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Coming to Grips with the Eel Stock Slip-Sliding Away

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Introduction

Eels are weird animals. Despite decades of scientific research, crucial aspects of their biology remain a mystery. In recent decades, juvenile abundance has declined dramatically: by more than 95% for the European eel *Anguilla anguilla* and by 80% for the Japanese eel *A. japonica*. Recruitment of American eel *A. rostrata* to Lake Ontario, near the species' northern limit, has virtually ceased. Other eel species, including Australian and New Zealand eels (*A. dieffenbachii* and *A. australis*), also show indications of decline. Aside from the implications for biodiversity, loss of eel resources will have considerable impact on the socio-economics of rural areas, where eel fishing still constitutes a cultural tradition. The scientific community working on eels has strongly urged precautionary protective action (Anonymous 2003).

The causes of the downward trends are still unclear. The lack of access to basic life history information about the oceanic phases makes it especially difficult to monitor and identify the cause of their population declines. This is in distinct contrast with other declining fishes such as anadromous salmon, whose localized spawning stocks can be relatively easily surveyed when the adults return to freshwater to spawn, and Atlantic cod *Gadus morhua*, which spawn in relatively open waters and can be surveyed by standard techniques.

In recent years, the alarming state of eel stocks has been recognized, and restoration plans are now being developed for the European and American eel. This article will review the status of the stock, the development of international recovery plans, and the interplay between scientists, governments and stakeholders. For pragmatic reasons, this article focuses predominantly on the European eel, but many of the results and ideas will also apply to other *Anguilla* species, especially those in temperate waters.

In this article, I will use the word *eel* (without qualification) to indicate the European eel, i.e. *Anguilla anguilla* (L.). Where confusion might arise, I will use *European eel*, but the latter is not meant to restrict the discussion to the European part of the distribution area.

Status of the Stock and Fishery

Following a brief introduction to the eel's life history, the current status of the stock and fishery will be described.

Life History

Although the eel's life cycle (Figure 1) is incompletely known, reproduction must take place somewhere in the Atlantic Ocean, pre-

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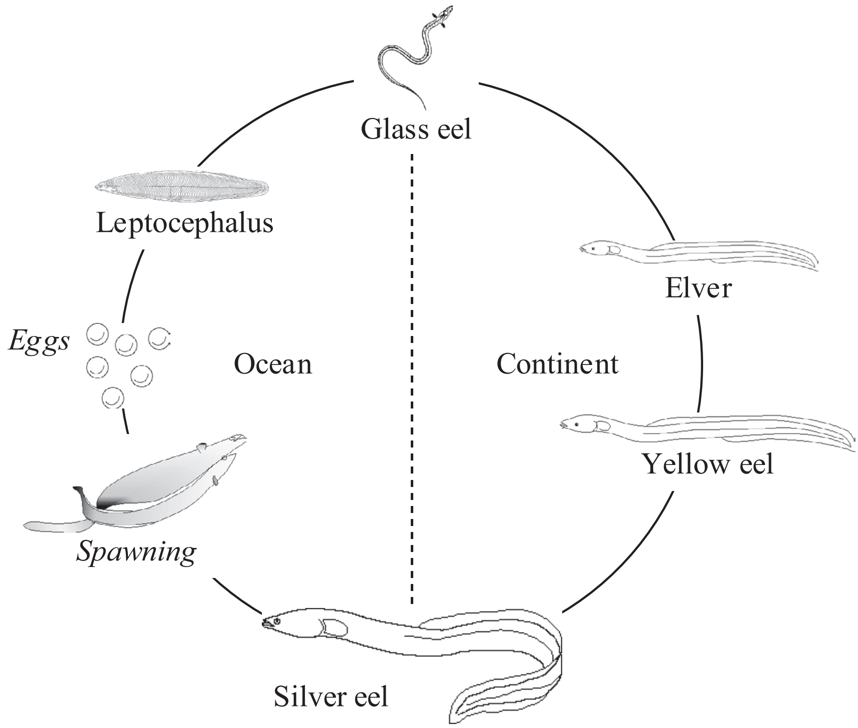

Figure 1. The life cycle of the European eel *Anguilla anguilla*. The names of the major life stages are indicated; spawning and eggs have never been observed in the wild and are therefore only tentatively included.

sumably in the Sargasso Sea area, where the smallest larvae have been found. No one has ever observed spawning adults or eggs in the wild. Larvae (*Leptocephali*) of progressively larger size are found as one moves from the Sargasso Sea to the European continental shelf. At the shelf edge, the laterally flattened *Leptocephalus* transforms into a rounded glass eel. This has the same shape as an adult eel, but is unpigmented. Glass eel migrate into coastal waters, estuaries, rivers and eventually into lakes and streams. Following immigration into continental waters, the prolonged yellow eel stage begins. This stage lasts for some 20 years. Yellow eels may occupy freshwater or inshore marine and estuarine areas where they grow, feeding on insects, worms, mollusks, crustaceans and fish, but–contrary to popular belief–not carrion. Sex differentiation occurs when the eel are partially grown; this mechanism is not fully understood and probably depends on local stock density. At the end of the continental growing period, eel start maturing and return from inland and coastal waters to the Atlantic Ocean; this stage is known as the silver eel. Female silver eel grow larger than and almost twice as old as males. The biology of the returning silver eel in ocean waters is completely unknown.

Population status

This section describes the spatial distribution, the temporal trends, and the factors affecting the population in space and time. Potential density dependence in the population dynamics is discussed, because of its relevance in understanding the historical decline, and its significance for future restoration actions.

Spatial distribution

The spatial distribution of the eel population exhibits fractal characteristics, showing large-scale as well as small-scale variation (Dekker 2000a).

On the global scale, the eel is distributed over Europe, northern Africa and Mediterranean Asia (Schmidt 1909; Dekker 2003a), covering an estimated water surface of 100,000 km^2 (Dekker 2003a). The overall distribution pattern is one of high recruitment in the area surrounding the Bay of Biscay, rapidly thinning out with distance. The Biscay area (<10% of the distribution area), receives three-quarters of the recruitment, while producing only 10% of the silver eel biomass (Dekker 2000b).

Within individual catchments, the eel stock is scattered over almost all water types, including open and sheltered coastal areas, lagoons, estuaries, main rivers, streams, brooks, ponds, lakes and ditches, ranging from oligotrophic to eutrophic. Under natural conditions, an open access route from the sea is required, but trap-and-transport operations within and between catchments, from southern to northern Europe, from western to eastern Europe far outside its natural distribution area, and even from Europe to natural waters in eastern Asia, has blurred the natural distribution pattern for many decades. Within single river systems, the stock composition shows considerable differentiation, even at short distances apart, as nearby waters can deviate, *inter alia*, in mean size, in sex composition, and in food habits (Dekker 2000a).

The contrast between the rural scale of stock and fisheries and the global need to protect and sustain the common spawning stock constitutes an unprecedented, major challenge for developing adequate governance, as will be shown below.

Temporal trends

Temporal trends in the eel population must be assessed primarily at a local scale, in regionally managed water bodies. However Dekker (2000a, 2003c, 2004a) showed that interregional time series usually correlate well, apparently indexing global trends in the stock.

Recruitment of glass eel towards the continent is monitored in most Western European countries, using statistics such as from scientific sampling, commercial or noncommercial fisheries, and import-export data (Moriarty 1986; Dekker 2002). General trends can be inferred from 1950 onwards (Figure 2): After a brief period of relatively low recruitment shortly after World War II, numbers of glass eel were high in the 1950s, 1960s and 1970s, reaching a peak in the late 1970s. Starting in 1980, a steady decline occurred, reaching a low level around 1990 at one order of magnitude below former levels. In the late 1990s, a further decline occurred leading to an all-time low in 2001, again an order of magnitude below the level observed only 10 years before. In most recent years, no substantial recovery in recruitment levels has been observed. Most data series from the British Isles showed a different pattern: a less severe decline than in mainland Europe.

Time series on yellow eel abundance spanning more than a decade are rare, and results are often unpublished. The research surveys on Lake IJsselmeer in the Netherlands are presumably the only long-time, fishery-independent data source (Dekker 2004b). Results indicate a gradual decline in abundance since 1960. Other sources of information (Moriarty and Dekker 1997) largely support the notion that the yellow eel abundance has declined over wide areas. Results from English re-surveys (Knights et al. 2001) are an exception, and have not indicated a general decline over the last 20–25 years.

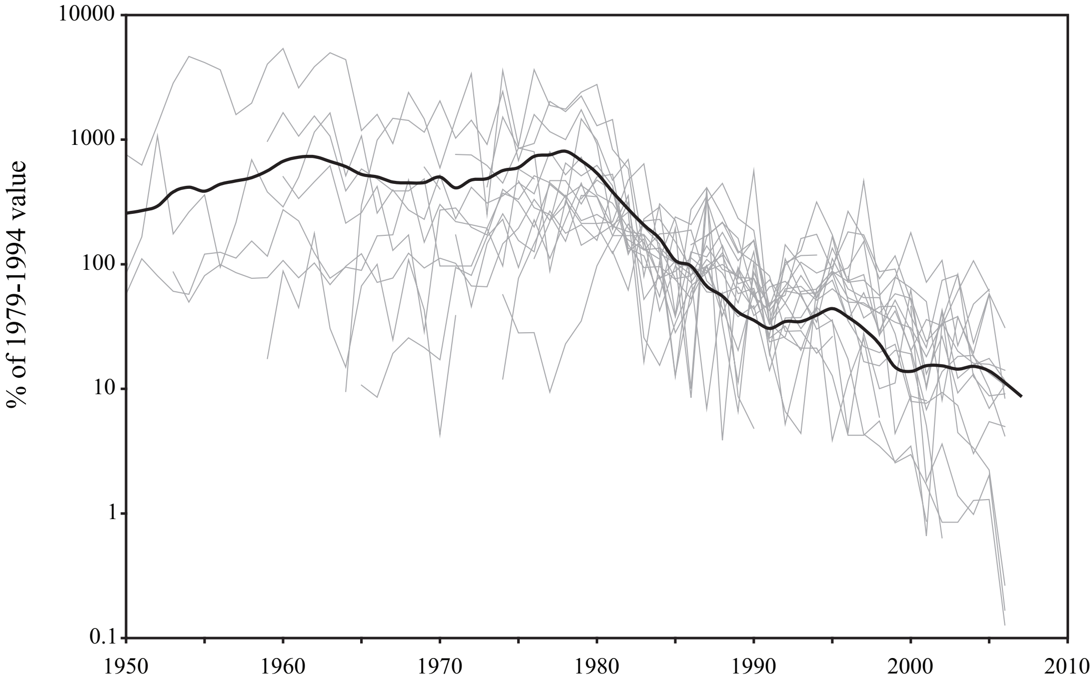

Figure 2. Trends in glass eel recruitment to the continent. Individual data series are given in gray; common trend (geometric mean of the three longest data series) in black (data from ICES 2006, updated).

Fishing yield, which are discussed in more detail below, is in decline in almost all the distribution area. Below, I will argue that this is presumably more indicative of the status of the stock than of the impact of fishing.

Overall, almost all time series indicate a decline of the population; from the 1960s onwards for stock and yield, and from 1980 onwards for recruitment.

Factors affecting the population abundance

Several hypotheses for the decline in recruitment have been suggested (Castonguay et al. 1994a; EIFAC 1993; Moriarty and Dekker 1997; ICES 2002), but without proper evidence no definite causes can be identified and a parallel effect of several of the proposed causative factors is most plausible (Dekker 2004a). The suggested hypotheses fall into two distinct groups. On one side, some process in the ocean possibly related to the North Atlantic Oscillation (ICES 2001a; Knights 2003), might have reduced larval survival and/or growth (Castonguay et al. 1994b; Dekker 1998; Desaunay and Guerault 1997). ICES (2001a) presented a correlation between recruitment indices and the most prominent climate index (NAO index; Hurrell 1995). Reanalysis of updated data series (Dekker 2004a; Figure 3) shows that the correlation between the NAO index and growth (glass eel length) is relatively strong ($r^2 = 0.24$) and continues till today. The correlation between the NAO index and glass eel numbers is weaker ($r^2 = 0.10$), and breaks after 2000. Since 2000, the NAO index returned to normal values, while the glass eel recruitment dropped to historically low levels.

On the other hand, a range of continental

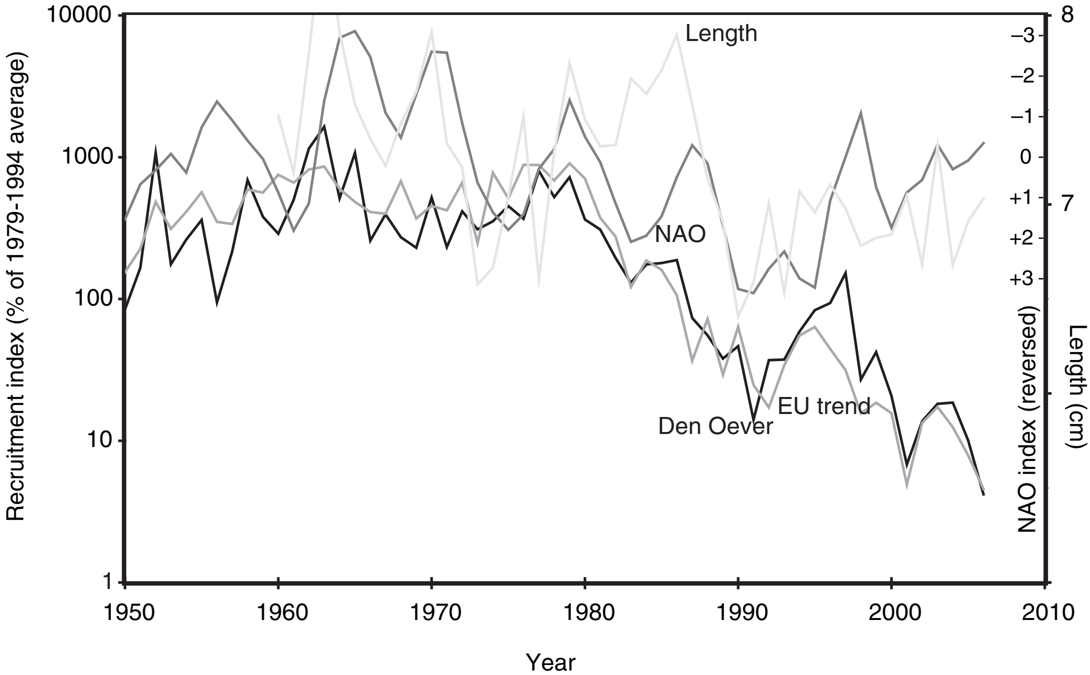

Figure 3. Trend in glass eel recruitment (in Den Oever, Netherlands, and European mean), and mean length (Den Oever), and the NAO index, averaged over three years. Data from Dekker (1998, 2004a, updated) and ICES (2006, updated); NAO winter index from Hurrell (1995, updated).

factors has been suggested, including pollution, habitat loss due to barrages and dams, overexploitation of either glass eel or yellow and silver eel, and human induced transfers of parasites and diseases (Castonguay et al. 1994a; Moriarty and Dekker 1997; ICES 2002; Robinet and Feunteun 2002). Re-stocking of recruits from the core of the distribution area to the fringes presumably has a positive effect on the production of spawners (see EIFAC/ICES 2006 for an overview). Local effects of these continental factors have been shown (and can be managed), but overall impacts on the eel population are generally unquantified (Dekker 2004a). Thus, the discussion on the relevance of various factors continues. In the absence of pertinent knowledge on the causes of the decline, ICES (1999) advised precautionary measures, restricting impacts where they exceed reasonable limits.

Density dependence

The anthropogenic factors affecting the continental stock (pollution, habitat and migration, fisheries, re-stocking) directly influence the continental stock. Density dependence, meaning that a lower natural mortality or better growth occurs under conditions of low stock abundance, will ameliorate the effect of these anthropogenic factors on the silver eel run. Density dependence might be a factor contributing to dispersal within rivers, to growth, mortality and to sex differentiation (see ICES; 2003 for an overview). Although the concept of density dependence is frequently cited in eel literature, evidence *for* and knowledge *of* the processes involved is almost nonexistent. Despite this, density dependence plays a key role in the assessment of the continental stock, and is the central argument justifying the intensive fishery on glass eel around the Bay of Biscay (Moriarty and Dekker 1997). Moreover, the general decline in recruitment since 1980 (see above), and the decline observed in yellow and silver eel fishing yields (see below), makes it increasingly unlikely that density dependence still plays a key role in stock dynamics (Dekker, in press). Even though the potential existence of density dependent processes in the continental phase is generally deemed as likely, their unquantified status makes them no argument against precautionary protective measures.

For the oceanic phase, Dekker (2004a) presented tentative evidence for a strongly depensatory stock–recruitment relationship (Figure 4), that is that recruitment is declining faster than the spawning stock. Disruption of social mating processes at low spawning stock densities is the most likely proximate explanation (Dekker 2004a), leaving only few spawning aggregations successful in finding a large enough group for social courtship. Recent analysis of spatial and temporal genetic patterns in oceanic recruitment (Maes et al. 2006) indeed shows that reproductive success varies at very short time intervals, which might reflect separate social events. The depensation hypothesis remains valid, even if ocean climate change is included as an additional explanatory variable (Dekker 2004a). If true, this hypothesis implies that protection and recovery of the eel can only be achieved if spawner escapement is restored to pre-1980 levels, which will be difficult to achieve at the current (poor) recruitment level. ICES (2005) therefore considered extensive use of glass eel re-stocking as a potential means to escape from the depensation trap.

Density dependence has been suggested

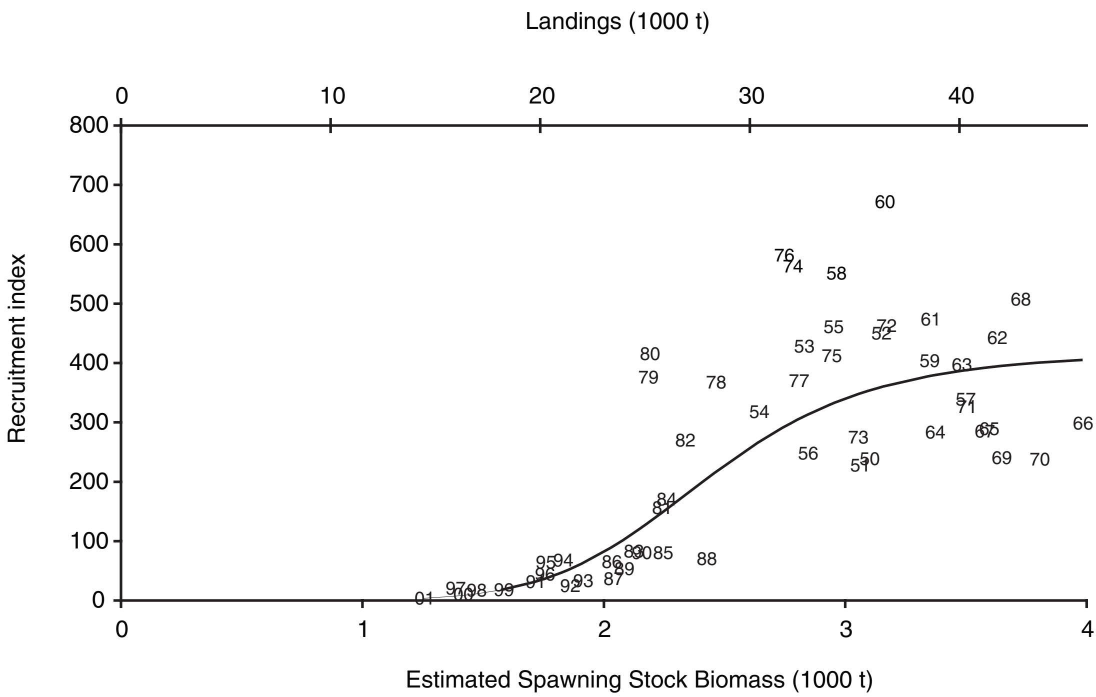

Figure 4. Tentatively estimated stock–recruitment relationship for the European eel. Numbers indicate the year of recruitment. The spawning stock (lower horizontal axis) is assumed proportional to the landings from the continental stock (upper horizontal axis). After Dekker 2004a.

in both the continental and the oceanic life stages. Note that for the continental stage a compensatory effect is assumed, while a depensatory effect was tentatively found for the oceanic stage. In the absence of adequate scientific evidence, the prudent approach to stock management is to assume the depensatory effect exists and to ignore the compensatory processes for the present. Consequently, scientific advice (ICES 1999, 2006) has focused on a reduction of anthropogenic impacts and advised to aim for a substantial increase in spawner production.

Fisheries and aquaculture

The eel is fished in all life stages appearing on the continent by commercial and recreational fishermen, in the whole of its distribution area, and outside the area where they have been re-stocked. Apart from local opportunities influenced by river morphology and infrastructure, local stock density appears to determine which life stage is targeted (Dekker 2003a). Glass eel fisheries are restricted to areas of highest densities, around the Bay of Biscay (northern Spain, southwestern France, southwestern UK), and in the semiarid regions (remainder of Spain, Portugal, Atlantic Morocco) where incoming recruits are more concentrated in river mouths. Yellow and silver eel fisheries are found throughout the distribution area, but silver eel fisheries dominate more to the north. However, this is due only to local contrasts between yellow and silver eel fishing opportunities, as the absolute abundance of silvers in southern regions is higher than in the north (Dekker 2003a).

The total catch of the glass eel fisheries in the early 1990s was estimated at 583 metric tons (Moriarty and Dekker 1997), but this is certainly an underestimate of the true catch as the landings are locally processed, often illegal, and frequently not documented. However, all indications are that commercial catches coincide with local trends observed in commercial catches and with scientific indices (see above). They indicate a sharp decline following 1980 to approximately 10% of former levels, gradually declining further to on average less than 5% since 2000. The most recent estimate for 2006 (EIFAC/ICES 2006) comes to 100 t, apparently achieving a better coverage than the 1990s estimate.

In addition to the fisheries on the wild stocks of yellow and silver eel, fisheries for glass eel have been developed to supply indoor and outdoor aquaculture with seed material, producing yellow and silver eel. This aquaculture takes place in Europe (production of approximately 10,000 t; EIFAC/ICES 2006) and in eastern Asia (production of approximately 10,000 t from European eel, in comparison to 100,000 t aquaculture production from Japanese eel). From a biological viewpoint, aquaculture is just one usage of wild-caught glass eel. Commercially however, aquaculture and re-stocking in support of fisheries compete for the limited glass eel resources (aquaculture taking more than half the total glass eel recruitment, Dekker 2003b), and compete with their products on the market.

Fisheries for yellow and/or silver eel are found throughout Europe. Statistics on landings are notoriously incomplete, and rarely include any from the substantial recreational fishing (ICES 2005). ICES (1988) and Moriarty (1997) have shown that official landing statistics for many countries comprised only about half the true catches in the 1980s and 1990s. Analysis of the trends in reported landings shows (Dekker 2003c; Figure 5), that total landings in the pre-WWII period averaged around 47,500 t/year^{-1}. Following a clear depression during WWII, landings gradually restored to 47,000 t/year^{-1} in 1964, to decline to an all time low of less than 10,000 t recently. These estimates exclude unreported commercial catches over the whole time span. Since unreported catches are of all eras, the reported trend probably reflects the true development. The decline in production since the mid-1960s started despite an initially high glass eel recruitment and an increasing amount of re-stocked glass eel. Clearly, the productive capacity of inland waters must have deteriorated (Dekker 2003c).

Globalization of the fishery, trade and management

Eel fishing companies are local, small-scaled rural enterprises fishing on an internationally shared stock and selling their products on a world market. For the international yellow and silver eel production, the relation between price and quantity produced (Figure 6) indicates a very high price elasticity of 0.67. A nearly constant amount of 195 M€ (2000 price level) is spent on eel in Europe (SD over the years: 29 M€). From 1950 until 1990, the declining fishing production came with increasing prices; since 1990, the growth of aquaculture production suppressed the price. In parallel to the official market, there is an unrecorded market of local sales, for local consumption, of about equal total turn-over (Moriarty and Dekker 1997). Apparently, this parallel market follows the main market without influencing its price. Additionally, the catch of American, Australian and New Zealand eel was sold to Europe in former decades, but this is a minor quantity in comparison to European catches (Dekker 2003b). These eels are now sold primarily in Eastern Asia. The production in Europe is traded, processed and consumed predominantly within Europe (Ringuet et al. 2002). Neither the trade statistics (Ringuet et al. 2002) nor the price elasticity show

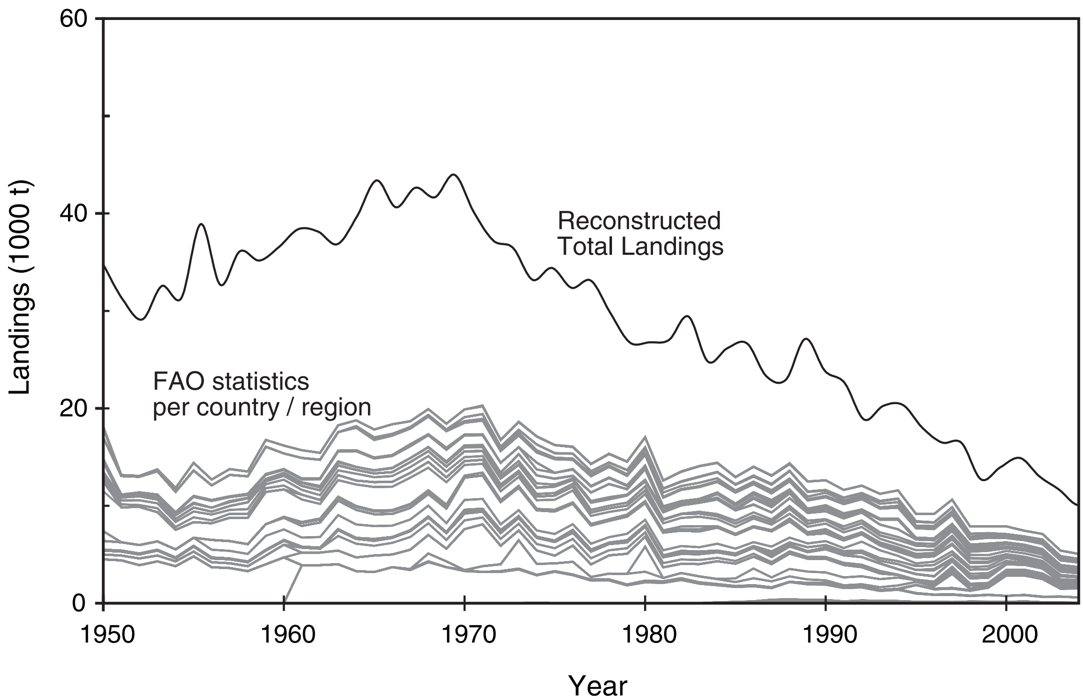

Figure 5. Trends in fishing yield. FAO statistics (in gray) include an increasing number of reporting countries, and therefore give a false suggestion of a stable or increasing yield. Analysis of the trends in individual data series results in a reconstructed trend (in black) for the whole population (From Dekker 2003c; updated).

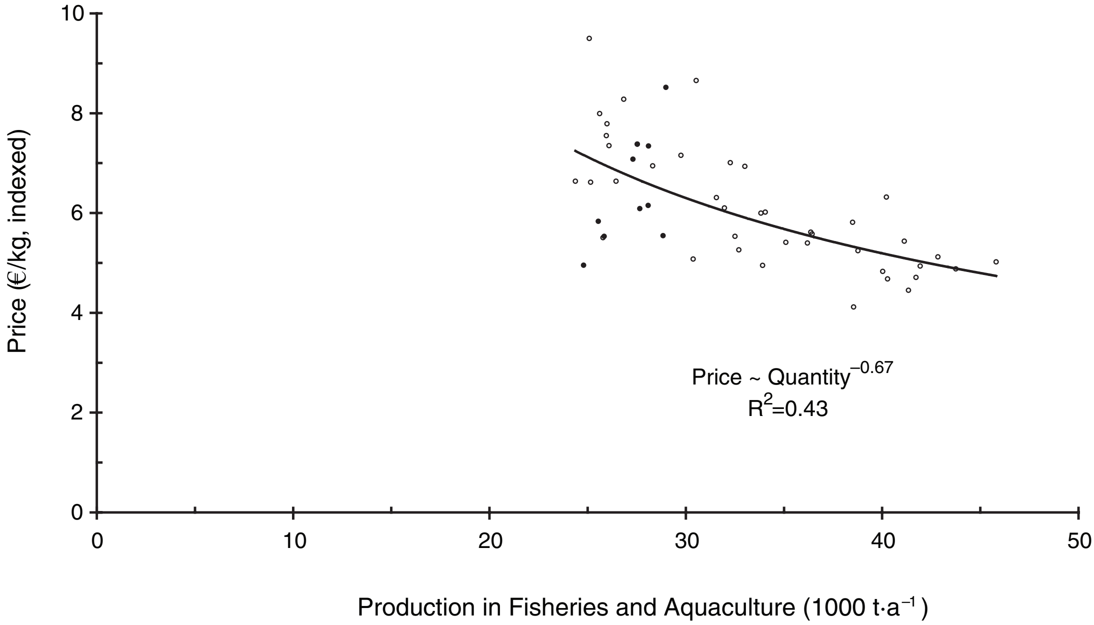

Figure 6. Relation between indexed market price for yellow eel (Netherlands, year 2000 price level) and the European production (fishing yield and aquaculture combined), per year since 1950 (○ before and • after 1990. Data from Dekker 2004a; updated).

any influence of the Asian aquaculture of European eel, indicating that the market is dominated by variation in the European supply. In the long run, it is unlikely that the European market will remain isolated from Asia. I expect that abundant Asian aquaculture production will penetrate the European markets sooner or later.

For the glass eel, time series on prices are lacking. The extreme price rise in the 1990s is often mentioned, but I do not know of any data analysis. ICES (1997) mentions a price of 18 €/kg (40 DFL/kg) in 1980. Ringuet et al. (2002) lists information for the 1990s, showing a variation between 119 USD/kg and 312 USD/kg, with a sharp rise in 1996/1997. In recent years, incidental prices of 1000 €/kg or more have occurred, peaking at the beginning of the fishing season but usually relaxing later on in the season. Over the years, prices are still rising. In 2006, however, a sharp recession was reported, said to be related to a stronger recruitment of the Japanese eel or problematic marketing of Asian production, which was said to be contaminated by antifungals in 2005. Whether this is a temporary development remains to be seen. Indications are that high demand completely determines current markets, primarily due to the Asian aquaculture of European eel.

The decline of the eel stock has led to scientific advice to restrict fishing and diminish other anthropogenic impacts on the stock. Subsequently, the European Commission has developed a European Eel Management Plan to protect and restore the stock (see below). Protection and restoration of the stock will involve almost all European countries and, due to the high impact of international trade in glass eel, even the Asian aquaculture industry. Consequently, the need to protect and restore the stock will lead to rapid globalization of the management for these rural fisheries.

Governance Structures

Management of eel fisheries and their ecosystems has traditionally operated only on a small local scale, and as far as the ecosystem is concerned, has addressed the needs of the eel most often only implicitly. The decline observed in the past decades has occurred almost throughout the distribution area, indicating shared or parallel problems. Therefore, eel specific governance structures are now being developed on the international level, which should bring the existing, local management structures within a common framework. Governance structures will be described below at both local and international scales.

The decline of the population is among others related to fisheries, water management, pollution and habitat deterioration. Consequently, governance must cover all of these aspects. Historically, however, the discussion focused initially on exploitation only (e.g., ICES 1976, 1999). Subsequently, the scope for discussion gradually widened (e.g., ICES 2002, discussing anthropogenic impacts other than fisheries, but excluding them from the recommendations), and recent discussions obviously aim at a balanced approach (e.g., ICES 2006). However, the starting point still is fisheries. Internationally, the discussion is held within frameworks primarily related to fisheries, and reductions on fisheries are seen as the most rapid and most easily arranged protection measures. Consequently, the discussion of local and stock-wide governance below will take fisheries as its starting point, but this is not meant to restrict the discussion in any sense.

Lower level governance

Eel fisheries are scattered over Europe, typically constituting local units of few fishermen, fishing a local water body of less than 10 km^2, and catching 1–10 t per annum (Dekker 2000a). Larger concentrations are rare, notably Lough Neagh in Northern Ireland and Lake IJsselmeer in the Netherlands which together yield only 5% of the European catch (Dekker 2000a). On the local scale, national, regional, or lower, fisheries management objectives are most often unspecified (Moriarty and Dekker 1997), although rural employment and yield maximization are implied by the actions taken. Use as a local staple food is no longer an issue. Stock protection is often mentioned, but very rarely practiced. A personal impression, based on visits to eel fisheries throughout the distribution area, is that in most cases local governance is primarily aiming at conflict resolution, such as between neighboring fishermen or between fishermen and other people, opportunistically supported by arguments concerning catch maximization, or even stock protection.

A wide range of management restrictions have been applied, including technical gear restrictions, closed seasons and areas, effort limitations, size limits, a few catch limits, and other measures (Moriarty and Dekker 1997; ICES 2003). Since almost none of these measures had a quantified objective, and almost none was geared to the actual status of the local stock, these measures only established diffuse governance. On the positive side, migration over barriers has been enhanced by trap-and-transport (Rigaud et al. 1988), and glass eel (or young yellow eel) has been imported and re-stocked (Wickström 2001; Dekker 2003b).

Trade and processing of eel is governed by general regulations aiming at food safety, sanitary control, and good labor standards. None of these is eel-specific, except for some food safety regulations regarding PCB and other pollutants. Lipophilic contaminants, such as PCB and dioxins are, due to their high fat content, found in high concentrations in eel (Knights 1996; EIFAC/ICES 2006). Fishing and/or trade restrictions exist in some countries (e.g., Belgium, Sweden, Netherlands), due to high contaminant levels (e.g., PCB and dioxin), but control of these restrictions is far from adequate.

Three special cases are worth mentioning. First, Lake IJsselmeer in the Netherlands is a former estuary, closed off from the sea by a dike in 1932. Following the closure, an intense eel fishery developed, employing over 1,000 boats. Over the decades, the number of companies and their yield have degraded to less than 10% of the former magnitude. The responsibility for fisheries management has resided with the State; from the mid 1990s onwards, the State aims at co-management. Detailed management regulations have been imposed based on extensive monitoring and research, including mesh sizes, closed seasons, closed daily hours, catch limits, restrictions on the number of nets used, and on the type of netting material. See van Densen et al. (1990) and Dekker (2004b) for details.

Secondly, Lough Neagh in Northern Ireland is a natural lake, supporting an intense eel fishery, employing around 200 boats. Following substantial conflicts between the foreign owners of the fishing rights and the traditional local fishermen in the 1950s, a local priest (Kennedy 1999) established a co-operative of all traditional fishermen, which acquired full fishing rights in the 1960s. The Lough Neagh Fishermen's Co-operative Society Ltd practices active fisheries management, and organizes the international trade of the unprocessed catch. The explicit objectives are a stable and reasonable income for the local fishing communities and good return for the Co-op's shareholders. Stability of catch levels up to 2000 indicates the Co-op's general success, although recently catches have started to decline. See Rosell et al. (2005) for details.

Thirdly, the Baltic silver eel fisheries, which are predominantly in Sweden and Denmark, are exploiting the silver eel run from a vast northern area in Scandinavia and Eastern Europe. Although the density of the stock in Scandinavia is low (Dekker 2003a), the total production from this vast area is considerable. The Baltic Sea has only a small connection to the Atlantic located between Denmark and Sweden, and emigrating silver eel concentrate here, allowing for a profitable (semi-) commercial and/or artisanal fishery, directed almost exclusively at silver eel. Total catch declined from over 6,000 t in the 1950s, to approx. 1,250 t recently. The density of the corresponding yellow eel stock, scattered throughout the Baltic region, is generally too low to allow exploitation (less than 500 t for the total Baltic region). Management of the yellow eel stock and that of the concentrated silver eel fishery is generally not coordinated. See Wickström (2005) for details.

Apart from these three special cases, a wide gamut of local governance structures exists. These include, among many others, local fisheries organized by a monastery on the River Nalón in Northern Spain, commercial fisheries in support of a research program organized by the hydropower company owning the fishing rights on the River Shannon in Ireland, local fisheries in privately owned waters based on commercial re-stocking on Masurian Lakes in Poland, privately owned fishing rights in state owned waters, and fishermen's organizations owning fishing rights in state waters.

The stock-wide governance structure discussed below will require national/regional authorities to develop Eel Management Plans for their rivers, aiming at internationally agreed targets. Since formal governance structures are currently almost absent on these lower levels, it will constitute a major challenge to develop these structures within the time left before the eel stock fades out (Anonymous 2003; EIFAC/ICES 2006).

Stock-wide governance

The contrast between the rural scale of stock and fisheries and the global need to protect and sustain the stock constitutes an unprecedented, major challenge in formulating advice on stock-wide governance aiming at sustainable management. Neither marine stocks under a central management regime, nor localized freshwater stocks under local governance set an example (Dekker 2000a). Management strategies readily applied to many other fish stocks might not work as well for eel. Rather than giving in to this seemingly impossible bargain (Feunteun 2002), Dekker (in press) presented a proposal for a governance structure at the 2003 eel symposium of the American Fisheries Society, addressing both the local and global levels. Crucial components of this proposal are:

• Establishment of national and international management systems, in which targets and tools are developed and postevaluated centrally, while measures are implemented locally. This requires, among others, the development of an adequate communication structure in-between the levels;

• Acceptance of an overall required protection level, as advised by ICES (2001a, 2001b);

• Translation of this rather theoretical protection level into practical targets, that is: selection of adequate proxy indicators, and reference values corresponding to sustainable protection levels;

• Actual implementation of protective measures, implemented several years before the latest recruitment decline (in 2000) might have translated into a further decline of the spawner production (that is, before 2010);

• Development of a stock-wide monitoring program, where the targets set, the protective measures implemented, the actual state of the stock, and the match between targets, tools and attainment is recorded at local management levels and reported to higher management levels, culminating in an up-to-date assessment of the state of the whole stock and the protection achieved.

Subsequently, the European Commission (the executive body of the European Union) has issued a Proposal for a Community Action Plan for the Management of European Eel (Commission of the European Communities 2003), in which the status of the stock, the need for international management, the legal background, and the Community Framework for Action were reviewed. Following additional scientific advice and extensive consultations with stakeholders and Member States, this plan was further developed in a proposal for a Council Regulation Establishing Measures for the Recovery of the Stock of European Eel (Commission of the European Communities 2005). This proposed Regulation was slightly amended and unanimously approved by the EU Parliament, and then awaited approval by the Council of Ministers. It contains the following elements:

• Conservation of the eel stock requires action in the field of fisheries, of habitat restoration, of hydropower generation, of nature conservation and so forth. The following legislative frameworks apply on an equal footing:

EU Directive 92/43/EC of the Council on the Protection of Wild Fauna and Flora, EU Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy and Council Regulation (EC) No 2371/2002 of 20 December 2002 on the Conservation and Sustainable Exploitation of Fisheries Resources under the Common Fisheries Policy.

For the Common Fishery Policy, eel specific measures will be developed. Since the Common Fishery Policy generally only covers marine waters, the proposed Regulation requires Member States to develop specific eel management plans for their freshwaters. For the other Directives, the efforts underway are assumed to achieve adequate results, also for eel.

• An overall target for sustainable management of the eel is set at the escapement to the sea of at least 40% of the biomass of adult eel relative to the best estimate of the potential escapement from the river basin in the absence of human activities affecting the fishing area or the stock.

• For each Eel River Basin (that is a term closely paralleling the River Basin District of the Water Framework Directive, but requiring further detailing), EU Member States will be obliged to prepare an Eel Management Plan, in which the above target is ensured by means of locally implemented measures.

• As an emergency measure, immediate restrictions to fisheries and other anthropogenic impacts have been proposed; details of this have varied from draft to draft, centering around a 50% reduction in mortality due to both fishing mortality and hydropower generation.

A decadal governance process

In the mid-1970s, the declining abundance and yield of the eel resulted in increased scientific interest in the dynamics of the eel stock (Thurow 1979). The European Inland Fisheries Advisory Commission EIFAC (a Commission of the FAO) and the International Council for the Exploration of the Sea ICES jointly (but in some periods separately) organized an Eel Working Group, which has since held meetings every one or two years (EIFAC/ICES 2006 is the most recent report). More than three decades after the start of this Working Group, the stock has dwindled to a fraction of former levels and is still slip-sliding. No management action has yet been implemented. Why was scientific advice developed so extremely slowly? Arguably, the fractal characteristics of the stock (single wide-spread stock, scattered over myriads of small-scale rural waters, with a meaningful differentiation on global and local scale; Dekker 2000a) hampered the development of adequate scientific advice and subsequent management action in the following ways:

• The small scale of most eel fishing in rural areas complicates the collection of essential stock-wide data, such as total fishing yield. Although the sum of all local fisheries is large enough to justify the collection of catch data, each separate local situation is considered negligibly small. In the essential decades of decline, almost no single country dedicated a permanent position on eel research. The inability to collect adequate basic data were the reason for abandoning the analysis of the stock decline in 1981 (EIFAC 1981) in favor of a free running "symposium style" meeting. The scientific community working on eels renounced their prime objective. Recent insights in stock-wide trends (Dekker 2000a, 2000b, 2003a, 2003b, 2003c, 2004a) are based on meta-analyses of local data. If and when a future international monitoring system will achieve a better coverage of the stock, this will constitute a major breakpoint in the available, but incomplete time series (Dekker 2005).

• Eel scientists analyze local stocks and fisheries, often in close co-operation with local fishermen. Due to high dependence and personal bonds, scientific views and stakeholder positions have sometimes been mixed, both in a positive or negative sense (e.g., Moriarty and Dekker 1997).

• Scientific observations and advice have been presented inadequately. European inland fisheries research and advice is co-ordinated by EIFAC, while ICES concentrates its efforts on marine research and advice. Since most eel scientists are more familiar with small-scale inland fisheries, EIFAC has been the dominant parental organization in the 1980s and early 1990s, while the Commission of the European Community deals more with large-scale fisheries and has a routine understanding with ICES. A priority switch in the mid-1990s (EU funded projects; prime communication through ICES) has improved the scientific communication to managers, though the typical inland aspects of eel management will require strong involvement of EIFAC too.

• The eel has been seen as small scale, economically insignificant business, while it is more likely to be the most wide-spread and highest-employing single fish stock in Europe. The objective of global stock protection and restoration is prioritized subjectively as if it concerns a localized problem.

In addition to these scale problems, there has been a strong belief that the development of aquaculture could substitute for the diminishing fishery (EIFAC 1985). However, in the absence of successful artificial reproduction, this industry still depends completely on dwindling natural seed stock. The aquaculture production since the mid-1980s meant increased competition for the fishery, but did not effectively result in substantially reduced exploitation and a recovery of the stock. Renewed interest in artificial reproduction now occurs, distracting political attention from urgent protection of the stock. Solving the artificial reproduction problem will require much more time, and won't be finished before the latest recruitment decline (in 2000) might have translated into a further decline of the spawner production (that is: before 2010).

Opinions and positions

The eel problem is a complicated enigma, in the sense that many stakeholders and parties are involved, and that most of these are scattered over all European countries. Since the development of an adequate governance system is still underway, it is definitely too early to compile a final overview of positions and opinions. Most statements are made informally or orally in meetings, and might be changed during further negotiations. Below, a brief and tentative overview is provided, as of Spring 2007.

The scientific community working on eel has issued a declaration of concern (Anonymous 2003), in which the deplorable state of eel stocks is highlighted and the urgent need to take protective measures is stressed. This declaration is largely in agreement with the scientific advice formally given. Within the scientific community, discussion exists on the causes of the decline, notably anthropogenic versus climatic causes, and on the appropriate severity of protective measures such as keeping fisheries in place or not; and focusing primarily on fisheries or taking account of other factors such as habitat modification and turbine mortality.

The relevant fishing sector is mostly weakly organized. National fishermen's organizations exist in most countries, but international cooperation is absent or informal, and no common position concerning management of the eel exists. Some national fishermen's organizations are represented in discussions with the Commission of the European Community, focusing primarily on their national interests. Although some individual fishermen around Europe doubt the decline of the stock or dispute its severity, the majority of fishermen and their organizations subscribe to the general downward picture. Discussions of the proposed restoration plans indicate that the need for a restoration plan is generally accepted, but that conflicts between national interests and between the fisheries on different life stages, dominate the thinking.

Nature conservationists have shown relatively little interest in eel, as the stock has always been abundant and heavily exploited. At national levels, conservationists' organizations have noted the decline, and have advocated restoration actions. Internationally, no coordinated action has been undertaken, except for the recent proposal to include the eel in Appendix II of the CITES convention (and for the EU, in Appendix B of EU Regulation COM 339/97) in which WWF-Sweden played a prominent role in the preparation (see also Ringuet et al. 2002). This proposal is now in a consultation process to be tabled at the 2007 meeting of CITES.

Angler organizations have recently taken an interest in eel. The European Anglers Alliance EAA has adopted a resolution in 2004 (EAA 2004), in which the bad state of the stock is recognized, and protective measures are advocated. The suggested actions agree reasonably well with the proposed regulation of the European Commission. The resolution is rather opportunistic, as it expresses no willingness to contribute actively to protection of the stock, leaving this to other stakeholders. This opportunistic attitude does not fully correspond with opinions expressed by national organizations.

The aquaculture industry uses live glass eel as an input, and is thereby just one of the users of a fishing product, and not directly involved in the management of the wild stock. However, fishing and aquaculture have always had a close link, in science, operation and trade. The Federation of European Aquaculture Producers FEAP has adopted a resolution in 2004 (FEAP 2004), in which the bad state of the stock is recognized, protective measures and further research are advocated, and research on artificial reproduction of the eel is urged. Although not stated in this resolution, the European aquaculture industry competes with Eastern Asian aquaculture for the scarce glass eel resource, and a ban on exports to China has been proposed. The resolution and the suggested export ban are rather opportunistic, since they express no willingness to contribute actively to protection of the wild stock on which this industry depends—while artificial reproduction is meant to release this dependence in the end. This opportunistic attitude does not fully correspond with opinions expressed by national organizations.

Water managers and hydropower companies across Europe are involved in the implementation of the EU Water Framework Directive (see above), which has some bearing on the management of the eel. Apart from this, some local projects focusing on eel migration have been executed, but no specific position on the eel issue has been taken.

National governments are involved in the discussion of the Regulation proposed by the European Commission. Generally speaking, the bad status of the stock and the need for action are well recognized. However, regional differences in fisheries characteristics have led most governments to focus on the conflict of interest between countries. In an earlier version (2003) of the restoration plan of the European Commission, a ban on silver eel fishing was proposed as an emergency measure. This proposal was not accepted as it was considered to restrict the northerly countries more than the predominantly glass eel fishing southerly countries, which caused a considerable delay in further developments. Final political discussions in Spring 2007 centered on financial consequences of protective measures for commercial fisheries in different countries. By focusing on conflicts between commercial fishing interests and financial consequences, national governments have implicitly ranked commercial fishing above other values, accepting the increased risk of a total collapse of the stock.

The European Parliament has unanimously accepted the 2005 proposal of the European Commission with minor amendments concerning a more realistic period for implementation, and some additional liberty for national governments to choose appropriate measures. Discussions between 2005 (proposal) and 2007 (decision) focused mainly on the type of legal instrument required. The European Commission proposed a Regulation that is obligatory and directly applicable in all member states, while others preferred a Directive that would be setting a common objective, but requiring Member State legislation for implementation. The latter legal instrument would parallel the Directives on Fauna and Flora, and on Water Policy, but would result in a slower implementation than justified, noting the state of the eel stock.

Overall, almost all involved recognize the bad state of the stock and endorse the need for protection and restoration. No lasting conflicts between parties or between countries have occurred.

Slipping Through Our Hands

The decline of the eel stock has been known for more than three decades, and has been extensively documented in recent years, potential causes have been discussed; available mitigation measures have been listed, management targets have been proposed; options for monitoring and post-evaluation have been explored, a conceptual framework for management has been suggested, a proposal for a recovery plan has been compiled, and the stakeholders and the general public have been alarmed about the bad status of the stock (Anonymous 2003; Dekker 2003d; many national publications by eel scientists—secondarily: Clarke 2003; Mackenzie 2003; Owen 2003; Stone 2003). However, the bottom line is that no action has been taken, and hardly any single eel has received adequate protection throughout its life. Why is timely and effective governance of the eel so obviously slipping through our hands? What can we learn from the past, to find better solutions for the future?

First, the species is vulnerable to fisheries and other anthropogenic mortalities, owing to such aspects as its longevity, its delayed semelparous maturation, its dependence on a series of interconnected habitats, its concentration in time and space during migration, and its high susceptibility to lipophilic pollutants. Clearly, protection and restoration will require a broad spectrum of actions, will involve many stakeholders, and will have to cope with a high degree of uncertainty. Indeed an effective and equitable action plan will be difficult to achieve. After decades of research, the picture of the dwindling eel stock is probably as complete as we can hope for. Precautionary action will have to cope with the unavoidable complexities and uncertainties involved.

The proposed framework for protection (see section on stock-wide governance) strongly resembles the principle of subsidiarity, meaning handling matters at the lowest competent level. For the eel case, however, national or lower level competence is incomplete. Since uncoordinated actions by individual parties are not likely to lead to a recovery of the stock, lower levels have no specific means to protect their resource, and therefore have no such aim. Unlike the subsidiarity principle, stating the objective and setting the target is necessarily an international issue meaning that the proposed EU Regulation is proportional and adequate, while the selection of actions and their implementation is most efficiently organized at lower management levels. Without authoritative international legislation, member states will not be inclined to act. For the marine fisheries, Member States transferred authoritative power to the EU under the Common Fishery Policy. For freshwaters, however, and for those aspects of eel protection that do not fall under the Common Fishery Policy, a Regulation is proposed that falls directly under Article 37 of the Rome Treaty. Effectively, this will require an additional transfer of power. The prolonged debate on the adequate legal instrument (see section on opinions and positions) indicates that some Member States prefer to keep a say in the matter, by influencing how a Directive is implemented in their national law. Moreover, the final political discussion in Spring 2007 focused on national commercial interests only. Thus, the "Tragedy of the Commons" persists for the eel.

Although the eel constitutes an international, shared stock, current research and management are almost exclusively based on national initiatives, without efficient coordination. ICES (2002) has proposed to establish an international commission, responsible for monitoring and research and acting as a clearinghouse, to facilitate and co-ordinate management action. This would parallel the North Atlantic Salmon Conservation Organization NASCO. The Action Plan proposed by the Commission (Commission of the European Communities 2003) considered the development of a management body under the FAO, but no follow up has been given. Establishment of such an international commission should enable a swift and cost-efficient development of management tools, and would enable exchange of experience and information between responsible agencies. More importantly, it might de-politicize current discussions, and thereby bring the "Tragedy of the Commons" to an end.

One has argued that eel management involves costs that are higher than the direct profits from eel fishing. True as this might be now, this argument disregards the value obtained before the historical decline, disregards the contribution of the eel to biodiversity, and disregards the societal value of rural economies (Moriarty and Dekker 1997). Moreover, acceptance of such a cynical approach undermines the general policy to protect natural resources. When resources are in a healthy state, protection is not required, while protection of dwindling resources can never be covered by contemporary exploitation of the resource. Acceptance of the fact that the eel slips through our hands, without taking adequate action, sets a dangerous precedent for future cases of declining species and thereby effectively undermines the general objectives of the Johannesburg Declaration on Sustainable Development (United Nations 2002). The symbol value of the weaker resources for common resource protection programs should therefore not be underestimated.

During the past century, from Schmidt (1906) to ICES (1999), the eel featured internationally, primarily as the subject of biological research. Scientists first noted the gradual decline in fishing yield (ICES 1976) and glass eel recruitment (EIFAC 1985), before they raised the alarm (Anonymous 2003). Fishers' organizations, anglers, conservationists, governments and political organizations have reacted only secondarily, and there is still no notable lobby for protection. The dominance of scientists among the spokesmen for the eel has blurred their role, venturing as far as taking up stewardship (e.g., Anonymous 2003) and leadership in the discussion about governance. Personally, I have deliberately undertaken this wider role during my period as chair of the EIFAC/ICES eel working group from 1996 to 2006 (Anonymous 2003; Dekker 2003d, in press). Following the proposals by the European Commission, the working group has re-focused on its typical tasks (EIFAC/ICES 2006), and its leading role in advocating protection has ended. Consequently, the posts of leadership and stewardship are vacancies. Administrators are legally bound to reach agreement with other parties (EU Commission and EU Parliament, both with the Council of Ministers). Others are usurped by internal rivalry, such as within fishers, governments, and thereby the Council of Ministers, or competition between fishers, anglers, and aquaculturists. Nature conservationists, however, do not suffer from these drawbacks, and could, or maybe should adopt both roles.

The legal basis for protection of the eel is currently fragmented and insufficient. In some countries, the species is effectively *res nullius*, while in others the stock in privately owned water is considered *res privata*. On the European level, three separate Directives and the Common Fishery Policy apply, possibly extended soon with the proposed

EU Regulation on eel. Mutual tuning and synchronization of legal instruments should facilitate implementation of protective measures. However, the ongoing discussion on regulative issues (see section on opinions and positions) completely masks the absence of a normative discussion, while the opportunities for protection and restoration of the stock are fading (EIFAC/ICES 2006). When nature conservationists would adopt the stewardship and leadership role, as suggested above, the goal of immediate protection should be their guiding light.

The eel is a weird fish. Several aspects of its biology, including the reproduction, are still essentially unknown. Considerable effort has been spent to unravel the eel mystery. Even if eel fisheries were banned immediately and completely, recovery of the stock is expected to take several decades or more (EIFAC/ICES 2006). None of the biologists involved in the advisory process, nor the politicians deciding on protection, nor the fishers involved or affected by the protection plan may live to see the recovery happen. Therefore, time is pressing to seize what may be the last chance during the forthcoming decades to unravel some of the mysteries of the eel, and to plan and execute a broad and well-coordinated research program on eel biology in the coming years.

Eels are not as attractive as pandas, nor as elegant as swans, and not as voracious as sharks, nor dangerous like venomous snakes, and yet they have icon value. Ever since Aristotle described how he scraped out an isolated pool, to find new eels after the rain had replenished the pool (spontaneous generation!), the curious biology of the species has puzzled mankind. Following the remarkable identification of *Leptocephalus* as the larvae of the eel by Grassi and Calandruccio in 1896 (Grassi 1897), Johannes Schmidt's quest for the spawning places, ending in the far-out Sargasso Sea (Schmidt 1923), has become a well-known legend. Eels that migrate over land, that are caught in dead horse heads, that mate with snakes in the dessert, and that are as slippery as their proverbs—all this deserves a better press than just some small fishery, unavoidably demising in modern times.

In medieval times, it was said *Anguilla est, elabitur*[1]—and yet *Folio ficulno tenes anguillam*.[2]

Postscript

In the period from the initial draft to the final manuscript for this article, governance for the eel was rapidly developing, among many others also influenced by an early draft circulating among stakeholders. The final text reflects the situation as of Spring 2007. Following lengthy discussions in the Council of Ministers in April and May on one specific restoration measure (re-stocking) and its costs, the EU Regulation proposed by the Commission has finally been accepted on June 11, 2007. On the same day, the proposal to list the eel in Appendix II (EU App. B) of the CITES convention was accepted too.

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[1] It's an eel—it's slipping away!

[2] You can grip an eel using a fig leaf.

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