reduced access to upstream habitats. Moreover, obstruction to downstream migration and mortality caused by turbines (direct mortality as much as 100% in some sites) considerably reduce the ability of the silver eel to reach its spawning grounds. Deteriorating water quality in water systems all over Europe may also have contributed to eel mortality (Knights, 1997; Robinet and Feunteun, 2001). Isono (1999) suggested water pollution as a major reason for the decline in Japan.

Eel fisheries - legal and illegal

The losses of eels incurred between the silver eel and spawning stages are not possible to assess. In Europe, the number of silver eels that succeed in reaching their spawning grounds is estimated to be very low (ICES, 2002). There is no information on the impact of glass eel fisheries on recruitment. In France, very high levels of fishing mortality have been recorded, ranging from 20-25%, in open estuaries such as the River Adour (De Casamayor, cited in ICES, 2002), to 98% in closed estuaries such as the River Vilaine (Briand *et al.,* in press).

The greatest proportion of the annual recruitment globally is for aquaculture, mainly in Asia; 20% is consumed as glass eels, 20% is trapped and transported to restocking areas and 15% freely migrate to inland waters (Dekker, 2002a).

Eel poaching mainly concerns glass eels and is particularly active in southern Europe. It is dependent on the migration of glass eels, which is affected by environmental conditions, the phases of the moon, temperature, and tides, all of which could be determining factors on catch variability. Furthermore, glass eels sometimes travel along the bottom of rivers and are then almost impossible to catch; if the range of the thermic variation exceeds 3-4 degrees, glass eel migration is inhibited. While poaching may not be constant throughout the season, it can be extensive. In Portugal, for example, net bags of 10-20 m in length are widely used illegally in all national rivers where glass eel fishing is prohibited (with the exception of Rio Minho) (C. Antunes, pers. comm., 2002). At the local level, poaching has led to numerous confrontations between poachers and professional fishermen. In the west of France (Loire-Atlantique, Gironde), poachers form bands of a dozen to about forty people, and are often armed.

A few years ago, it was estimated that during the open fishing season, tens of kilogrammes of the glass eels marketed had been landed by non-professionals: of the 520 t landed by 4360 fishermen in 1989, 73% were taken by non-professionals (Castelnaud *et al*., 1994). The turnover realized was estimated at more than USD34 million (Rigaud, 1998). In France, in 1997, the Brigade Mobile d'Intervention (BMI) of Garonne-Dordogne arrested two wholesale fishmongers who had no written proof of the origin of 62% and 80%, respectively, of their glass eel stock (Taillebois, 1998). According to a professional fisherman (pers, comm., 2001), glass eels poached in France and Belgium in 1998 to 1999 were exported to China via Madrid.

The demand for eels intensified in response to sharp price rises in 1997. Given the life cycle of the eel, glass eels catches have repercussions 10 to 15 years later on the number of potential spawners returning to the sea (Fontaine, 2001). Matsumiya *et al*. (1999) examined catch data for Japanese glass eels and found a significant negative correlation in the amount of Japanese eels cultured per year (t) with the amount of adults caught eight years later.

In Japan and other East Asian countries, non-glass eel fisheries are insignificant and are not considered a reason for the decline in eel numbers.

Invasive species of eels and parasites

The transfer of eels for trade and restocking purposes presents a risk of the spread of disease and the introduction of parasites. In Europe, in the 1980s, a parasite *Anguillicola crassus* invaded wild eel populations after being unintentionally introduced from East Asia (Ashworth and Blanc, 1997). Endemic to the Japanese Eel, the parasite causes severe damage to the swim bladder of the European Eel and its haematophagous diet (subsisting on blood) is thought to interfere with the oceanic migration of breeders (Bruslé, 1994).

The European Eel, in all its stages of development, has been observed in Japan and its presence is considered to be a problem (Tabeta *et al.*, 1977, 1979; Zhang *et al*., 1999; Aoyama *et al.,* 2000; Aoyama and Tsukamoto, 2001; Sawada and Yanagisawa, 2001, Han *et al*., in press). Its presence there has been attributed to stock enhancement carried out before the early 1990s, release of sick or slow-growing eels, or eels that have escaped from culture ponds. Fisheries laws in Japan may contribute to the problem of invasive species by insisting on enhancement of freshwater stocks without specifying with which species. Of particular concern has been the presence of silver eels of European and American Eels along the coasts and estuaries of Japan and Taiwan (Aoyama *et al*., 2000; Han *et al*., in press). These introduced species move into the vicinity of the spawning grounds of the Japanese Eel, which could result in interspecific hybridizations and the collapse of the species.

Climatic changes in the ocean

Knights *et al*. (1996) 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. Tzeng (1997) found a negative correlation between CPUE of Japanese glass eels and water temperatures in a river. Kimura *et al.* (1999) pointed out 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.

E. FEUNTEUN

European Eel Anguilla anguilla: a licence to fish commercially is required throughout Europe.

Conservation Status

In 1980, the European Committee for the Conservation of Nature and Natural Resources of the Council of Europe classified the eel as "vulnerable" (Lelek, 1980). Matsuda (1999) considers the Japanese Eel to be "Critically Endangered" according to IUCN Red List criteria, and ICES (1999) considers the European Eel "outside safe biological limits" in the context of the *Agreement for the implementation of the provisions of the United Nations Convention of the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks* (Anon., 2001d).

Conservation Measures

National fisheries and conservation regulations

Asia: In Japan, catching eels is usually prohibited although special permission may be granted by a prefecture. Although this regulation is generally respected, the fishery does exist but its extent is unknown. Some of those interviewed were unwilling to co-operate for fear of reprisals. In Miyazaki Prefecture, a legal fishery for glass eels takes place in some of the major rivers and is conducted by a parastatal organization only; one of the reasons for this is to eliminate the influence of the black market (the other reason is to ensure a stable supply of glass eels to eel farmers in the prefecture) (Sato, Hieshima, Saito and Takamura, pers. comm., September 2001).

Other eel fisheries in Japan for direct human consumption are small and are licensed. Stock enhancement of freshwater regions is required by law and glass, yellow and silver eels are released for this purpose.

Europe: There are strong regional differences in the measures taken to regulate eel fisheries, although a licence to fish commercially is required throughout Europe, with some countries or regions requiring submission of catch returns (Moriarty and Dekker, 1997).

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

- a ban on commercial fishing in Denmark, Germany, Netherlands, Northern Ireland, Republic of Ireland and Sweden;
- a requirement for elver passes in Denmark, France, Republic of Ireland, Great Britain, Netherlands and Sweden;
- gear type regulations in France, Great Britain, Portugal and Spain;
- closed seasons in France, Portugal and Spain;
- licences for fishing/dealing in France, Great Britain, Italy, Portugal and Spain.

Seven conservation measures have been drawn up for yellow and silver eel fisheries in Europe:

- gear controls in all countries;
- controls on net mesh sizes in Denmark, Italy, Netherlands, Republic of Ireland and Great Britain;
- closed fishing seasons in Denmark, France, Netherlands, Northern Ireland, Portugal, Republic of Ireland, Spain and Sweden;
- licences for fishing/dealing in France, Germany, Italy, Netherlands, Northern Ireland, Republic of Ireland and Great Britain;
- limits on the size of eels caught in Spain, Denmark, Italy, Netherlands, Northern Ireland, Republic of Ireland and Sweden;
- free gaps in weirs in Denmark; Northern Ireland, Republic of Ireland and Sweden;
- quotas in Northern Ireland.

In addition, Portugal banned eel fishing during the 2001-2002 season except on the Rio Minho (C. Antunes, pers. comm., May 2002).

International legislation

Eels do not receive protection under international law.

F. MUTO/TRAFFIC

Eel farming pond, Pingdong, Taiwan. Eels in Taiwan can grow in winter without the need for water heating, as is necessary in Japan. The quality of Taiwanese products are prized by professional eel cooks in Japan but in recent years increasing overhead costs have forced many farms to shift to the farming of softshell turtles or shrimps.

Inside an eel farm, Isshiki, Aichi Prefecture, Japan. The eel pond (left) contains algae to shield nervous eels from human activity. The shelter (centre) contains the feed, and the underwater nets containing bait are kept in the dry pond-area (right).

F. MUTO/TRAFFIC

Eel Farming

Fish culture is carried out in numerous ways. The raising of fish from eggs, larvae or juveniles can be divided into four stages (Table 3). The one most easy to control and for which there is a long tradition is that which involves the raising of juvenile fish to maturity in a closed, artificial environment. Ranching uses wild-caught larvae or eggs from wild specimens that have been raised in captivity but which have difficulty breeding in artificial conditions. The 'extension' method involves raising sexually immature fish, usually of recently introduced, high-value species. Finally, adult fish are fattened up - a process known as *Chikuyô* in Japan - until they have attained market size and quality.

Raising eel larvae to the glass eel stage has never been a success and eel farming can only succeed by using wild-caught juveniles, mostly glass eels. The principal eel species used in aquaculture are the European Eel, Japanese Eel and American Eel. Eel farmers need about three to four kilogrammes of European glass eels and two and a half kilogrammes of Japanese glass eels to produce about one tonne of commercial eels (Nielsen, 2000). Han (1999) estimated that 8000 European glass eels and 3900 Japanese glass eels were needed to produce one tonne of cultured eels of each species.

More than 90% of the world production of eels are cultured in Asia (Table 4), in particular Japan, Taiwan and mainland China. Many eel farms in mainland China use European glass eels as their culture material. Recent developments in aquaculture techniques has allowed for a reduction in glass eel mortality of both the European and Japanese Eels. The American Eel has been introduced in Taiwan (Liao, 1999), where aquaculture production for this species is below 50 t.

History

Asia: Eel aquaculture began in Asia in 1879 in Tokyo with the raising of elvers. It was not until 1931 that a culture trial using glass eels succeeded at the commercial level. Taiwan and mainland China provided Japan with glass eels and, after the end of World War II, eel farming grew into a stable industry until 1997 (Figure 5). A major reason for this loss of stability was the chronic shortage of glass eels (Otsuka, 1996). Eel farmers tried to import glass eels of 12 species/subspecies from European countries, the USA, Canada, Morocco, Cuba and others (Tabeta *et al*., 1979; Tabeta, 1991). However, the method used in Japan to culture Japanese Eels is very specialized and efforts to apply such techniques to the farming of other species have been unsuccessful at the commercial level. Imports of exotic eel species to Japan are now rather low (Table 5).

Taiwan started farming eels in 1923 and has been exporting eel products to Japan since 1969 (Liao *et al*., 1999). Eel farming was introduced in mainland China in the 1970s (Han, 1999) where it grew into an industry in the 1980s (Kuroda, 1999); by 1992, European glass eels were being used for breeding stock. The survival rate of farmed eels in mainland China increased from less than 20% in 1993 to up to 70% in 2000 (Anon., 2002d). With the relatively abundant supplies of European glass eels 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 (Anon., 2002d). Important eel farms in mainland China are located primarily in Guangdong province.

	Materials	Examples
Complete culture	Cultured seeds	Common Carp, trout, salmon
Ranching	Wild larvae, wild juvenile	Japanese Eel, European Eel, Yellow Tail
Extension	Wild, immature fish	Australian Eel, Southern Bluefin Tuna
Fattening	Adult	Atlantic Bluefin Tuna

Table 3. Division of fish cultures.

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Anguilla spp.[1]																	
China (mainland)	-	-	-	-	-	60000	67672	80582	91655	100000	110000	120000	147316	167208	163098	164484	160740
Taiwan	36621	36845	35975	42489	51577	48008	55816	55641	51023	39959	33364	25546	25063	22337	17241	16543	30480
Japan	38030	39568	36520	36994	39558	39704	38855	39013	36299	33860	29431	29131	28595	24171	21971	23211	24118
Others	3436	4066	5394	8091	7310	7557	10157	10072	11962	13239	14756	13169	33033	19802	23801	14457	17477
Total	**78087**	**80479**	**77889**	**87574**	**98445**	**155269**	**172500**	**185308**	**190939**	**187058**	**187551**	**187846**	**234007**	**233518**	**226111**	**218695**	**232815**
A. anguilla																	
Europe[2]	1950	2229	3448	4729	5517	5159	6667	6098	6349	6818	7721	7689	8935	9031	10646	11059	10839

Table 4. World culture production of eels and European Eel production in Europe (tonnes).
- = no data available
[1]*Source: Anon., 2001b*
[2]culture production in European Union countries (Italy, Netherlands, Denmark, Sweden, Germany, UK, Belgium/Luxembourg, Spain, Portugal and Greece) and non-EU countries (Norway, Morocco, Algeria, Tunisia, Macedonia, Yugoslavia, Croatia, Hungary and Czech Republic) according to FAO, FEAP data and others. *Source: ICES, 2002.*

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Main species
ASIA														
South Korea	400	1761	600	-	-	1174	2800	351	4357	1145	579	650	370	*A. japonica*
North Korea	208		43	12	21	-	-	2	21	-	-	-	-	"
China	944	3627	1094	-	-	32	1253	885	5304	1709	499	1510	-	"
Taiwan	1648	1150	676	123	-	-	3914	116	247	2935	107	1164	69	"
Hong Kong	6439	8181	2388	113	11	21	295	1434	5837	7407	4991	5995	-	Undetermined
Philippines	-	-	-	-	-	8	236	210	93	121	-	-	-	*A. japonica*
Indonesia	-	-	-	-	-	247	-	-	-	-	-	-	-	*A. japonica*
Total Asia	**9639**	**14719**	**4801**	**248**	**32**	**1482**	**8498**	**2998**	**15859**	**13317**	**6176**	**9319**	**439**	
EUROPE														
Sweden	-	-	-	-	258	1070	600	-	-	-	-	-	-	*A. anguilla*
Denmark	-	-	-	157	-	-	472	968	-	-	-	-	-	"
Ireland	-	-	-	-	-	-	-	74	-	-	-	-	-	"
UK	-	-	-	-	-	42	-	-	150	78	156	-	100	"
France	1792	1928	220	907	450	3088	1435	1284	1060	336	-	-	-	"
Total Europe	**1792**	**1928**	**220**	**1064**	**708**	**4200**	**2507**	**2326**	**1210**	**414**	**156**	**0**	**100**	
OTHERS														
Canada	-	-	-	-	-	-	-	-	-	30	-	-	-	*A. rostrata*
USA	-	-	-	-	-	5	945	64	357	-	126	100	-	"
Australia	-	-	-	-	-	-	-	30	-	-	-	-	-	*A. australis*
Total Others	**0**	**0**	**0**	**0**	**0**	**5**	**945**	**94**	**357**	**30**	**126**	**100**	**0**	
TOTAL	**11431**	**16647**	**5021**	**1155**	**897**	**5687**	**11478**	**4922**	**18394**	**13761**	**6458**	**9419**	**539**	

Table 5. Import of glass eels and young eels for culture in Japan by country of export (kg).
- = no data available *Source: Anon., 2002a.* Main species are detected by biological distributions.

F. MUTO/TRAFFIC

Grading eels by size, Hamamatsu, Shizuoka Prefecture, Japan. Medium-sized specimens, used for ***kabayaki***, fetch the highest price. After selection the eels are placed in baskets (left) and kept alive for a few days under water sprinklers to remove their "muddy" taste.

The yield has grown to two thirds of the world production (FIS, 2000a). The reasons for this success are thought to be down to the quality of aquatic worm species used as food (Fontenelle, 1997), and the cold, clean water of mountainous areas, which is more suited to the European than to the Japanese Eel (Han, 1999; Kuroda, 1999). In 1997, 90% survived from the glass eel stage to reach a weight of 10-12 g and gained a further three to four grammes within three to five weeks. The youngest specimens reached commercial size (200 g or larger) within 10 months (Fontenelle, 1997).

Farmed eels in mainland China are sent to more than 60 processing factories in the country (compared to eight in 1980), and are mainly exported to Japan after being processed (Luneau, 1998a; Anon., 2002f). Japan is the third eel producer in the world just behind Taiwan (Table 4), but its annual production decreased from 39 013 t in 1991 to 24 118 t in 2000 (Anon., 2001b).

Volume and value of eel farming in Asia

All Asian farming production depends on European and Japanese glass eel stocks. These vary from between 100 t and 300 t of glass eels of both species (FIS, 2000b). Asian glass eel stocks are mainly composed of European glass eels (up to 81% in 1997 and 63% in 2000) and amount to an average of 130 t/year since 1996, with a maximum of 240 t in 1997, which correspond to about 960 million glass eels. According to an industry newspaper for fish culture in Japan (Anon., 2002f), a total of about 30-160 t of glass eels are stocked each year in artificial ponds in East Asia. China supplies two thirds of the world production of eels - 130 000 t each year since 1998 (FIS, 2000b), worth over USD1.3 billion. Eel farming can be quite lucrative. For example, on one hectare of farmland, the net income from eel breeding can reach 1.2 to 1.35 million yuan (USD145 000 to USD163 000) in the cities of Nankai and Shunde in the delta of the Pearl River (Guangwei and Shishan, 1999). In Taiwan, the eel is the most important farmed fish, with an annual production which fluctuates at between 26 000 t and 56 000 t, and worth more than USD400 million (Anon., 2002h).

Europe: Aquaculture of the European Eel started in the early 1970s. In 1970, European production was estimated at 3400 t, while the culture of the Japanese Eel in Asia amounted to 17 000 t (ICES, 2002). Farming techniques can be divided into three main categories (Varadi *et al.,* 2001):

1) Extensive farming, the oldest technique, exploits the natural tendency of the fish to enter brackish lagoons to grow. After about five to seven years, the mature fish leaves the lagoon to migrate to its spawning grounds and is captured by fixed devices. This technique is mainly used in Italy.

2) Intensive farming using concrete or earth ponds for growing on, requires warmer waters, and is more commonly used in Italy, Spain and Greece.

3) Water recirculation systems also use intensive farming criteria and have been the basis for recent developments in the Netherlands, Denmark and Sweden. Eels are held within small concrete or fibreglass tanks (+/-25 m^2) and water is heated for maintaining optimal temperatures.

Aquaculture plants range from the highly industrialized, indoor facilities in northern Europe, to artificial ponds in southern Europe, while aquaculture facilities are also used for the quarantine of exotic species of glass eels that are used to restock semi-natural outdoor waters for fisheries in northern Europe (e.g. Sweden).

Volume and value of eel farming in Europe

According to FAO, FEAP (the Federation of European Aquaculture Producers) and other sources of data (ICES, 2002), eel farming production quadrupled from 1950 t in 1984 to 10 839 t in 2000 (Table 4) and, since 1998, has been stable (at about 10 500 t/year).

In 2000, the Netherlands, Denmark and Italy provided 87% of the total European Eel production, and held 80% of the 178 eel farms in Europe, which realized 80% of the turnover (USD84.9 million in 1996) (Nielsen, 1998; 2000).

Landings reported by FAO have declined from 20 000 t in 1970 to less than 10 000 t in 2000 (see above). During the same period, however, European aquaculture production rose from almost nil in 1970 to 10 839 t in 2000, which accounts for the total European production remaining level.

In 1996, the turnover of intensive farming reached about USD65 million, of which 80% is realized in Italy, the Netherlands and Denmark (Luneau, 1998b).

International Trade in Eels

Trends of international trade in live eels

The volume of live eel exports (all species and all biological stages) reached 25 794 t in 1997 (compared to about 5000 t before 1983) and was valued at USD385 million (e.g. an average price of USD15/kg) (Anon., 2000b). The relative stability of world exports during the last decade can be attributed to the involvement of Europe, Africa and Oceania in the world export markets which had hitherto been dominated by Asia, as well as to the numerous eel species now involved in the trade (Table 5).

From 1987 to 1997, the total volume of Asian exports decreased from 90% to 58% of world exports. Moreover, turnovers of European and Asian exports were respectively about USD204 million (e.g. USD22.3/kg) and USD168 million (e.g. USD11.2/kg) in 1997.

Trade in glass eels

A number of factors strongly suggest that Japanese Eel populations started to decline after the 1970s (e.g. see Tatsukawa, 2001). Certainly, from 1997, the catch of Japanese glass eels plummeted for a few years, and eel farmers using Japanese glass eels were badly affected by this shortfall. European glass eel users exploited this opportunity, in particular the Chinese eel farming industry, which increased its imports and the raising of European glass eels. The size of the farming industry is now so large that only limited amounts of Japanese glass eels are used.

According to one source, prior to 1994, less than 20 t of European glass eels 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 (Nielsen, 1998; 2000). However, sources from the Danish eel farming sector estimate that exports in total in 1996-1997 were 250 t, but dropped to 140 t the following season. Sources of OFIMER seem to confirm the latter trend (Anon., 1998).

Since 1993/94, European glass eels have been mainly exported to China and Hong Kong, and, to a lesser extent, to farms in Japan, Taiwan and Singapore, and then sold and consumed mainly in Japan (Fontenelle, 1997).

According to Anon., 1999b, France is the main EU country to export eels outside the EU (Table 9). It is apparent from comparison of the data available that these are wild-caught glass eels which are mainly exported to Asia. Exports from France were less than 10 t before 1994, and increased rapidly to 266 t in 1997 (Table 9). Since 1997 exports to Asia have decreased, falling to 78 t in 2000 (60 t and 18 t to Hong Kong and China, respectively) (Anon., 2000a). This can be attributed in part to price changes and more effective culture methods in China. In 2000, France exported 60 t and 10 t of European glass eels to Hong Kong and China, respectively.

Glass eel commerce in France is mostly managed by Basque traders. After cleaning, the dead eels are separated from the live specimens and sent to the Spanish market (Fontenelle, 1997; Nielsen, pers. comm., 2002); the remainder go to mainland China (Shanghai) and Hong Kong via European airports (Paris, Amsterdam or London). In 1997, about three cargoes of glass eels a day were sent by plane to China (Nielsen, pers. comm., 2002). One kilogramme of live glass eels are packed in the equivalent weight in ice into polystyrene boxes. On arrival, they are dispensed by a small number of distributors to a large number of farmers although sometimes glass eel wholesalers may negotiate directly with buyers in China (Fontenelle, 1997; Nielsen, pers. comm., 2002).

The distribution route of glass eels in Japan is unclear and Japan Eel Culture Associations have often proposed imposing stricter rules for such transactions (Anon., 2002f).

Taiwan banned the export of glass eels from 1973 to 2001, and exported elvers during this period. Formerly, the industry involved in raising elvers was large, but it no longer has any economic significance in Taiwan.

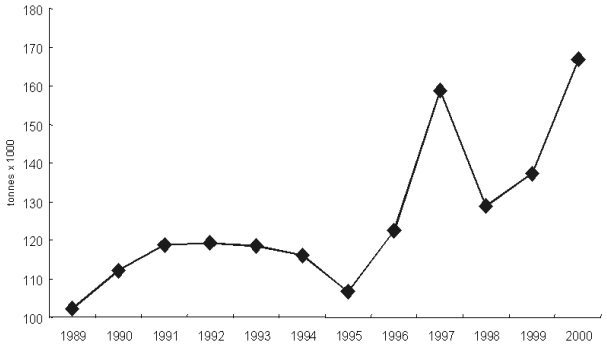


Figure 5. Japan's consumption of eels (green weight, t) (excluding glass eels). Sources: 2001a,b

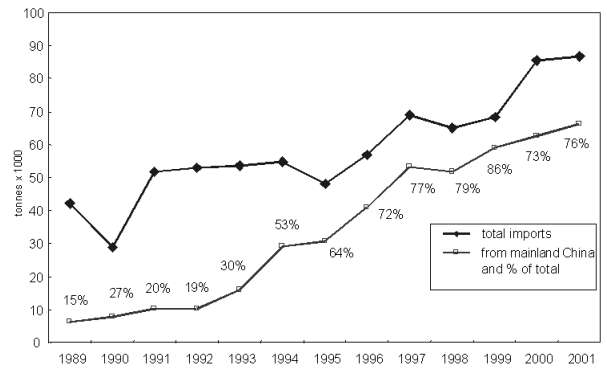


Figure 6. Japan's eel imports (green weight, t) (excluding glass eels). Source: 2002a

Glass eel price evolution

The growing demand for European glass eels in Asia led to a three-fold increase in prices between 1993 and 1997, with mean export prices rising from USD119/kg to USD312/kg. After a brief slump in price to USD188/kg in 1999, it increased to USD281/kg in 2000 (Nielsen, 1998; 2000; pers. comm., February 2002). Table 6 shows huge monthly fluctuations during 1993 to 2000, particularly during the 1996-1997 and 1997-1998 seasons, reflecting the fluctuating availability and demand.

The decline and rarity of Japanese glass eels led to an increase in their price: about USD11 800/kg in 1996 (USD2.4 each) compared to USD425/kg for European glass eels (USD0.17 each) (Luneau, 1998a). European glass eels imported by Japan from France, Denmark and the UK were on average 10 times cheaper than Japanese glass eels imported from other countries (for example, mainland China, Hong Kong, and Taiwan) in 1997 (USD280/kg vs. USD2934/kg) (Anon., 1975-1998).

The huge price differences between the two species may be explained by (i) the size of European glass eels, which are half as big as Japanese glass eels (Table 7) and (ii) the mortality rate of European glass eels, which is four times greater. As a consequence, breeders have to import eight times as many European glass eels as Japanese glass eels to maintain production. Another explanation of the difference in prices is that, prior to 1997, European eels had been difficult to culture at the commercial level to satisfy the quantity and quality needed for the Japanese market, and were sometimes used in the production of "fake" glass eels (Inaba, 1997b) (see box, page 96). One reason for the difficulty in using the European species is the size required for the final products, an important factor affecting the price of eels in Japan. Eels used in *kabayaki* need to be about 150g, with eels of a greater or smaller size being less valuable. For this reason, Japanese eel farmers try to produce eels of the same size and at the same time, generally six months after putting glass eels into an artificial pond. Differences in the shape and taste of the two species were also reasons for the difficulty in using the European Eel in eel culture for Japan's consumption.

The Chinese monopoly of the Asian market

In recent years, a large part of mainland China's eel production (European and Japanese Eels) has been for export, which, in 1990 and 1994, amounted to 10 000 t and 45 000 t, respectively. Since this period, these figures have increased on average by 10 000 t a year. In 1999, 95 000 t were exported with a value of USD0.67 billion, which represents 80% of the world trade in value (FIS, 2000b).

The traditional Japanese dish of *kabayaki* is actually prepared in mainland China, whose virtual monopoly of production has enabled it to increase the price of this product to Japan, while cheaper manpower than is available in Japan keeps overall prices competitive. Eels are also exported to the EU at lower prices than those of EU producers. For instance, the production of one kilogramme of eel costs USD6.7 in mainland China compared to USD8.2 in France (Anon., 1999a).

Processed eels

According to FAO (Anon., 2000b), more than 36 000 t of eels of all species were exported in 1997. These data correspond to Customs records. These took the form of live (fresh or chilled), smoked and frozen products which represented, respectively, about 6%, 1% and 16% of the international trade in eels during 1988-1997 (Table 10).

Trade in smoked eel is common in the EU. Formerly most trade to Asia was in live eels to provide material for *kabayaki*. However, following a growing trade in *kabayaki* and *shirayaki*, there has been an increase in trade throughout Asia of dead eel products for Japan's consumption. Most factories in mainland China cannot sustain the level of production for Japan without using European Eels. Smoked eel is not usually consumed in Asia.

Values	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01
Mean	119	123	200	312	252	207	188	281
Maximum[1]	161(10)	208(11)	230(5)	509(1)	569(3)	400(12)	239(5)	410(12)
Minimum[1]	89(1)	85(02)	160(12)	189(5)	129(12)	121(3)	109(11)	194(3)
Maximum deviation	72	123	70	320	440	279	130	216
Standard deviation	35.4	37.0	20.7	80.9	124.8	87.8	41.3	51.7

Table 6. Prices of European glass eels (USD/kg) for different fishing seasons in Europe.
[1]the number of the month is indicated in parentheses.
Source: Nielsen pers. comm., February 2002.

	No./kg	Note
Adult eels, Japan market	6[1]	Standard size in Japanese
Adult eels, EU	4[1]	Material to export
Glass eels (*A. japonica*)	5000[2]	
	6000[3]	
Seedlings (*A. japonica*)		
from Taiwan	100[4]	
from Korea	750[4]	
Glass eels (*A. anguilla)*		
from France and UK	2000[5]	
from Italy	3000[5]	
from France	2500-3200[6]	December to February
	3100-3500[6]	March and later
from UK	2800-3200[6]	
Glass eels (*A. anguilla)*		
from Europe (not specified)	3000[4]	

Table 7. Rate of conversion from weight to individual numbers.
Sources: [1]Otsuka, 1996; [2]Inaba, 1997a; [3]Tabeta et al., *1979; [4]Tabeta* et al., *1977; [5]Inaba, 1997b; [6]Han, 1999*

	1988		1989		1990		1991		1992		1993		1994		1995		1996		1997		1998	
	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg
AFRICA																						
Namibia	-	-	-	-	0.1	70.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ivory Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	61.0	-	-
Uganda	-	-	-	-	-	-	-	-	0.2	12.0	0.4	34.8	0.9	28.3	-	-	-	-	-	-	-	-
Réunion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	12.0	-	-	-	-	-	-
The Canaries	0.3	46.3	-	-	-	-	-	-	-	-	-	-	0.1	12.1	-	-	0.4	9.3	-	-	-	-
Ceuta and Mell	-	-	-	-	-	-	2.1	78.1	1.3	243.4	0.8	26.7	-	-	-	-	-	-	-	-	-	-
Morocco	-	-	-	-	-	-	3.4	112.1	7.6	84.4	-	-	-	-	-	-	-	-	-	-	-	-
Tunisia	-	-	-	-	-	-	5.6	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Egypt	0.5	60.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.8	55.0	0.0	0.0	0.1	70.0	11.1	50.8	9.1	105.5	1.2	29.4	1.0	26.7	0.1	12.0	0.4	9.3	0.8	61.0	0.0	0.0
AMERICAS																						
Mexico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	71.5	-	-	-	-
Honduras	-	-	-	-	-	-	0.4	21.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
USA	-	-	-	-	-	-	0.4	37.6	-	-	0.2	145.7	0.3	0.0	-	-	-	-	0.2	65.8	1.1	5.6
Canada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	45.3	-	-	1.2	8.3
Brazil	0.1	49.7	0.1	108.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antilles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.1	49.7	0.1	108.2	0.0	0.0	0.8	29.7	0.0	0.0	0.2	145.7	0.3	0.0	0.0	0.0	0.6	67.1	0.2	65.8	2.3	7.0
ASIA																						
China	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.4	98.5	23.0	161.8	106.1	109.5	40.8	203.7
South Korea	-	-	-	-	-	-	-	-	-	-	0.1	118.8	-	-	0.8	98.6	-	-	-	-	1.2	150.1
Japan	5.7	59.1	1.8	121.7	1.1	128.2	0.2	142.0	0.3	106.7	1.0	31.2	12.0	61.1	10.7	23.1	4.2	-	5.5	70.9	1.1	88.3
Taiwan	-	-	-	-	-	-	0.6	6.5	-	-	0.2	70.9	0.2	180.8	16.7	27.9	39.6	-	16.2	90.8	14.5	28.1
Hong Kong	-	-	-	-	-	-	0.8	107.2	5.2	87.6	26.1	114.1	76.5	119.4	139.4	80.2	183.6	-	341.0	144.8	95.1	236.6
Israel	0.1	55.4	-	-	-	-	10.0	20.8	1.1	23.4	0.4	23.2	-	-	-	-	-	-	0.3	276.8	-	-
Indonesia	-	-	-	-	-	-	-	-	2.4	44.3	3.1	33.9	1.8	129.9	2.6	78.3	-	-	1.7	229.8	-	-
Malaysia	-	-	1.0	8.6	0.3	8.7	-	-	-	-	-	-	-	-	2.1	57.9						
Singapore	-	-	0.9	10.0	1.6	8.9	-	-	-	-	0.1	141.0	2.6	136.2	-	-	1.5	175.2	-	-	-	-
Philippines	-	-	0.1	8.6	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	5.8	59.1	3.8	62.5	3.0	52.6	11.6	28.1	9.0	68.8	31.0	102.1	93.1	112.7	180.6	72.7	251.9	15.8	470.8	134.5	152.7	206.2
OCEANIA																						
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	0.5	433.1	0.5	404.2
Antarctic Ocean	-	-	-	-	-	-	-	-	-	-	0.7	61.6	-	-	-				-	-	-	
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	61.6	0.0	0.0	0.0	0.0	0.3	0.0	0.5	433.1	0.5	404.2
EUROPE (excluding EU)																						
Czechoslovakia	0.4	33.9	-	-	0.4	63.1	0.6	4.5	4.0	39.9	-	-	-	-	-	-	-	-	-	-	-	-
Czech Republic	-	-	-	-	-	-	-	-	-	-	0.4	107.8	0.7	88.4	0.6	124.3	1.9	39.8	-	-	-	-
Slovakia	-	-	-	-	-	-	-	-	-	-	-	-	5.8	27.2	3.5	34.8	1.4	35.5	0.3	421.4	-	-
Hungary	1.9	88.5	0.1	9.5	5.5	42.8	16.6	7.6	1.1	109.9	-	-	0.2	90.8	11.0	4.4	0.1	296.2	-	-	-	-
Gibraltar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0	4.4	-	-
Malta	-	-	-	-	-	-	-	-	0.1	41.9	-	-	-	-	-	-	-	-	-	-	-	-
Yugoslavia	-	-	1.0	9.9	1.0	9.7	0.9	28.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Former Rep. Yugoslavia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	36.7	-	-	1.0	18.8
Switzerland	0.6	11.0	2.1	7.8	1.0	8.7	0.9	7.6	0.7	9.7	0.6	7.7	1.0	7.5	-	-	-	-	0.1	13.6	0.1	21.1
Turkey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
USSR	1.8	53.5	-	-	-	-	2.1	14.2	0.7	128.6	-	-	-	-	-	-	-	-	-	-	-	-
Poland	1.6	85.8	8.6	31.8	5.6	20.1	0.9	102.9	2.2	111.5	3.7	55.8	3.2	80.3	4.1	89.1	3.7	53.1	8.9	29.6	3.1	40.1
Bulgaria	-	-	-	-	-	-	2.7	11.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Russia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Norway	0.3	54.8	1.6	43.6	1.1	77.9	1.1	96.0	1.2	88.3	-	-	-	-	-	-	-	-	0.2	48.8	0.2	43.7
Estonia	-	-	-	-	-	-	-	-	-	-	-	-	0.6	144.2	-	-	0.5	288.5	-	-	-	-
Latvia	-	-	-	-	-	-	-	-	-	-	0.2	95.5	-	-	1.0	47.9	-	-	-	-	-	-
Lithuania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	104.1	0.4	199.7	0.1	195.3		
Total	6.6	66.4	13.4	27.7	14.6	32.7	25.8	16.2	10.0	73.3	4.9	55.8	11.5	51.2	20.4	33.3	9.0	68.0	12.6	34.4	4.4	35.0
TOTAL	**13.3**	**62.0**	**17.3**	**35.8**	**17.7**	**36.3**	**49.3**	**27.0**	**28.1**	**82.3**	**38.0**	**93.4**	**105.9**	**104.9**	**201.1**	**68.6**	**262.2**	**17.7**	**484.9**	**132.1**	**159.9**	**199.3**

Table 8. Exports (tonnes) and prices ([1]ECU/kg) of eels (including glass eels) from the EU to non-EU Member States. ([1]ECU=USD1.099 in 1998). - = 0 *Source: Anon., 1999b*

Eels are highly esteemed for food, especially in Europe and Japan, and some examples of how they are served are described below.

Smoked eel is eaten in Europe, particularly in Scandinavia, Germany, Netherlands, and in North America; Spaniards favour eel larvae/glass eels (*angulas*) as a traditional appetizer or *tapas*, particularly over Christmas, New Year's Day and on 7 January (*Mahaut, pers. comm., 2002*), and in parts of Italy, a dish of eel (*Capitone*) is also traditionally served on Christmas Eve. In UK coastal towns and London's East End, jellied eels (eels cut into chunks and served in a savoury jelly), sprinkled with vinegar, are sold from street stalls. Eel specialities in France include *Anguilles au vert* (eels cooked with spinach and sorrel leaves in white wine) and *Matelotte d'anguille* (eels braised in a red wine sauce). In Belgium, stewed eels in chervil sauce - *Paling in 't groen* - is eaten, and the central region of Portugal specializes in eel stew. Fake glass eels made of white meat fish paste (*surimi*), shaped to resemble glass eels, are taking over large parts of the glass eel market as they are much cheaper, are readily available in shops and are very close in taste and consistency to the real thing. *Surimi* are mainly available in Spain.

In Japan, eels (*unagi*) are prized not only for their flavour but for what the Japanese believe are their stamina-giving properties. They are eaten particularly during the hottest days of summer, during July and August, in the belief that they will provide strength and vitality for the rest of the year. Only adult eels are used and the most popular dish is *kabayaki* - eels grilled, steamed and smoked a number of times after being basted with a sweet soy-based sauce. *Shirayaki* - similar to *kabayaki* but without the sauce - is also popular. In South Korea, barbeque restaurants serve sliced eel, which customers roast on burners placed at each table.

Sources: www.gastronomica.org; TRAFFIC International

Potential action in the context of the World Trade Organization (WTO)

Eel imports to Japan from mainland China have grown rapidly in recent years (Figure 6), a factor that many of Japan's eel farmers consider to be a serious obstacle to their industry.

Multilateral Agreements set out under the General Agreement on Tariffs and Trade (GATT) of the World Trade Organization (WTO) have established a system for member States to safeguard industries that may be damaged by a rapid increase in imports (WTO, 1995). In 2001, this safeguard ("Provisional Safeguard" (Art. 6)) was used in Japan for three agricultural products: spring onions, shiitake mushrooms, and tatami-grass mat covers, all of which are mainly imported from mainland China. This system allows for an increase in Customs tariffs to allow for a balance in the prices of domestic and imported products and can only be applied within 200 days.

Following strong lobbying from the Japan Eel Culture Associations, on 27 March 2001 Japan's Minister of Agriculture demanded that the Ministers of Finance and of Economics and Industries carry out preliminary research into the feasibility of applying such measures to eel imports. Several problems have arisen as a consequence of such research: an increase in Customs tariffs for a specific item should apply to all countries importing such goods. Taiwan, as a key exporter of eels to Japan (Table 4), would therefore also need to apply the same safeguard measures. The safeguard is a tentative action, and importing countries must make a counter measure in this period. Eel farmers in Japan have already cut their production costs many times (Otsuka, 1996), and are unable to do so again. In such a situation, the safeguard poses drawbacks for both exporting and importing countries. A number of concerned groups - among them the Japan Eel Culture Associations, the China Chamber of Commerce of Importers and Exporters of Foodstuffs, Native Produce and Animal By-Products, Taiwan Eel Development Funds and Japan Eel Importers Association - met to find ways to avoid application of these safeguard measures. Following the meetings, Japanese eel farmers insisted at first that the balance of supply and demand be modified by entering European Eel products in the market, and proposed that mainland China bans the importation of European Eel (Anon., 2002f). While China initially agreed to this proposal, it was vehemently opposed by eel farmers in some provinces of mainland China, and by the Japan Eel Importers Association. It was finally agreed that an import quota be established in mainland China for European glass eels, and a restriction placed on the number of ports of entry. The quota system was introduced at the start of the 2001 season and it is too early to assess its impact at the time of writing.

Retail Markets

Asia: Japan is the largest consumer of *Anguilla* eels. It consumed 140 000 t in 1999 (FIS, 2000a), estimated to be 57% of world production by green weight, and equalling some 800 million eels of traditional standard size in Japan (Table 11 shows green weight/product conversion factors). Japan produces less than 20% of eels for its own consumption, and imports 70-90% from mainland China (Figure 6). Comparing FAO and MOF data, mainland China exports about 60% of its eel products to Japan.

F. MUTO/TRAFFIC

A *kabayaki* take-away shop, Hasaki, Ibaraki Prefecture, Japan. To prepare the eel, the specimen is paralyzed by an electric current, its head fixed by a pick, and the body opened from the back to remove the spine.

F. MUTO/TRAFFIC

Frozen *kabayaki* on sale at Tsukiji market, Tokyo, Japan.

C. RAYMAKERS/TRAFFIC

Vacuum-packed fake glass eels (*surimi*), Seafood Expo, Belgium, 2001.

C. RAYMAKERS/TRAFFIC

Marinated eel fillets, Seafood Expo, Belgium, 2001.

F. MUTO/TRAFFIC

Packaged eel on sale in Shanghai market, China. Their robust body shape would suggest that these are European Eels - *kabayaki* style (left), and (right) for soup, with onion and ginger.

Japan only consumes adult eels. The most popular dish is *kabayaki* (Yamanaka and Tanaka, 2001) (see boxes, left). The peak time for consumption of this and other eel preparations is 18 days over July and August, and in particular on one or two days during that period, a tradition based on a combination of two ancient calendar systems which has been kept for several hundred years. Glass eels reared in an artificial pond early on in the season can reach commercial size by the following *kabayaki* season, which is cheaper than purchasing adult eels. Eel industries work throughout the month of August and those servicing Japan use the "eel year" calendar, which is from September to August. Statistics are sometimes gathered according to this calendar year.

This imbalance in the periods during which eels are consumed has an influence on the price. As mentioned above, the most suitable weight for eels used in *kabayaki* is around 150 g (Inaba, 1997b), and prices for eels of this size determine the prices for eels of other weights. Size preferences vary geographically, but the recent trend is for larger specimens (Anon., pers. comm., 17 September 2001). Eels weighing more than 150 g are priced low, or are not on sale in Japan; they are sometimes exported to Europe as smoked eels (Tsunogai, 1997).

In China, eels were formerly consumed mainly in Guangdong, Fujian, Jiangsu and Zhejiang provinces as a substitute for the eel-shaped fish *Fluta alba*, known as Yellow Eel (Shu, 1976). Some Chinese people never eat eel, believing that *Anguilla* eels eat the body of a drowned person, but this custom is changing. Live *Anguilla* eels and related products are now commonly available in markets in mainland China and Taiwan (Kuroda, 1998; Muto, pers. obs., November to December 2001). Most products, however, are exported to Japan.

South Korea traditionally consumed eels for medicinal purposes but over the past year eels, imported from Taiwan, have been served in restaurants (Anon., 2002f).

Europe: While wild-caught glass eels are mostly exported to China, almost all the European Eel catch and farmed specimens are consumed in Europe. The market mainly consists of the following eel sizes: young eels weighing 50-65 g (15-20 pieces/kg) available mainly in Italy, France and Portugal; medium-sized eels weighing 120-250 g (eight pieces/kg), popular in the Netherlands, and large specimens consumed, in particular, in Germany and, to a lesser extent, Spain (Nielsen, pers. comm., 2002).

Spain is the largest consumer of eels in Europe. Glass eels are used in appetizers known as *tapas*. Around 20 t of glass eels were imported in 1997 for domestic consumption, purchased by consumers at an average price of 100 ECU/1kg (USD125/kg) (Frost, 2001). However, the domestic market is unstable as consumers are not willing to pay more than 100 ECU/kg (Frost, 2001). If prices on the international market are higher, the Spanish market is not supplied.

The methods used to catch glass eels have an important bearing on their survival (see Fishing Methods); the damaging techniques employed in some areas of France, (in the Loire/Vilaine region, for example), together with the eels' natural mortality after they have been caught and are awaiting sale (according to a French fishmonger (pers. comm., 2001), about 10% of glass eels die within three to five days of being caught), means that there will always be bad quality batches on the market. Even though Spanish consumers prefer the highest

	1988		1989		1990		1991		1992		1993		1994		1995		1996		1997		1998	
	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg	t	ECU/kg
France	7.8	56.0	1.9	121.6	1.1	128.2	0.9	118.9	0.5	116.3	8.9	120.0	63.7	132.5	63.3	97.7	84.1	159.5	266.2	157.4	91.5	237.4
Belg./Lux.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	9.0	113.4	7.0	11.6	48.2
N'lands	0.1	4.3	2.1	9.8	1.9	8.9	1.0	26.8	1.3	29.0	2.1	10.0	5.8	27.2	3.5	34.9	50.3	12.5	3.9	158.7	14.0	17.7
Germany	1.8	48.2	8.6	31.8	4.6	22.1	0.9	102.9	2.3	113.3	5.1	90.9	4.1	71.2	4.1	89.1	4.5	69.9	16.5	176.0	16.0	238.8
Italy	0.3	9.8	1.9	12.9	6.8	28.4	23.6	6.5	0.6	9.0	0.4	23.2	0.8	8.1	11.0	4.5	-	-	0.6	12.7	1.2	8.3
UK	2.8	54.8	2.3	31.6	2.0	89.0	1.2	96.3	8.3	97.7	19.8	117.0	19.3	73.1	70.6	77.9	69.7	116.8	63.5	249.2	18.6	218.9
Ireland	-	-	-	-	-	-	0.6	6.5	-	-	-	-	0.3	0.0	-	-	0.6	21.5	-	-	-	-
Denmark	0.2	25.8	0.5	13.4	0.3	10.2	2.1	14.2	1.4	27.6	1.3	33.9	11.8	67.6	47.8	31.9	46.0	56.5	16.8	63.5	1.2	88.1
Greece	-	-	-	-	-	-	2.7	11.1	-	-	-	-	-	-	-	-	1.0	36.7	-	-	1.0	18.8
Portugal	-	-	-	-	1.0	11.0	-	-	-	-	-	-	-	-	-	-	0.2	159.3	-	-	-	-
Spain	0.3	47.4	-	-	-	-	16.3	47.5	13.7	80.3	0.8	26.7	0.1	34.7	0.8	88.8	5.0	154.8	3.8	246.2	4.6	282.6
Sweden	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	48.8	0.2	43.7
Total	**13.3**	**52.6**	**17.3**	**36.4**	**17.7**	**36.4**	**49.3**	**27.0**	**28.1**	**82.3**	**38.4**	**102.7**	**105.9**	**104.9**	**201.1**	**68.7**	**262.2**	**99.0**	**484.9**	**132.1**	**159.9**	**199.3**

Table 9. Eel exports (including glass eels), from EU to non-EU member states (in tonnes, values in [1]ECU/kg). [1]1 ECU = 1.099 USD in 1998. - = 0
Source: Anon., 1999b

quality product, the relatively short journey time to Spain could give damaged specimens sent from France a better chance of surviving long enough to allow them to develop their pigmentation before being cooked (Nielsen, 2000). But fish paste used to make fake glass eels (*surimi*) is taking over large parts of the real glass eel market, particularly in Spain.

Conclusions

Concerns about the origins and consequences of the decline in eel recruitment, the decline in and present level of existing fisheries, and the sufficiency of spawning stock abundance, has prompted a development of an Atlantic States Marine Fisheries Commission (ASMFS) interstate management plan for American Eels.

In 1998, the ICES/EIFAC Working Group on Eels, which has been compiling data on eels in Europe for more than a decade, recommended "*that an international rebuilding plan is developed for the whole stock. Such a rebuilding plan should include measures to reduce exploitation of all life stages and restore habitats. Until such a plan is agreed upon and implemented, ICES recommends that exploitation be reduced to the lowest possible level*".

Meanwhile, recruitment trends continue to show a decline, posing a serious threat to the future of the species, as well as to its fisheries and aquaculture (Dekker, 2002a). Several hypotheses for this decline have been suggested including overexploitation, pollution, habitat loss, parasites and diseases, or climatic changes (Bruslé, 1994; Moriarty and Dekker, 1997).

Is trade to Asia a driving force for the threat to European Eels?

A major decline in European Eel stocks has occurred since the middle of the 1900s (Dekker, 2002a) and during this time, European Eels have been consumed in large quantities in Europe, mainly by Spain. Since the 1990s, however, an increase in Asia's demand for European glass eels to supply eel farms has driven up glass eel prices, which, in turn, has stimulated smuggling. Substantial quantities are being purchased on the European market at "excessive" prices. Increasingly, European users of glass eels are out-competed and restocking programmes in certain European countries are consequently jeopardized (Moriarty and Dekker, 1997).

Although the immediate link between the increased demand for European Eel (glass eels) in Asia and the decline of the species population is still being debated (FIS, 1998; Dekker, pers. comm., 2002), it is at least clear that the involvement of Asian countries - particularly China - in the eel market has resulted in a trade that is more difficult to manage: live glass eels as well as semi-processed and processed eel products are now transported all over the world. Consequently the status of this resource has grown from being a small European fishery to one of global significance (Dekker, 2002a).

Taking remedial action

Whatever the cause of the decline, it is clear that a management plan for European eel stocks is urgently needed (Moriarty and Dekker, 1997; ICES, 2002). Therefore, considering the precautionary principle, various European experts have recommended taking measures to increase recruitment in order to enhance breeding stock and ultimately protect the eel in the wild. In particular, French experts have advised that the decrease in number and quality of silver eels reaching their spawning grounds, mostly owing to obstacles along their downstream migration and to the deterioration of freshwater quality in wetlands and rivers, should be reduced (Lambert and Feunteun, 1998). Guidelines for integrated river management have been proposed, including water catchment and hydraulic infrastructure measures, combined with international initiatives that tackle eel conservation issues in trans-border river basins and possibly also on an oceanic scale.

Recommendations

A number of recommendations should be acted upon by range States, countries and international institutions involved in the eel trade if the management of stocks is to be achieved:

TRADE

At present the international trade monitoring system in place to record eel markets around the world is weak and does not allow for the level of exploitation of the species at their different life stages to be estimated, or to ensure that the products are from legal sources. Suggestions to improve the current situation are set out below:

1. Improving the monitoring of international trade.

While much effort has been made to improve the monitoring of eel production, both from fishing and farming, much remains to be done on issues relating to the trade. Moreover, understanding commercial activities relating to eels through existing statistics is very difficult. Indeed, most data available on the international and European trade in eels concern live *Anguilla* spp. (EUROSTAT) or different types of products for commercial species (FAO). Japanese Customs officers were trained to separate information on imports and exports of "eel fry for fish culture" and "other live eel". This allows the statistics of the Ministry of Finance of Japan (e.g. Anon., 2002a) and secondary data cited by others (e.g. Anon., 1975-1998) to report on these different products. However, most national and international databases, such as EUROSTAT (European Union), do not distinguish trade in glass eels (specimens weighing about 1 g) from trade in silver eels (weighing several hundred grammes each), for instance. Under the Harmonized Commodity Description and Coding System, there is only one category for "Live *Anguilla* spp." (Code: 0301 92 00). As most international commercial trade of live eels concerns glass eels, it is recommended that Customs authorities in all countries trading in eels introduce a separate and standard code for this category of eel and another that covers all the other stages of the eel's life cycle. Until such a system between trading nations is in place, data relating to the eel trade and the role played by countries will remain unclear. Following the discrepancy between FAO and FIS data, all countries would contribute to the FAO work in its efforts to collect data in order to have a better understanding and vision of international trade in eels.

Given that eels are in trade at all stages of their life cycle, identification to species level is difficult. Establishment of practical identification guidelines is therefore essential.

2. Improving transparency in the chain of custody of glass eel catch and trade.

Following interest shown by traders in Asia and Europe on eel issues in general, there seems to be potential to involve all key stakeholders (fishermen, wholesale fish merchants, eel farming and processing industries, etc.) in creating a certification system and launching a "label" that would be verified by an independent - possibly government - body, to ensure that a product has been legally acquired and exported. In the European Union, such labelling could be seen as part of the implementation of Article 6 and 7 of *Council Regulation (EC) No 104/2000* of 17 December 1999. The promotion of such "labelling" is closely related to the need to raise consumers' awareness about the requirement for improved management of eel stocks in the wild. Consumers should be informed of the existence of such a "labelling" system, and its purpose. This could be made possible by promoting it at the retail market, particularly in Japan, to optimize its impact on trade channels.

3. Preventing the introduction of invasive eel species.

Despite suggestions that Asian countries should ban the importation of European glass eels (Matsumiya, 1999), the industry has grown so rapidly that any efforts

	Fresh or chilled eel			Frozen eel			Smoked eel			Main
	1977	1987	1997	1977	1987	1997	1977	1987	1997	species
Asia	4	-	104	-	-	3757	-	< 0.5	-	*A. japonica*
Australia	855	15	44	-	736	589	59	45	16	*A. australis*
America[1]	-	-	474	-	136	2526	-	-	-	*A. rostrata*
Europe	9268	9490	1732	876	890	737	367	317	368	*A. anguilla*
Others	15	26	4	-	-	15	-	-	1.5	Undetermined
Total	**10142**	**9531**	**2358**	**876**	**1762**	**7624**	**426**	**362.5**	**385.5**	

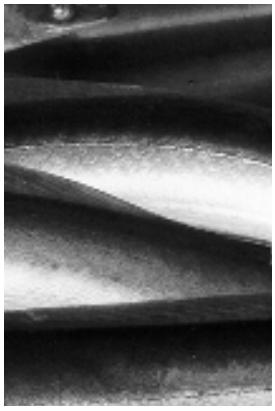
Table 10. Exports (in tonnes) of non-live eel products. - = 0 *Source: Anon., 2000b*
Main species are detected by biological distributions. [1]Mainly Suriname and Canada for chilled eel, and USA and Canada for frozen eel.

Categories	Main products	Exchange rate	Note
Eel (*Anguilla* spp.), live		1	
Eel, fresh or chilled	Meat with skin	1.43	
Eel, prepared or preserved	*Kabayaki* (baked in sauce)	1.79	
Eel, frozen	*Shirayaki* (baked)	1.54	Product from Asia
Eel, frozen	Smoked, whole	1.42	Product from EU
	Smoked, prepared	1.94	

Table 11. Names in statistics of import, and rate of conversion from product weight to green (original) weight. *Source: Tsunogai (1997)*

C. RAYMAKERS/TRAFFIC

THE LACK OF SUCCESS AT REPRODUCING EELS IN CAPTIVITY, AND THE CONSEQUENT DEPENDENCE ON SUPPLIES FROM THE WILD, POSES PERHAPS ONE OF THE GREATEST THREATS OF ALL TO THE SPECIES.



to impose such a ban would now be difficult to enforce. However, imports of exotic eel species must be fully controlled to prevent the introduction of new parasites and such controls could be improved by training enforcement agents to recognize the main eel species in trade. These measures could help in monitoring the trade.

Considering the counter actions established under the WTO safeguard, banning trade in European glass eels in mainland China is not realistic, but China should consider using a closed culture system to farm eels.

Article 13.2 of Japan's *Fishery Resource Protection Law*, established to prevent disease or the introduction of parasites on important native fish species, could be applied to invasive species such as *Anguilla* species.

Articles 16, 17, and 44 of mainland China's *Fisheries Law*, which recommend the inspection of fish seeds and stipulate that permission be sought to import fish seeds, could be applied to *Anguilla* eels (Shindo, 2001); Article 44 sets out penalties.

4. Consideration of listing in the CITES Appendices.

There are no international rules to monitor, control or limit international trade in eels. The listing of the American Eel in CITES Appendix III has been suggested by various authors (American Eel Plan Development Team, 2000; Anon., 1999c; Kim, 2000). It is at least as threatened as its European "relative", but certainly less threatened than the Japanese Eel.

A CITES Appendix II-listing of the entire genus is a possible approach as most *Anguilla* species are threatened to some degree and the difficulty of species identification would create enforcement problems. However, the status of at least one of the species would need to meet the biological criteria for listing. The main benefit of such a listing would be the improvement of information on international trade in glass, yellow and silver eels. Species, volumes, sources (farmed or wild), country of origin and destination, etc., would be reported, which would support better planning of catch levels in the various range States and provide the basis for guidance on the adoption of conservation measures.

CONSUMERS

The decline in eel numbers needs to be publicized and consumers persuaded to modify their choices and eating habits. Suggestions to improve the current situation are set out below:

1. Making consumers sensitive to eel issues.

Traditionally, eels are consumed during July and August in Japan; efforts could be made to change consumer tastes by discouraging consumption at other times of the year. After 1996, the balance between demand and supply was changed, and recently the market has been oversupplied. In order to find new markets, a number of advertisements designed to expand the season for eel consumption have been produced. If the Japanese tradition of consuming eels during the summer months is to be sustained, consumers must consider reducing consumption at other times of the year.

2. Promoting the consumption and culture of larger specimens.

After reaching a body weight of 350 g, the growth of the Japanese Eel slows down, while the European Eel continues to grow quickly. If larger eels were consumed, fewer eels overall would need to be caught to achieve the same total weight in trade.

Research and International Co-operation

Eels are among the most mysterious of fish species. Little is understood of their life cycle in the wild and the science of eel farming has so far failed to devise a way of raising larvae artificially. This lack of success at reproducing eels in captivity, and the consequent continuing dependence on supplies from the wild, poses perhaps one of the greatest threats of all to the species. Nonetheless, continued efforts must be made to maintain or enhance the species' survival in the wild.

1. Master the life cycle of eels in captivity.

Trials on eel biology are key to experiments on induced spawning; nutrition of eel juveniles should be promoted in Asia and Europe in order to produce greater quantities of glass eels in hatcheries and reduce dependence on wild specimens.

2. Research into the impact of invasive eel species.

Research is needed, particularly in mainland China where specimens of European Eel have escaped from farms and have apparently survived in the wild. The potential risks of competition for food and of the rather improbable, but eventually possible, interbreeding between European and Asian Eel species should be taken into consideration.

3. Stock assessment and enhancement: support and develop research on eels.

Supporting research: there is a need to define a joint assessment of wild stocks of eels. This step includes quantitative parameters of the world populations (distribution, structure and abundance) for each biological stage and qualitative ones (especially the "quality", e.g. fecundity, of spawners) in order to define appropriate stock enhancement targets. It is also necessary to improve the monitoring of eel stocks in order to appreciate the efficiency of stock enhancement programmes. Moreover, assessment of the changes in population parameters (migratory and sedentary populations) and fisheries at relevant times (e.g. the duration of the biological cycle), as well as the spatial scales (e.g. the hydrosystem) is necessary to evaluate the impact of restoration programmes. Furthermore, increased research into *Anguillicola crassus* to determine its possible effects on mature eel migration survival is needed.

Developing research: the Taiwan Fisheries Research Institute has been releasing hormone-induced mature Japanese Eels since 1976, but the effect on the eels is unknown (Kuo, 1999). In Japan, stock enhancement of Japanese Eels has been carried out by each fisheries association and, in 1999, the Japanese Fisheries Agency conducted joint research of the resource by stakeholders (Japan Fisheries Resource Conservation Association, 2001).

Because of the biological similarities between most *Anguilla* species, benefits from new research on anguillids may have a global application (Haro *et al*., 2000). Efforts to co-ordinate international research efforts and management approaches therefore need to be supported.

4. Enhancing international co-operation.

If one considers, as do many specialists, that European and American Eels are panmictic, there is clearly a need for international co-operation in fisheries management - in particular in monitoring and research and of harmonization of the various eel monitoring methods in place in various river systems in the EU. The building of a monitoring network in areas throughout the species' range (Europe and North Africa) could help provide information on the distribution of the eel and evolution of stocks at their different life stages. International programmes to improve knowledge about migration (paths and reproduction zones, for example) and the manner and conditions of reproduction of European eels and other species *in natura* should be developed. Also, consideration should be given to the creation of an international commission for the management of the European Eel stock that would be responsible for organizing monitoring and research on eel stocks and fisheries, and which would serve as a clearing house for the regular exchange of information regarding landings and resource status as well as facilitating and co-ordinating management action (ICES, 2002).

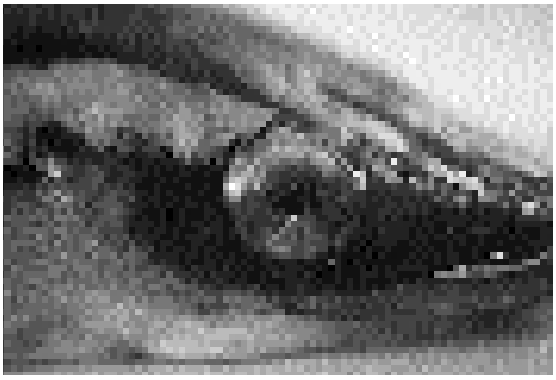
5. Stricter measures for the conservation of eels.

Owing to the lack of scientific information on the population dynamics and recruitment characteristics of eels and because of the panmictic nature of the species, a Total Allowable Catch (TAC) "strategy" is not appropriate. However, an agreement on catch limits for eels could be established in the EU, East Asia and North America. To this end, further biological research on stock and recruitment assessments and identification of escapement targets (i.e. the proportion of spawners surviving or escaping human-induced mortality and reaching the spawning area) should be carried out without delay. Consideration could be given to the measures in place in Miyazaki Prefecture, which has the strictest regulations relating to eel fisheries in Japan and where the "Fishery Promoting Center" - jointly funded by the prefecture and fisheries associations - is the only body permitted to fish and supply glass eels. This practice has started to eliminate the influence of mafias involved in the glass eel fishery/trade in this prefecture.

UNCLOS Article 67, established for the conservation of catadromous species such as eels and sturgeons, does not seem to be working well. It is hoped that international regulations for eel conservation could be established on the bases of Article 67.

FISHERIES

Stabilizing fisheries efforts to permit the recruitment of eels (at each biological stage) and to enable breeders (silver eels) to continue their journey to the sea should be the primary objective of measures taken by eel fishing nations around the world. Improved controls on fishing of both glass and silver eels, particularly in Europe, that are directly dependent on increased funding and commitment by governments to control poaching and related laundering activities to export eels are crucial to achieve this goal. Challenges faced by enforcement authorities are illustrated by the fact that these activities take place over several months and over a wide geographical area and which, in Europe for instance, may involve organized crime.



E. FEUNTEUN

There are currently no international laws to monitor, control or limit international trade in eels.

Action to be taken by national authorities to improve monitoring, control and management of eel fisheries could involve any or a combination of the following:

- introducing legislation that will require all sales and exports of eels to be licensed and registered;

- making controls easier by standardizing regulations that currently vary from country to country, or from region to region, and even within the same catchment area as is the case in France;

- reinforcing waterways control and surveillance during key important migration seasons, such as December to February in much of western Europe, when 80% of eels arrive at European coasts and estuaries, by creating teams composed of representatives from different administrations (police, fishing and hunting brigades, Customs, and veterinary inspection);

- increasing controls at the wholesale level in an effort to eradicate the laundering of glass eels from illegal sources;

- encouraging the judiciary to impose penalties for illegal activities as required under the provisions of fishing regulations and, where necessary, reviewing the level of such sanctions;

- encouraging fishermen to employ careful handling techniques similar to those now being used for the harvesting of live glass eels for eel culture in East Asia;

- defining landing size limits to help reduce excessive exploitation of yellow and silver eels;

- defining closed seasons (taking into account periods of vulnerability);

- encouraging a reduction in catches at all stages in the eel's life cycle;

- licensing fishermen, setting quotas for each licence and compulsory daily reporting of their catches which would help to limit and monitor the level of catches, create reliable landing statistics and contribute to information gathered on the Catch Per Unit Effort (CPUE);

- supporting restocking of glass eels in the wild when eel passes are not sufficient to maintain upstream migration;

- prohibiting the expansion of existing fisheries and the introduction of new fisheries.

HABITAT

Action on trade, fisheries and research will not have a positive impact on the status of eel populations so long as national and international authorities responsible for the management of freshwater systems are not involved in the reduction of habitat loss and the restoration of key areas, especially streams and wetlands. Such initiatives should be initiated as soon as possible through collaboration between fisheries and water-use authorities. This approach should include:

- taking measures to minimize obstructions, particularly to downstream migration of silver eels by installing appropriate fish passes and adapting the management of hydraulic works, for example;

- detecting the presence of pollutants in relevant river basins (e.g. residues of pesticides) and parasites that can possibly affect the growth and reproduction of eels, and adopting the necessary measures to restore the water quality; and

- identifying areas of specific importance to eels, for instance feeding and "resting" grounds and, on the basis of the local characteristics of eels and fisheries, declaring the most important ones as protected areas where no exploitation would be permitted.

Acknowledgements

With thanks to Markus Burgener, TRAFFIC East/Southern Africa, for his comments on an early draft of this manuscript, and to colleagues at TRAFFIC East Asia-Japan. The following people are also thanked for their co-operation during the process of compiling information for this study: I.C. Liao, Taiwan Fisheries Research Institute; W.N. Tzeng, National Taiwan University of Taipei; M. Nishida, K. Tsukamoto, K. Tatsukawa, K. Aida, University of Tokyo; T.W. Lee, Chungnam National University of Republic of Korea; C.W. Park, Korea Ocean Research and Development Institute; N. Mochioka, Kyushu University; President C.T. Chen and Y. Tu, National Kaoshiung Institute of Marine Technology; H. P. Oka and N. Horie, Irago Institute; T. Iwata, Inland Fisheries Institute, Aichi Prefectural Fisheries Institution; K. Suzuki, Shizuoka Prefectural Fisheries Institution; Y. Ng and S. Lin, Taiwan Eel Development Funds; H.L. Wu Han-Lin and Xiao-Jie Dai, Shanghai Fisheries University; E. Zhan and L. Xu, Putong University; K. Tanaka, Isshiki Eel Culture Association; C. Tabata, Oosumi Eel Culture Association; N. Sato, T. Hieshima, Y. Saito, and Y. Takamura, Miyazaki Prefecture; President S. Takashima, Nihon Yoshoku Shinbun; Y.M. Wang, Bureau of Fisheries Management and Fishing Port Superintendence, Republic of China; H.F. Xu, TRAFFIC East Asia-China; G.C. Lei, WWF China; C.R. Kirkpatrick, TRAFFIC East Asia; S. Goshima of Hokkaido University; J.C. Avise, University of Georgia; S. Dufour, National Museum of Natural History, France; D. Jellyman and J. Boubée, National Institute of Water and Atmospheric Research Ltd of New Zealand; R. Lecomte, University of Perpignan, France; M.J. Miller, Ocean Research Institute, the University of Tokyo; T. Yamamoto, Japan Sea National Fisheries Research Institute, Fisheries Research Agency, Japan; M. Weber, Biologo Marino, Estação Litoral Agunda, Portugal; J.M. Casselman, Ontario Ministry of Natural Resources; A. Acou, Tour du Valat, France; E. Feunteun and A. Robinet, University of Rennes I, France; C. Jiaxin, Yellow Sea Fisheries Research Institute, China; C. Antunes, Centre for Marine and Environmental Research, Portugal; C. Briand, Management Institute of Vilaine, France; G. Castelnaud and P. Elie, CEMAGREF (Agricultural and Environmental Engineering Research), Bordeaux, France; T. Changeux, B. Rousseau and G. Simon, CSP (Superior Council of Fisheries), France; P. Steinbach, CSP, Regional Direction of Environment, Loire, France; I. Terrier, OFIMER (Interprofessional National Board for Sea and Fish-farming products); L. Vilaine, President of the Commission of Migratory Fishes and Estuaries, France; C. Guernalec, General Secretary of the National Committee of Marine Fisheries and Marine Cultures, France; D. Mahaud, professional fisherman, Adour, France; M.-A. Marcellier, Director of the North Atlantic Salmon Fund, France; C. Moriarty, University of Dublin, Ireland; W. Dekker, Chairman of the ICES/EIFAC Working Group on Eels, Institute for Fisheries Research, Netherlands; B. Bauduin and P. Pilliteri, DGDDI (Directorate General of Customs and Excise), France; B. Boutbien, DGCCRF (French Competition and Consumer Protection Agency), France; P. Boisneau, President of the National Co-ordination of Professional Fishing in Freshwater, France; I. Costa and T. Fournigault, Brigade Convention of Washington of ONCFS (National Hunting and Wildlife Office), France; J. Allardi and P. Keith, Ministry of Landing Management and Environment, France; F. Volckaert, Laboratory of Aquatic Ecology, Belgium; H. Wickstom, Institute of Freshwater Research, Sweden; G. Sancho, Fisheries Resources Department, AZTI, Spain; G. Fontenelle, ENSAR (National Institution of Higher Learning in Agronomica), France; R. Gascoin, National Union of Fishing and Fish Farming Fédérations, France; F. Grebo, Association Truit-Ombre-Salmon, France; A. Legault, Fish Pass, France; T. Nielsen, France; P. Prouzet, IFREMER (French Research Institute for the Management of Maritime Resources), France; C. Dennison, General Secretary of the Eel Study Group, UK; M.V. Ninassi, D. Moreau, M. Arnould, V. Graffin and L. Debas, WWF France. Mr Shimazaki of Hokkaido University assisted with finding the black and white cover illustration.

The authors would also like to express their sincere thanks to an eel trader in Japan, who shall remain anonymous, for providing information relating to trade routes, customs and traditions of Japan's domestic eel trade.

References

American Eel Plan Development Team (2000). Interstate fisheries management plan for American Eel. http://www.asmfc.org/. Atlantic States Marine Fisheries Commission, USA. Cover + xiii +79pp.

Anon. (1969-2000). *Gyogyô Yôshoku-gyô Seisan Tôkei Nen-Pô*. [Statistics of production of capture and aquaculture for calendar year.] Norin Suisan Shô Tôkei Jôhô Bu, Tokyo, Japan.

Anon. (1975-1998). Japanese imports of marine products (statistics). (1974-1997). Japan Marine Products Importers Association. Tokyo, Japan.

Anon. (1998). Commerce Exterieur des Produits de la Mer et de l'Aquaculture, OFIMER Rapport Annuel. Pp.1-72.

Anon. (1999a). *La filière Anguille, d'après le dossier d'étude de l'ISARA*. Cogepomi RMC, DIREN - Délégation de bassin. 31pp.

Anon. (1999b). Exports of *Anguilla* spp. from European Union member countries. 1988-1998. EUROSTAT. Comext2 k0234947.prt. 13 October.

Anon. (1999c). American Eel Board approved draft eel FMP: final approval slated for November. *ASMFC Fisheries Focus,* 8(8/9):4.

Anon. (2000a). Commerce extérieur des produits de la mer et de l'aquaculture. *OFIMER Rapport Annuel 2000*. Pp.1-73.

Anon. (2000b). Commodities trade and production of fishery products 1976-1999.ftp://ftp.fao.org/fi/stat/windows/fishplus/fishcomm. zip. The Food and Agricultural Organization. FISHSTAT: ftp://ftp.fao.org/fi/stat/windows/fishplus/fst_plus.zip.

Anon. (2001a). Total production 1950-2000. ftp://ftp.fao.org/fi/stat/windows/fishplus/fstat.zip. The Food and Agricultural Organization for FISHSTAT:ftp://ftp.fao.org/fi/stat/windows/fishplus/fs_plus.zip.

Anon. (2001b). Aquaculture production: quantities 1970-2000. ftp://ftp.fao.org/fi/stat/windows/fishplus/aquaq.zip The Food and Agricultural Organization. FISHSTAT:-ftp://ftp.fao.org/fi/stat/windows/fishplus/fst_plus.zip.

Anon. (2001c). Capture production 1970-2000. ftp://ftp.fao.org/fi/stat/windows/fishplus/capdet.zip. The Food and Agricultural Organization. FISHSTAT: ftp://ftp.fao.org/fi/stat/windows/fishplus/fst_plus.zip.

Anon. (2001d). Report of the ICES Advisory Committee on Fishery Management. Copenhagen, 22-31 May 2001, Copenhagen 9-17 October 2001. ICES *Cooperative Research Report* 246. International Council for the Exploration of the Sea. Copenhagen, Denmark. Three volumes.

Anon. (2001e). World Register of Dams. http://www.dams.org. ICOLD.

Anon. (2002a). Trade Statistics. Year of month [sic]. Commodity by country. http://www.customs.go.jp/toukei/download/index_d011_e.htm. 24 September.

Anon. (2002b). Agricultural item list. http://www.moftec.gov.cn/moftec_cn/tga/taiwan/taiwan-2-a.html. Ministry of Foreign Trade and Economic Co-operation, People's Republic of China. 15 February.

Anon. (2002c). Tariff search. Department of Customs, Administration Ministry of Finance, Republic of China. 15 February.

Anon. (2002d). A brief history of Eel farming. http://www.eel-fry.com. Wai Kee Industrial Co. 5 October 2001.

Anon. (2002e). *Customs tariff schedules of Japan 2002*. Japan Tariff Association, Tokyo. 997pp. [In Japanese and English]

Anon. (2002f). *Nihon Yôshoku Shinbun, compiled edition for year 2001*. The Nihon Yôshoku Shinbun, Tokyo. [In Japanese]

Anon. (2002g). Catching methods of glass eels. http://www.glasseel.demon.co.uk./Catching%20Methods.html. UK. July.

Anon. (2002h). Eel farming in Taiwan. http://www.american.edu/projects/mandala/TED/eelfarm.htm. August.

Antunes, C. and Tesch, F.N. (1997). A critical consideration of the metamorphosis zone when identifying daily rings in otoliths of European eel, Anguilla anguilla (L.). *Ecology Freshwater Fish* 6:102-107.

Aoyama, J. and Tsukamoto, K. (2001). Identification of eel species by genetic analysis. In: Japan Fisheries Resource Conservation Association (ed.) (2001). Naisuimen Juyôsyu Sigennzôdai Taisaku Itakujigyô *(Unagi Shigen Chosa)* (eel resource research). Japan Fisheries Resource Conservation Association, Tokyo. Pp. 129-133. [In Japanese]

Aoyama, J., Watanabe, S., Miyai, T., Sasai, S., and Nishida, M. (2000). The European Eel, *Anguilla anguilla* (L.), in Japanese waters. *Dana* 12:1-5.

Ashworth, S.T. and Blanc, C. (1997). *Anguillicola crassus*, a recently introduced aggressive coloniser of European Eels stocks. *Bulletin Français de la Pêche et de la Pisciculture* 344/345:335-342.

Avice, J.C. (2001). Catadromous eels of the North Atlantic: a review of molecular genetic findings relevant to natural history, population structure, speciation, and phylogeny. In: Aida, K., Tsukamoto, K. and Yamauchi, K. (eds), *Proceedings of the International symposium: Advanced Eel Biology.* Research for the Future Program, Japan Society of the Promotion of Science. Pp. 4-6.

Briand, C., Fatin, D., Fontenelle, G. and Feunteun, E. (in press). Estuarine and fluvial recruitment of European glass eel in an Atlantic exploited estuary. *Fisheries Management and Ecology.*

Bruslé, J. (1994). L'anguille Européenne, *Anguilla anguilla*, un poisson sensible aux stress environnementaux et vulnérable à diverses atteintes pathogènes. *Bulletin Français de la Pêche et de la Pisciculture* 335:237-260.

Castelnaud G., Guerault D., Desaunay Y. and Elie, P. (1994). Yield and abundance of the glass eel (*Anguilla anguilla* L.) at the beginning of the nineties. *Bulletin Français de la Pêche et de la Pisciculture* 335:263-287.

Castelnaud, G. (2000). Fishing location, fishermen and production of migratory species fisheries in the French rivers. *Bulletin Français de la Pêche et de la Pisciculture* 357/358:439-460.

Castelnaud, G. (2002). *Caractéristiques de la pêcherie civellière du golfe de Gascogne*. Contrat européen n°99/023. IFREMER, CEMAGREF, Groupement de Bordeaux. 32pp.

Dekker, W. (2000a). The fractal geometry of the European Eel stock. *ICES Journal of Marine Science* 57(1):109-121.

Dekker, W. (2000b). A Procrustean assessment of the European Eel stock. *ICES Journal of Marine Science* 57(4):938-947.

Dekker, W. (2002a). Status of the European Eel stock and fisheries. Proceedings of the International Symposium: Advances in eel biology, University of Tokyo, September 2001 (in press).

Dekker, W. (ed.) (2002b). Monitoring of glass eel recruitment. Netherlands Institute of Fisheries Research, report C007/02-WD, 256 pp.

Dufour, S. (1996). An example of a reproductive cycle under environmental control: the case of eel. *Comptes Rendus des Séances de l'Académie d'Agriculture de France* 82(7):17-26.

FAO (1993). Report of the Eighth Session of the Working Party on Eel. Olsztyn, Poland, 24-29 May 1993. *EIFAC Occasional Papers,* 27:21.

FIS (Fish-Info Service) (1998). Eel market report. The European Eel Resource. Published fortnightly at http://www.fis.com.

FIS (Fish-Info Service) (2000a). Eel market report. Consumption of eel in Japan form 1991 to 1999. Published fortnightly at http://www.fis.com.

FIS (Fish-Info Service) (2000b). Anguilla Eel farming in China. Consumption of eel in Japan from 1991 to 1999. Published fortnightly at http://www.fis.com.

Fontaine, Y.-A. (2001). *Les anguilles et les hommes.* Odile Jacob (ed.). 226 pp.

Fontenelle, G. (1997). Observations on the glass eel fishery. In: Moriarty C. and Dekker W. (eds). Management of the European Eel. *Marine Institute* 15:108-109.

Frost H. (2001). A socioeconomic cost-benefit analysis of the use of glass eel. Rapport nr. 118. Ministeriet for Fodevarer, Landbrug og Fiskeri, Copenhagen, Denmark. 68 pp.

Guangwei, D., and Shishun, L. (1999). Analysis of impetuses to change agricultural land resources in China. *Bulletin of the Chinese Academy of Science* 13(1).

Han, Z.C. (1999). Chapter IV. Fresh water culture of European Eel. In: Xie, Z.M. (ed.), *European Eel: Culture techniques.* Chinese Agriculture Publishing, Beijing. Pp. 41-131. [In Chinese]

Han, Y.S., Yu, C.H., Yu, H.T., Chang, C.W., Liao, I.C., and Tzeng, W.N. (in press.) The exotic American Eel *Anguilla rostrata* (Le Sueur) identified in Taiwan: Ecological implications. *Journal of Fish Biology*.

Haro, A., Richkus, W., Whalen, K., Hoar, A., Busch, W.-D., Lary, S., Brush, T. and Dixon, W. (2000). Population decline of the American Eel: implications for research and management. *Fisheries management* 25(9):7-15.

ICES (1994). Report of the 1994 session of the joint EIFAC/ICES Working Group on Eel from the meeting in Oviedo, Spain, 26 September-1 October 1994. EIFAC occasional paper 30:21 pp.

ICES (1996). Report of the second session of the joint EIFAC/ICES Working Group on Eel from the meeting in Ijmuiden, the Netherlands, 23-27 September 1996. EIFAC occasional paper 33:21 pp.

ICES (1999). ICES cooperative research report no. 229, Report of the ICES Advisory Committee on Fisheries Management, 1998. Part 2, 446 pp.

ICES (2000). Report of the EIFAC/ICES Working Group on Eels from the meeting in Silkeborg, Denmark, 20-24 September 2000. ICES CM 2000/ACFM. 6:27 pp.

ICES (2002). Report of the EIFAC/ICES Working Group on Eels from the meeting in ICES Headquarters, 28-31 August 2001. ICES CM 2002/ACFM. 3:54 pp.

Inaba, S. (1997a). Chapter V. Types of methods of culture, and merit/demerit of each. In: Inaba, S., Matui, I., Aoe, H., Tsunogai, H. and Oogami, H. (eds), *Lecture of Fish Culture. 9th edition 7. Eel.* Midori-Shobo, Tokyo. Pp. 38-60. Shiiku Hôhô No Shurui To Tokushoku. In: *Yôgyo Kôza Dau 7 Kan. Unagi*. [In Japanese]

Inaba, S. (1997b). Chapter VII. Material for ranching, and their capture. In: Inaba, S., Matsui, I., Aoe, H., Tsunogai, H. and Oogami, H. (eds), *Lecture of Fish Culture. 9th edition* 7. Eel. Midori-Shobo, Tokyo. Pp. 83-89. Shubyô To Saiho In: *Yôgyo Kôza Dai 7 Kan. Unagi.* [In Japanese]

Isono, T. (1999). Glass eel immigration to land. *Kaiyo Monthly* ex (18):156-163. [In Japanese]

Japan Fisheries Resource Conservation Association (ed.) (2001). *Naisuimen Juyôsyu Sigennzôdai Taisaku Itakujigyô (Unagi Shigen Chosa)* (eel resource research). Tokyo. 168 pp. [In Japanese]

Kato, M. (1999). Resource of Japanese Eel: decline, reasons, and measures. *Kaiyo Monthly* ex (18):174-177. [In Japanese]

Keith, P. and Allardi, J. (co-ord.) (2001). Atlas des poissons d'eau douce de France. *Patrimoines Naturels*, 47:387pp.

Kim, L.S. (2000). Atlantic States Marine Fisheries Commission prioritized research needs in support of interjurisdictional fisheries management. http://www.asmfc.org.

Kimura, S., Inoue, T. and Sugimoto, T. (1999). Transportation system of larval Japanese Eel. *Kaiyo Monthly* ex (18):53-59. [In Japanese]

Knights, B., White, E. and Naismith, J.A. (1996). Stock assessment of European Eel, *Anguilla anguilla* L. In: Cowx, I.G. (ed.). *Stock assessment in inland fisheries*. Hull International Fisheries Institute. University of Hull, UK. Pp. 431-447.

Knights, B. (1997). Risk assessment and management of contamination of eels (*Anguilla* spp.) by persistent xenobiotic organochlorine compounds. *Chemistry and Ecology* 13(3):171-212.

Kuo, C.L. (1999). Research of eel resources in Taiwan. *Kaiyo Monthly* ex (18):171-173. [In Japanese]

Kuroda, T. (1998). *Kôryû De Manabu Chûgoku Suisan.* [=Chinese Fisheries, learning by friendly relationship.] Seizandô, Tokyo. 5+247 pp. [In Japanese]

Kuroda, C. (1999). 1.4. Freshwater aquaculture in China. *Kaigyokyô(Shi)* 156:83-96. [In Japanese]

Lambert, P. and Feunteun, E. (1998). Compte rendu des journées anguilles de Paimpont du 23 au 25 septembre 1998. Rapport GRISAM/Groupe Anguille, 8 pp. + annexes.

Lee, W.T., Pak, S., and Pak, C.W. (1999). Recent state of research of eel resources in Republic of Korea. In: Tatsukawa, K., Matsumiya, Y. and Tsukamoto, K. (eds). *Proceedings of symposium: Present Status and Conservation Measures of Eel Resources.* Ocean Research Center of the University of Tokyo, Tokyo, Japan. P.25.

Lelek, A. (1980). *Les poissons d'eau douce menacées en Europe*. Collection sauvegarde de la nature (Conseil de l'Europe). Strasbourg, France. 275 pp. [In French]

Liao, I.C. (1999.) Aquaculture in Taiwan. *Kaigyokyo (Shi)*, 156:141-169. [In Japanese]

Liao, I.C., Liao, S. K., Kuo, C.L., Tzeng, W.N., and Kuo, C.L. (1999). Leptocephalus research by r.v. Fishery Researcher 1. *Kaiyo Monthly* ex (18):27-33.

Luneau, S. (1998a). Un marché asiatique juteux. *Eaux libres 2*4:18-19.

Luneau, S. (1998b). Elevage en Chine: les revers du succès. *Eaux libres* 24:20-22.

Matsuda, H. (1999). Resource management from point of view of biological resource conservation. In: Aida, K., Tsukamoto, K. and Yamauchi, K. (eds), *Proceedings of symposium: Present Status and Conservation Measures of Eel Resources.* Ocean Research Center of the University of Tokyo, Tokyo, Japan. Pp. 47-48.

Matsumiya, Y. (1999). Problems on import and release of eels, and perspective on the stock enhancement. In: Aida, K., Tsukamoto, K. and Yamauchi, K. (eds), *Proceedings of symposium: Present Status and Conservation Measures of Eel Resources.* Ocean Research Center of the University of Tokyo, Tokyo, Japan. Pp. 54-55. [In Japanese]

Matsumiya, Y., Tatsukawa, K. and Sakai, T. (1999). Analysis of catch data of glass eels and resource problems. In: Aida, K., Tsukamoto, K. and Yamauchi, K. (eds), *Proceedings of symposium: Present Status and Conservation Measures of Eel Resources.* Ocean Research Center of the University of Tokyo, Tokyo, Japan. P.37. [In Japanese]

Mochioka, N. (2001). Leptocephalus. In: Tatsukawa, K., Matsumiya, Y. and Tsukamoto, K. (eds). *Proceedings of the International symposium: Advanced Eel Biology.* Research for the Future Program, Japan Society of the Promotion of Science. Pp. 10-11.

Moriarty, C. and Dekker W. (1997). Management of the European Eel. *Fisheries Bulletin (Dublin)* 15:1-125.

Muchiut, S., Gallet, F., and Aubin, D. (2002). Principaux facteurs à prendre en compte pour une meilleure gestion de l'anguille européenne *Anguilla anguilla*. Institut des Milieux Aquatiques. Observatoire des pêches et des cultures marines du golfe de Gascogne. 4 pp.

Nelson, J.S. (1994). *Fishes of the World. Third edition.* John Wily & Sons, Inc., New York, USA. 600 pp.

Nielsen, T. (1998). Elevages en Chine: les revers du succès. *Eaux libres* 24:20-22.

Nielsen, T. (2000). Trading and transport of European glass eels for aquaculture purpose. http://www.ifrance.com/euroeel. June 2002.

Otsuka, H. (1996). Economics of eel culture. Nôrin Tôkei Kyôkai, Tokyo. 212 pp. (In Japanese with English summary)

Perraudeau, Y. (2000). "Les pêches maritimes estuariennes françaises en 1997-1998 (hors Méditerranée)": note de synthèse sur l'étude socio-économique (LEN-CORAIL, oct. 2000), 4 pp.

Rigaud, C. (1998). Des connaissances en pleine évolution. *Eaux libres.* 24:11-12.

Robinet, T. and Feunteun, E. (2001). Sublethal effects of exposure to chemical compounds: a cause for the decline in Atlantic eels? *Ecotoxicology* 11:265-277.

Sawada, T. and Yanagisawa, T. (2001). Aichi-ken. In: Japan Fisheries Resource Conservation Association (ed.) (2001).

Naisuimen Juyôsyu Sigennzôdai Taisaku Itakujigyô (Unagi Shigen Chosa) [eel resource research]. Japan Fisheries Resource Conservation Association, Tokyo. Pp. 42-48.

Schmidt, J. (1922). The breeding places of the eel. *Philosophical Transactions of the Royal Society of London. Series B* 211; 179-208.

Shi, D.L. (1993). Glass eel of Yangtze River at Chongming Isl., usage and management of resources. *Marine Fishery* 15(6):264-266. [In Chinese]

Shindo, S. (2001). On the Chinese Fisheries Law which was amended after an interval of 14 years. *Kaigai Gyogyô Kyôryoku* (18):1-21. [In Japanese]

Shu, T.S. (=Zhou, D.S.) (1976). Description of foods in China. Sogensha, Osaka. ii+259+18 pp.+map. [In Japanese]

Taillebois, L. (1998). Deux mareyeurs épinglés. *Eaux libres* 24:32-33.

Tabeta, O. (1991). Eel species of the world suitable for culture. *Aquaculture* 39(2):224-225. [In Japanese with English title]

Tabeta, O., Takai, T., and Matsui, I. (1977). On the foreign eels in Japan. *Aquaculture* 24(4):116-122. [In Japanese]

Tabeta, O., Nonaka, S., and Tanase, N. (1979). Occurrence of elvers of European Eel, *Anguilla anguilla* L. in Shizuoka and Kanagawa Prefectures, Japan, in 1977. *Bulletin of Japanese Society of Fisheries Sciences* 45(4):437-441. [In Japanese with English summary]

Tanaka, K., Oka, H., and Motonobu, T. (1999). Sagitta in gut contents of leptocephali. *Kaiyo Monthly* ex (18):113-117. [In Japanese]

Tatsukawa, K. (2001). The present state of population dynamics studies on unagi, *Anguilla japonica. Aquabiology* 133(23):108-114. [In Japanese]

Tatsukawa, K., and Matsumiya, Y. (1999). Resource management and conservation of Japanese eel: the start of research of Japanese Eel. *Kaiyo Monthly* ex (18):148-155. [In Japanese]

Temminck, C.J. and Schlegel, H. (1846). *Anguilla japonica*. P. 258, Pl. 13 (fig. 1). In: *Pisces. Fauna Japonica*, sive descriptio animalium quae in itinere per Japoniam suscepto annis 1823-30 collegit, notis observationibus et adumbrationibus illustravit P.F. de Siebold. Parts 10-14.

Tesch, F.W. (1977). *The Eel. Biology and Management of Anguillid Eels*. Chapman and Hall, London, UK. xiv+434 pp.

Tsukamoto, K. (1992). Discovery of spawning area for Japanese Eel. *Nature* 356 (6372):789-791.

Tsukamoto, K., Nakai, I., and Tesch, W.V. (1998). Do all freshwater eels migrate? *Nature* 396:635.

Tsunogai, H. (1997). Chapter XIV. Processing and cooking. In: Inaba, S., Matui, I., Aoe, H., Tsunogai, H. and Oogami, H. (eds), *Lecture of Fish Culture. 9th edition* 7. *Eel*. Midori-Shobô, Tokyo. Pp.229-239. Kakou to Ryouri. In: Inaba *et al*. (ed.). *Yougyô Kouza Dai 7 Kan*. Unagi. [In Japanese].

Tzeng, W.N. (1997). Short and long-term fluctuations in catches of elvers of the Japanese Eel, *Anguilla japonica*, in Taiwan. In: Hancock and Smith. (eds), *Developing and sustaining world fisheries resources. Proceedings of 2nd World Fisheries Congress.* CSIRO press. Pp.85-89.

Tzeng, W.N. (1999). Glass eel in Taiwan, resource and ecological research. *Kaiyo Monthly* ex (18):164-170. [In Japanese]

Varadi, L., Szucs, I., Pekar, F., Blokhin, S. and Csavas, I. (2001). Aquaculture development trends in Europe. In: Subasinghe, R.P., Bueno, P., Phillips, M.J., Hough, C., McGladdery, S.E. and Arthur, J.R. (eds). Aquaculture in the Third Millennium. *Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000*. Pp.397-416. NACA, Bangkok and FAO, Rome.

Watanabe, S. (2000). Taxonomy of the freshwater eels, genus *Anguilla*. *Aquabiology* 133(2):115-122. [In Japanese with English abstract]

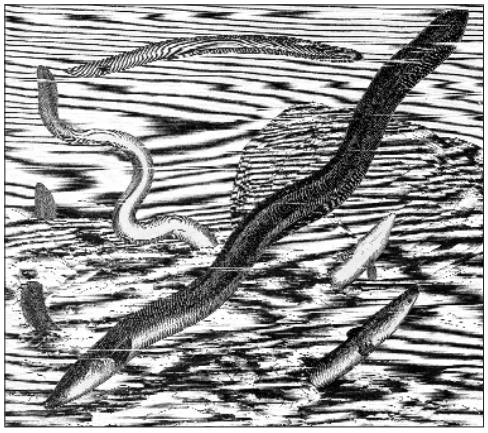
Williamson, G. R. and Tabeta, O. (1991). Search for *Anguilla* eels on the west coast of North America and on the Aleutian and Hawaiian Islands. *Japanese Journal of Ichthyology* 38(3):315-317.

Wirth, T. and Bernatchez, L. (2001). Genetic evidence against panmixia in the European Eel. *Nature* 409:1037-1040.

WTO (World Trade Organization). (1995). Annex 1. A Multilateral Agreements on Trade in Goods. Agreement on Safeguard. In: World Trade Organization, *Agreement Establishing the World Trade Organization*. http://www.wto. org//english/docs_e/legal_e/05-anx1a.pdf Pp. 273-281. 16 May 2002.

Yamanaka, H., and Tanaka, T., (2001). *Suisanbutsu no Riyou. Genryou Kara Kakou/Chori Made. Kaitei Ban.* [*Utility of fisheries products. From materials to processing/cooking. Amended edition*.] Seizando, Tokyo. 2+10+172pp. [In Japanese]

Zhang, H., Mikawa, N., Yamada, Y., Horie, N., Okamura, A., Uto, T., Tanaka, S., and Motonobu, T. (1999). Foreign eel species in the natural waters of Japan detected by polymerase chain reaction of mitochondrial cytochrome *b* region. *Fisheries Sciences* 65:684-686.



Stéphane Ringuet, *Programme Officer, TRAFFIC Europe-France, c/o WWF-France, 188, rue de la Roquette, F75011, Paris, France. E-mail: sringuet@wwf.fr*

Fumihito Muto, *Regional Fisheries Officer, TRAFFIC East Asia-Japan, 6th Fl. Nihonseimei Akabanebashi Bldg., 3-1-14, Shiba, Minato-ku, 105-0014 Tokyo, Japan. E-mail: muto@klact.co.jp*

Caroline Raymakers, *Director, TRAFFIC Europe, Bd Emile Jacqmain 90, B-1000 Brussels, Belgium. E-mail:craymakers@traffic-europe.com*