Management of the eel is slipping through our hands! Distribute control and orchestrate national protection.

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Abstract

Following a multi-decadal decline of the European eel stock all across the continent, the EU adopted a protection and recovery plan in 2007, known as the Eel Regulation. Implementation, however, has come to a standstill: in 2015, the agreed goals had not been realised, the required protection had not been achieved, and from 2012 to 2015, no further reduction in mortality has been accomplished – while the stock is at a historical minimum. To analyse this manifest impasse, this article characterises the steering framework of the Eel Regulation as a governance problem. The Eel Problem is found to be extremely complex, due to many knowledge uncertainties and countless societal forces having an influence. The Eel Regulation divides this complexity along geographical lines, obliging national governments to implement national protection plans. This deliberate distribution of control has improved communication between countrymen-stakeholders, and has stimulated protective action in most EU Member States and elsewhere. In the absence of adequate international coordination and feedback on national plans, however, coherence is lacking and the common goals are not met. Actions and achievements have been assessed at the national level, but these assessments have not been evaluated internationally. Full geographical coverage has not been attained, nor is that plausible in future. Meanwhile, ICES' advice remained focused on whole-stock management, a conservative approach not matching the structure of the Eel Problem or the approach of the Eel Regulation. Hence, essentially localised problems (non-reporting, insufficient action) now lead to a hard fail, paralysing the whole European eel recovery plan. Here I argue that immediate re-focusing protective actions, assessments, evaluations and advice on mortality goals and indicators, for each management area individually, will enable feedback on national protection plans, and in that way, will break the impasse.

Key words: European eel, *Anguilla*, protection, governance, impasse, uncertainty, hard fail, distributed control, feedback, mortality limits.

Introduction

The stock of the European eel *Anguilla anguilla* (L.) is at a historical minimum. In 2007, the EU adopted a European recovery plan (Anonymous, 2007a), but recent post-evaluation indicates that implementation has come to a stand-still (ICES, 2016). This article analyses the background of this stagnation, discusses the steering framework of the recovery plan and the role of scientific advice, and suggests improvements.

Since the mid-1900s, fishing yield of eel has diminished to below 10 % of the quantity caught before, and over the last three decades, recruitment of glass eel has rapidly fallen to 1-10 % of the 1960-1970s level (Dekker, 2004; ICES, 2016). In 2007, the European Union adopted a protection and recovery plan for the eel (Anonymous, 2007a). This so-called 'Eel Regulation' instructed EU Member States to develop national Eel Management Plans by 2009, aiming at a common objective: to reduce anthropogenic mortality in order to restore a spawner run of at least 40 % of the notional pristine run. Accordingly, national management plans have been developed, protective actions have been implemented and more information on the status of the stock has been compiled in nineteen EU countries.

Since the adoption of the Eel Regulation, the absence of reliable catch and effort data for the stock as a whole has made ICES invariably advise on precautionary grounds – to reduce all anthropogenic mortality to a minimum (ICES, 2007, 2015a). ICES has not evaluated the Eel Regulation.

National post-evaluations in 2012 have shown that most countries by far did not reach the objectives specified in the Eel Regulation and – noting the high average anthropogenic mortality reported – these objectives are very unlikely to be approached in future (ICES, 2013a). Post-evaluation in 2015 recently indicated that hardly any improvement in the status of the stock has been achieved, and that – on average – mortality has not been reduced any further since 2012 (ICES, 2016). That is: implementation of the European recovery plan has essentially come to a standstill, while the required protection has not been achieved.

In this article, I will argue that the international scientific advice plays a key role in this impasse. The conservative advice, focused on whole-stock management, does not lead to effective management of a stock as unconventional as the eel. Analysing sustainable management of the eel as a steering problem, the setup of the Eel Regulation is evaluated as a viable model. But without scientific advice providing feedback on its operation, it will fail hard.

In the following, I will present a brief description of the eel, its fisheries and other anthropogenic impacts (the system to be controlled), and discuss the ways the eel has been managed in the past and since the adoption of the Eel Regulation (the controlling system). Subsequently, I will analyse eel management as a complex governance problem and the Eel Regulation as a simple cybernetics system, identifying bottlenecks and breakdowns in current eel management. Finally, suggestions will be given, to slip out of the impasse and to get better grip on the eel's recovery.

Eel, fisheries and other impacts

The European eel occurs in habitats as diverse as the open ocean, high seas and sheltered coasts, large lakes and small ponds, main rivers and smallest streams. Continental habitat-units are typically less than 10 km^2 in size (Dekker, 2000). Yet the eel constitutes the most widely distributed single fish stock in Europe, spread all over the continent and the Mediterranean (Europe, northern Africa and Mediterranean parts of Asia; Dekker, 2003a). Natural reproduction has never been observed in the wild. The occurrence of the smallest larvae in the Sargasso Sea indicates the most likely location of the spawning place (Schmidt, 1922). Noting the remarkably low genetic variation observed in eels from continental waters, the whole stock is considered to constitute a single panmictic population (Palm *et al*., 2009). However, it is not known which part (or all) of the continental distribution actually contributes to the oceanic spawning stock. Spent eel has not been observed returning to the continent; they are supposed to die in the Sargasso Sea, spawning only once in their lifetime (semelparity).

In almost the whole distribution area, commercial eel fishing provides an essential income to small-scaled inland fisheries (Moriarty and Dekker, 1997; Dekker, 2003a; Dekker & Beaulaton, 2016a). The targeted life stage varies by region. Glass eel, recruiting from the ocean towards the continent, is exploited in the countries around the Bay of Biscay. Silver eel, returning to the ocean after 3-30 years on their spawning migration, is fished throughout the distribution area, and dominates in areas of low abundance, especially in the north. The growing stages in-between, the yellow eel, is exploited throughout the distribution area, though less in areas of low abundance. Recreational fishing for eel is wide-spread, but rarely documented (e.g. Dorow, 2014; van der Hammen *et al*., 2015).

In addition to these fisheries, many other anthropogenic activities have an impact on the stock, including land reclamation, water management, water pollution, hydropower generation, and many more. Their impacts vary from country to country, as well as from habitat to habitat type. Recent assessments (ICES, 2016) indicate that fishing and non-fishing mortalities often have a comparable impact.

Over the decades, fishing yield has gradually diminished by approx. 5 % per year to below 10 % of the quantity caught half a century ago (Dekker, 2003b; ICES, 2016; Figure 1), and there are unquantifiable indications of a substantial decline before (Dekker & Beaulaton, 2016a). Since 1980, recruitment of glass eel has rapidly fallen by approx. 15 % per year to 1-10 % of the 1960-1970s level (Dekker, 2000; ICES, 2016; Figure 2). Since 2010, however, recruitment indices have generally turned upwards, though not in 2015.

From 2011 to 2014, the average reported survival from anthropogenic mortality decreased from 14 % (in comparison to a situation without any anthropogenic mortality) to 11 %, while the estimated spawner escapement went slightly up from 8 % to 10 % of the pristine escapement (ICES, 2016). That is far below the objective of the Eel Regulation of 40 % escapement, while a survival from anthropogenic mortality below 40 % is not likely to enable approaching that objective (Dekker, 2010).

The long-lasting downward trends in stock and fishing yield have been noted through times, all across Europe (Italy: Bellini, 1899; France: Anonymous, 1865; Germany: Walter, 1910; Sweden: Puke, 1955; European: EIFAC, 1968; Dekker, 2003b). Since the mid-1800s, attention of managers and scientists focused on optimistic compensation measures, including artificial reproduction and restocking, but these measures have failed to sustain the stock (Dekker and Beaulaton, 2016a). Artificial reproduction has not been achieved. Instead, young recruits are taken from the wild and raised in (indoor) culture facilities, a practice known as aquaculture. Aquaculture made a slow start in the 1960s, and since 1995, its production exceeds the fishing yield in the wild (Figure 1).

The existing management system

Traditionally, eel fisheries throughout Europe have been managed as freshwater fisheries, on a very local geographical scale. Objectives were often unspecified, and governmental actions predominantly focused on local conflict resolution, among fishers or between fishers and non-fishing stakeholders involved in water management, hydropower generation or many land uses (Dekker, 2008). In the late 1800s, technical developments (glass eel restocking, eel-ladders, gears, hot-smoking, long-distance trade, etcetera) led to a rapid exchange of expertise all over the continent, but not to coordinated action. It was only in 1925, that German glass eel imports from England to Hamburg for restocking were shared with neighbouring countries – but that cooperation ended in World War II, and did not resume afterwards (Dekker and Beaulaton, 2016b).

Deelder (1970) summarised existing protection and management, without even considering management of the whole stock. Local management actions were strictly aimed at improving the income of fishers. Actions included minimum legal sizes, closed seasons, restocking, restricted licensing, gear restrictions, and more. Figure 3 presents an example of how complex national legislation often could be, and in many cases still is.

The majority of eel fisheries are small-scaled and scattered over rural areas. Larger concentrations (e.g. Comacchio, Lough Neagh, and L. IJsselmeer) are rare, and jointly, these exploit only a few percent of the total stock (Dekker, 2000). More often, fisheries, and its interactions with non-fishing stakeholders, occur in very local settings with little governmental involvement. Consequently, the boundaries between documented and undocumented, commercial and non-commercial fisheries, recreational catch and poaching can be extremely vague (ICES, 2016).

For the interactions with non-fishing stakeholders, there is ample evidence of early (e.g. water management), frequent (e.g. agricultural pollution), wide-spread (e.g. migration barriers) and overwhelming (e.g. industrial spills) impacts on local eel stocks. Commonly, eel fishing ranked below the interest of competing stakeholders (e.g. hydropower generation). Impacts thus being accepted, sometimes mitigated (e.g. elver ladders) or compensated (e.g. restocking) – but rarely fully remedied – detrimental effects on local eel stocks ordinarily persisted. In most cases, governments initiated mitigation and compensation programmes, often funding and controlling implementation themselves.

Ultimately, the decline of the stock over the whole continent led to a call for international action (EIFAC, 1968; Dekker *et al*., 1993; Sjöstrand & Sparholt, 1996; Dekker, 2003c; Dekker *et al*., 2003; Dekker and Casselman, 2014). Since the early 1970s, the European Inland Fisheries Advisory Commission (EIFAC, 1971) and the International Council for the Exploration of the Sea (ICES, 1976) organised a standing Eel Working Group, to document the status of the stock and to investigate potential mitigation measures. Although this group eventually discussed the need for continent-wide protection in the 1990s, its recommendations primarily focused on national or even localised protective measures.

The state of Monaco (1996) was the first to propose continent-wide coordinated action, under the Bern Convention – but when others questioned the need for action, Monaco disappointedly withdrew its proposal. Meanwhile, the European Commission had asked (Cavaco, 1997) and received scientific advice (ICES, 1999) on the alarming state of the stock. Following a period of stakeholder consultation and deliberations, the Commission proposed establishing detailed targets for eel abundance in each life stage, across all rivers in Europe (Anonymous, 2003). Existing knowledge, however, was considered insufficient to develop such a system. Emergency measures were investigated, but equitable and effective measures were hard to find. Ultimately, a fortnightly closure of all fisheries throughout Europe was proposed (Anonymous, 2003).

Subsequently, Dekker (2004, 2009) questioned the need for a detailed international control over all rivers and lakes. Local eel stocks in different catchments interact only through the oceanic life stages. Hence, international interventions in national management practices need only concern the inputs (glass eel) and outputs (silver eel) of national systems, not their internal state and local means and consequences. Setting a shared target for silver eel outputs at the international level, taking into account (past and present) glass eel inputs, could suffice to protect the oceanic stock - while the means to achieve those targets in each particular river could be managed under national responsibility. Though somewhat naively expressed in common words, Dekker (2004, 2009) essentially proposed a system of distributed control (Trentesaux, 2009), under the supervision of international orchestration and coordination. Following this proposal, the European Union adopted a stock recovery plan, the Eel Regulation (Anonymous, 2007a), in which common objectives, uniform reference points and an international evaluation process were specified, while design and implementation of protective actions and monitoring were delegated to the Member States. Accordingly, Member States developed national Eel Management, either for their whole territory or for specific areas, so-called Eel Management Units (often in accordance with the Water Framework Directive river basin districts; Figure 4).

In complement to the Eel Regulation, a proposal to list the European eel on Appendix II of the CITES convention was prepared (Anonymous, 2007b), which was adopted on the same day as the Regulation and came into effect in spring 2009. Since the end of 2010, trade of European eel to or from the EU has been prohibited; internal trade is not affected.

Eel management as a steering problem

In past decades, radically different steering frameworks for management of the European eel stock and fisheries have been attempted: uncoordinated local action (traditional); uniform actions throughout Europe (initial discussions in EU); and a hierarchical system of distributed control (the Eel Regulation). The first has failed; the second was considered unworkable; and the third is now sliding into an impasse. In order to analyse this sombre track-record, I will apply a typology of steering strategies developed by Voß *et al*. (2007). Obviously, this typology is not set in stone, but the line of reasoning on which it is built might shed some light on the issues involved in the current impasse. The typology of Voß *et al*. characterises steering problems in three dimensions: the ambivalence of goals, the distribution of power, and the uncertainty in knowledge (Table 1). First, I discuss each of these dimensions for eel; then I type-cast the eel in this typology, and type-cast the steering model of the Eel Regulation.

Ambivalence of goals

Historical sources rarely identify the goals of management actions, but their actions and expectations often allow us to deduce implicit objectives (Dekker & Beaulaton, 2016a, b). Before the mid-1800s, fishers have been exploiting local eel stocks, and conflict resolution between them has been the prime goal of governmental interventions. Other fisheries (e.g. on salmon: Anonymous, 1958; on crayfish: Svärdson, 1972) experienced the eel as an unwanted competitor or a voracious predator, leading to further conflicts between fishers. Additionally, commercial and recreational fishers often had conflicting interests.

In the late-1800s, non-fishing impacts had seriously deteriorated the habitats, and actions were initiated in many countries to expand or recover local eel fisheries. Though stated objectives and actions were clearly and unanimously aiming to support the fisheries, a clash of interests with non-fishing stakeholders (water managers and many land-based actors) was the ultimate reason to act. At best, those non-fishing stakeholders intended to minimise their (compensation costs for) collateral damage to the eel stock, but otherwise, they had no objectives on eel by themselves.

It was only in the late 1990s, after the crash in glass eel recruitment had begun, that focus gradually shifted towards protection and recovery of the depleted stock. Those objectives now dominate the discussions, though support for the waning fisheries is also pursued. The Eel Regulation formulates its aims as “protection and sustainable use”, but societal discussion remains whether the state of the stock currently allows any exploitation or not (e.g. Seeberg *et al*., 2015).

The international discussion on protection and recovery has been initiated by scientists, and the Eel Regulation was compiled and debated primarily in discussions with and among national governments. Consulted stakeholders (anglers, conservationists, water managers, hydropower industry and most fishers) participated in that process only marginally (Dekker, 2008). Hence, it is rather doubtful to what degree opposing forces have really united on the common goals – though few parties nowadays doubt the depleted state of the stock, or doubt the need for protection.

In conclusion: there is a recent unification on protection and recovery as a minimal precondition for all anthropogenic impacts on the stock.

Distribution of power

“Who is in charge here? […] In modern political life, the power to influence outcomes of societal processes is shared across society” (Meadowcroft, 2007), and fisheries management is no exception to that. Amongst other fisheries, however, management of the eel appears to be one of the most complex cases, due to the extreme number of parties involved. First, like any other inland fishery, the small size of typical habitats amidst many other human activities results in frequent interaction with many other (land-based) stakeholders. Additionally, there are multiple fishing stakeholders (commercial and non-commercial fisheries, recreation and poaching). Secondly, the vertical layering of political jurisdictions involved in eel management may concern local fishers, water owners, municipalities and provincial authorities, national and international governments – each of them often represented by different functional divisions. Finally, the sheer scattering of the stock over all of Europe and the Mediterranean means that each of the powers described in the previous sentences occurs in an endlessly replicated form, with endless small variations (Dekker, 2000).

The historical decline of the stock indicates that uncoordinated actions by local managers alone could not sustain the stock. Following the total ban on eel exports from Europe in 2010, evidence on substantial illegal exports of glass eel out of Europe (Shiraishi and Crook, 2015) illustrates the limits of centralised powers. In conclusion: to recover the depleted eel stock, cooperation from an extremely numerous and diverse group of entities, high and low, big and small, is required.

Uncertainty in knowledge

Effective steering requires knowledge of the system state, its dynamics, and a realistic view on available options. Below, I will discuss the uncertainties in each of these.

System state

Though it has taken decades to figure out the continental scale of the locally observed downward trends (Dekker, 2004; Dekker and Beaulaton, 2016a), the current depleted state of the whole stock is now well recognised (Jacoby and Gollock, 2014). In on-going debates, some still deny or question the facts, but with diminishing impacts on the discussions.

The stock is scattered over a myriad of small habitats all over Europe and the Mediterranean. Compilation of stock-wide statistics (e.g. recruitment, abundance, landings, etc.) is hampered by the absence of information from many areas, and incomparable statistics from many others (ICES, 2016). Local monitoring, on the other hand, is easily adapted to local information needs, but these rarely match the stock-wide information needs. Though coordination and standardisation can undoubtedly improve, it is unlikely that local monitoring agencies address the stock-wide requirements adequately, or that a stock-wide assessment can cope with all locally relevant details. Bounded rationality - of the local monitors, and of the international compilers - restricts our view on the status of the stock at a far from “near-optimal” level (Simon 1955).

Both the scientific advice on reference points (ICES, 2002) and the objective of the Eel Regulation refer to a percentage of pristine spawner production. Since the estimation of pristine production is far from straightforward (including or excluding habitats lost, restocking, human-induced eutrophication, increased abundance of cormorants, etcetera) and often highly speculative, the reference to a percentage of an unknown, notional quantity incorporates a high degree of uncertainty in the perception of the current state of the stock.

System dynamics

For the development of national management plans, all Member States constructed some model to quantify their stocks and to assess the effect of their protective actions (ICES, 2013b). Implicitly, this presupposed that local stock dynamics were well understood and quantifiable – even complex processes such as potential density-dependence of growth, mortality and sex-determination. Noting the on-going scientific debates about, among others, carrying capacity and about natural mortality, national assessments in general had a rather optimistic view. In particular, the slow but persistent decline of the continental stock in the decades before the onset of the recruitment failure is rarely addressed (Dekker, 2004; Dekker and Beaulaton 2016a) and not understood.

Since 1980, glass eel recruitment across Europe has shown a downward trend (Figure 2), which persisted until 2010. For the causes, it has been hypothesised that either spawner escapement from the continent might have been restricting the production of progeny (Dekker, 2003b), or spawner quality (ICES, 2015b), or oceanic survival and productivity (reviewed by Miller *et al*., 2009). The rather abrupt onset (in 1980) and prolonged duration of the decline (an almost constant rate of decline of 15% per year over three decades) remains largely unexplained, though Dekker (2004) speculated on a depensatory stock-recruitment relation. In the absence of conclusive evidence to either side, ICES recurred to precautionary advice: to reduce anthropogenic mortalities in order to restore spawner escapement, provisionally aiming at 30-50 % of the pristine escapement (ICES, 2002). Whether an increase in spawner escapement will indeed restore recruitment remains to be seen.

Predictability and uncertainty

Glass eel recruitment is currently at 1-10 % of its abundance before 1980. Hence, even if all anthropogenic mortalities would be reduced to zero immediately, it is unlikely that spawner production can restore to the level aimed for by the Eel Regulation (40 %) within one generation. In fact, a speculative assessment of the full life cycle dynamics indicates, that at least four generations might be required, and much longer so if mortality cannot be zeroed completely (Åström and Dekker, 2007). Planning protective actions with effects a full generation time ahead (3-30 years) involves a high degree of uncertainty, and the stronger so for multi-generational effects. The reproductive process in the ocean undoubtedly involves spawners derived from much more than a single Eel Management Unit in continental waters. Multi-generational effects in individual Eel Management Units depend strongly on future recruitment, which in turn depends on (future) spawner abundance, and thus on protective actions in other Eel Management Units. Because of this interdependence between management units, a goal formulated in terms of (future) spawner biomass is fully unpredictable for the individual management unit, until it has been nearly met.

Several Member States decided in their national management plans to intensify research on topics such as artificial reproduction, restocking, eel ladders, screening of migration barriers, and more. The effect of some of their protective measures relies on the success of that research to solve the knowledge problems and some measures were postponed until such was achieved. Noting that some of these research lines have been pursued for over a century, and all of them for many decades, without solving the underlying problems, the expected success-rate of this approach appears to be less than optimal (Dekker and Beaulaton, 2016a).

Summarising the above discussion of the system state, its dynamics and predictability, a number of crucial uncertainties has been identified. These fall into two distinct groups: short-term local problems (local stock dynamics) versus long-term global issues (dynamics of reproductive phase, multi-generational effects, spatial coverage and intensified research).

Type-casting the Eel Problem

In the 1800s and 1900s, eel fisheries developed in many countries in parallel: sharing the aim to develop (restore) national fisheries, uncoordinated actions were taken across the stock, with a high level of uncertainty (though the latter was not foreseen in the mid-1800s). In the typology of Voß *et al*. (2007; Table 1), the poor understanding of the dynamics of the stock, and the divergent objectives of fishing and non-fishing stakeholders definitely classify those developments as Awkward Drifting. Contemporary people involved in eel management, however, usually focused exclusively on the development of the fisheries (a shared objective) while ignoring the other impacts. Additionally, one had an over-optimistic view on the effectiveness of the mitigation measures (perceived understanding of system dynamics, ignorance of the deteriorating system state. Dekker & Beaulaton 2016a). Hence, the development of the eel fisheries was historically perceived as Collective Action, all over Europe. In as far as the poor understanding of eel biology was faced - in particular considering the unknown reproduction ("the Eel Problem") - the hope to, one day, find the spawning places and to achieve artificial reproduction remained – a Utopian deadlock, that persists until today (Dekker & Beaulaton 2016a). An extremely prolonged decline in fishing yields; recruitment crashing after 1980; a continued poor understanding of eel biology; fishers uninvolved, often in denial; ignorance from non-fishing stakeholders and governments; and scientists alarming for years – Awkward Drifting it was.

Following the adoption of the Eel Regulation in 2007, there is now unanimity on the need to protect and recover the stock – though the unanimity concerns the objectives, not the means. Restocking and fishing restrictions are the main tools of the Eel Regulation to achieve a rapid recovery, and both are considered controversial (e.g.: Westin, 2003 versus Brämick *et al*., 2016 on restocking; Seeberg *et al*, 2015 versus sources quoted in van Herten and Runhaar, 2013, on fishing). Addressing the resulting Utopian deadlock, some (national management plans, fishing stakeholders) promote intensifying research (reducing uncertainties to achieve Collective Action), while others (conservationists) call upon the central force (the EU Commissioner) to accrue more power and close all fisheries (act as a Blind Goliath, setting forceful but untested measures). Noting on the one side the unpredictable outcome of research, and on the other side the many non-fishing impacts and the limited central power, neither of these advocacies will constitute a secure tactic to break the Utopian deadlock. Actually, the disagreement on the means appears to drown the unity on the objectives in ongoing discussions, leading to a relapse to Awkward Drifting.

Type-casting the Eel Regulation

The current impasse in the implementation of the Eel Regulation signals a continuation of the historical Awkward Drifting. Is that due to "bungling craft and lacking will" (Voß *et al*., 2007), or is there a more fundamental shortcoming in the steering framework of the Eel Regulation? To examine this, I will analyse the Eel Regulation as a supervised system of distributed control, successively type-casting the dispersed management units, the central supervision and their interrelations. Alternative steering systems will be contrasted in the Discussion.

National management plans

In accordance with the Eel Regulation, nineteen EU Member States have developed and implemented national Eel Management Plans (Anonymous, 2014), for 89 Eel Management Units in total. In 2012, estimates of biomass of the silver eel run were reported for 56 areas, and independent estimates of anthropogenic mortality for 39; in 2015, 80 areas reported on biomass, and 31 provided independent estimates of mortality (ICES, 2016). This indicates that the majority of areas considered their understanding of local stock dynamics to be sufficient to develop an assessment, although these assessments have not been evaluated independently.

The level of stakeholder involvement has varied from country to country – but to my knowledge, no international overview of the societal discussions on Eel Management Plans has been compiled. Though fierce discussions between opposing stakeholders occurred and still occur in many countries, nowhere have conflicts completely blocked the development and implementation of national management plans.

According to the Eel Regulation, the objective for all national management plans shall be "to reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40 % of the silver eel biomass [relative to the notional pristine biomass]". Though this objective is first and foremost centred on a reduction in mortality, most national Eel Management Plans have expressed their goals in terms of biomass (or numbers), and have focused their post-evaluation on biomass indicators. Those Eel Management Plans generally note well that achieving the biomass goals from the current poor recruitment is beyond their own control (e.g. Brämick *et al*., 2016). Apart from this inability to control, the choice for out-of-reach biomass goals has led to pointless discussions on their quantification (e.g. Eijsackers *et al*., 2009) and increased tension between opposing stakeholders (e.g. van Herten and Runhaar, 2013). Refocusing future post-evaluations on mortality indicators, on actually achievable protection levels, will refocus the discussion on controllable aspects, can reduce uncertainty in the evaluations, and reduce conflicts between opposing stakeholders.

In theory, the development of national Eel Management Plans could classify as a case of successful Collective Action: agreement on the objectives to protect and restore national stocks; no major obstacles due to misunderstanding the system state and dynamics (or existing ones can be solved by refocusing on mortality goals and indicators); and cooperative involvement of all EU Member States and stakeholders. In reality, the recent post-evaluation evidences that current national control is ineffective, revealing the incapacity of many governments to achieve their objectives on eel protection on their own (ICES, 2016). While each national Eel Management Plan strives for a Utopian recovery, the Awkward Drifting effectively continues.

International coordination

Distributed control systems can range from fully supervised, strongly hierarchical systems to unsupervised, heterarchical systems (Trentesaux, 2009). Until recently, the eel was managed by a fully unsupervised management, on local objectives only – but the historical stock decline has evidenced the failure of this approach. At the opposite end, authoritarian centralisation has been advocated recently (e.g. Svedäng and Gipperth, 2012; Seeberg *et al*., 2015), but this approach has never been applied for eel before. Though authoritarian centralisation might be feasible, introducing such a radical overhaul of the management system, now, would bring about many avoidable risks in a time of crisis. Therefore, I will approach the problem here from the reverse side, in a conservative and risk-averse approach: identifying the minimum functionalities of the supervisor, i.e. those functionalities that are not or cannot be covered by the dispersed management units. Three aspects will be discussed: cooperation among management areas (including their communication), coherence of their actions, and control-uncertainty (Decker, 1987).

Horizontal cooperation and communication among areas on eel management have never occurred in history (with the exception of the German restocking supply to other countries in the 1920s and 1930s). Rivalry or local conflicts between countries dominated discussions (Dekker, 2008, 2009). Since the adoption of the Eel Regulation, however, there is general agreement on the objectives to protect and restore, and national action is taken by countries in parallel. Nonetheless, horizontal communication and cooperation between countries are still uncommon, and these are exclusively focused on shared waterbodies. To establish adequate communication and cooperation for the whole stock, supervisory orchestration is required.

In the years following the adoption of the Eel Regulation, a standardised reporting system for national stock indicators has been developed, that allows for mutual comparison, international integration and evaluation against the targets, at a minimum of communication costs – the so-called 3B&ΣA indicator system (Dekker, 2010; ICES, 2010; ICES, 2016). This reporting system is focused on the quantification of the silver eel run (Biomass of the current run, Biomass of the potential run without anthropogenic impacts, and Biomass of the notional pristine run; the 3 B's) and their relation to the incoming recruitment, i.e. the lifetime ('∑') Anthropogenic mortality ΣA. This exceptional assessment framework is adapted to the peculiarities of the eel. For any semelparous species, the spawning stock size is directly related to the lifetime mortality, more than to conventional annual mortalities. For eel, both once-in-a-lifetime as well as continuously impacting anthropogenic mortalities occur. Since average lifetimes may vary from 3-30 years, depending on the location, these different mortalities are difficult to compare when expressed on a per annum basis. Hence, the choice for a lifetime mortality approach, relating the silver eel output directly to the glass eel input from which it originated.

Though not quite all countries provided estimates of the 3B&ΣA indicators, the vertical communication between the national authorities and the international level, as well as the international integration based on these indicators were effective: the achievements by area were assessed and problems (non-reporting or under-achievements) identified (ICES, 2016; Figure 4, Figure 5). However, that information has not been used in providing management advice (ICES, 2015a), and so far no supervisor feedback on the achievements of national management plans has been given (Anonymous, 2014). That is: the upward communication of assessment results (sensory information) has been achieved, but the downward communication providing feedback on achievements (actuator signals) has not. Without two-way communication, the supervisory feedback system is doomed to fail.

Since the adoption of the Eel Regulation, nineteen EU Member States have implemented protective actions. All those protective actions will have benefitted the recovery of the eel stock to some degree and at some time – no countries have reported antagonistic behaviour. Though global coherence has thus been achieved in principle, major differences exist between countries, in the degree to which their goals have been achieved. The estimates of the silver eel run reported by different countries for 2014 (ICES, 2016) range from 1 % to 55 % of the pristine biomass; net survival from anthropogenic mortalities ranges from 2.5 % to 96 % (in comparison to a situation without any anthropogenic mortality). While some countries transcended, others by far did not even reach the common goal. That is: no full coherence has been achieved, and gains accomplished in some countries have been annihilated by the underachievement in others. To improve coherence, the international supervision will need strengthening, providing feedback to countries on their individual achievements.

Uncertainty in the control-information is a major issue. It has been the reason for ICES to recur to default precautionary advice (ICES, 2015a). Incomplete data coverage, untested data quality, a wide range of incomparable and unevaluated assessment methods have been mentioned. All of these issues occurred in the 2012 post-evaluations, and remained in the 2015 post-evaluations – signalling a lack of standardisation between management units, and their inability to address their common problems. Strengthening the international orchestration and coordination will be required to reduce this uncertainty. Additionally, a major control-uncertainty stems from the incongruity between the control-information and the control-decisions (Decker, 1987): the mismatch between, on the one side, ICES advice – addressing a centralised, top-down management model – and, on the other side, the Eel Regulation and national Eel Management Plans – implementing a distributed control system.

Type-casting the supervisory control system of the Eel Regulation according to Voß *et al.* (2007), there appears to be no doubt on the objectives and goals, and agreement on the need for a supervisory power. In the absence of adequate control-information, however, the international supervision does not achieve Full Control, but acts as a Blind Goliath.

Discussion

The eel is an extraordinary fish, and managing this fish might call for unconventional approaches. Traditional eel management was based on uncoordinated local action, as for a typical freshwater fish. Current scientific advice by ICES is focused on a whole-stock approach, as for a typical marine fish. But the eel is neither, and the analysis of the ambivalence in goals and the distribution of power, discussed above, indicates that neither the ‘freshwater’ nor the ‘marine’ steering model is likely to be effective. Whatever steering model is embraced, one has to deal with uncertainties and unknowns, the most prominent ones being the incomplete understanding of the population dynamics, the imperfect information on the status of the stock, and the absence of a well-tried steering model.

To deal with the latter uncertainty (absence of a well-tried steering model), I have tested the typical freshwater approach (uncoordinated), the typical marine approach (centralised), and the Eel Regulation (distributed under supervision) against the criteria of a typology of steering models (Voß *et al*., 2007). This identified likely grounds for management failures in past and present. Applying this typology to examine alternative steering models, however, I run the risk of overrating the criteria of the typology as normative conditions, when their universal value has been questioned (Meadowcroft, 2007). Is the approach of the Eel Regulation a viable option, or the only feasible one? Rather than addressing that type of questions, Voß *et al.* (2007) state that "[applying] this typology allows for deliberation of the match between the problem and the strategy in [this] particular context of steering for sustainable development".

The objective of the Eel Regulation is alternately worded as either "the protection" (e.g. Article 1) or "the recovery" (e.g. the title of the Regulation) of the stock of European eel. Whereas protection can be achieved immediately and by each management area independently, recovery is necessarily a long-term, global objective, outside the competence of individual management areas, and overshadowed by uncertainties about stock dynamics. The effectiveness of steering towards sustainable management would greatly improve by refocusing in the short term on mortality goals and indicators, on protection. However, establishing an agreed level of protection does not guarantee a recovery, due to unavoidable uncertainties in stock dynamics. In the long-term, an international strategy will be required addressing those uncertainties. Mixing up short-term and long-term requirements, however, is confusing societal debates, and thereby postpones the urgently required protection.

The spatial coverage of management reports and monitoring information is by far not complete (Figure 4). Despite recent efforts to establish a major expansion in the Mediterranean (ICES, 2016), complete coverage is unlikely to be achieved, ever. This incomplete coverage increases the uncertainties at the international, long-term scale. Compensatory actions in other areas can be considered, but – in the absence of information on the non-reporting areas – these cannot be quantified.

In the absence of feedback on the status of the stock and the level of protection, societal discussions have drifted away from the objectives and achievements, towards questioning the means to protect, which have their uncertainties indeed. Local monitoring, evaluation and feedback would have dealt with these uncertainties by signalling the (in)-adequate results of actions taken, even in a rather short run. Without feedback, however, the control-decisions have become ambivalent, and irresolute actions are taken. Collective Action from national protection plans thus degenerates into Awkward Drifting, again.

The elusiveness of the eel and its management, the Eel Problem, is an extraordinarily complex issue. That complexity has troubled effective management for a century or more. The approach, adopted in the Eel Regulation, has been to divide the complexity along geographical lines, into independent parts that can be managed more successfully. This deliberate distribution of control has triggered societal discussions between countrymen-stakeholders, has initiated the national assessments of stock status and potential actions, and has (re)-focused national discussions on protection and recovery. Current scientific advice (ICES, 2015a), however, is focused on the whole stock (all of Europe and the Mediterranean). For the whole stock, though, no comprehensive assessment could be and will ever be achieved. Hence, restricted by the absence of control-information, international evaluation of control-decisions considered the implementation only; the achievements of national protection plans have not been evaluated (Anonymous, 2014).

Distributed control systems are renowned for their reliability, amongst others due to their ability to handle 'soft fails' (Decker, 1987): local problems can be handled locally, without paralysing the whole system. Incomplete data coverage, untested data quality, a wide range of incomparable and unevaluated assessment methods – all of these are wide-spread, but essentially local problems, which can be addressed locally under international orchestration. Analysis of the international advice on eel, however, indicates that the absence of reliable information from many areas currently blocks all feedback, even on other, more successful areas. Localised problems thus have led to a 'hard fail' of the whole system, obstructing the evaluation and adjustment of protective measures actually taken – and hence, the Awkward Drifting perpetuates. The whole-stock approach of the current scientific advice (ICES, 2015a) does not match the characteristics of the Eel Problem or the strategy of the Eel Regulation, and does not relate to on-going management actions. It is merely an echo of the advice given in 2000 (ICES, 2000).

Conclusions

In my opinion, the current impasse in the implementation of the protection and recovery plan for the European eel can be broken by immediately re-focusing all protective actions, assessments, evaluations and advice on anthropogenic mortality goals and indicators – considering each of the management areas (countries) individually. This will provide feedback to each area and all societal parties currently involved, and improve effectiveness and consistency of the protection given. Second priority, although no less urgent, is the compilation of a strategic plan to scrutinise and consolidate existing assessments and management plans, and to expand their spatial coverage, ultimately striving towards full geographical coverage of the whole population. Finally, but not as a matter of urgency, there is a requirement for a comprehensive strategy, on how to deal with all the uncertainties surrounding the long-term dynamics of the population – if a fully rational strategy may exist for this extraordinary fish at all. However, it is only through adopting distributed control and strengthening international orchestration that a feasible management model for the European eel can be developed, eliminating the most crucial uncertainty for the protection of this severely depleted stock. Only then can the current Awkward Drifting turn into successful Collective Action.

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Table 1 Typology of steering problems according to Voß et al 2007. Their table 1 (a list of cases) is slightly reworded and fully re-formatted here as a 3D-table. Horizontal: uncertainty in knowledge; vertical: ambivalence of goals; shading: distribution of power. The examples by Voß et al (2007) are given in italics.

	Knowledge and uncertainty		
	Not understood, high uncertainty	**Well understood, low uncertainty**	
	Utopia *Fighting detrimental effects of auto-mobility*	Collective Action *Commuters avoiding congestions*	**Shared**
	Blind Goliath *Natural parks managing ecosystem stability*	Full Control *Company management decisions*	**Central**
	Awkward Drifting *Global policy on sustainable development*	Clash of Interests *Extensions to public transport*	**Shared**
	Disoriented power *A moronic dictator issuing arbitrary decrees*	Value conflict *Decommissioning nuclear power*	**Central**

Figure 1 Time trend in eel production, combining fishing yield from the wild stock with aquaculture (using wild glass eel). Data from ICES (2013a); fishing yield for non-reporting countries has been reconstructed using the model of Dekker (2003b). For the fishing yield, the hatched part is what Dekker & Beaulaton (2016b) attribute to restocking. Data for later years are incomplete (ICES, 2016).

Figure 2 Time trends in 28 glass eel recruitment data series. Data from ICES (2016). Dashed lines: North Sea area; solid lines: elsewhere. Bold lines: general trends - see ICES (2016) for details on individual series and the trend analysis. Note the logarithmic scale of the vertical axis.

Figure 3 Minimum legal size limits over time in Swedish lakes and rivers, by ICES subdivision (SD) into which they drain; some lakes are identified individually, by name. Dashed: applied to silver eel in lakes but not in rivers, and to all yellow eel; solid: applied to all life stages in all waters. For coastal waters, another equally complex set of minimum size limits applied. (After Dekker et al., 2011).

Figure 4 Estimates of silver eel runs and management targets per eel management unit, reported in 2015. This figure presents the estimates as reported by the countries – inconsistencies in assessment methods and in interpretations exist. For each area, estimates are given for the current silver eel run (cur., green), the potential run given the current low glass eel recruitment (best, orange), the escapement target of the EU Eel Regulation (40%, red), and the notional pristine biomass (prist., grey); for areas without information, a weeping smiley (☹) is shown. (Data from ICES, 2016).

Figure 5 Modified Precautionary Diagram, presenting the status of the stock (horizontal) and the anthropogenic impacts (vertical) for each reporting Eel Management Unit as reported in 2015; the size of each bubble is proportional to the potential silver eel run. The left axis shows the lifetime anthropogenic mortality, while the right axis shows the corresponding survival rate. Note the logarithmic scale of the horizontal and right axis, corresponding to the inherently logarithmic nature of the left axis. (Data from ICES, 2016).