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The precautionary approach and the management of the European eel (*Anguilla anguilla*) – Critical remarks

Der Vorsorgeansatz und die Bewirtschaftung des Europäischen Aals (*Anguilla anguilla*) – Kritische Anmerkungen

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Abstract

Recruitment and commercial catches of European eel have been in decline since the late 1970s. So far, the reasons are not well understood. A range of potential natural and anthropogenic reasons have been discussed, but the relative importance of the factors is unknown. As a consequence of the decline in recruitment an urgent need for protective management measures was concluded. The main approach is to restrict the fishery on eel, in particular with reference to the precautionary approach. However, in view of the lack of knowledge on the factors responsible for the recruitment decline and by considering that many yellow and silver eel stocks in freshwaters depend on re-stocking by the fishery, such simplified conclusions are critically discussed. A concept for the sustainable management of eel has to include 1) research on the factors determining the population dynamics, in particular during the oceanic stages, 2) a stronger consideration of socio-economic aspects, and 3) intensified research on artificial reproduction and rearing of eel.

Kurzfassung

Das Glasaalaufkommen ist im gesamten Verbreitungsgebiet seit den späten 70er Jahren des letzten Jahrhunderts stark zurückgegangen. Die fischereiliche Erträge an Gelb- und Blankaalen sind ebenfalls gesunken, jedoch nicht im selben Ausmaß wie das Glasaalaufkommen. Die Gründe für den Bestandsrückgang sind bisher noch nicht vollständig aufgeklärt. Es wurde eine Reihe möglicher Ursachen diskutiert, darunter ozeanisch-klimatische Faktoren, Überfischung und Export von Glasaalen aus dem natürlichen Verbreitungsgebiet, verringerte Zugängigkeit oder völliger Verlust von Habitaten, Mortalität an Turbinen oder anderen technischen Einrichtungen, Krankheiten und Parasiten, Schadstoffbelastung oder die stark angestiegene Prädation durch Kormorane. Die relative Bedeutung dieser Faktoren ist unbekannt. Es wurde ein dringender Bedarf an Maßnahmen zur Erhaltung ausreichend großer Laicherbestände festgestellt, wobei ein international koordiniertes Vorgehen zum Schutz der Aalbestände notwendig ist. Als wesentlichster Punkt werden häufig Einschränkungen der Fischerei gefordert, insbesondere unter Berufung auf den Vorsorgeansatz. In Anbetracht der Unklarheit über die für den Bestandsrückgang verantwortlichen Faktoren und der Tatsache, dass die befischten Gelb- und Blankaalbestände bereits heute zu einem großen Teil aus Besatz resultieren, bedürfen solche vereinfachten Interpretationen jedoch einer kritischen Betrachtung. Einschränkungen der Fischerei unter Berufung auf das Vorsorgeprinzip sollten zunächst nur kurzfristigen Charakter haben. Ein tragfähiges zukünftiges Bewirtschaftungskonzept muss 1) die Erforschung der bestandsbestimmenden Faktoren, insbesondere der ozeanischen Faktoren, 2) eine stärkere Berücksichtigung sozio-ökonomischer Aspekte und 3) intensive Bemühungen zur künstlichen Reproduktion und Aufzucht des Aales beinhalten.

Introduction

The recruitment of European eel (*Anguilla anguilla*) into the continental waters has been in steep decline since the late 1970s (Fig. 1). On a European scale, yellow and silver eel catches have also decreased in the last decades (Ringuet et al. 2002; Dekker 2003; FAO 2003; FAO 2006). So far, the reasons for the decline are not well understood. A range of potential causes has been suggested, including oceanic-climatic factors (Castonguay et al. 1994; ICES 2001; Knights 2003), overfishing and increased export of glass eel outside the distribution area, reduced accessibility or even the total loss of freshwater habitats (Ringuet et al. 2002), mortalities at turbines and other technical constructions, diseases (van Ginneken et al. 2005) and parasites (mainly with the exotic swim bladder parasite *Anguillicola crassus;* e. g. Kirk 2003), pollution (e. g. dioxin-like PCBs; Robinet and Feunteun 2002; Palstra et al. 2006) or increased predation by cormorants (Knösche et al. 2004; Brämick and Fladung 2006; Carss 2006). Obviously, depending on the actual conditions in the respective water body, these factors act simultaneously, but the relative importance is unknown.

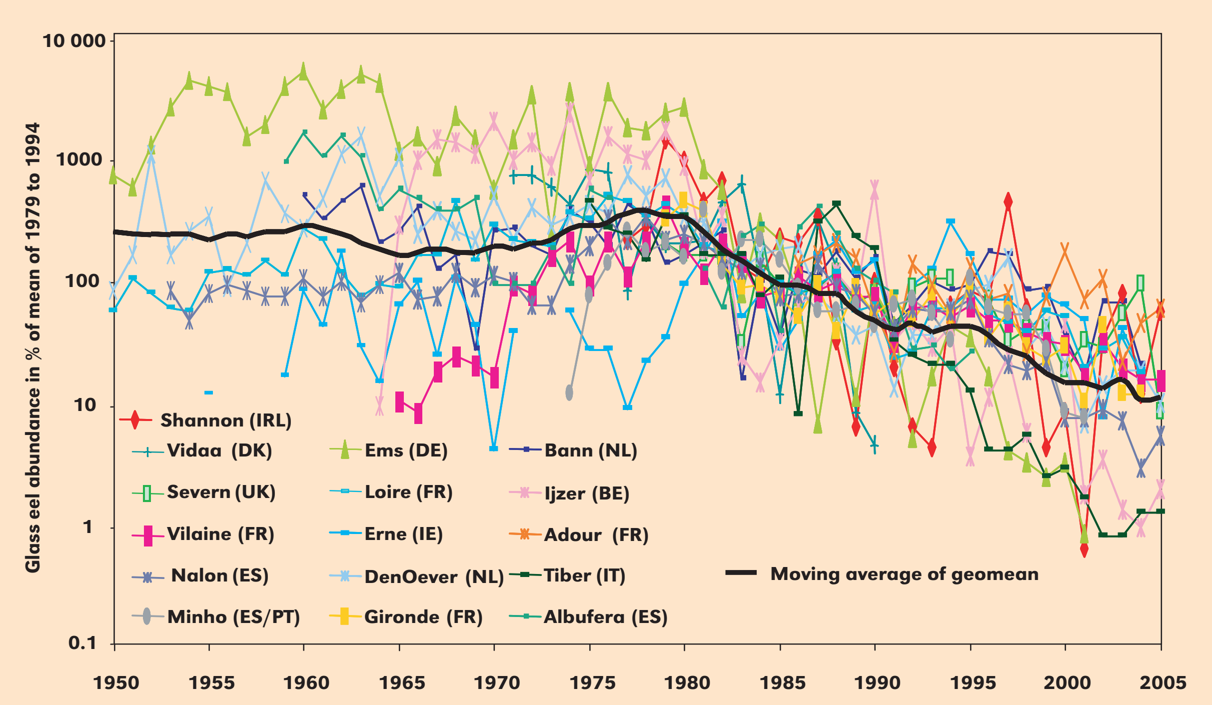

Figure 1: Time-series of monitoring glass eel recruitment in European rivers. Each series has been scaled to the 1979 to 1994 average (FAO 2006).

Abbildung 1: Zeitserie des Glasaalmonitorings in verschiedenen europäischen Flüssen. Jede einzelne Serie ist auf den Mittelwert des Zeitraumes 1979 bis 1994 bezogen (FAO 2006).

The European eel is an important species for the fishery sector. According to Moriarty and Dekker (1997), the total annual landings of European eel amounted to approximately 30 000 t, and about 25 000 people in Europe received income from eel fishing. Due to strongly increased export of glass eel to Asia (mainly to China), the status of the resource has grown from being a small European fishery to one of global significance (Ringuet et al. 2002).

The present decline in recruitment appears to be dramatic and consequently it was concluded that there is an urgent need for management measures to ensure that adequate spawning stocks are being conserved (Russell and Potter 2003). Even though there has recently been some controversial discussion, the European eel population most likely can be considered a panmictic population (Wirth and Bernatchez 2001; Dannewitz et al. 2005). Thus, an international approach to protect the stocks is necessary. The European Commission has prepared a proposal for a Community Action Plan for the management of the European eel, which aims at the recovery of the stock. Currently, a discussion is ongoing about a proposal for an EU Council Regulation establishing measures for the recovery of the stock of the European eel. As a consequence of previous scientific advice the main approach to protect the stock is to restrict the fishery.

The precautionary approach in fisheries and special aspects of eel management

It is commonly agreed that fisheries management strategies should follow the precautionary approach to take into account uncertainties and limited knowledge on quantitative relationships in the life cycle of the respective populations or species. By defining the precautionary approach for fisheries, FAO (1995) stated that the absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures. In case of eel, a problem matching the point "absence of adequate scientific information" is the lack of precise knowledge about a stock-recruitment relationship. Yet, in that case, the precautionary approach dictates that, unless the opposite can be demonstrated scientifically, a relationship between stock and recruitment should be assumed to exist (ICES 1997). The precautionary approach also includes that if a natural phenomenon has a significant adverse impact on the status of living aquatic resources, conservation and management measures should be taken on an emergency basis to ensure that fishing activity does not exacerbate the problems (FAO 1995). The potential for depensation (Myers et al. 1995; Liermann and Hilborn 1997; Dekker 2004b) may require compensation by fisheries measures to protect the stocks (Russell and Potter 2003).

Without questioning the principal need to follow the precautionary approach in fisheries, some interpretations and conclusions probably have to be discussed in more detail in case of eel.

Even though the continental eel catches started to decrease before the decline in recruitment (Dekker 2003), there is no proof that overfishing caused this decline; instead, there is also evidence that fishing mortality has not been a major cause of the decline of the stock (Knights 2003). The fact that the eel catches decreased 1) before recruitment started to fall and 2) in periods of high recruitment may indicate that continental factors outside the fishery had a considerable effect on yields and stocks. The development of landings is also influenced by economic conditions and it appears that the conditions for an economically viable fishery on yellow and silver eel have deteriorated since the 1970s/80s (competition from farmed eels, declines in catch values in real terms; Knights et al. 2006). In that case, commercial catches may not be an appropriate index for population density. It is also noteworthy that recruitment declined much stronger than the yellow and silver eel stocks. Furthermore, before the present decline a long period of increasing recruitment has been documented in the available long-term data series from the rivers Loire and Ems and at the Ijsselmeer/Den Oever (ICES 2005). Thus, the discussion on the decline in eel recruitment may also reflect the general difficulties in the assessment of problems, which are or may be subject to substantial long-term variability as is the case for many issues related to climate. The frequent use of the high recruitment period (1960 to 1970s) as reference level could be discussed as an example for the *shifting baseline syndrome* (Pauly 1995). If compared to the levels from the beginning of the 20th century (Knösche et al. 2004; Dekker 2004a, ICES 2005), the present decline would seem to be less dramatic than if compared to the 1970s. In fact, according to catch per unit effort data (glass eel) from the Ijsselmeer published by Dekker (2004a), the catches at the beginning of the 20th century have been in the same order of magnitude than they are at present. Similarly, an analysis of the available long-term data series on yellow and silver eel stock densities by Knights et al. (2006) revealed decadal-scale patterns that suggest recent stock levels are not abnormally low compared to historical ones.

Problems and open questions at different levels

The discussion on the eel problem and on the required measures is difficult because problems and open questions exist at different levels. First, the mechanisms, which are responsible for the decline, so far are not fully understood. If the most important factors or mechanisms are not under direct human control, the question arises, if any management measures can potentially be successful. Without this knowledge, certain management measures may only be enforced by adopting the precautionary approach. By selecting the respective means, there are again different aspects, which need to be considered. The continental part of the life cycle of eel includes several life stages (glass eel, elvers, yellow eel, silver eel), different migratory behaviours (upstream, downstream), which are related to different problems (access to habitats; mortality at technical constructions, e. g. turbines), a broad range of mortality factors and a great diversity of the fishery (very intensive on glass eel, usually less intensive on yellow and silver eel). This makes the problem complex and difficult to handle.

Problem 1: The lack of knowledge about the relative importance of climatic-oceanic factors

One basic problem is that until now it is not fully clear if oceanic or continental factors are mainly responsible for the decline of the stock. All regulations and measures can only be successful, if factors during the continental stages (including coastal waters) have a distinct effect. If the opposite is true and oceanic factors are by far more important, as was suggested by Knights (2003), all efforts to support the stocks may possibly not yield any marked effects.

The "oceanic or continental factors" dimension of the discussion includes the question of stock-recruitment relationships. There has been a discussion if such relationships generally exist or if recruitment depends too strong on environmental conditions and consequently is mainly related to environmental variability (e. g. Gilbert 1997; Hilborn 1997; Myers 1997). The idea behind questioning stock-recruitment relationships is of course not the assumption that offspring could be produced without spawners (see Gilbert 1997 and Myers 1997). If environmental variables, which influence recruitment, vary randomly, it is likely that a positive relationship will be found. However, if the relevant environmental variables are permanently adverse or shift continuously towards a negative direction, the relationship may be obscured. Under unfavourable conditions, even high spawner stocks may result in very low recruitment.

In eel, recruitment is measured as abundance of glass eels at the continental coasts or in the estuaries or as number of elvers and small yellow eel in the Baltic region. The fate of the offspring between hatching of the larvae and arrival of the glass eel at the continent after about three years most likely depends largely on environmental factors related to climate (Knights 2003;

Knights et al. 2006). Slower currents resulting in longer time for the transport may cause higher losses due to predation (Knights 2003). The recruitment into the Baltic is influenced by the prevalence and strength of westerly winds in winter and spring, which also depend on the oceanic-climatic conditions (Knights et al. 2006). It appears also possible that the availability of oceanic plankton has decreased, thereby causing stronger competition for food and a lower condition of the Leptocephali (Knights 2003). In particular, it has been noted that during warm Sargasso periods, winter cooling could be reduced relative to the long-term average, thus inhibiting spring mixing, nutrient recirculation and productivity (Bates 2001). If the timing of processes has changed (plankton development, spawning and hatching) the eel larvae may face a match-mismatch problem (Cushing 1990). From an analysis of data from 50 marine spawning fish species Gilbert (1997) concluded that periods of low recruitment are probably environmentally induced and unavoidable.

Whereas significant correlations between the North Atlantic Oscillation index (NAOI) and sea surface temperature anomalies in the Sargasso Sea and glass eel recruitment have been shown (Knights 2003), it has also been discussed that variation in the NAOI would only explain a minor part of the variation in eel recruitment (Dekker 2004b). However, in the model used in this analysis, the commercial catches of eel were used as an index for spawning stock biomass. As discussed above, this might be misleading since commercial catches also depend on economic conditions (Knights et al. 2006). Furthermore, the NAOI is a climatic index calculated from air pressures in different areas. Even though it is correlated to oceanic conditions (currents, temperatures), probably inducing several indirect effects, one should probably not expect that such an index is directly and linearly reflected in biological processes like recruitment of glass eels – even if it is the best index available. This does, however, not necessarily mean that the importance of the oceanic processes is low. As a negative correlation between NAOI and eel recruitment has been demonstrated (Knights 2003), it has to be noted that during the last about 20 years high positive NAOI values have been recorded nearly exclusively. Additionally, the centres of the oscillation have shifted eastwards and the potential effects of these changes on eel recruitment are completely unknown.

Recently, Tsukamoto (2006) precisely identified a spawning location of the Japanese eel (*Anguilla japonica*) and demonstrated that spawning occurs in a narrow range of latitudes. Otherwise the larvae would not find the right oceanic currents. The importance of climate and oceanic currents was also demonstrated by Kim and Kimura (2006). By using a numerical particle tracking model they showed that in El Niño years the number of eel larvae (*A. japonica*), which migrated into the Kuroshio current was about 4 times lower than in non-El Niño years. These quantitative results corresponded to the data on glass eel catches around the Japanese Islands and consequently, it was suggested that interannual variation in the climatic-oceanic system determines the recruitment of *A. japonica*. As the Leptocephali of the European eel also depend on oceanic currents, similar mechanisms are conceivable. Climate-induced changes in the currents possibly may cause that an unknown proportion of the larvae gets lost in the ocean. The importance of climatic factors is also evidenced by the results of Wirth and Bernatchez (2003) who related a decline in effective population sizes of *A. anguilla* and *A. rostrata* (concluded from genetic studies) to the maximum of the Wisconsinan glaciation, which also had a direct impact on oceanic circulation.

Problem 2: Diversity at the continental stage – life stages, mortality factors, fisheries

Another level of problems includes the different approaches to protect the stock during the continental stages. At present the majority of the recommended measures focus on the protection of silver eels to guarantee sufficient spawner escapement. This could be seen as a misinterpretation: of course, since silver eels are the last continental stage (and among all stages which are at least somehow under control, it is the one closest to spawning), the number of escaping silver eels could be used as an index for the success of protection and enhancement of the population during the complete continental stage. However, it does not make any sense to reduce the protection measures mainly to this stage. If the mortality prior to the silver eel stage is too high, any measures at this stage will not lead to a sufficient overall effect. While measures are recommended to ensure sufficient silver eel escapement, it is still common practise to export huge numbers of glass eels outside the natural distribution area (Ringuet et al. 2002). These fish will never contribute to the spawning stock. As a consequence of the shared responsibility for the stock it is a central point that, if the fishing mortality has to be reduced, the restrictions have to be distributed equally to all sectors of the fishery (glass, yellow, silver eel).

With regard to the low recruitment, an urgent requirement for management action has been concluded several times (e. g. Moriarty and Dekker 1997; Dekker 2000). This usually means *fisheries management* and at this point it becomes obvious that fisheries management still is not fully understood as part of an integrated management of fresh and coastal waters. It is well known that the freshwater part of the eel population is influenced by multiple factors. The construction of dams and weirs has reduced the accessibility of habitats for eel and not in all these waters this is compensated for by re-stocking. The number of large dams in Europe rapidly increased in the second half of the last century with a peak in the 1960s and 1970s – just before recruitment of eel began to fall (WCD 2000). Retention areas in the former floodplains have been lost on a large scale (Ringuet et al. 2002) and habitats in coastal areas disappeared due to land reclamation (e. g. the surface area of the Commacchio lagoons was reduced from about 50 000 ha to 11 000 ha at present; E. Ciccotti, pers. comm.). These types of habitats usually are very well suited for eels and can support high densities.

Evidence has also been presented that even very low concentrations of dioxin-like PCBs possibly reduce the ability of eel to produce viable offspring (Palstra et al. 2006). A debate is continuing on the role of increased cormorant predation on eel. In some regions, the reduction of the eel stock by cormorants is estimated to be in the same order of magnitude as the yield of the commercial fishery (Knösche et al. 2004; Brämick and Fladung 2006; Carss 2006). However, despite this multi-factorial influence, the first approach usually is that the problems shall be solved by restrictions of the fishery whereas other approaches are recommended as complementary measures. This might reflect a kind of psychological problem: the fishery (commercial and recreational) is using eel directly as a resource whereas many of the other factors do not focus on eel. However, this actually does not say anything about the impact of the activity on the stock. If retention areas in floodplains, backwaters or coastal / brackish habitats get lost due to human activities, the eel just disappears together with the habitat. Nobody is charging the industry for potential reductions of eel recruitment due to contaminants (e. g. PCBs or dioxins), except for catastrophic events. At present, mortality at turbines is an issue in the public, but without the pressure from the fishery it probably would not be one. Intuitively, it is assumed that fishery is a major, if not the most decisive factor for the population development of the eel. The conclusion from this assumption would be that regulations of the fishery can solve the problem – but there is no proof for this conclusion.

The present situation shows that political pressures and decisions usually reflect economic importance. Compared to the economic power e. g. of the hydropower industry, the small scale (eel) fisheries are much less important. If the term "exploitation" is defined in a broader sense by including non-targeted mortalities or stock reductions (the eel is "exploited" as a component of the environment, which is used for navigation, production of electricity, transport of effluents and so on), this is at least partly in line with the rather pessimistic view of Ludwig et al. (1993) who state that economic motivation and political pressures inevitably lead to an overexploitation of resources.

The special aspect of re-stocking

In contrast to the situation at the sea, fisheries management in freshwaters does not only consist of reductions in the number of fishes but also includes (re)-stocking – an anthropogenic increase in population size, at least on a local or regional scale. Again, this makes the situation and the discussion more complex and complicated. The degree of eel re-stocking varies from intensive stocking to no stocking at all. How should this be reflected in catch restrictions? Re-stocking is usually done by the fishermen resulting in a considerable financial effort. By doing this, the fishermen also compensate for the reduced accessibility of habitats which has not been caused by the fishery. Consequently, this aspect should be considered. For example, in Germany re-stocking of glass eels started around 1910 (Knösche et al. 2004) or even earlier (Dersinske 2006), and this may hold also for other European countries. If it is assumed that variability in the freshwater population of eel has an effect on spawning stock and recruitment of eel, the higher levels of eel recruitment in the 1960–70s could also be discussed as a consequence of active fisheries management including an enormous re-stocking of glass eels. It is very likely that re-stocking despite an existing fishery in these waters may have resulted in an overall surplus to the population or at least to silver eel escapement (Knösche 2006).

The resulting difficulties in the implementation of the precautionary approach in eel management and options for the future

The eel problem and the debate on it show that the perspective is important and that different approaches may exist. In the first, which obviously is applied at present, it is tried to solve the problem within one sector (here: the fishery). Even though the European scale is considered, this is more or less a one-dimensional approach, applied to a multi-dimensional problem. Yet, even this approach could work, if the relative impact of the sector or factor is big enough. However, this is not known in case of eel and consequently, the success is questionable. Furthermore, it also includes an unfair treatment of one sector: the fishery has to pay for all. It is obvious that in many cases the legal frame to treat the problem as a whole is not everywhere available and it will likely take time until such regulations will be established – if this will ever happen.

Another possibility would be first to determine all factors involved in the problem and to analyze their relative importance. This would enable assessment, in which sector management action would result in the highest overall effect. Such an approach would include intensified research on the subject – what is the most precautionary approach in the long run. It may, however, not be sufficient in an "emergency case" and this is the only acceptable reason for the present approach. Due to the long generation cycle of eel, the effects of the recruitment decline will become obvious also with a time lag. With reference to the precautionary approach, this causes the need to reduce the mortality of the year classes living now to keep the possibility of the recovery of the stock in the future.

It is obvious that knowledge is most restricted for the oceanic stages. However, consequent approaches for research on these stages are rare, most likely due to higher costs and technical limitations. FAO (1995) stated that the absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures. Yet, this does not replace the need to achieve this knowledge. In this meaning, the precautionary approach should only be used as a short-term management option, which has to be scrutinized when more detailed knowledge on the issue becomes available.

Good science is a key to the precautionary approach. In the case of strongly restricted knowledge on an issue, the (apparent) implementation of the precautionary approach may lead to vague and sometimes even contradictory management recommendations. There is, e. g., nearly no recruitment to many river basins in the Baltic region. Without re-stocking, there will be a very low silver eel escapement from these waters. However, there is also some evidence that eels from re-stocking programmes (usually glass eels from the UK or France) as silver eels possibly may fail to find their way out of the Baltic Sea (Westin 1998) due to a lack of imprinting of the migration route. Under these conditions, it seems hard to decide, which of the recommendations ("re-stocking" or "no re-stocking") represents the precautionary approach.

This indicates an inherent problem of the precautionary approach in cases like this: it is applied in situations of restricted knowledge and uncertainty. However, a basic assumption (even if this is not always mentioned) is that good knowledge on the present situation exists, whereas the effect of a certain activity is considered to cause a risk. If, as in the case of eel, even the mechanisms determining the present situation are not really clear, the recommendations have a very weak basis and most likely the success cannot be guaranteed. Even this approach is legitimate but some points should be noted. If there is no guarantee for the success of the recommended measures, this has to be stated honestly. Nowadays, the term "precautionary approach" is an important political argument and it is necessary to notice this aspect. One of the major tasks of scientists is to give advice to political decision makers, who are no experts on the respective issues. The statement that a management strategy is recommended by adopting the precautionary approach will signalise an apparent safety to the decision makers – but, as explained above, this is not true for eel. Yet, a politician who has to make a decision should know, whether the alternative is "strong restriction of the fishery, including the risk of collapse of the fishery and loss of employment but the species in question will be safeguarded" or "strong restriction of the fishery, including the risk of collapse of the fishery and loss of employment and the outcome still is unclear". This might influence the decision. Additionally, when measures, which may cause severe problems for stakeholders, are recommended on the basis of such arguments, it is not surprising if there is resistance against the measures instead of compliance. However, studies in the field of sustainable development concluded that beside good science willing compliance is a basis for the success of the measures (Mehner et al. 2000).

Consequently, in future approaches, the socio-economic dimension has to be included stronger than has been the case so far (Arlinghaus et al. 2002). This holds for both research and the development and implementation of management strategies. Fisheries management is increasingly seen to be as much about managing people as about fish stocks (Arlinghaus et al. 2002). There will be a better chance to achieve the management goals, if the stakeholders are involved in the development of management strategies and the decision making process.

In the long run it is not satisfactory to base decisions only on assumptions. Therefore, as a further conclusion, research on the oceanic stages of eel clearly needs to be intensified. Even though Ludwig et al. (1993) state that ecological research will not solve exploitation problems, in case of eel such results would help to define the problem and deliver better arguments for management decisions. The need for research on the oceanic stages in the life cycle of eel results also from the fact that the precautionary approach includes an appropriate placing of the burden of proof. If the fisheries stakeholders want to continue the fishery on eel on a certain level, they have to demonstrate that this will not cause a significant risk to the stock. As a decline in recruitment compared to the high levels of the 1960s–1970s is beyond question the responsible factors and mechanisms have to be identified. In the end, this will not be possible as long as the oceanic mechanisms remain unclear.

A third conclusion is that artificial breeding and rearing of eel would enable a much more stable production of eel and would allow to release the population at least partly from fishing pressure. This may be of particular importance, if environmental variation strongly influences recruitment of a species as is assumed for eel. Consequently, research in this field also has to be intensified in the future.

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